

Chapter 2

Behavioural Influences on the Environmental Impact of Collection/Delivery Points

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Abstract For more than a decade, business-to-consumer parcel deliveries have been growing rapidly. Despite this, the ‘last mile’ of the supply chain, which involves the final physical transfer of goods to the customer, is particularly problematic for many customers, as delivery times are often unpredictable and/or not convenient. An increasingly prevalent alternative to conventional delivery is the collection/delivery point (CDP), where parcels are delivered to a CDP of the customers’ choosing, and picked up at a more convenient time. From an environmental perspective, CDPs can reduce failed deliveries and allow consolidation of the delivery schedules. However, a full environmental assessment should also consider the customers’ movements required to make the pickups. In this chapter, competing delivery and pickup offerings are framed in terms of the utility that each provide to the customer. A random parameter error components logit model is estimated, using stated choice survey data, to uncover what is influencing the choice of these market offerings. The last mile alternatives investigated extend beyond a pickup-conventional delivery dichotomy, to include alternative CDP locations, pickup access modes, and ways in which the pickups might be integrated into existing travel. We find that changing the price, quality and location of the CDP and delivery offerings can disproportionately influence more environmentally friendly means of picking up from CDPs, such as walking, cycling, and integrating the pickup into an existing car trip. This provides the groundwork for a more complete, behaviourally informed quantification of the last mile parcel delivery and pickup environmental footprint.

Keywords Parcel delivery • Last mile • Collection/delivery point • Environmental impact • Mode choice • Trip chains • Time windows • Online shopping

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2.1 Introduction

For more than a decade, business-to-consumer parcel deliveries have been growing rapidly, driven to a large extent by a corresponding growth in e-commerce. However, the ‘last mile’ of the supply chain, which involves the final physical transfer of goods to the customer, is particularly problematic for many customers. Failed deliveries are common, notwithstanding some market moves to extend delivery hours and narrow delivery time windows. An alternative to conventional delivery that has become increasingly prevalent is the collection/delivery point (CDP). Parcels are delivered to a CDP of the customers’ choosing, which is either a locker, or an existing business. The parcel is then picked up at the customers’ convenience. CDPs have been adopted in a number of countries, including Germany (e.g., DHL Packstation), the United Kingdom (e.g., CollectPlus) and The Netherlands¹ (e.g., Kiala). The uptake has been more recent in Australia, where the government owned postal service Australia Post has introduced both parcel lockers, and a parcel pickup option from existing post offices. The leading competitor to their service, ParcelPoint, offers pickup from existing businesses.²

Of interest is what is driving the uptake of CDPs, and what will lead consumers to choose CDPs over conventional delivery, given that the two are often in competition. Last mile parcel delivery can be viewed as a customer oriented service with a strong behavioural component. Different delivery and pickup alternatives provide different amounts of utility, and the consumer chooses an alternative so as to maximise their utility, subject to various constraints that are imposed on them, such as when they can accept a delivery, and what modes they have available to travel to a CDP. A CDP has various sources of utility and disutility, including those based on location (distance from the customer, parking availability, etc.), quality (opening hours, days before returned to sender, etc.), and cost. Conventional delivery also provides a mix of product features and price. Decisions must be made by CDP providers as to what sort of CDP network to assemble, with decisions made on each of these utility bearing product features.

The decisions that CDP providers make regarding their network will also have an impact on the environmental footprint of the last mile. Contributions to this footprint will come from the delivery of parcels either to the end customer as with conventional delivery, or to the CDP locations under the CDP model. From the environmental perspective of the carrier, the CDP approach greatly reduces failed deliveries, and allows consolidation of the delivery schedules to only include CDP locations. At the holistic level, offsetting these advantages are the customers’ movements required to make the pickups, where a full environmental assessment of the end-to-end supply chain would also consider these pickup movements. This is complicated by the possibility of incorporating car pickup trips into existing trip

¹See Weltevreden (2008) for analysis of the uptake of CDPs in The Netherlands.

²As this book went to press, Australia Post had approximately 180 parcel lockers and 3500 collection points across Australia, while ParcelPoint had over 1300 locations.

chains, where this could greatly reduce or even eliminate the environmental impact of the pickup. This has been recognised in the context of store shopping (Mokhtarian 2004), and applies also to pickup from a CDP (McLeod et al. 2006). Further, where a shopping trip is made by walking, cycling or public transport, the environmental footprint is either eliminated or greatly reduced (Keskinen et al. 2001). Again, this logic extends to pickup from a CDP. Therefore, an assessment of the extended environmental impact of CDPs should consider the mode choice of the customer making the pickup, as well as their trip chaining behaviour. Again these are behavioural influences, and the location, quality and price of the CDPs, as well as the quality and price of any competing delivery service, will have an impact on choice of delivery or CDP, mode choice, and trip chaining choice, all of which have environmental consequences.

Several existing studies have considered the environmental impact of last mile parcel delivery. McLeod et al. (2006) considered CDPs as an alternative to re-delivery after a failed delivery attempt, rather than an independent last mile alternative available to the consumer. They calculated the total delivery and pickup distance travelled under alternative scenarios, varying factors such as the delivery failure rate and CDP network configuration. However, by not considering CDP use as an explicit choice on the part of the consumer, with conventional delivery as a competing alternative, their simulations do not capture the market dynamics of CDP offerings in many parts of the world. McLeod and Cherrett (2009) extended this approach by determining a variety of emission impacts, including carbon dioxide and particulates.

The last mile footprint investigated herein will only consider parcel delivery. A more complete modelling effort might also include conventional shopping as another choice alternative, along with the associated environmental footprint stemming from shopping trips. Various studies have considered the choice of store shopping versus e-shopping with conventional delivery. Rotem-Mindali and Salomon (2007, 2009) did so with revealed preference data, while Hsiao (2009) did so with stated preference data. However, this chapter will instead focus on the nuance of alternative delivery options conditional on already making a purchase that requires parcel delivery.

