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Consumer preferences for innovative and traditional last-mile parcel delivery

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ABSTRACT: The purpose of this research is to reveal consumer preferences towards innovative last-mile parcel delivery and more specifically unmanned aerial delivery drones, in comparison to traditional postal delivery (postie) and the recent rise of parcel lockers in Australia. We investigate competitive priorities and willingness to pay for key attributes of parcel delivery (mode, speed, method and time window), the role of contextual moderators such as parcel value and security, and opportunities for logistics service providers in the growing e-commerce market. A survey involving stated choice experiments has been conducted among 709 respondents in urban Australia. We estimated panel error component logit models, derived consumer priorities and deployed 576 Monte Carlo simulations to forecast potential delivery mode market shares. Our results suggest that people prefer postie over drone delivery, all else equal, but that drone deliveries become competitive with large market shares if they live up to the premise that they can deliver faster and cheaper. Both drone and postie become less attractive relative to parcel lockers when there is no safe place to leave a parcel at a residence, highlighting the importance of situational context and infrastructure at the receiving end of last-mile delivery. We identified opportunities for chargeable add-on services, such as signature for postie and 2-hour parcel deliveries for drones. We offer timely and novel insights into consumers preferences towards aerial drone parcel deliveries compared to postie and lockers. Going beyond the extant engineering/OR literature, we provide a starting point and add new dimensions/moderators for last-mile parcel delivery choice analysis and empirical evidence of market potential and competitive attributes of innovative versus traditional parcel delivery alternatives.

KEY WORDS: ***Last-mile delivery, WTP, Choice experiments, e-commerce, Aerial drones, Parcel lockers***

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Introduction

Designing, managing and pricing last-mile delivery is a critical strategic decision not only for logistics companies but also for shippers including online retailers. E-commerce has substantially increased the number of deliveries from Businesses to Consumers (B2C) and is forecasted to grow globally beyond US$2.7trn in 2021 (Statista, 2020). As last-mile delivery can introduce complexity, inefficiencies and costs to value chains, literature investigating innovative solutions has emerged (Mangiaracina et al., 2019).

At the forefront of technological advancements parcel lockers and drones have become potential game changers and it is no longer inconceivable that both could soon be the norm in the last-mile parcel delivery context. Aerial drones are rapidly implemented in ever more innovative use cases (Merkert and Bushell, 2020) including last-mile delivery of parcels (Pugliese et al., 2020), food (Hwang et al., 2021) and medical supplies (Prasad et al., 2019) as both distribution companies and regulators have paved the way for large scale drone delivery services in an increasing number of jurisdictions (Joerss et al., 2016). For example, in 2020 Amazon received regulatory approval to deploy a fleet of airborne drones for its Prime Air parcel deliveries in the United States (Levin, 2020) and start-ups offering innovative last-mile delivery services to retailers and individuals received in 2019 far more funding than any other segment that aimed to challenge the traditional industry segments of logistics and supply chain management (Hausmann et al., 2020). Despite, or perhaps because of, such hype around aerial delivery drones, it is worth asking whether the cautious consumer values such services and whether there is indeed a market for them. The general public has privacy, safety and security concerns around the use of aerial drones (Zwickle et al., 2019; Watkins, et al., 2020; Merkert et al., 2021), especially in the context of unattended delivery of valuable shipments (McKinnon and Tallam, 2003; Zhou et al., 2020).

Setting out, our research was guided by Svanberg (2020). Initial consultations with industry were undertaken to learn about their views on disruptive alternatives to the traditional post (wo)man called a 'postie' in Australia. Conversations with drone operators and Unmanned Vehicle Systems International confirmed that it is technically possible to deliver parcels of up to 5kg today and in fact trialled in many parts of the world. Based on discussions with local and global logistics service providers, namely Australia Post, DHL, Fedex, UPS and Toll, we know that they are looking to heavily invest into parcel lockers (e.g., in partnership with 7-Eleven, Australia Post doubled the number of its parcel locker locations in August 2021; see Post&Parcel, 2021) but do not see widespread aerial drone implementation as a realistic near-term scenario. Reportedly this is mainly due to the lack of public acceptance and regulatory frameworks, although the latter seems only a matter of time. Public acceptance and, more importantly, consumer willingness to pay for aerial drone parcel delivery services, and last-mile delivery more generally, are a different matter though. Without robust evidence, logistics service providers may miss investing in drone delivery technology and may also fail to tailor current service offerings and business models to a more competitive environment.

To emphasize the relevance of this research, we note that while the trend towards e-commerce and technology acceptance has been firmly established over the last decade (Mansur et al., 2019), demand for e-commerce and home deliveries has been booming amid the COVID-19 pandemic despite disruptions. Global parcel shipping has exceeded 131bn parcels in 2020, tripled in the past six years and is predicted to more than double again by 2026 (Pitney Bowes, 2021), with some countries, including Australia, observing year-on-year growth in parcel deliveries above 80% (Deloitte, 2020). There are thus anecdotal claims that COVID-19 is not only benefiting last-mile logistics and vice versa (Choi, 2020) but has also accelerated the drone revolution in the parcel delivery sector (The Economist, 2020).

Does the future of last-mile parcel delivery belong to aerial drones, or parcel lockers and is the postie dead yet? Would consumers pay more for speedier delivery of areal drones and if so under what conditions? Do traditional logistics providers need to adapt in terms of markets impacting on their competitive position? These are the key questions this paper aims to investigate through the lens of random utility theory and discrete choice models (McFadden, 1973, 2001). More systematically, we aim to examine which characteristics and contextual moderators of parcel delivery are most important when consumers choose the physical mode of delivery. Building on that evidence we then aim to compute the willingness to pay (WTP) for key attributes of parcel delivery. Drawing the attention to logistics service providers we then examine potential market shares for posties, aerial drones, and lockers and what helps each of them to be competitive. By deploying stated choice experiments in the parcel delivery context, we aim to contribute a starting point for future choice analysis and add new dimensions/moderators to generate empirical evidence on consumer priorities around last-mile parcel delivery and potential market shares of innovative versus more traditional delivery modes. Rather than pure e-commerce experiences, we are interested in consumers preferences related to physical distribution aspects of parcel delivery and what moderates those views, such as value and content of parcels or contextual factors including availability of a safe place at the receiving end of physical distribution and last-mile delivery.

