FRANKFURT UNIVERSITY OF APPLIED SCIENCES

Would customers be willing to use an alternative (chargeable) delivery concept for the last mile?

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Working Papers
Fachbereich Wirtschaft und Recht
Frankfurt University of Applied Sciences
www.frankfurt-university.de/fb3

Nr. 17

Dezember 2020
ISSN-Nr. 2702-5802

Fachbereich 3
Wirtschaft und Recht | Business and Law

Frankfurt University of Applied Sciences
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Funding: This work was supported by the Hessian Ministry of Economics, Energy, Transport and Housing, Wiesbaden, Germany [grant number: 2695 0458 2019 00]

Please cite this article as: Tobias Hagen, Sabine Scheel-Kopeinig, Research in Transportation Business & Management (pre-print)
https://doi.org/10.1016/j.rtbm.2021.100626

Abstract

B2C e-commerce is still one of the fastest growing marketing channels in almost all product categories yielding to less bundled direct-to-consumer deliveries. Last mile deliveries cause costs and emissions especially in urban areas with a high density of e-customers. Therefore, stakeholders in the context of last mile parcel deliveries are interested in implementing efficient, innovative and ecological last mile concepts. Additionally, such concepts must fulfill the requirements and expectations of online customers as parcel recipients because last mile delivery is the critical link between an online purchase and the delivery to the address stated by the customer. In our customer-driven central last mile micro depot (CMD) project a potential analysis was carried out for the implementation of a CMD with the aim of environmentally-friendly and bundled last mile delivery. Our paper tries to close a research gap by examining acceptance and willingness-to-pay for an alternative last mile delivery concept from the perspective of the customer. Our empirical results based on a survey among German major city residents indicate that city residential areas are potentially more suitable for the realization of a CMD-project than other areas. Furthermore, younger and employed inhabitants are most willing to use the CMD. Based on our statistical model we are able to predict values for the willingness to pay per parcel for a specific population of urban inhabitants. A high proportion of the population in cities (60%) would be interested in participating. However, only 36% are willing to pay in addition to the usual parcel delivery charges. 26% are willing to pay €1.00 or more.

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1. Introduction and background

1.1 Study introduction

This case study examines customer acceptance and willingness-to-pay for a last mile micro depot in which goods from different freight carriers are consolidated before the final delivery by cargo-bikes. We designed a (still) hypothetical micro depot concept called "DeinDepot" and carried out a representative survey in major German cities. An essential difference to previous micro depot concepts is that in our case, consumers trigger the delivery of the online ordered goods to the micro depot. In the following this concept is called “customer-driven” central last mile micro depot (CMD). Research on CMDs in terms of acceptance and willingness to pay from an online-customer point of view does not exist so far. This paper closes this research gap by posing the following research questions: “*Would online customers be willing to use a customer-driven CMD?”* and “*Would online customers be willing to pay for a customer-driven CMD?”*

The need for new concepts arises from the development of e-commerce. In the past decade the number of B2C-related parcel deliveries has increased significantly. E-commerce is still one of the fastest growing marketing channels over almost all product categories leading to less bundled direct-to-consumer deliveries (Schöder *et al.*, 2016). Accordingly, the B2C-share of the annual revenue of the total European parcel market (B2B, C2X, B2C) has seen strong growth. It has increased from 15% in 2010 to 33% in 2019 (35% in 2020) (Statista Research Department, 2019). In Germany, for example, the number of parcel deliveries is expected to rise by an annual rate of 4.7% for the next four years which is higher than the mean growth rate of 4.1% for the years 2000 to 2018 (BIEK, 2020). Especially in the current pandemic situation and the resulting increase in online sales, an even stronger growth in last mile parcel delivery is expected. Those last mile deliveries cause (external) costs and emissions especially in urban areas with a high density of e-customers.

Therefore, stakeholders in the context of last mile parcel deliveries are interested in implementing efficient, innovative, and ecological last mile concepts. Such concepts must additionally fulfill the requirements and expectations of online customers as parcel recipients because last mile delivery is the critical link between an online purchase and the shipment to the delivery address stated by the customer (Esper *et al.*, 2003).

The article is structured as follows. Section 1.2 provides background information on alternative last mile delivery and last mile concepts as well as research on these concepts. In Section 1.3 we provide a literature review and summarize studies that focus on the expectations and experiences of online customers in relation to last mile deliveries.

Section 2 outlines our micro depot concept “DeinDepot” and summarizes the role of last mile stakeholder groups within the concept. Section 3 describes the data collection process

and presents some descriptive statistics. The empirical results on customers' acceptance and willingness to pay are presented in Section 4. Section 5 provides more information on the importance of different attributes of delivery services for consumers, such as time slots for delivery, importance of communication and ecological transport. Section 6 gives an illustrative example by applying the empirical results to a city district in Frankfurt. Section 7 concludes the results and gives recommendations.

1.2 Existing last mile delivery and micro depot concepts

Last mile deliveries fall into the thematic complex of urban (city) logistics or urban transport, respectively. Last mile concepts haven been investigated in different disciplines (logistics, transport planning, traffic planning, supply chain management and others), from different points of view (carriers, companies, customers, municipalities, and others), and with different focuses (efficiency, sustainability, ecological impact, or level of innovation).

Therefore, the relevant literature is fragmented. Lagorio *et al.* (2016) made a valuable contribution to systematizing this fragmented literature and breaking 104 studies on urban (city) logistics and last mile (urban) delivery from a logistics and management perspective down into subject areas (topics). Mangiaracina *et al.* (2019) provide a literature review of innovative solutions aiming to make the last mile delivery process more efficient.

One way of making last mile deliveries more efficient, innovative and sustainable are urban consolidation centers (UCCs). According to Allen *et al.* (2012, p. 473) UCCs are logistics facilities that are situated in relatively close proximity to the geographic area they serve, be that a specific site (e.g. shopping centre or airport), city centre, or an entire urban area. By implementing a common receiving point, with the last-mile delivery being shared by the consignments in sustainable and ecological freight vehicles, UCCs can represent an example of multi-stakeholder collaboration (Paddeu *et al.*, 2018, p. 913). Cárdenas *et al.* (2017) show that aggregating and consolidating urban last mile deliveries can reduce external costs.

Central micro depots (CMDs) are a type of UCC that are located *within* the urban areas in which the goods are consolidated before the final delivery to the customer (Janjevic and Ndiaye, 2014). Numerous CMD projects have been implemented in recent years. See Janjevic and Ndiaye (2014) for an overview of micro depot initiatives across Europe and Lee *et al.* (2019) for Canada. In many cases, these trials were failures, which could possibly have been prevented by appropriate potential analyses.

Research on CMDs exists for different perspectives. From the perspective of local authorities and/or parcel (logistics) service providers, see, for example, Conway *et al.* (2011) or Gevaers *et al.* (2014) as well as Gammelgaarda *et al.* (2017) for a Danish B2B-microhub solution. Buldeo Rai *et al.* (2019) propose policy implications for sustainable urban freight transport in the future.

From the perspective of e-retailers last mile delivery is the last step of the supply chain which connects retailers with their customers. Paddeu (2017) appraises the benefits of shared last mile deliveries focusing on the perspective of participating e-retailers (see also Paddeu *et al.* (2018)). Frederick *et al.* (2018) provides a literature review on different last mile logistics models in consumer-driven e-commerce. Furthermore, Frederick *et al.* (2019) propose a set of prescriptive guidelines for retailers to reconfigure their last mile distribution.