The chapter will investigate the environmental footprint of the last mile of parcel delivery from a behavioural perspective. Competing delivery and pickup offerings will be framed in terms of the utility that each provide. A discrete choice model will be estimated, using stated choice survey data, to investigate what is influencing the choice of these market offerings. The last mile alternatives investigated will extend beyond a CDP-conventional delivery dichotomy, to include various ways in which pickups from CDPs might be integrated into existing travel patterns. The environmental footprint will be evaluated in terms of the propensity of customers to choose environmentally friendly alternatives. A final assessment in terms of VKT or emissions will not be provided, but the methodology herein provides a framework in which such simulations could incorporate the behaviour of the customer, thus quantifying the total environmental footprint given the probabilistic choice over a number of market offerings.

2.2 Data

This chapter utilises data collected from a survey that was run in Sydney, Australia in June 2014. The survey was conducted online, with respondents recruited through an online research panel. To be eligible for the survey, respondents had to be 18, live in the Sydney metropolitan area, and have had at least one parcel delivered for non-work purposes in the most recent 12 months. After some respondents were omitted due to concerns about excessively fast survey completion, a sample of 504 respondents remained. A good coverage was achieved in terms of geographic spread over the Sydney region, and the sample was broadly representative in terms of gender and age. The survey contained questions on household composition, the frequency with which someone in the household is at home through the day, regular and online shopping patterns, work status and hours, car availability, work and regular grocery shopping location, and socio-demographic characteristics.

Stated choice methods work by presenting decision makers with a set of hypothetical alternatives, and asking them to make a choice between them (Louviere et al. 2000). Multiple such choice tasks are typically presented to every decision maker. The choice tasks form a key part of this survey, as they facilitate choice between alternative hypothetical delivery and CDP offerings, and allow systematic influences on this choice to be modelled (the model applied will be introduced in Sect. 2.3). An example choice task is presented in Fig. 2.1.

First, the scenario surrounding the choice task was framed. Each of the six choice tasks presented to the respondents involved the recent purchase of a particular good that needed to be either delivered or picked up from a CDP. Three broad types of goods were presented with two choice tasks apiece, where they differed by weight and value: a bulky item worth about \$80 AUD, a book worth about \$45, and a non-bulky electronic item worth about \$500.

Four elemental alternatives were presented: delivery, pickup from home, pickup from work, and pickup from the respondents' regular grocery shopping location. If neither they nor their partner worked, the work alternative was omitted. The respondents were asked to only consider the three or four alternatives presented, and not consider any real market offerings available to them. Three distinct CDP locations were potentially presented because it is likely that each of these would be integrated into daily travel patterns in different ways, and thus the behavioural response to changes in CDP location, quality and price may differ accordingly.

Of the further questions asked of the respondents within each choice task, two are of particular interest in this study. They were only asked in choice tasks in which one of the pickup alternatives was selected. First, whether they or someone in their household would make a dedicated pickup trip, or whether they would try and include it in an existing trip, and second, the mode of transport they would use for the pickup: car, walk, bike or public transport. It is reasonable to expect that such decisions will not always be the same, as circumstances and constraints in the household will vary day to day and week to week. Thus, part of the scenario formation in this study was for the survey software to pick a random day over the next

Please imagine the following scenario:

- About a week ago you purchased a **bulky item**, such as a household item, a sporting item, or a six pack of wine.
- The item is worth about \$80, and weighs about 8kg, so is not easy to carry.

When you made the purchase, you were only told that delivery would be roughly 1-2 weeks.
Look at the 4 delivery and pickup options below, and the features and information provided for each.
However, do not consider any real delivery or pickup options that may be available to you - assume that these 4 are your only options.
You can [click here](#) to revisit an explanation of the available options, and their features.

First select the delivery or pickup option you would have chosen at the time of purchase.

	Delivery		Pickup		
			From home	From work	From regular grocery shopping location
Delivery charge	\$9.50	Delivery charge	\$11.00	\$8.00	\$11.00
Delivery day	No choice, next 3 weekdays, no advanced notice	Days before returned to sender	4 days	14 days	4 days
Time window, weekdays	No choice, 9am-5pm	Opening hours (7 days/week)	9am - 9pm	9am - 6pm	9am - 6pm
Time window, Saturday		Distance from home/work	2.0km	1.2km	4km
		Parking	Difficult some of the time	Easy at all times	Difficult some of the time
		Locker or service point	Locker	Locker	Service

a. I would choose:

☐ Delivery

☒ Pickup - From home

☐ Pickup - From work

☐ Pickup - From regular grocery shopping location

b. If these were your only delivery and pickup options, would you still have made the purchase?

☒ Yes

☐ No

This next Tuesday you receive notice that the item will be available for pickup from the next day, **Wednesday**.

Now, answer the following questions about how you or someone in your household would make the pickup.
You may want to consider your likely schedule from the Wednesday onwards when making your choices.

c. What day would the pickup likely be made?

d. What time would the pickup be made?

e. How would the pickup fit into your/your household's existing travel?

☒ I would make a dedicated trip for the pickup

☐ I would try and include the pickup in an existing trip

☐ Someone else in my household would make a dedicated trip for the pickup

☐ Someone else in my household would try and include the pickup in an existing trip

f. How would the pickup be made?

Fig. 2.1 Example choice task

week from which the parcel becomes available for delivery or pickup. The respondent can thus answer these supplementary questions subject to whatever constraints they may have in the days subsequent. Thus, whilst the choice alternatives remain purely hypothetical, the personal constraints that may very well influence the choice of delivery or CDP remain real and consideration of these was encouraged.