Literature review and development of research questions

There is a growing literature around innovative last-mile delivery solutions in the B2C context, with streams emerging around how technology can improve supply chain efficiency (Mangiaracina et al., 2019), environmental sustainability (He, 2020) and consumer acceptance and value proposition (Zhou et al., 2020). We focus on the last stream, as while customers generally value freight transport time savings (Goenaga and Cantillo, 2020), there are usually choice alternatives of last-mile delivery modes even in e-fulfilment environments (Wang et al., 2014). With the boom of e-commerce and technological advancements, the focus has shifted towards urban last-mile distribution and innovations such as parcel lockers (Vakulenko et al., 2018), and drone deliveries (Pugliese et al., 2020). The literature on crowdsourced delivery (Ciobotaru and Chankov, 2021) focuses on in-person deliveries by people other than a postie, and while an interesting proposition we consider it out of scope for our analysis.

Aerial drones for parcel delivery have the greatest potential for disruption in the supply chain and physical distribution context (Shahzaad et al., 2019). Their deployment in broader delivery services and large-scale industrial applications may only be a few steps away as the advantages of drones – fast delivery at relatively low cost – are increasingly noted (Merkert and Bushell, 2020; Boysen et al., 2021). However, the public acceptance concerns have been evidenced in relation to ethics and privacy (Luppicini and So, 2016) as well as safety, security and public concerns regarding regulation (Zwickle et al., 2019) and use of drones in urban areas (Watkins, 2020). Issues such as 'fear of theft' and 'fear of delivery to an incorrect address' (UPS, 2016) and technological malfunctions are also an area of concern (Zhu, 2019). It is against that background that previous studies have often narrowly focused on risks (Choe et al., 2021) and how to overcome initial privacy concerns (Khan et al., 2018; Nelson et al., 2019). In addition, trust has been identified as a barrier for drone deliveries while financial and time-saving motives have so far not been shown to influence drone delivery attractiveness (Mittendorf et al., 2017). As such, the extant literature does not seem to suggest that consumers are willing to accept, let alone pay, for parcel deliveries by aerial drones. However, these studies (e.g., Mittendorf et al., 2017; Choe et al., 2021) have neither deployed choice experiments nor captured willingness to pay for aerial drone delivery. More importantly, they have not fully accounted for personal and environmental circumstances of parcel delivery consumers, such as availability of a safe place to drop a parcel at the receiving end of physical distribution in the last-mile delivery context. Furthermore, much of the extant delivery literature is focused on the consumers' online shopping experiences and e-fulfilment. We take this further to investigate consumer preferences related to physical last-mile parcel distribution, including aerial delivery drones. In that context, previous studies may have underestimated technological acceptance (Cai et al., 2021) which may now be much higher due to COVID-19 and societies and the urban fabric increasingly ticking at a faster pace. While certain risk factors may influence and impede people's use and acceptance of aerial drones, if they are fast and cheap, they may be persuaded.

Moreover, previous studies on last-mile delivery have used theoretical constructs from theoretical frameworks such as unified theory of acceptance, theory of planned behaviour and theory of reasoned action (for a review see, Nguyen et al., 2019). This literature predominantly uses surveys, factor analysis and structural equation modelling (e.g., Wang et al., 2019, Cai et al., 2021) with a focus on attitudinal questions to explain behaviour and purchase intention, e.g., personal innovativeness driving attitudes towards drone delivery (Yoo et al., 2018 and Hwang et al., 2021), without asking consumers to choose a delivery service in a specific context. In this paper, we develop and estimate a novel model based on random utility theory and discrete choice modelling (McFadden, 1973, 2001). The underlying theory assumes that decision-makers/consumers are rational and choose the alternative among a set of options (described by specific characteristics that consumers will need to trade-off on) that yields maximum utility in the last-mile delivery context. While choices are observed, underlying utilities are latent and have therefore to be considered partially parametric. Relatively simple models of this theory have been deployed in supply chain management (Garver et al., 2012; Gawor and Hoberg, 2019), in acceptance of autonomous ground transport delivery robots (Pani et al., 2020) and in emergency logistics (Holzmann et al., 2021), but not in the airborne drone parcel delivery context relative to lockers or traditional postal services and not related to specific attributes of such deliveries.

The extant literature is nevertheless useful to guide the selection of the most important attributes in last-mile parcel delivery. It is important to acknowledge that not just drones but also parcel lockers have been identified as a promising response to retail and last-mile delivery challenges (Vakulenko et al., 2018), most notable as a potential to the widely discussed failed home delivery problem (Buldeo Rai et al., 2021). An attribute that has received much attention in the relation to both drone delivery (Mittendorf et al., 2017; Osakwe et al., 2021) and parcel lockers (Zhou et al., 2020) is perceived risk (e.g. delivery failures due drone malfunctioning or hacking and financial or performance risks related to lockers). An issue that affects both postie and drone deliveries but not parcel lockers is that of security and illegal intent as consumers may worry about unattended deliveries to their homes (McKinnon and Tallam, 2003; Zhou et al., 2020). Consumers of last-mile delivery services appear to prefer trustable (Pani et al., 2020), assuring and secure solutions (Wang et al., 2019). As the e-commerce boom has also driven up the value of delivered goods (Statista, 2020), the security attribute is worth further investigation. In addition, self-service parcel lockers have, while being popular with e-commerce retailers, been shown to lack valued human interaction (Chen et al., 2018) and we argue that the same could be said for drones, leaving postie as the only alternative with a human touch.