From the perspective of sustainable delivery findings, Conway *et al.* (2017) show that cargo bicycles can provide a competitive last mile delivery option in urban areas. [1] In addition, (Melo and Baptista, 2017) state that cargo bicycles are a promising solution for congested and polluted urban centres and their usage for last mile deliveries can be successful from a public and logistic perspective. Schliwa *et al.* (2015) develop a typology of cycle logistics and argue that urban authorities have a key role in creating conditions that incentivise the use of cargo bikes. German authorities currently support companies to purchase cargo bikes by refunding 30% of the purchasing price up to €2,500 (Bundesamt für Wirtschaft und Ausfuhrkontrolle, 2018).

Based on the described research findings, we have developed our micro depot concept "DeinDepot" which is described in detail in Section 2.

1.3 Perceptions and experiences of online customers

Because e-commerce is driven by customers, last mile delivery services also have to deal with customer-expectations in order to fulfil the supply chain and satisfy the needs of customers (Cárdenas *et al.*, 2017). Vakulenko *et al.* (2019a) indicate that last mile delivery mediates the relationship between customer online shopping experience and customer satisfaction, which implies that a flexible and personalized last mile order fulfillment can be a tool to increase customer satisfaction. From the customers' point of view, home delivery with flexibility options, for example the choice of time frames seems to be the most attractive last mile delivery service (Schnedlitz *et al.*, 2013). Holdorf and Haasis (2014, p. 5) state that it would be necessary to provide uniform collection points where parcels from all freight carriers can be received. If such "collection points" were extended by preferred last mile services such as home delivery, flexible time frames, possibility of communication with the delivering company or ecological means of transport, customer satisfaction could possibly be increased.

Several empirical studies analyse the perceptions and experiences of online customers regarding last mile delivery services as well as the acceptance of and preferences for different last mile delivery concepts. TABLE 1 summarizes the main findings of previous research. It becomes clear that different last mile delivery settings matter for customers' perceptions and preferences. Vakulenko *et al.* (2019a) show that last mile delivery experience has a direct effect on customer satisfaction. Consumers prefer delivery to their home address ideally within fixed times and appreciate the possibility of communicating with the carrier.

Previous research suggests that online customers increasingly expect special last mile delivery services and options (for example, evening delivery, time slots for delivery, ecological transport, etc.), without being willing to pay an adequate amount for it (Horst and Rahn, 2015). However, Joerss *et al.* (2016) and Prümm *et al*. (2018) come to the conclusion that customers are quite willing to pay for more flexible, faster and, in some cases, more environmentally friendly deliveries.

[1] Rudolph and Gruber (2017) identify six relevant market segments for cargo cycles, among others an emission-free last mile delivery from mobile or stationary micro depots.

However, so far there are no empirical findings available as to whether customers are willing to use and to pay for a customer-driven CMD. Our paper closes this research gap by examining the acceptance and willingness-to-pay for an alternative last mile delivery concept from the online customer perspective.

Authors (Year)	Method, Data, Country	Outcome, Variable	Influencing Factors	Main Findings
Holdorf and Haasis (2014)	online survey n = 180 Germany	Customer satisfaction	delivery options	Positive impact: low delivery price, quick distribution, possibility to arrange delivery time frames, delivery to the home address, reputation of the parcel delivering company and the possibility to communicate Negative impact: parcel terminal, parcel shops
Esper *et al.* (2003)	experimental webpage and survey n = 222, USA	consumers' expectations, perceptions, satisfaction	carrier related issues	Study indicates that the disclosure of carrier information on retail websites affects willingness to purchase and the delivery expectations of online customers.
Joerss *et al.* (2016)	Survey n = 4,700, China, Germany, USA	consumers' relative preferences	delivery options	30% of the respondents are willing to pay significant premiums for reliable and timed, same-day and instant delivery.
Madlberger and Sester (2005)	face-to-face-interviews n = 180 Austria	perceived delivery service level	product and consumer attributes	Product category has a strong impact on customers' expectations on last mile logistics services whereas customers' flexibility in terms of time/location does not influence last mile requirements.
Niehaus (2005)	Structured interviews, n = 189 Austria	customers' preferences	delivery options	The most important criteria regarding the customer's delivery-decisions are delivery-place and delivery-price over all product categories. Quick delivery is not as important as the customers' knowing of the concrete delivery timeframes.
Prümm et al. (2018)	Survey n = 1,000 Germany	customers' preferences, willingness to pay (WTP)	delivery options	4 out of 10 Germans would pay an average of €2.40 for a self-selected delivery window. One in three would be willing to pay for environmentally friendly delivery (average €2.34). Younger generations have a higher WTP.
Schnedlitz *et al.* (2013)	online survey n = 846 Austria	customer satisfaction	delivery options	Customers prefer home delivery with defined timeframes. Concepts based on a people-to-people communication are preferred.
Seeck and Göhr (2018)	face-to-face-interviews n = 378 online survey n = 1877 Germany	consumers' experiences and expectations	delivery options	Evaluation of past last mile deliveries: delivery place: only a quarter of the respondents receive their parcel personally (80% neighbors, 13% post or parcel shops) Desired delivery services: 83% digital communication, 69% granted personal delivery (timeframes), 68% return-shipment hand-offs. Heavy users desire bundled deliveries by only one delivery company.
Vakulenko *et al.* (2018)	focus group interviews n = 26 Sweden	customer value	parcel lockers	Usage of parcel lockers in the last mile delivery algorithm results in functional, emotional, social, and financial customer value.
Vakulenko *et al.* (2019a)	Survey n = 252 Sweden	customer satisfaction	e-retail and last mile delivery experiences	Consumers who report better online experiences have experienced better last mile delivery: last mile delivery experience has a direct effect on customer satisfaction.
Vakulenko *et al.* (2019b)	focus group interviews n = 26 Sweden	e-customer behavior	parcel lockers	Study provides conclusions about dynamics of e-customer behaviour triggered by delivery service innovations (parcel lockers).
Verlinde *et al.* (2018)	online survey n = 61 Belgium	consumers' perceptions	parcel lockers	Parcel locker-solutions are not popular among customers. Study provides insides in what e-consumers who do not use parcel lockers (yet) like/dislike.
Xu *et al.* (2008)	e-mail survey n = 125 Great Britain	consumers experiences and perceptions	delivery options, unattended delivery	Reasons of dissatisfaction if home delivery was not possible: pick-up at a parcel shop, waiting for delivery. Customers would prefer the pick-up of the parcel at a depot if otherwise the delivery would be unattended. Shipment tracking is favoured.
Zhang and Li (2018)	Survey n = 161 Sweden	consumers' preferences	delivery options	Fast-moving consumer goods: customers prefer a free of charge and ecologically packed last mile delivery within one day. Respondents are cost conscious, but they are willing to make trade-off for premium logistics services.

Table 1: Empirical studies – Perceptions and experiences of online customers regarding last mile deliveries

2. Customer-driven central last mile depot – "DeinDepot"

The following section outlines the CMD concept "DeinDepot" which will be analysed later in this paper. Our CMD may be interpreted as a special type of UCC being located *within* urban areas in which goods are consolidated before the final delivery to the customer. In order to show this in detail we characterize our CMD by using the factors influencing the nature of a UCC according to Browne *et al.* (2005). As this characterization is not necessary to understand our concept, we moved it in Table A1 in the Appendix.

Figure 1 summarizes our customer-driven CMD concept.