Each of the alternatives were described by various attributes, where each can assume a number of possible levels or states. The attributes and their levels are listed in Table 2.1. The range of possible delivery charges depended on whether the scenario was for the delivery of a book (lower range), or bulky items or an electronic item (higher range). The distances of the CDPs were shorter from work than from home. Constraints were imposed on the delivery quality attributes, so that the ‘no advanced notice’ and ‘morning notice of delivery’ attribute levels for delivery

Table 2.1 Attribute levels in choice tasks

Attribute	Delivery	CDP	Attribute levels
Delivery charge	X	X	\$4.00 AUD, \$5.00, \$6.00, \$7.00 (books) \$8.00, \$9.50, \$11.00, \$12.50 (bulky or electronic items)
Delivery day	X		No choice, next 3 weekdays, no advanced notice No choice, next 3 weekdays, morning notice of delivery that day Choice of 1 of the next 5 weekdays Choice of 1 of the next 5 weekdays, or Saturday
Time window, weekdays	X		No choice, 9 am–5 pm Choice of a 4 h window (9 am–1 pm or 1 pm–5 pm) Choice of a 2 h window (8 am–10 am, ... , 4 pm–6 pm) Choice of a 2 h window (8 am–10 am, ... , 6 pm–8 pm) Choice of a 2 h window (6 am–8 am, ... , 4 pm–6 pm) Choice of a 2 h window (6 am–8 am, ... , 6 pm–8 pm)
Time window, Saturday	X		Blank Choice of a 2 h window (10 am–noon, ... , 2 pm–4 pm)
Days before returned to sender		X	2, 4, 7, 14 days
Opening hours (7 days/week)		X	9 am–6 pm, 9 am–9 pm, 7 am–6 pm, 7 am–9 pm, 24 h
Distance from home/work		X	0.5, 1.0, 1.5, 2.0 km (home) 0.3, 0.6, 0.9, 1.2 km (work)
Parking		X	Easy at all times, difficult some of the time, difficult most of the time
Locker or service point		X	Locker, service

day only coexisted with the ‘no choice’ level for the time window. The option of Saturday delivery was only possible with two hour time windows. Narrow time windows were deemed an important delivery feature to include in the choice tasks, as they are recognised as being valued by the customer, but also impose a significant cost burden on the carrier (Cullinane 2009). Further, narrower windows will lead to a worse environmental impact. The experimental design, which determines the specific combinations of attribute levels to present in each choice task, was generated with the Ngene software package, as an efficient design with optimisation on the *d*-error of the design (Rose and Bliemer 2009).

2.3 Methodology

This chapter will utilise a random parameter error components logit (RPECL) model. For a more detailed exposition of this model, the reader is referred to Train (2009). The objective is to estimate a model that can explain the choices between a

set of J discrete alternatives, for a sample of N decision makers. Each decision maker n will derive some utility U_{nj} from each alternative j , where

$$U_{nj} = \alpha'x_{nj} + \beta'_ny_{nj} + \mu'_nz_{nj} + \varepsilon_{nj}.$$

In this generalised utility function, x_{nj} , y_{nj} and z_{nj} are vectors of observed variables related to the alternative j and decision maker n , α is a vector of fixed coefficients representing the tastes of the sample as a whole, β_n is a vector of coefficients representing the tastes of decision maker n , μ_n is a vector of random terms with zero mean, and ε_{nj} is an independently and identically distributed (IID) extreme value error term representing unobserved influences on choice.

The two vectors that vary over the decision makers, β_n and μ_n , do so with densities $f(\beta)$ and $f(\mu)$ respectively. The shape of $f(\beta)$ gives an indication of the nature of the preference heterogeneity across the decision makers, and forms the ‘random parameter’ component of the model. The assumed shape of density $f(\beta)$ is determined by the analyst, and controlled by one or more structural parameters to be estimated. Density $f(\mu)$ represents the ‘error components’ (ECs). It is typically specified as a normal distribution, and relaxes the IID restriction of ε_{nj} . By introducing the normal disturbances into subsets of alternatives, the unobserved component of utility can be correlated across alternatives. This can result in potentially more realistic substitution patterns between the alternatives, such that as the probability of one alternative changes due to a change in some systematic influence on utility, the percentage change in probability of the remaining alternatives need not be identical. Instead, some alternatives may draw disproportionately.

It is necessary to integrate over the three densities, $f(\beta)$ and $f(\mu)$ and ε_{nj} . Integration can be performed analytically for ε_{nj} . The choice probability for alternative i conditional on any given values of β and μ can be expressed as

$$L_{ni}(\beta_n, \mu_n) = \frac{e^{\alpha'x_{ni} + \beta'_ny_{ni} + \mu'_nz_{ni}}}{\sum_j e^{\alpha'x_{nj} + \beta'_ny_{nj} + \mu'_nz_{nj}}}.$$

Integration of $f(\beta)$ and $f(\mu)$ is typically performed with simulation, resulting in a choice probability of

$$P_{ni} = \iint \left(\frac{e^{\alpha'x_{ni} + \beta'_ny_{ni} + \mu'_nz_{ni}}}{\sum_j e^{\alpha'x_{nj} + \beta'_ny_{nj} + \mu'_nz_{nj}}} \right) f(\beta, \mu) d\beta d\mu.$$

We employ Halton draws to boost the efficiency of the simulation, and have selected 500 draws.