Acknowledging possible trade-offs between attributes, delivery cost is arguably one of the most important factors (Kapser et al., 2021; Nguyen et al., 2019). Equally important in this context is delivery speed (Garveret al., 2012), as consumers are anecdotally increasingly impatient (Daugherty et al., 2019). Aerial drones may offer deliveries within 30 minutes for less than US$1 (Keeney, 2015; we confirmed with aerial drone operators Amazon Prime and Wing that this is still the case in 2021), making them a competitive proposition (Perera et al., 2020). Similarly, time-based parcel deliveries (Goebel et al., 2012) and time windows, common in urban freight transport contexts (Akyol and de Koster, 2018), have been shown to matter in last-mile delivery (Nguyen et al., 2019). In that sense, parcel lockers are seen as more convenient (Tsai and Tiwasing, 2021) than traditional parcel services, but airborne drones could offer similar, possibly even more convenient, time-based delivery services and hence warrant investigation. In addition to attributes related to economic sustainability (i.e., cost versus speed, security, convenience), environmental sustainability of last-mile delivery has received considerable attention (Buldeo Rai et al., 2019; Ignat and Chankov, 2020; Caspersen and Navrud, 2021). Battery-operated drones are often considered environmentally friendly (Hwang and Kim, 2019), although this opinion is not conclusively supported due to potential noise issues (Watkins, et al., 2020). For this reason, we suspect the presence of notable heterogeneity regarding preferences for drones versus other delivery modes that we need to account for in our analysis.

What further encouraged us in this view were findings related to contextual moderators of online shopping such as parcel content (or product categories that are purchased; Nguyen et al., 2019) and value (Tokar et al., 2020; Gawor and Hoberg, 2019). Notably, neither of these moderators have been investigated in the context of mode specific delivery alternatives. Overall, the extant literature lacks quantitative measurement of consumer preferences towards, and willingness to pay (in monetary terms) for, specific characteristics of last-mile parcel delivery solutions (i.e., aerial drones). There exist no previous studies that have deployed stated choice experiments tailored to the individual consumer and their residential situation at the receiving end of last-mile parcel delivery in the context of having all three delivery modes available to them, traditional postie, parcel locker and aerial drones.

In addition to literature focused on consumers, there is also an emerging theme around what capabilities logistics service providers need to acquire to be competitive and attractive to consumers. Time and convenience have been shown to be of importance for being selected as provider (Gawor and Hoberg, 2019), as has security capability (Williams et al., 2019). That said, without investigating mode alternatives, Buldeo Rai et al. (2019) suggest for the omnichannel retail environment that consumers may prefer slower delivery or indeed pick-up solutions providing both are free of charge. Such evidence is vital for shippers and retailers, but arguably even more decisive to logistics service providers who may currently ponder about what service offerings they should strategically invest in; particularly as aerial drones are unchartered territory. To the best of our knowledge, there is no study that has conducted a stated choice analysis and performed market share simulations (sensitivity analysis) in this context. We aim to reveal strengths and weaknesses of each delivery option, which could enable niche markets but could also inform management what pricing strategies will enable them to win the game of drones. We investigate what opportunities exist to keep posties relevant while also charting perceived benefits of and WTP for innovative last-mile delivery solutions.

Data collection and methodology

With the aim to elicit preferences towards last-mile parcel delivery options, stated choice experiments were conducted using an online survey. This section describes the design of the survey and experiment as well as data analysis methods.

Survey and sample

A 10-minute questionnaire was designed, consisting of three parts. The first part consisted of questions to determine eligibility to complete the survey. Respondents needed to have had a parcel under 5 kg and up to 44 (W) x 28 (L) x 17 (H) cm delivered to their home address in the past 12 months, to capture information about their most recent parcel delivery (e.g., estimated size and weight of the parcel, content of the parcel, estimated value of the content), and to capture information about their home address (e.g., availability of a safe place to leave a parcel by postie and drone). The second part of the questionnaire consisted of ten choice tasks in a stated choice experiment tailored to the circumstances of each respondent. The third and final part of the questionnaire consisted of socio-demographic questions.

The questionnaire was implemented in SurveyEngine, an online survey instrument particularly suitable for conducting choice experiments that is mobile device friendly. An online consumer panel provided by SurveyEngine was used to recruit consumers and obtain 709 completed questionnaires. The survey was conducted in two waves for efficiency purposes. In Wave 1 (25-27 March 2020, which we also refer to as Pilot study) we collected data from 70 respondents in metropolitan areas in Australia, and in Wave 2 (9-20 April 2020, which we also refer to as Main study) we collected data from another 639 respondents. It is worth noting that the Australian Federal government implemented a nationwide lockdown[1] due to COVID-19 between our two data collection waves, and Australia Post no longer required signatures for parcel deliveries due to physical distancing measures, which we will consider when analysing the data.

Table 1 presents the socio-demographic characteristics of our sample in comparison with the population of Australia (ABS, 2016), noting that our sample excludes people in regional areas. Our sample is to a high degree representative for the metropolitan population where education and employment levels are higher than in regional areas (ABS, 2021).

Table 1. Sample characteristics

Characteristics	*Category*	*N=709*	*ABS Census 2016*

[1] From 29 March 2020 until end of April, people were only being allowed to leave their homes for four reasons: food/supplies; medical care; exercise; and work/education. Gatherings of more than two people (unless members of an immediate household) were prohibited. Other measures included closing international and interstate borders and there was closure of non-essential services (e.g., cafes/restaurants, except takeaways).