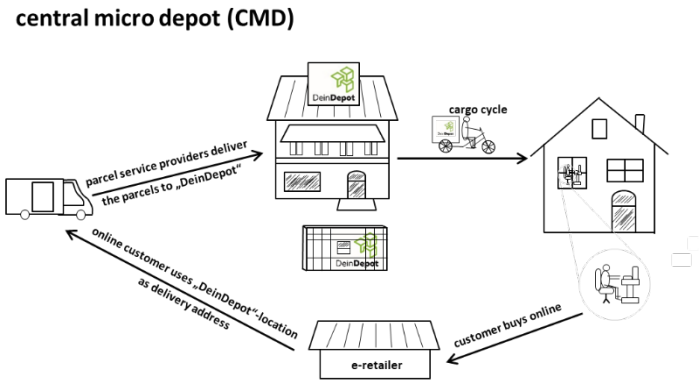

Figure 1: Central micro depot „DeinDEPOT"

The starting point is the customer who orders a product on the internet (Figure 1). As Ducret (2014) notes, parcel delivery is determined by the consumer. Instead of giving their home address as a delivery address, the customer gives the address of the CMD. This way, involvement of parcel service providers in the CMD concept is avoided which is an advantage since their cooperation has turned out to be particularly challenging. Using the CMD location as a delivery address forces parcel service providers (customer-initiated) to deliver the parcels to the CMD.

The concept provides three delivery options. Firstly, parcel recipients can pick up their parcel at the CMD. Secondly, since pick-up is only possible during the opening hours of the store, pick-up at a parcel terminal is also offered. At the parcel terminal customers can pick up the parcel at any time. The third option is a bundled delivery using a cargo bike. The concept may include an optional delivery timeframe. The CMD can be integrated into a retail store, for example, which offers the possibility to provide additional services depending on the business environment in which it is embedded.

TABLE 2 summarizes the role of last mile stakeholder groups within our CMD concept. As described above, online customers are the "acting players" in our setting, while all the other stakeholders (shippers, freight carriers, local couriers) in the delivery process are "reacting players". Institutional stakeholders (local and regional authorities) are currently not included in our concept.

Stakeholder Group	Role of Stakeholder	Type of Action
Institutional		
Local and regional authorities	This stakeholder group is currently not included in our concept.	
Industrial		
Shippers	E-retailers arrange delivery of the ordered goods to the delivery address specified by the online customer.	reacting
Freight carriers	Carry out transport request.	reacting
Local couriers (DeinDepot)	Notifies customer about the arrival of the package or parcel and carries out desired delivery.	reacting
Consumer	Online customers use address of DeinDepot as delivery address and thus trigger a last mile delivery. Consumer: - collect the parcel personally either during the opening hours or 24/7 at the parcel locker; - arrange home delivery.	acting

Stakeholder groups according to Harrington *et al.* (2016).

Table 2: Role of "last mile" - Stakeholder groups in the CMD concept "DeinDepot"

3. Data collection & description

In September 2019, an online survey was conducted targeting potential users of the CMD with an online questionnaire including the following topics: socio-demographic characteristics (for example, gender, age, living conditions, education, and employment status) as well as information about previous online-purchases and experiences with last mile parcel deliveries. The questionnaire was pretested and led to a final dataset of n=2,017 observations (full sample) from 80 major German cities, such as Berlin, Munich, Cologne, or Frankfurt. Survey participants were panel members of a German market research company. The results are representative with regard to the distribution of age and gender in major German cities (>100,000 inhabitants).

The online survey provided an introduction to the "DeinDepot"-CMD concept, including a graphical explanation similar to Figure 1. It was also explained that cargo bikes are used for the deliveries. Based on this, the interviewees indicated their willingness to use the CMD and their willingness to pay for it. The key questions in the questionnaire were:

a) *Have you understood the CMD concept?*
   The response options were either "*yes*" or "*no*". Interviewees who ticked "*yes*" were asked (→ sample II):

b) *Would you be willing to use the CMD for your deliveries in the future?*
   Interviewees who ticked "*yes*" again were asked (→ sample III):

c) In addition to the delivery cost, how much would you be prepared to pay: nothing, €0.50, €1.0, €1.5, €2.0, €2.5 or €3.0?

Question a. refers to the problem that although the concept is explained at the beginning of the survey using simple language and a picture similar to Figure 1, not all interviewees may be able to understand the concept, which is a precondition for any further questions. This will be analysed in the next section.

We present some descriptive statistics of the full sample as well as for subsamples (sample II and sample III) in TABLE 3. These samples are analysed in the next sections.

Sample	**full sample**		**sample II** [1)]		**sample III** [2)]	
No. of obs.	2017		1,893		1,145	
Variable	Freq.	%	Freq.	%	Freq.	%
Gender						
Female	1,057	52.4	990	52.3	608	53.1
Male	956	47.4	899	47.5	534	46.6
Diverse	4	0.2	4	0.2	3	0.3
Age						
18-29	363	18.0	349	18.4	266	23.2
30-39	298	14.8	274	14.5	193	16.9
40-49	385	19.1	363	19.2	240	30.0
50-59	320	15.9	306	16.2	193	16.9
60+	651	32.3	601	31.8	253	22.1
District type						
City residential area	573	28.4	534	28.2	367	32.1
Residential area	799	39.6	747	39.5	395	34.5
Mixed area	635	31.5	603	31.9	374	32.7
Commercial/industrial districts	10	0.5	9	0.5	9	0.8
Type of household						
Single household	702	34.8	658	34.8	396	34.6
Family household	1,315	65.2	1,235	65.2	749	65.4
Employment status						
Employed (employee, freelancer)	1,173	58.2	1,114	58.9	755	66.0
Homemaker, student, retired person	844	41.8	779	41.1	390	34.0
Income class						
< €1,300	356	17.7	326	17.2	179	15.6
€1,301 – €2,600	701	34.8	659	34.8	376	32.8
€2,601 – €5,000	756	37.5	713	37.7	468	40.9
€5,001 – €10,000	176	8.7	167	8.8	111	9.7
> €10,000 €	28	1.4	28	1.5	11	1.0

[1)]: Sample of those respondents who understood the DEINDEPOT-concept (n=1,893). Due to a too small number of cases (gender: "diverse", district area: "commercial/industrial districts") 13 observations had to be dropped for some of our analysis (n=1,880)

[2)]: Sample of those respondents who would use DEINDEPOT.

Table 3: Descriptive statistics of the samples

4. Empirical results on consumers' acceptance and willingness to pay

4.1 Has the CMD concept been understood by the respondents?

The CMD concept was explained to the interviewees both in textual form and by means of the diagram in Figure 1. 94% (=1,893 of 2,017) of the respondents understood the CMD concept. On average, respondents who understood the CMD concept are somewhat younger (48 versus 51 years old). They are also better educated on average, i.e. they spent more years in education and training on average (14 years versus 13.4 years)[2]. Moreover, a higher proportion has already ordered goods online (97% versus 83%). Finally, respondents who understood the CMD concept receive more shipments on average.

For the rest of this paper, we assume that in the case of an implementation of the CMD it would be possible to make the concept understandable to the entire relevant population.

4.2 Analysis of the proportion of potential users of the CMD concept

For our further analysis we had to drop 13 observations due to a too small number of cases (gender: "diverse" and district area: "commercial" and "industrial districts") leading to 1,880 observations. 60.3% (n = 1,133 of 1,880) of the respondents would use the CMD (Figure A1 in the Appendix). This implies that the average proportion of potential users per adult population in German large cities is 60.3%. Since similar questions have not been examined in empirical research yet, no comparative values are available. There are surveys on whether parcel shops are chosen as delivery addresses (for example Prümm et al., 2018 with a share of 2%). However, these are not comparable with our customer-driven micro depot concept.