Stated choice datasets typically contain multiple observations per respondent. The panel nature of these data can be accommodated in the RPECL model. Consider a sequence of alternatives being observed across T choice tasks, $\{i_1, \dots, i_T\}$. The probability of this sequence being observed is

$$L_{n\{i_1, \dots, i_T\}}(\beta_n, \mu_n) = \prod_{t=1}^T \frac{e^{\alpha' x_{ni_t} + \beta'_n y_{ni_t} + \mu'_n z_{ni_t}}}{\sum_j e^{\alpha' x_{njt} + \beta'_n y_{njt} + \mu'_n z_{njt}}},$$

and after integration of $f(\beta)$ and $f(\mu)$, the final choice probability becomes

$$P_{n\{i_1, \dots, i_T\}} = \iint \left(\prod_{t=1}^T \frac{e^{\alpha' x_{ni_t} + \beta'_n y_{ni_t} + \mu'_n z_{ni_t}}}{\sum_j e^{\alpha' x_{njt} + \beta'_n y_{njt} + \mu'_n z_{njt}}} \right) f(\beta, \mu) d\beta d\mu.$$

A simulated log-likelihood (SLL) function can be expressed as

$$SLL = \sum_{n=1}^N d_{n\{i_1, \dots, i_T\}} \ln P_{n\{i_1, \dots, i_T\}},$$

where $d_{n\{i_1, \dots, i_T\}}$ is an indicator variable, set to one if respondent n chooses the sequence of alternatives $\{i_1, \dots, i_T\}$. The model can be estimated by maximising this SLL.

Several points need to be made regarding the specification of the utility functions in the models to be estimated. Not all of the attributes of the choice alternatives entered into x_{nj} and y_{nj} will directly correspond to the attributes and levels specified in Table 2.1. Some will be recoded to get the most meaningful outputs and model fit. Population density (a characteristic of the decision maker and their household) will also be employed, as will the type of good specified in the scenarios used to frame the choice tasks (e.g. bulky goods). Other decision maker and household characteristics were not tested, however entering these variables either as main effects or interactions with choice task attributes would allow market segments to be identified, and the analysis could be disaggregated to these segments.

In terms of model outputs, of interest is what is systematically influencing utility and hence choice. Willingness to pay (WTP) measures could be calculated but will not be a focus of this chapter. Elasticities can be calculated to determine the percentage change in choice of an alternative, in response to a percentage change in a particular attribute. However, given the often categorical nature of the attributes and their levels, a more useful approach is to calculate choice shares for each alternative for various scenarios, and compare the changes in these shares. A caveat must be issued since with the stated choice data employed herein, it is not possible to calibrate the model constants. While the exact market shares should be treated with caution, the relative changes in shares of the alternatives are useful, especially where they have environmental implications. The error components in the model play a particularly useful role in accommodating complex substitution patterns across the alternatives.

The proposed methodology cannot quantify the final VKT for carriers and customers under different scenarios. Such an approach, extended to include the behavioural realism proposed in this chapter, will be discussed in Sect. 2.5. However, the scenarios will give indicative shifts between various last mile choices by the customer, where each will have varying levels of environmental impact.

2.4 Results

2.4.1 Model Specification and Results

The RPECL model is reported in Table 2.2. The table lists each parameter estimated, and its associated *t*-ratio, together with markers indicating under which of the 10 alternatives those parameters enter into the utility expressions of the choice model. The reported model constitutes a highly significant improvement in model fit over both a constants only model, and the MNL model that omits the random parameters and error components.

Recall that each choice task presented a scenario which involved the delivery of a particular type of parcel. It is found that there is a tendency to choose the three other pickup mode (walk, cycle, public transport) alternatives less when the scenario involves a bulky parcel. This parameter was specified with a constrained triangular distribution, and thus there is heterogeneity in terms of how much the bulky parcel matters. This finding is plausible, as a bulky item is likely to be difficult or inconvenient to carry, and the extent of this inconvenience is likely to vary across individuals. The finding suggests that the type of product might influence the environmental impact over the last mile.

The cost of the delivery was also specified as a constrained triangular random parameter. As expected, the parameter is negative and highly significant. The magnitude of the coefficient is not so meaningful in itself. A more intuitive way to interpret it is by considering how much respondents are prepared to trade off other delivery and pickup features, by calculating WTP measures. This will not be the focus of this chapter, but we will report them for the various delivery quality features.

The key utility generating features of the delivery alternative centre on provision of advanced notice of a delivery date, the ability to choose a delivery time window, and the width of the window. These features were dummy coded, with two hour windows forming the base level. Coefficients for no notice of delivery, advanced notice, and four hour windows of -1.278 , -0.924 and -0.67 , respectively, suggest that any deterioration in quality from the two hour windows will lower the probability of choosing delivery. The addition of a late delivery option (6 pm–8 pm) will increase the probability of choosing delivery. This will be investigated in one of the scenarios in Sect. 2.5. These coefficients can also be expressed as the mean WTP to transition from each of the product features to two hour windows. In the same order as above, these WTP values are \$1.46, \$1.06, and \$0.77. A further \$0.56 could be extracted by offering late delivery. So for example, the average customer would be prepared to pay $\$0.77 + \$0.56 = \$1.33$ to narrow the time windows from four hours to two hours and have a late delivery option. These values can be compared to the increased cost of delivery, for example that incurred by imposing narrow time windows on the vehicle routing, to see if these delivery features are commercially viable.

As well as a preference for a late time window, there is evidence that shopping opening hours beyond 6 pm is likely to increase the share of driving trips to a

Table 2.2 Model results

	Param.	t-ratio	Alternative membership									
			Delivery	Home car ded.	Home car exist.	Home other	Work car ded.	Work car exist.	Work other	Shop car ded.	Shop car exist.	Shop other
Cost ^a	-0.875	-23.23	X	X	X	X	X	X	X	X	X	
Bulky parcel scenario ^a	-1.573	-8.74				X					X	
No notice of delivery ^b	-1.278	-6.10	X									
Advanced delivery notice ^b	-0.924	-4.44	X									
4 h time windows ^b	-0.670	-2.98	X									
Late delivery (6–8 pm)	0.487	3.42	X									
Open late (after 6 pm)	0.260	1.57							X	X		
Days before return to sender	0.031	2.00								X		
Parking difficult mostly/sometimes	-0.619	-3.83		X	X							
Parking difficult mostly	-0.769	-2.38					X	X				
Parking difficult sometimes	-0.397	-1.52					X	X				
Parking difficult mostly	-1.022	-2.88								X		
Distance (km)	-0.482	-3.15				X						
Distance (km)	-1.242	-4.24										
Distance (km)	-0.195	-5.95									X	
Population density ^c	0.155	3.18				X						
Population density ^c	0.165	3.41										
Population density ^c	-0.089	-1.27								X		
Population density ^c	0.245	5.01									X	