		Sample (%)	Population (%)
Gender	Male	50	49
	Female	50	51
Age (in years)	18-29	24	21
	30-39	19	18
	40-49	18	17
	50-59	17	16
	60-69	12	14
	70 and above	10	14
Annual household income (A$) before taxes	51,999 or less	26	23
	52,000-103,999	34	28
	104,000-155,999	17	20
	156,000-259,999	9	14
	260,000 or more	5	4
	Not answered	9	11
Employment	Employed, working full-time	41	36
	Employed, working part-time (including students)	28	20
	Unemployed, looking for full-time work	8	4
	Not in the labour force	25	35
	Not answered	1	7
Highest education attained	Postgraduate degree or higher	19	5
	Bachelor's degree and diplomas	40	17
	Associate degree (or Trade diploma)	18	25
	Year 12 or less	22	41
	Not answered	1	12
Marital status	Married/partnered/de facto/living with a partner	60	39
	Widowed/Divorced/Separated	12	14
	Never married	27	28
	Not answered/Not applicable	1	19
Household size (number of people living in the house)	1	20	24
	2	54	34
	3	13	16
	4	9	16
	5 or more	4	10
Household composition	Single without children	31	26
	Single with child(ren)	8	11
	Couple without children	27	29
	Couple with children	34	34
House type	Separate house (detached)	60	71
	Semi-detached, row or terrace house, townhouse etc.	14	13
	Flat, unit or apartment	25	14
	Other	1	2

Stated choice experiment

In a stated choice experiment, also referred to as choice-based conjoint analysis (Orme, 2020), respondents are asked to choose their preferred option from a set of alternatives, each described by a hypothetical profile consisting of specific levels of attributes. In such an experiment, a respondent is generally faced with multiple of such hypothetical choice tasks where profiles of the alternatives are systematically varied. Based on the chosen options, the analyst can derive preferences towards alternatives and attributes, determine WTP, and forecast market shares. Stated choice experiments are common in several fields of applied economics, including health and transport, but less common in logistics although exceptions exist especially more recently and if delivery mode specific usually related to lockers only (Garver et al., 2012; Collins, 2015; Gawor and Hoberg, 2019; Buldeo Rai et al., 2019; Rossolov, 2021; Caspersen and Navrud, 2021).

Different to the extant literature, which focuses on either retail e-fulfillment or pricing bundles, we consider three physical delivery modes as alternatives: postie, aerial drone, and parcel locker. Whilst we acknowledge that aerial drone delivery can be multimodal starting from vans rather than from depots or warehouses (Boysen et al., 2021), for simplicity reasons we focus on what the delivery customer gets to see and that is solely an aerial drone.

The key attributes considered in our study were determined based on our literature review, pre-experiment consultations with industry, and feedback from a pre-pilot survey. Delivery cost was included as an important attribute (Kapser et al., 2021; Ignat and Chankov, 2020), while also delivery speed (Ignat and Chankov, 2020; Daugherty et al., 2019; Garver et al., 2012), delivery method/security (Zhou et al., 2020; Mittendorf, 2017) and delivery time window (Nguyen et al., 2019) were found to be relevant. In addition to these key attributes, we also considered the content and value of the parcel delivery as relevant contextual factors for choosing a certain delivery mode. We framed the choice context for each respondent based on the respondents' self-reported content (X) and value (Y) of the most recent parcel delivery by describing the following scenario in the choice experiment: "Consider buying X online or via phone[2] from a domestic retailer (so the goods are in the country already), with an estimated value of *Y* Australian dollars", where *X* could be content in one of the following eight categories books, consumer electronics, household items, clothing, jewellery, sport items, toys, or other items. Table 2 shows the levels used for each attribute.

Levels for delivery cost and speed were varied around existing characteristics of Australia Post in 2020 (ranging from AU$8.95 for a small standard parcel with a delivery within 2-5 days to AU$25.50 for a large express parcel with next business day delivery), where for drones we allowed faster delivery speeds and lower costs as expected advantages of drone delivery (Merkert and Bushell, 2020; Keeney, 2015). As with Australia Post, a "small" parcel in our survey was defined as a parcel of up to 1kg with dimensions not exceeding 24 (W) x 19 (L) x 12 (H) cm). A "large" parcel was defined as weighing up to 5kg and larger than a typical shoebox with dimensions not exceeding 44 (W) x 28 (L) x 17 (H) cm.

Table 2. Delivery attributes and their levels

Attribute	*Alternative*	*Attribute levels*
Speed	Postie	5 business days; 3 business days; 2 business days; Next business day
	Drone	5 business days; 3 business days; 2 business days; Next business day; Same day; 2-hours;
	Locker	5 business days; 3 business days; 2 business days; Next business day
Method/ security	Postie	Leave at front door; Leave in a safe place; Signature required
	Drone	Leave at front door; Leave in a safe place
	Locker	Secure in locker
Time window	Postie	daytime (9am-5pm); 2-hour choice daytime; 3-hour choice daytime; evening (6pm-9pm)
	Drone	daytime (9am-5pm); 2-hour choice daytime; 1-hour choice daytime; 30-min choice daytime
	Locker	24/7 (kept for two days)
Cost	Postie	Small Standard Parcel: AU$6; AU$8; AU$10; AU$12
		Small Express Parcel: AU$12; AU$14; AU$16; AU$18
		Large Standard Parcel: AU$12; AU$14; AU$16; AU$18
		Large Express Parcel: AU$18; AU$20; AU$22; AU$24
	Drone	Small Standard Parcel: AU$2; AU$4; AU$6; AU$8
		Small Express Parcel: AU$8; AU$10; AU$12; AU$14
		Large Standard Parcel: AU$8; AU$10; AU$12; AU$14
		Large Express Parcel: AU$14; AU$16; AU$18; AU$20
	Locker	Small Standard Parcel: AU$6; AU$8; AU$10; AU$12
		Small Express Parcel: AU$12; AU$14; AU$16; AU$18
		Large Standard Parcel: AU$12; AU$14; AU$16; AU$18
		Large Express Parcel: AU$18; AU$20; AU$22; AU$24

Levels for delivery method were also taken from Australia Post with the addition of "leave at front door" as a new option. Selecting a delivery time window is currently not possible with Australia Post, but we anticipate that this may be offered in the future and therefore several levels were included,

[2] Since not all stores have a web shop, phone was included as a medium for making a purchase.

ranging from “daytime” as the status quo to selecting a specific “1-hour window”. As with Australia Post, the locker time window is 24/7 and if not collected within 48 hours the parcel will be available for collection at a nearby post office. In the survey it was explained that lockers are available at each post office and shopping centre, which in urban areas are typically located within 1 kilometre distance.