In the following, we differentiate this proportion of potential users by spatial and personal characteristics. A methodological challenge arises from the fact that although the full sample is representative with regard to the age and the gender distribution in large cities, this does not necessarily have to be the case with regard to all sub-samples (for example, in sub-samples by district type). Therefore, we apply a probit model to correct possible lack of representativeness. Note that this probit model is not specified with the aim of gaining insight into causal relationships, but to get average adjusted predictions of proportions in different sub-samples (Williams, 2012). In the first step a probit model was estimated to explain the willingness to use the CMD including all possible explanatory variables.[3] In the second step, this model was used to predict average proportions of potential users in different sub-samples (such as different district types, city sizes, age groups etc.) It turns out that several differences in the proportion of potential users in the population between sub-samples are not statistically significant. This is indicated graphically by overlapping confidence intervals.[4]

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[2] The variable "years of schooling" is defined as follows: no school-leaving qualification or secondary modern school: 9, general certificate of secondary education: 10, general qualification for university entrance: 12,5 years, as well as bachelor: + 3, master: + 2, doctorate, +2, completed vocational training: +1,5 years, see therefore Franz (1991).

[3] Estimation results of the probit model are available upon request.

[4] So-called "logit transformed confidence intervals" are shown (either the 90% or 95%). This ensures that the confidence limits are within the [0,1] interval, see Dean and Pagano (2015).

TABLE 4 shows the proportion of potential users of the CMD in percent by district type. *City residential area*s show the highest proportion of potential users (68.7%), followed by *mixed areas* with 62.2%. In *residential areas* this proportion is only 52.7%. This result indicates that *city residential areas* are potentially most suitable for the realization of a CMD project.

TABLE 4 suggests that the proportion of potential users decreases with the city size if the city has more than 200,000 inhabitants. However, these differences are not statistically significant.

In contrast, large and statistically significant are the differences by age group. With increasing age, the proportion of potential users decreases dramatically. In the age group of 18 to 29, the proportion is 76%, in the age group of 40 to 49 it is still 66%. The proportion of potential users declines to 43% in the age group of over 60 years old people.

TABLE 4 furthermore shows the proportion of potential users by choice of means of transport for their way to work. Obviously, the proportion is higher for public transport users (64.3%) and cyclists (69.5%). In contrast, the proportion is lower for people using the car (59.6%) or walking to work (48.9%). On the one hand, these numbers may reflect differences in attitudes towards environmental protection and socio-demographic characteristics (age, income, employment status etc.). On the other hand, it may show practical concerns for those who do not have a car to pick up packages from the CMD (which is one option besides the delivery by cargo bike).

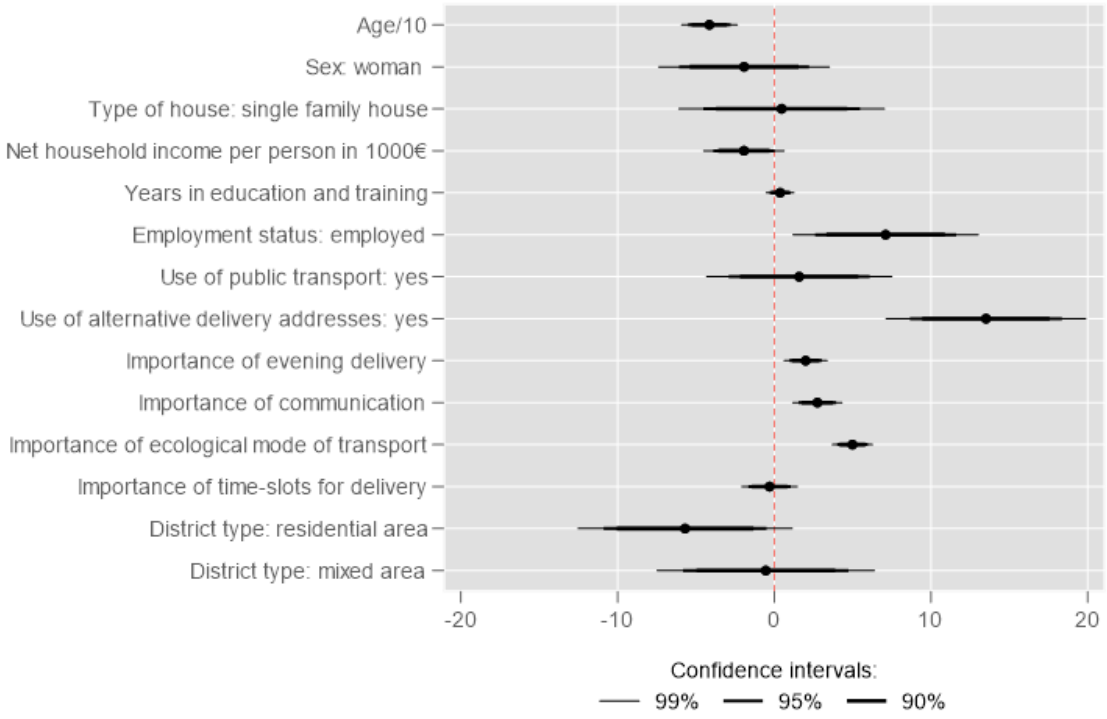
By Variable	Percent	[90% Conf. Interval]	
District type			
City residential area	68.7	65.7	71.6
Residential area	52.7	50.0	55.4
Mixed area	62.2	59.3	65.1
City size			
> 100,000 inhabitants	60.7	57.0	64.3
> 200,000 inhabitants	64.8	59.7	69.9
> 250,000 inhabitants	62.9	58.6	67.2
> 500,000 inhabitants	59.2	55.8	62.6
> 1 mio. inhabitants	58.2	55.3	61.1
Age groups			
18-29	76.3	73.4	79.2
30-39	71.1	68.5	73.6
40-49	66.0	64.0	68.1
50-59	59.1	56.9	61.4
60+	43.2	40.5	45.9
Choice of means of transport (journey to work)			
Car	59.6	57.0	62.1
Bike	69.5	64.8	74.2
Public transport	64.3	61.3	67.3
Walk	48.9	44.9	53.0

Table 4: Proportion of potential users of the CMD in Percent

4.3 Determinants of consumers' willingness to use the CMD

By calculating the proportion of potential users in the last section, it is possible to identify urban areas (city, districts, towns) in which there are many potential users. In this section,

the determinants of the willingness to use the CMD are analysed, in order to better understand what makes people interested. This is done by the means of a probit regression model which is shown in Table A2 in the Appendix. Figure 2 visualizes average marginal effects of explanatory variables on the willingness to use the CMD.



Note: Based on the probit model shown in Table A2 in the Appendix the base categories are: apartment building, not employed (including unemployed, students and retirees), not using public transport, not using alternative delivery addresses, living in a city residential area.