(continued)

Table 2.2 (continued)

	Param.	t-ratio	Alternative membership									
			Delivery	Home car ded.	Home car exist.	Home other	Work car ded.	Work car exist.	Work other	Shop car ded.	Shop car exist.	Shop other
ASC ^d 1	-4.072	-15.13	X									
ASC 2	-3.544	-15.23			X							
ASC 3	-2.903	-9.72				X						
ASC 4	-5.189	-15.91					X					
ASC 5	-4.378	-14.70						X				
ASC 6	-3.011	-8.45							X			
ASC 7	-4.587	-16.12								X		
ASC 8	-3.584	-10.25									X	
ASC 9	-4.180	-13.20										
Error component 1	2.287	14.75	X	X	X	X	X	X	X	X	X	
Error component 2	0.751	3.59	X	X	X	X						
Error component 3	1.369	7.76					X	X				
Error component 4	1.594	10.13								X	X	
Error component 5	2.076	11.17	X	X	X		X	X		X		
Error component 6	2.079	10.98	X				X			X		
Model fit												
LL		-3726.87										
LL (MNL)		-4432.03										
Pseudo r-squared		0.464										
AIC/N		2.491										
Number of parameters		34										
Number of respondents		504										

^aConstrained triangular random parameter. ^bBase level of 2 h time windows. ^c1000 people/km². ^dAlternative specific constant

shopping centre CDP, although the statistical significance of this relationship is marginal. The impact was not detected on other modes of transport to the shopping location, suggesting that extended opening hours may disproportionately favour less environmentally friendly modes when a parcel pickup is made. The days before the parcel is returned to sender (RTS) was only found to have a significant influence for pickup from a shopping location in an existing trip, with more days making this alternative more attractive. This is quite plausible, as people may wish to fit the pickup into their regular shopping trip, and short RTS periods, especially those under seven days, are likely to prevent such a pickup. Thus, longer RTS periods at shopping locations should have an environmental benefit, particularly since there is likely to be no extra VKT from an existing trip to a shopping location (and unlike existing trips from home and work, where the pickup may be integrated into a trip chain, with some degree of detour from the existing route).

Parking influences are evident for all CDP alternatives with car access. From home, there is no estimable distinction between difficult parking some of the time and most of the time. Such a distinction can be made for CDP pickup from work, although the significance of difficult parking some of the time is marginal. For shopping, there is only significance for difficult parking most of the time, suggesting that if parking is difficult only some of the time, and difficult parking matters to them, they might choose a shopping time in which there is adequate parking. Clearly, an increase in car trips has negative environmental impacts. One scenario will test the impact of a change in parking.

The distance of the CDP from home or work was only significant for the other modes. This may have been due to the range of distances employed in the stated choice tasks (0.3–2 km), which may have been too short to have any impact on driving. Distance appears to have a much greater impact on utility for pickup from work. However, the alternative specific parameters must be interpreted in the context of those alternatives, and the impact of the distance is best tested in the simulations. In terms of the propensity to utilise other modes for pickup, over and above the measurable impact of distance, population density also has an influence. The greater the population density at the home, work or shopping location, the more likely the individual is to take other modes. There are numerous possible reasons for this, including a higher quality of public transport supply and walking and bicycling infrastructure, habit formation as other trip attractions are also more likely to be within walking and cycling range, and home and work self-selection whereby those with a higher propensity to use these other modes will locate themselves where these modes are more prevalent or easier, i.e. in regions with higher population density. Higher population density is also associated with a lower share of existing shopping trip pickup, although the influence has low statistical significance.

The constants must be interpreted carefully, since they are in part a consequence of the stated choice approach. Nonetheless, they do imply that delivery is a dominant alternative. More interesting are the error components, which allow for greater rates of substitution between various subsets of the alternatives. Six ECs are found to be significant. One encompasses all pickup alternatives, implying that respondents are prone to choosing between delivery and pickup, and if they choose

the latter, they will switch disproportionately between the various locations, modes and levels of existing trip integration. One EC is specified for each of home, work and shopping pickup, where each includes the three possible access modes (car dedicated, car existing, and other). These imply a tendency to choose one of the three pickup locations, with a greater tendency to switch mode or trip chaining behaviour to retain this location choice. The fifth EC spans all pickup alternatives that have car access, and implies some tendency to switch between locations, with some varying amount of unobserved (dis)utility associated with the car mode. The sixth EC is similar to the fifth, but only includes dedicated car trip alternatives. This reveals variation in the propensity to trip chain, with environmental consequences over and beyond the tendency to use a car.

2.4.2 Scenarios

In these scenarios, we wish to test the impact that changes in the location, quality and price of the delivery and CDP alternatives have on the choice shares of each of the alternatives. Since the focus is on the environmental impact, particular attention is paid to the increases and decreases of shares of the more environmentally friendly alternatives. For each scenario, the before and after choice shares are reported for all alternatives, as well as the shares aggregated over CDP location of dedicated car trips, existing car trips, and other modes. For all of the shares reported, the percentage shift from the before scenario is also reported.