For realism purposes, profiles had to satisfy several constraints on attribute level combinations. For example, whenever “next business day” delivery speed was shown, only higher express delivery costs were shown. Also, evening delivery was not available to drones for safety reasons due to flying in darkness not being permitted in the current regulatory global framework, while narrow delivery time windows were not available for postie due to practical limitations.

Hensher (2010) recommends referencing to a real experience to reduce biased responses when asking hypothetical questions. In our choice experiment we reference a respondents’ recent parcel delivery (with specific parcel content and value) in the choice scenario and by considering only attribute levels that are feasible for that individual, i.e., whether they have a safe place available for delivery (e.g., a backyard for drone delivery or a place in the front of the house not visible to others). Further, we tailored choice tasks for each respondent by only showing price levels appropriate for the parcel weight/size of their recent delivery. Each respondent was given ten different choice tasks, an example is illustrated in Figure 1. The order in which delivery mode alternatives were shown was randomised across respondents to account for possible left-to-right order bias in model estimation.

In total there exist 589,824 unique choice tasks with different attribute level combinations. Instead of randomly selecting choice tasks from this full factorial, it is common to select a small subset of choice tasks, referred to as a fractional factorial design, based on criteria such as attribute level balance (in which each attribute level appears more or less equally within the experiment), non-dominance (such that respondents are forced to make trade-offs across attributes), and efficiency (to maximise information). We generated D-efficient fractional factorial designs where the selected choice tasks maximise the determinant of the (Fisher) information matrix of the conditional logit model obtained from McFadden (1973), which is equivalent to minimising the determinant of the covariance matrix, referred to as the D-error (Rose and Bliemer, 2009; Huber and Zwerina, 1996). This experimental design strategy results in smaller standard errors and hence more reliable parameter estimates without increasing sample size.

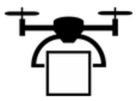
	Postie	Drone	Locker
			
Speed	Next business day	3 business days	2 business days
Delivery method	Leave in a safe place	Leave at front door	Secure in locker
Time window	6pm - 9pm (no choice)	9am - 5pm (1-hour)	24/7 (kept for two days)
Cost	$14	$8	$6
Which would you choose?	○	○	○

Figure 1. Example of a choice task presented to participants

To be able to generate D-efficient designs, parameter priors are needed. Priors for our specific study are not available in the literature, therefore we adopted a sequential process with two waves. In Wave 1 (Pilot), we assumed noninformative zero priors and generated 8 D-efficient experimental designs for different combinations of parcel size (small or large), availability of a safe place for postie (yes or no), and availability of a safe place for drone (yes or no). These designs were used to collect choice observations from 10% of our sample and model parameters were estimated. These parameter estimates we used as Bayesian priors to generate 8 new D-efficient designs using the approach of Sándor and Wedel (2001). The profiles in these designs were used in Wave 2 (Main) to collect information from the remaining 90% of our sample. All experimental designs were generated using the modified Federov algorithm in the Ngene software package in conjunction with constraints to avoid dominant alternatives as they could potentially bias parameter estimates (Bliemer et al., 2017). All 160 choice tasks in the 16 experimental designs are shown in supplemental Appendix A and an example of an experimental design is shown in Table 3.

Given that the questionnaire in Waves 1 and 2 is the same (except for specific attribute level combinations shown in the choice experiment), we can pool the data of the two waves and compensate for any differences in the two data sets within the econometric model. Data collected when testing the questionnaire prior to Waves 1 and 2 was excluded from this data set.

Table 3. Experimental design in main study for respondents that recently had a small parcel delivered and have a safe place for both postie and drone

	Postie				Drone				Locker	
Choice task	*Delivery time*	*Delivery method*	*Delivery window*	*Delivery cost*	*Delivery time*	*Delivery method*	*Delivery window*	*Delivery cost*	*Delivery time*	*Delivery cost*
1	next day	signature required	evening	$12	within 2 hours	leave at front door	no choice daytime	$8	3 business days	$12
2	next day	leave at front door	no choice daytime	$12	within 2 hours	leave at safe place	1-hour daytime	$12	5 business days	$12
3	next day	leave at safe place	evening	$16	same day	leave at front door	1-hour daytime	$8	5 business days	$12
4	2 business days	leave at front door	2-hour daytime	$12	same day	leave at safe place	30-min daytime	$12	next day	$14
5	5 business days	leave at front door	no choice daytime	$12	3 business days	leave at safe place	2-hour daytime	$4	next day	$12
6	next day	leave at safe place	2-hour daytime	$16	within 2 hours	leave at front door	30-min daytime	$8	2 business days	$6
7	3 business days	signature required	2-hour daytime	$8	2 business days	leave at safe place	1-hour daytime	$6	next day	$16
8	next day	signature required	no choice daytime	$16	same day	leave at safe place	2-hour daytime	$12	3 business days	$6
9	2 business days	signature required	evening	$10	next day	leave at safe place	no choice daytime	$8	3 business days	$12
10	3 business days	leave at safe place	evening	$12	5 business days	leave at front door	30-min daytime	$8	next day	$12

Choice model specification

Data from the choice experiment is used to estimate a discrete choice model. More specifically, we estimate a conditional logit model (McFadden, 1973) with added error components to describe preference heterogeneity with respect to different delivery modes. Such a model is called an error component logit (ECL) model, which is a special case of the well-known mixed logit model (Hensher and Greene, 2003).