Figure 2: Average marginal effects in percentage points – willingness to use the CMD

The effect of the explanatory variable *age* is significant at the 1%-level. For example, an increase by 10 years reduces the probability to use a CMD by 4 percentage points. The probability to be willing to use a CMD significantly increases by 13 percentage points if interviewees have already used *alternative delivery addresses*. Being *employed* increases the probability significantly by 7 percentage points. The importance of queried parcel delivery services "*evening delivery*, *communication* and *ecological mode of transport*" indicated by the respondents have a significantly positive effect on their willingness to use a CMD. The perceived relevance of the respondents increases the probability by 2 up to 5 percentage points. The perceived importance of the parcel delivery service "*time-slots for delivery*" is not statistically significant. Living in a residential area reduces the probability to use CMD by 6 percentage points compared to living in a city residential area. In contrast, the gender of the interviewees does not matter for the willingness to use the CMD. At first glance, this finding somewhat contradicts previous studies that found that women report greater concerns towards environmental issues than men (see, for example, Fan, 2017) and women have stronger preferences for the environmentally-friendly attributes of vehicles (Sovacool *et al.*, 2019). However, we included variables in our model, which may control

exactly for these differences in preferences by gender. Hence, after controlling for variables such as the “perceived importance and of ecological mode of transport” and “use of public transport” there are no differences between women and men with regard to the willingness to use the CMD.

In summary, we are able to state that younger and employed inhabitants with higher environmental awareness who already use alternative delivery addresses and who live in city residential areas are most willing to use the CMD. For example, the predicted probability of the willingness to use the CMD for a 28-year-old employed person living in a city residential area is 71.4% in comparison to 60.3% in the whole population. If this person already uses an alternative delivery address, then the probability increases further to 80.4%.

4.4 Analyses of consumers’ willingness to pay for the CMD

The willingness to pay was queried directly from the respondents who stated that they wanted to use the CMD. The results from the question "*What would you be prepared to pay for the DeinDepot delivery services per package as a maximum?*" can be seen in Figure 3. Almost 60% of the respondents who have identified themselves as potential users of the CMD have a positive willingness to pay (WTP). For this group the mean WTP is €1.2 (median: 1, sd: 0.67). Among all potential users of the CMD (including those with a zero WTP), the mean WTP is only €0.72.

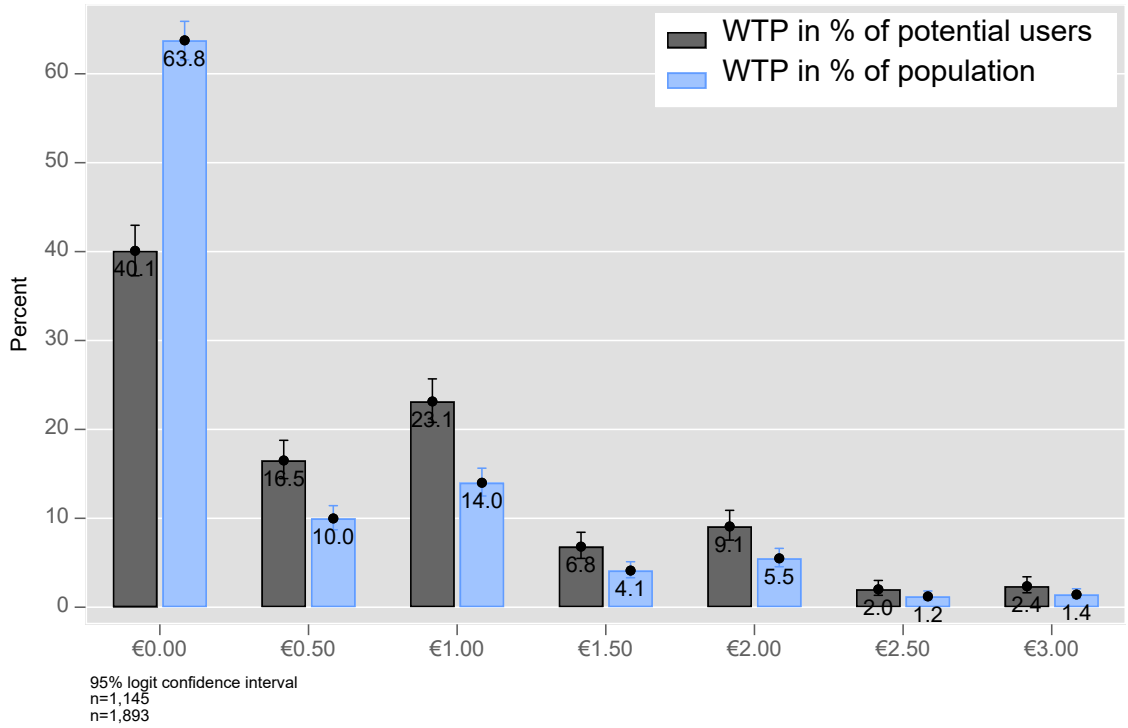


Figure 3: WTP per parcel in percent of potential cmd-users and the entire population

If we look at the entire population in German cities (including those who state *not* to be potential users of the CMD) only 36% are willing to pay to use the CMD (have a positive WTP), since 64% would not accept additional delivery costs as shown in Figure 3. The mean

WTP for the entire population is €0.43 per parcel. 12% would pay at least €1.50, 26% would pay at least €1.00 and 36% €0.50.

In the following, we differentiate the probability of a positive WTP as well as the amount of WTP by spatial and personal characteristics. We do this by estimating a multinomial probit model with the dependent variable "WTP for the CMD" which is explained by several regressors (especially socio-demographic characteristics).[5] Using this we predict adjusted values of the WTP for different subsamples. The reason is again to correct possible lack of representativeness (see Section 3.2).

As shown in Table 5 inhabitants of city residential areas have the highest proportion of a positive WTP with 41.2% on average, followed by mixed areas with 35.8%, and 32.5% in residential areas. 9.4% of the population in city areas are even willing to pay €2.00 or more per parcel. With regard to city sizes, we see almost no differences. In contrast, we can see substantial variation by age groups. In the age group of 18 to 29, the proportion of the population with a positive WTP is 53.3%. In the age group >65 years this proportion is only 18.1%. 39.1% of the 18-29-year-old population is willing to pay at least one euro per parcel. The mean WTP per parcel of those persons with a positive willingness to pay over different subpopulations does not vary strongly. It is in the range between €1.16 and €1.20.

The underlying multinomial probit model can be used to predict values for specific subpopulations. As an example, we predict the values for the 29-year-old population in city residential areas. The results can be seen in the last row of Table 5.

[5] The possible values for our dependent variable are: "CMD negative", which means that the respondent does not want to use CMD, "no WTP", which means that the respondents ticked "nothing", "WTP €0.50", "WTP €1.00", "WTP €1.50", "WTP €2.00" and "WTP >€2.0" if the respondents ticked "€2.0", "€2.50" or "€3.0" in their questionnaires. Estimation results of the multinomial probit are available upon request.

	Proportions of the population			
	with WTP>€0.00	with WTP≥€1.00 per parcel	with WTP≥€2.00 per parcel	Mean WTP per parcel of persons with WTP>€0.00
Total population	36.1%	26.2%	8.1%	€1.18
By district type				
City residential areas	41.2%	30.0%	9.4%	€1.19
Mixed areas	35.8%	26.0%	7.5%	€1.19
Residential areas	32.5%	23.5%	7.6%	€1.16
By City size				
100,000-199.999	35.5%	25.9%	8.5%	€1.20
200,000-249.999	35.8%	25.4%	7.3%	€1.17
250,000-499.999	36.4%	26.5%	8.0%	€1.17
500,000-999.999	36.9%	26.6%	7.9%	€1.14
≥1,000,000	35.7%	26.1%	8.2%	€1.20
Age group				
18-29 years	53.3%	39.1%	11.5%	€1.17
30-64 years	36.5%	26.4%	8.4%	€1.19
≥65 years	18.1%	13.1%	3.9%	€1.16
Example:				
29 years, city residential area	51.6%	35.7%	9.1%	€1.10

Note: Predicted values based on a multinomial probit model.