Consider first some alternative scenarios wherein the level of control of the delivery process by the recipient is increased (see Table 2.3 and Fig. 2.2). The delivery choice share increases dramatically, from a base of 42.55 % for no notice of pending delivery, to 46.44 % if advanced notice is provided, to 49.23 % if four hour windows are offered, with a large jump to 56.57 % with two hour windows, and finally to 61.76 % if the two hour windows include a 6 pm–8 pm option. This most attractive option represents a 45 % increase in delivery market share over the least attractive option. In terms of the corresponding decreases in shares of other alternatives, there is a disproportionate decrease in the more environmentally friendly modes. For example, with no notice replaced by two hour time windows with the 6 pm–8 pm option, total dedicated car pickup trips across locations decrease by 27.48 %, existing car trips by 32.27 %, and other modes by 39.45 %. No conclusions are drawn here about the environmental performance of the delivery option, for example by comparing the routing performance when the demand points are final customers to when they are CDPs, however some conclusions can be drawn about the customer-side environmental impact.

The provision of narrow time windows will have a detrimental impact on the efficiency of vehicle routing. A second set of scenarios were run in which the price of the delivery service increased in line with the narrowing of time windows and extending of delivery hours (see Table 2.3, second part). Price increases specified are \$0.50 for four hour windows, \$1 for two hour windows, and \$1.25 for two hour

Table 2.3 Delivery scenarios

Alternative(s)	No notice		Advanced notice		4 h windows		2 h windows		2 h windows w. 6 pm–8 pm option	
	Share	Change	Share	Change	Share	Change	Share	Change	Share	Change
Delivery	42.55		46.44	9.12	49.23	15.69	56.57	32.94	61.76	45.12
Home car dedicated	7.14		6.75	-5.52	6.46	-9.55	5.68	-20.48	5.11	-28.51
Home car existing	6.48		6.05	-6.73	5.73	-11.59	4.90	-24.44	4.31	-33.55
Home other	8.84		8.05	-8.96	7.49	-15.25	6.08	-31.20	5.14	-41.90
Work car dedicated	2.78		2.65	-4.68	2.55	-8.17	2.28	-17.82	2.08	-25.05
Work car existing	3.22		3.03	-5.75	2.89	-9.98	2.53	-21.37	2.26	-29.67
Work other	6.64		6.15	-7.38	5.80	-12.68	4.88	-26.50	4.24	-36.17
Shopping car dedicated	7.31		6.92	-5.28	6.64	-9.15	5.87	-19.66	5.31	-27.39
Shopping car existing	9.83		9.20	-6.46	8.74	-11.12	7.52	-23.47	6.66	-32.28
Shopping other	5.21		4.77	-8.32	4.47	-14.21	3.68	-29.25	3.15	-39.49
All car dedicated	17.23		16.32	-5.28	15.65	-9.16	13.84	-19.70	12.50	-27.48
All car existing	19.53		18.27	-6.43	17.36	-11.09	14.95	-23.44	13.23	-32.27
All other	20.69		18.97	-8.29	17.76	-14.16	14.65	-29.20	12.53	-39.45
Alternative(s)	4 h windows, delivery cost +\$0.50		2 h windows, delivery cost +\$1.00		2 h windows w. 6 pm–8 pm option, delivery cost +\$1.25					
Delivery			Share	Change	Share	Change	Share	Change	Share	Change
Home car dedicated			44.54	4.67	47.21	10.93	50.18	17.92		
Home car existing			6.94	-2.87	6.66	-6.79	6.34	-11.17		
Home other			6.26	-3.46	5.96	-8.11	5.62	-13.30		
Work car dedicated			8.44	-4.57	7.91	-10.53	7.33	-17.07		
			2.71	-2.38	2.62	-5.72	2.51	-9.50		

(continued)

Table 2.3 (continued)

Alternative(s)	No notice		Advanced notice		4 h windows		2 h windows		2 h windows w. 6 pm-8 pm option	
	Share		Share	Change	Share	Change	Share	Change	Share	Change
Work car existing					3.12	-2.92	2.99	-6.91	2.85	-11.42
Work other					6.39	-3.82	6.05	-8.91	5.68	-14.50
Shopping car dedicated					7.12	-2.67	6.84	-6.37	6.54	-10.59
Shopping car existing					9.51	-3.28	9.07	-7.73	8.58	-12.76
Shopping other					4.99	-4.21	4.70	-9.80	4.37	-16.02
All car dedicated					16.76	-2.70	16.12	-6.44	15.39	-10.66
All car existing					18.89	-3.28	18.02	-7.72	17.04	-12.72
All other					19.81	-4.24	18.65	-9.83	17.38	-15.98

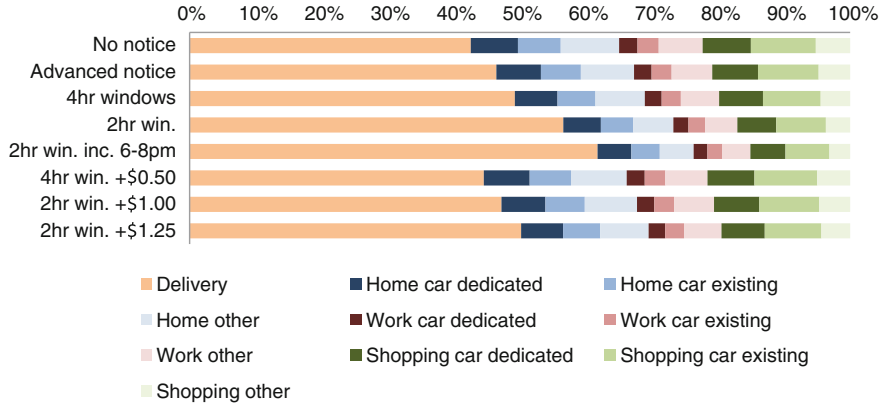


Fig. 2.2 Delivery scenarios

windows with the late delivery option. Delivery choice shares still increased, but to a lesser extent. Once again, these increases drew disproportionately from the more environmentally friendly modes.

Next, in Table 2.4, various changes are made to the home and work based pickup alternatives. The baseline scenario is based on the choice shares in the data. First, the distance to the CDPs was reduced by 25 %. The key increases in share come in home and work CDP pickups with the other modes, with 8.56 and 12.13 % increases over the baseline, respectively. Delivery decreased by just over one percent. The net increase in other modes is 6.9 %, with the percentage decrease for car dedicated and existing roughly equal.