In our ECL model, let y_{nsj} denote an indicator variable that equals 1 if respondent *n* chooses delivery mode alternative *j*, i.e., postie, drone and locker, in choice task *s*, and zero otherwise. Based on random utility theory, we assume that decision makers are rational and select the alternative with the highest (perceived) utility U_{nsj},

$$y_{nsj} = \begin{cases} 1, & U_{nsj} > U_{nsi}, \text{ for all } i \neq j, \\ 0, & \text{otherwise.} \end{cases} \qquad n = 1,\ldots,709; s = 1,\ldots,10; j = 1,2,3. \tag{1}$$

Utilities can be computed as $U_{nsj} = V_j(\mathbf{x}_{nsj}) + \eta_j + \varepsilon_{nsj}$, where $V_{nsj}(\cdot)$ is the systematic utility function based on a vector of variables $\mathbf{x}_{nsj}$ consisting of levels of our chosen delivery attributes as main effects (delivery speed, delivery method, delivery time window, and delivery cost), and characteristics of the parcel (size, value of the content) and characteristics of the residential environment of the respondent (availability of a safe place of delivery for postie and drone) as interaction effects. These utility functions have associated unknown, and to be estimated, parameters, including alternative-specific constants. Further, $\eta_j \sim N(0, \sigma_j^2)$ is an alternative-specific normally distributed error component where the same draw from the distribution is used across all choice tasks to account for correlation between choices made by the same respondent (Revelt and Train, 1998). Finally, in a logit model, ε_{nsj} is an extreme value type I distributed unobserved utility component such that the probability p_{nsj} that respondent *n* chooses alternative *j* in choice task *s* is given by (McFadden, 1973):

$$p_{nsj} = \Pr\left(y_{nsj} = 1\right) = \frac{\exp\left(V_{nsj} + \eta_{nsj}\right)}{\sum_i \exp\left(V_{nsi} + \eta_{nsj}\right)}, \qquad n = 1,\ldots,709;\ s = 1,\ldots,10;\ j = 1,2,3. \tag{2}$$

For parameter identifiability reasons, we normalise the alternative-specific constant and standard deviation of the error component of the delivery mode locker to zero. Normalising a different constant has no impact on model results. Based on 7,090 choice observations, we obtained ECL model parameter estimates by maximising the simulated loglikelihood function with 500 quasi-random Sobol draws in R using the Apollo package. All categorical attributes and characteristics of the parcel and residential environment were included in the utility function using dummy coding. We tested hundreds of different specifications for utility functions $V_j(\cdot)$, including models with various interaction effects and nonlinear effects, and selected the final specification by comparing model estimations based on the Bayesian Information Criterion (BIC). BIC is defined as $K\ln(7090) - 2\ln(L)$, where K is the number of estimated parameters (less is better for parsimony) and L is the final loglikelihood value (higher values indicate a better model fit).

Results

Choice model estimations

Table 4 presents the estimation results of our ECL model for the pooled choice data set, as well as separate model estimations for the Waves 1 and Wave 2 data sets.[3] The corresponding utility functions are available in Appendix B. The BIC and loglikelihood values are reported and were used to compare the various models estimated within each of the data sets but cannot be compared across data sets. We observe that the parameter estimates across Waves 1 and 2 are mostly consistent. We carefully examined differences across the two data sets due to the lockdown in Australia during Wave 2, but only found a statistically significant effect in the delivery method. We accounted for this effect in the pooled data set via an interaction effect with "signature required". When pooling the two data sets, we estimated heteroscedastic models but found no statistically significant differences in the variances of ε_{nsj} and therefore could combine the data without adjusting for scale in the logit model. In the remainder of this section, we focus our discussion on the pooled data set.

Looking at *delivery mode*, the alternative-specific constant for 'Postie' (1.049) is larger than for 'Drone' (0.146), which indicates that, ceteris paribus,[4] people on average prefer postie over drone delivery. However, the estimated standard deviations of the error components for postie (2.192) and drone (2.419) are large and highly statistically significant, implying that a substantial amount of preference heterogeneity is associated with delivery mode preferences. Note that the constants for 'Postie' and 'Drone' cannot be compared directly to the constant of 'Locker', which was normalised to zero, because the parcel locker has unique fixed levels for delivery method and time window, namely, 'Secure in locker' and '24/7 (kept for two days)', see Figure 1, hence these attribute levels are confounded with the constants. The strong negative and statistically significant parameters for the interaction effects of 'Postie' with 'No safe place for postie' (-2.093) and 'Drone' with 'No safe place for drone' (-2.133) indicate that having no safe place available for these delivery modes makes them much less attractive (relative to parcel locker). The positive and statistically significant parameters for the interaction effects of 'Drone' and 'Locker' with 'Parcel value ≥AU\$100' (0.957 and 0.642, respectively) means that drones and parcel lockers become more attractive for parcels with high value content (relative to postie). We also tested whether content impacted preferences but found that content itself did not have a significant impact on delivery mode choice, likely because there is substantial variation within each content category. For example, category "consumer electronics" has a median price of AU\$100 and a coefficient of variation (CV) of 5.4 based on a mean price of AU\$225 and a standard deviation of AU\$540. CV values are even larger for the other categories except clothing and toys. In contrast, we found parcel value having a strong significant effect on delivery mode choice.

[3] The order dummy parameter estimates (included in the model to account for potential left-to-right bias of the main effects) were statistically insignificant and not further relevant to our analysis and thus omitted in Table 4.
[4] Assuming that all else is equal, i.e., the same delivery speed, method, time window, cost.