Table 5: Willingness to Pay – Percent of Population and Mean WTP of People with Positive WTP

5. Importance of delivery services

Previous research mentioned in Section 1.3 indicates that online customers increasingly expect special last mile delivery services (for example, evening delivery, time slots for delivery, ecological transport, etc.). Their WTP for these services is unclear. How does the assessment of the importance of delivery services differ between potential users of the CMD with a positive WTP and persons without a positive WTP?

The survey includes the question "*How important are (would be) the following parcel delivery services to you*?" The respondents were able to tick a value between 1 (*not important*) and 7 (*very important*).

A comparison of mean values (mv) across all respondents (regardless of their willingness to use and pay) showed that the importance of "*time slots for delivery*" is highest with a mv of 5.44. "*Possibility of communication (for example by e-mail, in person or via an app) with the parcel delivery company*" is the second most important attribute (mv = 5.02). The third most important attribute of delivery services is "*evening delivery*" with a mv of 4.28 and least important is "*ecological transport*" with a mv of 4.01.

The following figures show the results for the different attributes (Figure 4 to Figure 7) in detail, differentiated between respondents with a positive WTP and the respondents who either are no potential users of the CMD or have a WTP of zero. For all four attributes, the answers of persons with positive WTP are clearer in favor of importance than the answers of persons with zero WTP. The highest relative difference is with regard to the importance of ecological transport (Figure 7) indicating that persons with a positive WTP care much more for ecological transport.

In summary, it can be concluded that persons with a positive WTP (36% of the population in major cities) differ significantly with respect to their assessment of the importance of delivery services from persons without a positive WTP. All services are more important for persons with a positive WTP. The greatest differences are in the assessment of the importance of ecological transport. This implies that a successful implementation of a CMD requires a target group specific approach to individuals that care for ecological transport, for communication with the parcel delivery company and time slots for delivery.

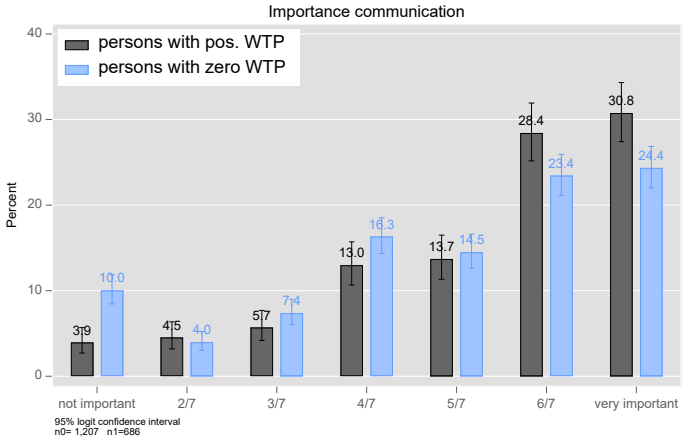


Figure 4: Importance communication

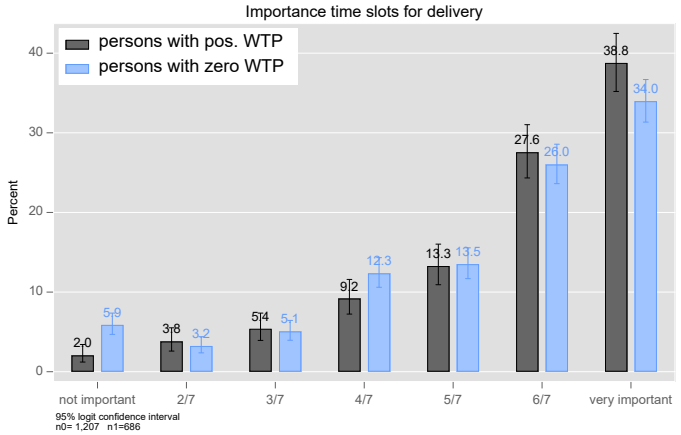


Figure 5: Importance time-slots for delivery

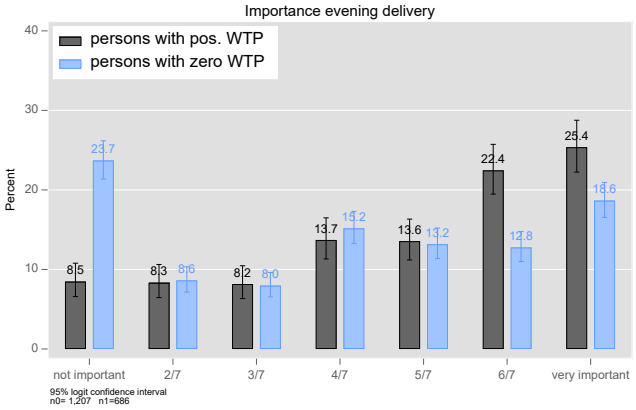


Figure 6: Importance evening delivery

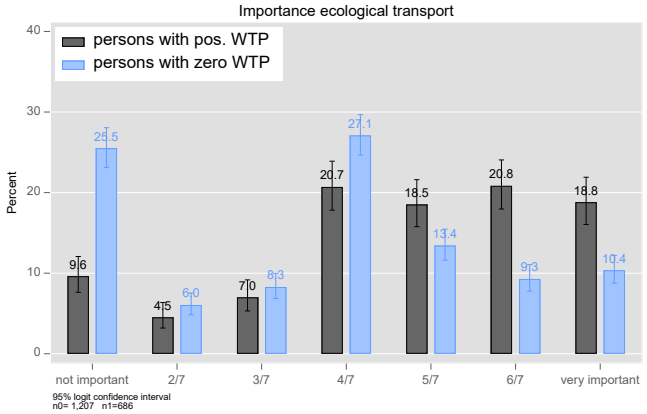


Figure 7: Importance ecological transport

6. Illustrative example for a city district in Frankfurt

As shown in Section 4.4, using the results from our multinomial probit analysis we are able to differentiate WTP by characteristics. In Table 6 these amounts are shown for three age groups highlighting that younger people are more willing to use and to pay for our described CMD.

Willingness to pay	18-29	30-64	≥65
WTP €0.00 or no potential user	46.7	63.5	81.9
WTP €0.50	14.2	10.1	5.0
WTP €1.00	21.7	13.8	7.1
WTP €1.50	5.9	4.2	2.1
WTP €2.00	8.0	5.5	2.8
WTP ≥€2.50	3.5	2.9	1.1

Table 6: Share of willingness to pay amounts by age group – whole sample (all district types)

Following our results for the district type "city residential area" and the three age groups we analyse the potential revenue from the CMD in Frankfurt am Main. We choose the district "Nordend", one of eight city districts in Frankfurt am Main, which is characterized by middle class inhabitants with above average incomes. Given the distribution of inhabitants in this district for the stated age groups, we are able to estimate the proportion for each age group and each WTP-amount. The following calculation is set out in Table A3 in the Appendix.

First, we calculate the number of online customers using the empirical online-shopping-proportions by age group from our dataset. In the age group of the 18 to 29 years-old, 99% have already shopped online. In the age group 30 to 64 this proportion is 97%, and 93% in the age group of the 65 and older. Following this, we calculate the amount of expected monthly parcel deliveries via the CMD. In order to do so, we use the empirical means of online ordered shipments per month by age groups and the willing-to-use-CMD-proportion by age group (76%, 62%, and 40%). This leads us to 17,440 parcels in the age group 18-29, 55,491 parcels in the age group 30-64, and 5,440 parcels in the age group 65 and older. This implies a CMD parcel volume of 3,200 parcels per day of delivery in our chosen district. Finally, we calculate the maximum potential revenues of a CMD in our district by multiplying the age specific WTP proportions with the age specific parcel amounts and the monetary WTP-amounts. This leads to a maximum potential monthly revenue of approximately €39,400.