Table 2.4 Home and work pickup scenarios

Alternative(s)	Baseline	25 % shorter distance		Good parking	
	Share	Share	Change	Share	Change
Delivery	55.31	54.72	−1.07	54.03	−2.32
Home car dedicated	5.76	5.67	−1.42	6.85	19.01
Home car existing	4.97	4.86	−2.15	6.08	22.25
Home other	6.15	6.68	8.56	5.77	−6.27
Work car dedicated	2.35	2.30	−2.38	2.67	13.26
Work car existing	2.62	2.53	−3.51	3.05	16.22
Work other	5.09	5.71	12.13	4.80	−5.85
Shopping car dedicated	6.07	6.03	−0.66	5.63	−7.28
Shopping car existing	7.78	7.71	−0.96	7.34	−5.67
Shopping other	3.89	3.79	−2.60	3.80	−2.31
All car dedicated	14.18	14.00	−1.26	15.14	6.80
All car existing	15.37	15.10	−1.78	16.46	7.09
All other	15.14	16.18	6.90	14.36	−5.11

Table 2.5 Introduction of shopping pickup scenario

Alternative(s)	Baseline	Introduce shopping CDPs	
	Share	Share	Change
Delivery	63.95	55.31	−13.50
Home car dedicated	8.27	5.76	−30.42
Home car existing	6.98	4.97	−28.78
Home other	7.81	6.15	−21.26
Work car dedicated	3.27	2.35	−28.11
Work car existing	3.54	2.62	−26.02
Work other	6.17	5.09	−17.49
Shopping car dedicated	0.00	6.07	–
Shopping car existing	0.00	7.78	–
Shopping other	0.00	3.89	–
All car dedicated	11.54	14.18	22.81
All car existing	10.52	15.37	46.12
All other	13.99	15.14	8.22

In the next scenario, parking was changed to be easy all of the time, for the home and work alternatives (see Table 2.4). Predictably, car usage increased for these two alternatives. In aggregate, delivery decreased by 2.32 % and other modes to CDP locations by 5.11 %, while dedicated car trips increased by 6.8 %, and existing car trips by 7.09 %.

In the study area of Sydney, a large majority of existing CDPs are not located at conventional grocery shopping destinations, meaning that for many, picking up a parcel at their regular shopping location is not an option. Part of the appeal of these locations is that customers can pick up the parcel either during a regular shopping visit, or opportunistically do some shopping when picking up the parcel. Further, if a car is typically used for shopping, heavy parcels may not be so much of a burden. In this next scenario, presented in Table 2.5 and Fig. 2.3, the shopping CDP alternatives are omitted in the baseline scenario, and then subsequently introduced. The largest absolute change comes to the delivery alternative, from 63.95 to 55.31 %, a 13.5 % decrease. Aggregated across CDP locations, dedicated car trips

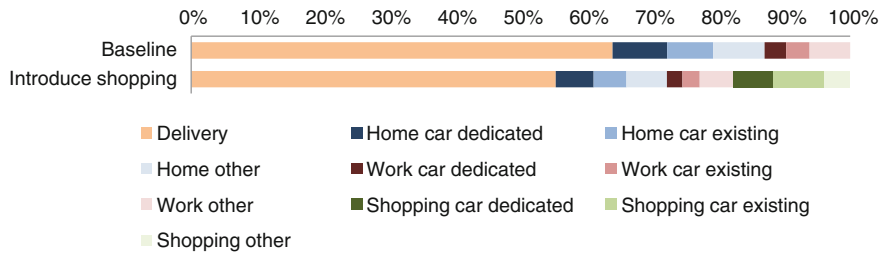


Fig. 2.3 Introduction of shopping pickup scenario

Table 2.6 Varying days before return to sender at shopping pickup scenarios

Alternative(s)	RTS 2 days	RTS 4 days		RTS 7 days		RTS 14 days	
	Share	Share	Change	Share	Change	Share	Change
Delivery	55.62	55.51	-0.19	55.35	-0.48	54.93	-1.24
Home car dedicated	5.79	5.78	-0.28	5.75	-0.69	5.69	-1.74
Home car existing	5.04	5.01	-0.61	4.96	-1.57	4.85	-3.91
Home other	6.19	6.17	-0.23	6.15	-0.61	6.09	-1.57
Work car dedicated	2.37	2.36	-0.21	2.35	-0.59	2.33	-1.52
Work car existing	2.66	2.64	-0.56	2.62	-1.39	2.57	-3.46
Work other	5.12	5.11	-0.21	5.09	-0.55	5.05	-1.37
Shopping car dedicated	6.24	6.18	-0.95	6.09	-2.39	5.87	-5.93
Shopping car existing	7.00	7.29	4.07	7.73	10.40	8.84	26.26
Shopping other	3.98	3.95	-0.75	3.90	-1.91	3.79	-4.78
All car dedicated	14.40	14.32	-0.56	14.19	-1.41	13.89	-3.52
All car existing	14.70	14.94	1.63	15.31	4.16	16.25	10.54
All other	15.29	15.23	-0.36	15.14	-0.93	14.93	-2.34

increase by 2.63 % in absolute terms, from a 11.54 to 14.18 % share. The increase for existing car trips is greater, at 4.85 % in absolute terms to a new total of 15.37 %, while the share for other modes increases from 13.99 to 15.14 %. Overall, the introduction of CDPs at shopping destinations leads to a disproportionate increase in more environmentally friendly access modes.