Table 4. ECL model estimation results

	Wave 1 data set		**Wave 2 data set**		**Pooled data set**	
Number of respondents	70		639		709	
Number of choice observations	700		6390		7090	
Parameter	*Estimate*	*t-ratio* [a)]	*Estimate*	*t-ratio* [a)]	*Estimate*	*t-ratio* [a)]
Delivery mode (constants)						
Postie	1.269	2.922 ***	0.988	5.981 ***	1.049	6.681 ***
x Safe place for postie (base)	0.000	--	0.000	--	0.000	--
x No safe place for postie	-2.205	-2.707 ***	-2.062	-6.993 ***	-2.093	-7.375 ***
Drone	-0.257	-0.450	0.184	0.957	0.146	0.791
x Parcel value <AU$100 (base)	0.000	--	0.000	--	0.000	--
x Parcel value ≥AU$100	0.230	0.372	0.947	3.612 ***	0.957	3.839 ***
x Safe place for drone (base)	0.000	--	0.000	--	0.000	--
x No safe place for drone	-2.221	-3.217 ***	-2.070	-6.589 ***	-2.133	-7.448 ***
Locker (base)	0.000	--	0.000	--	0.000	--
x Parcel value <AU$100 (base)	0.000	--	0.000	--	0.000	--
x Parcel value ≥AU$100	0.921	1.796 *	0.560	2.484 **	0.642	3.049 ***
Delivery speed						
Five business days (base)	0.000	--	0.000	--	0.000	--
Three business days	0.199	0.852	0.313	3.781 ***	0.297	3.818 ***
Two business days	0.503	2.383 **	0.523	6.115 ***	0.502	6.422 ***
Next business day	0.677	4.080 ***	0.917	11.619 ***	0.893	12.139 ***
Same business day	1.547	3.073 ***	1.343	11.455 ***	1.290	11.412 ***
Two hours	1.827	3.304 ***	1.463	11.741 ***	1.431	11.783 ***
Delivery method						
Leave at front door (base)	0.000	--	0.000	--	0.000	--
Leave in safe place	0.229	1.233	0.261	3.019 ***	0.256	3.184 ***
Signature required	0.061	0.394	-0.201	3.019 ***	0.119	0.884
x Safe place for postie (base)	0.000	--	0.000	--	0.000	--
x No safe place for postie	1.233	1.539	1.097	4.331 ***	1.155	4.685 ***
x No lockdown (base)	--	--	--	--	0.000	--
x Lockdown	--	--	--	--	-0.669	-2.384 **
Delivery time window						
Daytime no choice (base)	0.000	--	0.000	--	0.000	--
Daytime 2-hour window	0.465	1.891 *	-0.231	-2.771 ***	-0.171	-2.174 **
x Safe place (base)	0.000	--	0.000	--	0.000	--
x No safe place [b)]	0.100	0.269	0.341	2.203 **	0.320	2.262 **
Daytime 1-hour window	0.006	0.012	0.066	0.689	0.103	1.128
Daytime 30-min window	0.892	1.810 *	0.013	0.124	0.084	0.849
Evening	0.329	1.385	-0.219	-2.059 **	-0.175	-1.819 *
Delivery cost						
Cost	-0.341	-3.963 ***	-0.389	-14.854 ***	-0.381	13.717 ***
x Parcel value <AU$50 (base)	0.000	--	0.000	--	0.000	--
x Parcel value AU$50-AU$100	0.061	0.522	0.099	3.074 ***	0.093	2.836 ***
x Parcel value ≥AU$100	0.195	2.199 **	0.189	5.986 ***	0.191	6.094 ***
Error components						
Standard deviation Postie	1.765	5.300 ***	2.283	15.333 ***	2.192	15.869 ***
Standard deviation Drone	2.019	5.913 ***	2.446	19.789 ***	2.419	20.403 ***
Model fit						
Loglikelihood (0)	-769.03		-7020.13		-7789.16	
Loglikelihood (final)	-525.43		-4468.58		-5009.46	
Bayesian Information Criterion	1221.19		9164.99		10258.31	

[a)] * = weakly significant (p<0.10,t>1.645), ** = significant (p<0.05,t>1.96), *** = strongly significant (p<0.01,t>2.58)
[b)] This interaction is generic across all daytime windows (i.e., it also applies to 1-hour window and 30-min window)

With respect to *delivery speed*, with '5 business days' being the base level with zero utility, all parameters are highly statistically significant, i.e., the faster the delivery, the more preferred, as expected.

The *delivery method* describes the way a parcel is left by postie or drone and the positive and statistically significant parameter for 'Leave in safe place' (0.256) shows that consumers prefer the option of leaving/dropping the parcel at a safe place compared to leaving it visibly at their front door (set as the base level with zero utility). As mentioned earlier, 'Leave at a safe place' for postie and drone was only shown to those respondents that indicated to have a safe place for these delivery modes at their home address. Requiring a signature on delivery, only possible with a postie, is only found to become significantly desirable when a safe place for postie is not available (1.155), although the data collected during lockdown in Wave 2 shows an aversion (-0.669) to it due to obligatory physical distancing.

In regard to the *delivery time window*, most parameters are small and not statistically significant, meaning that this attribute is not very important to most people. Evening deliveries are mostly disliked (-0.175), while a specific time window during the daytime mainly becomes attractive (0.320) for a certain delivery mode when a safe place is not available for that delivery mode.

The parameter for *delivery cost* is negative and highly statistically significant, which is expected as consumers are generally price sensitive. However, price elasticity decreases with the value of the parcel content, with low value (less than AU$50), medium value (between AU$50 and AU$100), and high value (more than AU$100) parcels having cost parameters of -0.381, 0.093-0.381, and 0.191-0.381, respectively.

Relative importance of delivery attributes and willingness to pay

Based on the parameter estimates in Table 4, we were able to determine the relative importance of the delivery attributes based on part-worth utility ranges of each attribute (Orme, 2020). As shown in Figure 2, delivery cost contributes more than 50% to utility, where the relative importance of delivery cost decreases with the value of the parcel.