Is a monthly revenue of €39,400 enough to run a CMD? Firstly, it should be noted that this is a maximum amount for the theoretical and unrealistic case that price discrimination would be perfectly possible. In reality, it is likely that there is one price for all customers, for example €1.00 per delivery.[6] The results of such a consideration are in Table 7, where

[6] There may be other strategies to take full advantage of the willingness to pay, for example, additional services. In order to keep the analysis simple, we ignore this possibility.

the price per parcel P and the corresponding numbers of monthly parcels Q, the monthly revenues $P \cdot Q$, the price elasticity of demand ε as well as other numbers are shown. Not surprisingly, demand (Q) falls as P rises (see Table 7 as well as Figure A2 in the Appendix). The absolute value of the elasticity $|\varepsilon|$ as well as $P \cdot Q$ increase with P up to a $P = €1.00$. If $P > €1.00$, $P \cdot Q$ decrease with increasing P, which is in line with $|\varepsilon| > 1$.[7] Put differently, the price that maximizes monthly revenues is €1.00 per parcel (€24,128).

Price per parcel P	Monthly number of parcels Q	Monthly revenues $P \cdot Q$	Price elasticity of demand ε (arc elasticity)	Parcels per delivery day (assuming 25 days per month)	Number of necessary cargo bikes (assuming 120 parcels per day and bike)
€0.00	53,093	€0		2,124	18
			-0.2		
€0.50	33,110	€16,555		1,324	11
			-0.5		
€1.00	24,128	€24,128		9,65	8
			-1.8		
€1.50	11,441	€17,162		458	4
			-1.4		
€2.00	7,627	€15,253		305	3
			-4.5		
€2.50	2,562	€6,406		102	1

Table 7: Monthly number of parcels, revenues from a cmd and Number of necessary Cargo Bikes in "Frankfurt am Main, Nordend" by Price

Secondly, with an increasing number of deliveries the variable costs increase. As an example for variable costs, Table 7 shows the number of necessary cargo bikes, based on the assumption that there are 25 delivery days per month on average and that a cargo bike can deliver approximately 120 parcels per day (IHK Mittlerer Niederrhein, 2019). Naturally, the number of necessary cargo bikes decreases from 18 in case of a price of €0.00 up to one cargo bike in case of a price of €2.50. The monthly revenues per cargo bike remain constant at €3,000. This quantitative analysis shows that revenue from parcel recipients could be a possible source of revenue in a real customer-driven micro depot setting.

Since no comparable empirical study exists, it is unfortunately not possible to compare this estimated value with other data.

[7] If $|\varepsilon| < 1$ an increase in P leads to an increase in revenues. If $|\varepsilon| > 1$ an increase in P leads to a decrease in revenues.

7. Conclusions and recommendations

The paper has closed a research gap by examining the acceptance and willingness-to-pay (WTP) for an alternative last mile delivery concept, a customer-driven central last mile micro depot (CMD) with cargo bike delivery, from the online customer perspective. The research is based on survey data from the population in German cities, which has allowed to gain insight into the number of potential customers, their WTP, and their preferences with regard to different aspects of the delivery services. With these data and a statistical model, potential revenues of such an alternative delivery concept have been estimated.

While this is not a comprehensive potential analysis, it can be used to draw conclusions and to derive recommendations: A high proportion of the population (60%) would be interested in being customers. However, only 36% of the population in German major cities is willing to pay for it in addition to the usual parcel delivery charges. 26% would be willing to pay €1.00 or more per parcel. This result corresponds to that of some other previous studies mentioned in Section 1.3, according to which there is at least some WTP for additional services (the numbers of these studies are not directly comparable). This proportion of paying users could be increased by focusing on appropriate districts: city residential areas with a young population having an above-average income. We implemented this idea by calculating the WTP and potential total revenues for a district in Frankfurt in Germany, which can be characterised by being a city residential area with a relatively young population and an above-average income. It turns out, that – given certain assumptions – the monthly revenues per cargo bike remain constant at €3,000, which may not be enough to run a micro depot and cargo bikes. This implies, that a micro depot on its own, that is based on delivery fees only, without other sources of income, is not economically viable. Further income sources are necessary. So, a CMD could be integrated e.g. within an existing convenience store or a petrol station to achieve synergy effects (Iwan *et al.*, 2015).

Additionally, every alternative delivery concept must take into account consumer preferences: for all respondents most important are time slots for delivery as well as the communication between consumers and the parcel delivery companies. In contrast, ecological aspects are less important. People with a positive willingness to pay (WTP) for the CMD differ significantly with regard to their assessment of the importance of delivery services from people without a positive WTP. Above all, they care much more for ecological transport. The other service aspects are also more important for persons with a positive WTP.

In conclusion, we have shown that some e-consumers in cities are quite willing to contribute a certain amount to the last mile costs. This implies that a successful implementation of a CMD requires a target group specific approach to young individuals with above-average income living in city residential areas who care for ecological transport, for communication with the parcel delivery company, and time slots for delivery. This insight can help stakeholder groups to develop innovative last mile delivery concepts.

Further research should assess if potential CMD-users would accept a monthly CMD-flat rate. Furthermore, a comprehensive potential analysis has to be conducted including a cost analysis integrating technical aspects as well as geographical characteristics of the specific area.

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9. Appendix

Factors	DeinDepot
1. Objectives of the UCC:	
– reducing road freight traffic levels	Reducing goods vehicle movements through consolidation from different parcel service providers and modal shift to cargo bikes.
– altering road goods vehicle types used	Cargo bikes instead of delivery trucks.
– reducing the environmental impacts associated with goods vehicle activity	Use of environmentally-friendly vehicles (cargo bikes).
– improving the efficiency of urban freight transport operations (through improved load factor, and the need for fewer deliveries)	Bundled and environmentally friendly last mile delivery. Parcel service providers have, for example, fewer stops because they no longer have to deliver parcels individually in the DeinDepot delivery area.
– reducing the need for goods storage and logistics activities at urban premises which could result in improved turnover	Multiple delivery attempts due to absence of parcel recipients are avoided.
2. Location of the UCC	Within the area served.
3. Spatial coverage of the UCC	District or part of a district. Spatial coverage depends on factors such as the size of DeinDepot's storage facilities, the number and types of cargo bikes, etc.
4. Range and type of products handled	All types of parcels as long as they can be delivered by cargo bike (package size vs. loading capacity) and as long as no special storage or transport is necessary.
5. Transport modes utilised	Conventional delivery truck to the DeinDepot; from there deliveries with cargo bikes.
6. Range of additional activities provided	Additional offered activities are possible and depend on the specific DeinDepot-business model and its explicit design, for example, laundry or concierge services.
7. Flexibility of operations, for example fixed delivery schedules or on demand	Fixed delivery schedules as well as desired delivery time slots are possible.
8. Ownership and operation of UCC	Private company
9. Finance issues, particularly the nature of any financial support	Not yet considered, municipal funding opportunities have to be examined.
10. Responsibility for transport operations	Various business models are conceivable, for example, DeinDepot operator takes over delivery on the last mile or commissions bicycle delivery staff.
11. Degree of permanency of the centre and its operations	Designed for long-term business operations.
12. Role of local authorities and other public sector bodies	No yet considered. The involvement of local authorities or other public sector bodies is not a necessary condition.
13. Compulsory or voluntary	Online customers can use DeinDepot voluntarily.
14. Freestanding initiative or incorporated into the widerpolicy and regulatory framework of an urban area or region	Freestanding initiative.