Finally, in Table 2.6, four scenarios were run, where the days before the parcel is returned to sender progressively increased. Reflecting the utility expression specified for the choice model, only the shopping alternative with an existing car trip benefits from this increase. Its share increases from 7.00 % to 7.29, 7.73 and 8.84 % for days before RTS of two, four, seven and 14 respectively. These increases are relatively small, but not trivial in the context of annual parcel flows. No particular pattern is discerned in the decreases of the shares of the other alternatives, except for a slightly larger percentage decrease for the non-shopping alternatives that incorporate existing trips.

2.5 Discussion and Conclusions

This chapter has investigated the environmental impacts of parcel delivery over the last mile, in which CDPs and conventional delivery compete against each other. The modelling employed has focused on the behavioural response of the consumer to the products offered, and the associated total environmental footprint. An online survey was used to collect stated choice data, on which a RPECL model was estimated. The environmental impact has been examined through a set of scenarios, with changes in shares of more and less environmentally friendly alternatives calculated.

Some caveats regarding the methodology are in order. The choice tasks as specified provide a degree of abstraction from the reality of the individual decision maker. Explicit home and work CDP locations are not specified—only a distance from home or work is provided. The advantage of this is that such an abstract representation avoids the potential for large unobserved effects associated with specific and problematic CDP locations. However, it does make the dedicated verses existing car trip less meaningful. The grocery shopping location, however, was framed as their regular shopping location, so the dedicated/existing decision is arguably more meaningful for this alternative. Further, the choice tasks were also framed around the next week or two, and they were asked to consider their schedule over that time. It was also made clear that someone else in the household could make the pickup or receive the parcel, furthering the realism of the choice task.

The proposed methodology cannot alone quantify the final VKT or emissions for carriers and customers under different scenarios. A larger modelling effort would consider a real network of CDPs, and the actual locations of customers. Routing plans could be generated for parcel deliveries to customers and CDPs (see, for example, McLeod et al. 2006). Travel to pick up the parcels from the CDPs would also be modelled.³ This would allow the choice shares reported in this paper to be converted to aggregate VKT and emissions under a range of scenarios, in a way that accommodates behavioural responses to the location, quality and price of the CDP and delivery offerings. This will remain an avenue for future research.

Various changes to CDPs were investigated through the scenarios, and will be discussed further here. A CDP network with higher density would imply a shorter distance for many customers. It was found that this would lead primarily to a shift to walk, cycle and public transport modes, although the absolute shift is relatively small. A large increase in CDP uptake can be gained from locating them at shopping centres, if they were not previously located there. Here, from an environmental perspective, the largest percentage increase will come in existing car trips, however dedicated driving trips increase also. More broadly, this finding suggests that CDP locations that integrate into existing trip destinations will lead to a large increase in CDP usage, with much but not all of this travel integrating into existing trips. Distribution efficiencies are likely to be particularly strong for CDPs at shopping locations, given the well established distribution into these locations, often with large vehicles. Sufficiently long number of days before the parcel is returned to sender can also stimulate integration into existing trips.

An increase in the prevalence of CDPs may trigger a competitive response from conventional delivery, where narrow time windows is an obvious tool to increase market share and/or yields. This chapter has shown that narrow windows lead to a clear and dramatic increase in delivery choice share. Further, this increase draws disproportionately from the more environmentally friendly CDP access modes. However, before being able to draw definitive conclusions about the environmental

³The integration of pickups into existing travel patterns would be the most challenging component of this model.

impact, the net impact would need to be calculated. Environmental benefits would accrue from the reduction in dedicated car trips to the CDP, and to a lesser extent from the reduction in VKT from existing trips that integrated the pickup, but required extra VKT to do so. Even with advanced notice of delivery and choice of time windows, missed deliveries can still occur. Nonetheless, the narrowing of the window should reduce the prevalence of missed deliveries, and the associated VKT either from a redelivery, or a subsequent customer pickup from a warehouse or even a CDP. Environmental costs would stem from a less efficient delivery schedule associated with narrow windows. The net change would require further research.

References

- Cullinane, S. (2009). From bricks to clicks: The impact of online retailing on transport and the environment. *Transport Reviews*, 29(6), 759–776.
- Hsiao, M. (2009). Shopping mode choice: Physical store shopping versus e-shopping. *Transportation Research Part E: Logistics and Transportation Review*, 45(1), 86–95.
- Keskinen, A., Delache, X., Cruddas, J., Lindjord, J. E. & Iglesias, C. (2001). A purchase and a chain: Impacts of e-commerce on transport and the environment. Report of Working Group 3 to the European Commission Joint Expert Group on Transport and the Environment, November 15.
- Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). *Stated choice methods: Analysis and applications*. Cambridge: Cambridge University Press.
- McLeod, F. N., & Cherrett, T. J. (2009). Quantifying the environmental benefits of collection/delivery points. *OR Insight*, 22(3), 127–139.
- McLeod, F., Cherrett, T., & Song, L. (2006). Transport impacts of local collection/delivery points. *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management*, 9(3), 307–317.
- Mokhtarian, P. L. (2004). A conceptual analysis of the transportation impacts of B2C e-commerce. *Transportation*, 31(3), 257–284.
- Rose, J. M., & Bliemer, M. C. J. (2009). Constructing efficient stated choice experimental designs. *Transport Reviews*, 29, 587–617.
- Rotem-Mindali, O., & Salomon, I. (2007). The impacts of E-retail on the choice of shopping trips and delivery: Some preliminary findings. *Transportation Research Part A: Policy and Practice*, 41(2), 176–189.
- Rotem-Mindali, O., & Salomon, I. (2009). Modeling consumers' purchase and delivery choices in the face of the information age. *Environment and Planning B: Planning and Design*, 36(2), 245–261.
- Train, K. (2009). *Discrete choice methods with simulation* (2nd ed.). New York: Cambridge University Press.
- Weltevreden, J. W. J. (2008). B2c e-commerce logistics: The rise of collection-and-delivery points in The Netherlands. *International Journal of Retail & Distribution Management*, 36(8), 638–660.

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