*) According to Browne *et al.* (2005)

Table A1: Characterisation of DeinDepot with regard to the Factors influencing the Nature of a UCC*

Pseudo R^2	0.148
No. obs.	1,880
age (years/10)	**-0.041*****
gender (woman)	*-0.019*
house type (single family house)	*0.004*
net household income per person in €1,000	**-0.019***
years in education/training	*0.004*
employment status (yes)	**0.071*****
use of public transport (yes)	*0.016*
use of alt. delivery addresses (yes)	**0.135*****
importance of evening delivery	**0.020*****
importance of communication	**0.028*****
importance ecological transport	**0.050*****
importance time slots for delivery	*-0.003*
district type: residential area	***-0.057*****
district type: mixed area	*-0.005*
***, **, *: significant at the 1, 5, 10 percent level	

Table A2: Factors influencing the potential use of CMD (Probit Modell)

	WTP proportion by age group			Monthly CMD-revenue by age group		
Willingness to pay	18-29	30-64	≥65	18-29	30-64	≥65
WTP €0.00 or CMD negative	44.3%	59.9%	79.6%	€0	€0	€0
WTP €0.50	15.3%	10.8%	5.9%	€1,334	€2,997	€160
WTP €1.00	22.4%	15.0%	8.4%	€3,906	€8,324	€457
WTP €1.50	6.2%	4.7%	2.3%	€1,622	€3,912	€188
WTP €2.00	8.5%	6.2%	2.6%	€2,965	€6,881	€283
WTP ≥€2.50	3.5%	3.4%	1.2%	€1,526	€4,717	€163
Potential monthly CMD-revenues by age group				€11.353	€26.830	€1.251
Overall monthly CMD-revenue					**€39,434**	

Table A3: Amount of willingness to pay by age group and Maximum potential monthly revenue from a cmd in "Frankfurt am Main, Nordend"

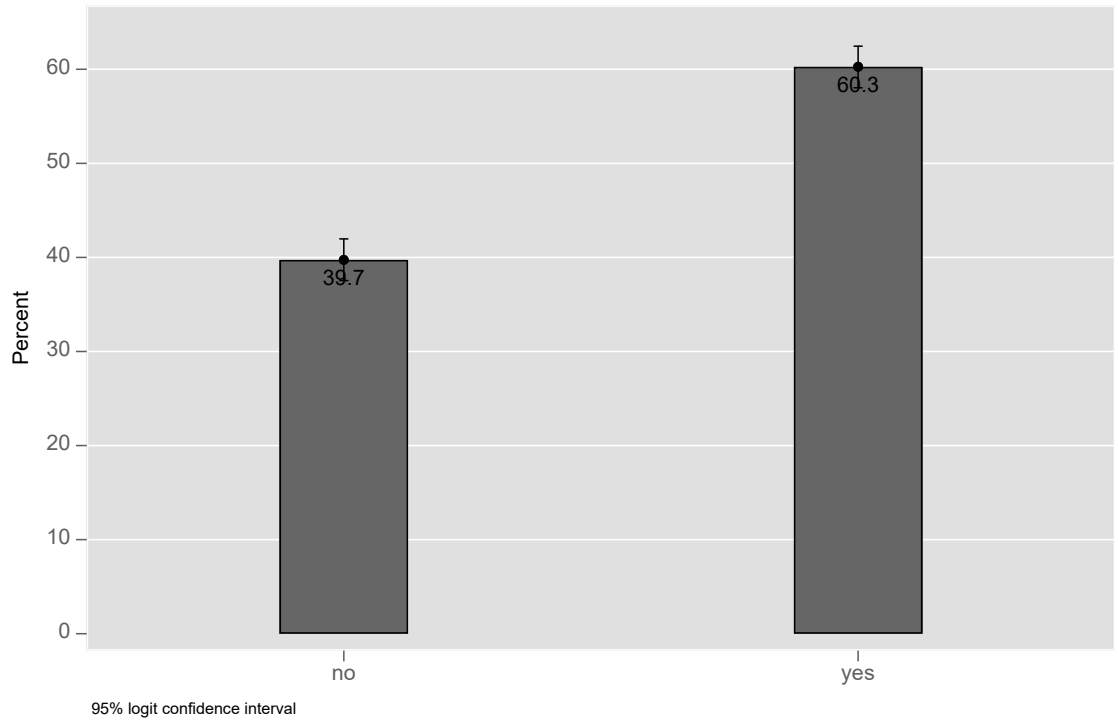

Figure A1: Proportion of potential users of the CMD

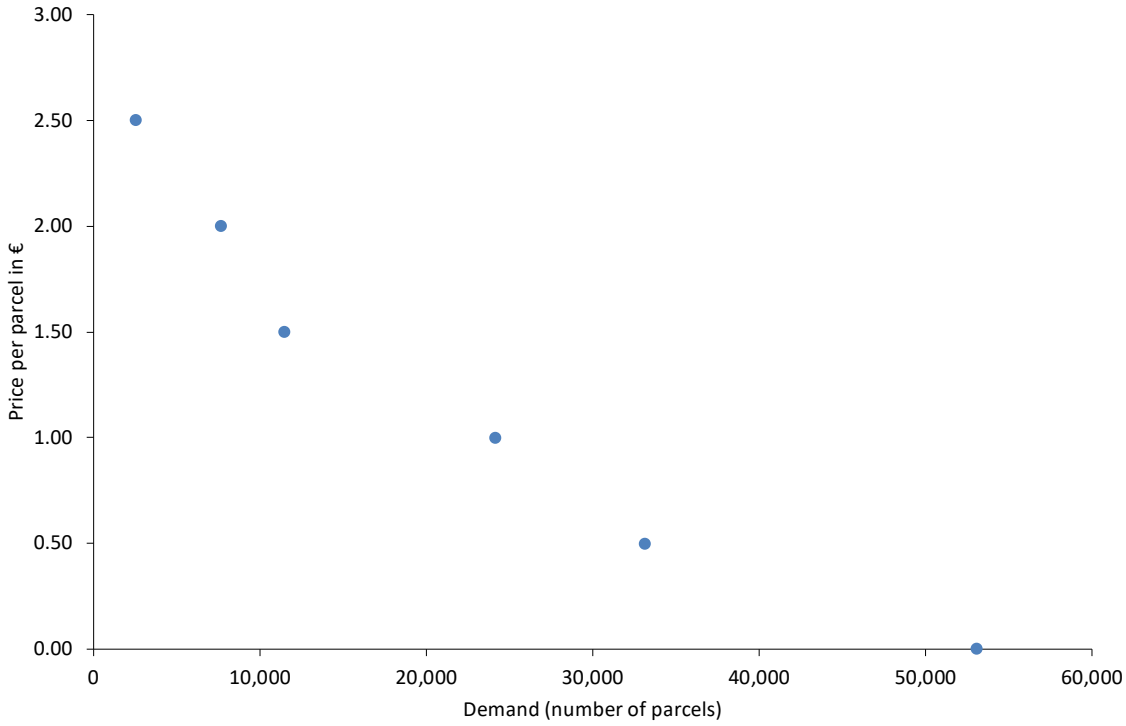

Figure A2: Price and Corresponding Potential Demand

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