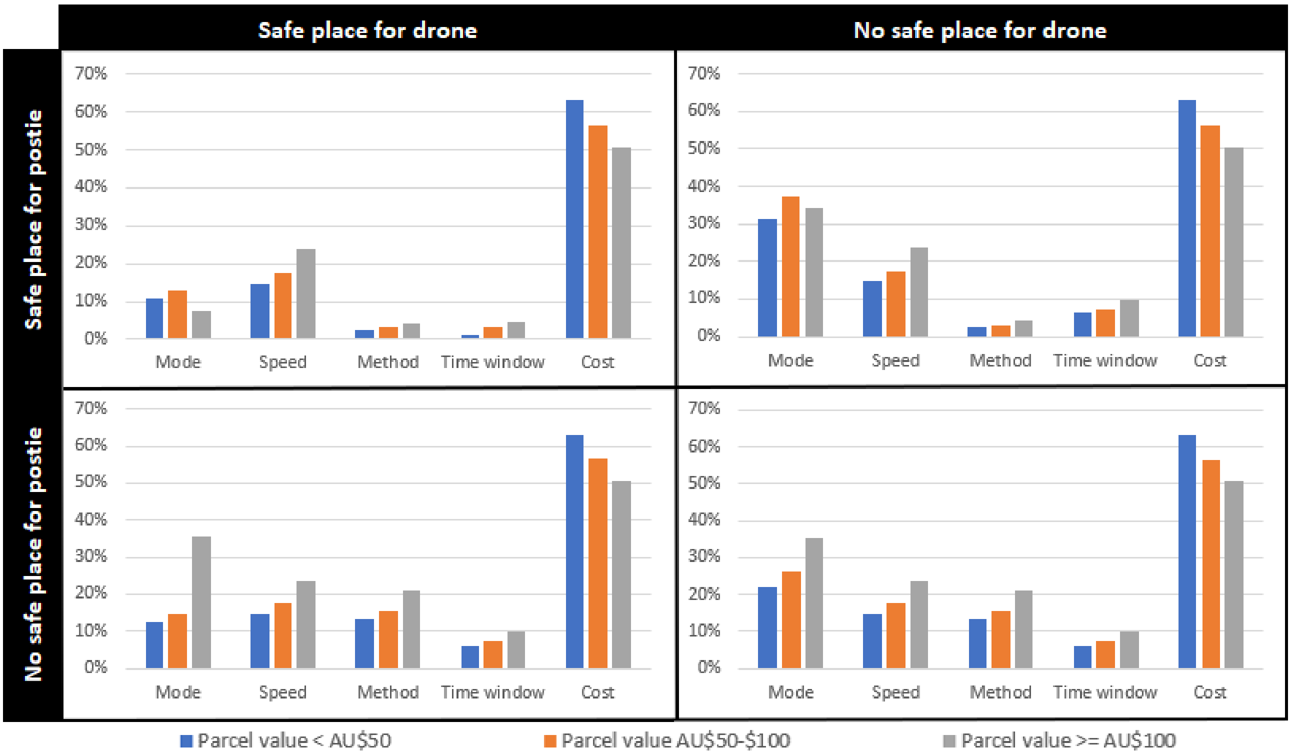


Figure 2. Relative importance of attributes

After delivery cost, delivery speed is generally most important if consumers have a safe place for drone, while delivery mode is most important if consumers have no safe place available for drone. Further, we observe that if no safe place is available for postie, then delivery mode becomes much more important for parcels of high value. Finally, delivery method only seems to play a role for consumers who have no safe place for postie, while delivery time window is overall least important. Given that drone delivery is expected to be faster and cheaper than postie, there seems considerable scope for drones to gain market share if these benefits are indeed realised (see market share section).

In Table 5 we present monetary WTP values by people in urban areas in Australia for various levels of delivery mode, speed, method, and time window, based on the parameter estimates in Table 4. Relative to delivery within five business days, our data suggests that they are willing to pay up to AU$7.52 (=1.431/(0.191–0.381)) for delivery within 2 hours of a high value parcel. If drones can deliver faster than a postie (same business day delivery or within 2 hours) then drone delivery can present considerable value for consumers.

Table 5. Willingness to pay for key attributes of last-mile parcel delivery

		Parcel value	
Attribute level	< AU$50	AU$50-AU$100	>=AU$100
Delivery mode *(Relative to drone)* [a]			
Postie:			
- if safe place for postie & drone available	AU$2.37	AU$3.13	-AU$0.29
- if no safe place for drone available	AU$7.96	AU$10.52	AU$10.92
- if no safe place for postie available	-AU$3.12	-AU$4.13	-AU$11.29
- if no safe place for postie & drone available	AU$2.47	AU$3.26	-AU$0.08
Delivery speed *(Relative to 5 business days)*			
3 business days	AU$0.78	AU$1.03	AU$1.56
2 business days	AU$1.32	AU$1.74	AU$2.64
Next day	AU$2.34	AU$3.09	AU$4.69
Same day	AU$3.38	AU$4.47	AU$6.78
2 hours	AU$3.75	AU$4.96	AU$7.52
Delivery method *(Relative to leave at front door)*			
Leave in safe place	AU$0.67	AU$0.89	AU$1.34
Signature required:			
- if safe place is available & no lockdown	AU$0.31	AU$0.41	AU$0.62
- if safe place is not available & no lockdown	AU$3.34	AU$4.41	AU$6.69
- if safe place is available & lockdown	-AU$1.44	-AU$2.89	-AU$2.89
- if safe place is not available & lockdown	AU$1.58	AU$2.09	AU$3.17
Delivery time window *(Relative to daytime no choice)*			
Evening 3-hour time window	-AU$0.46	-AU$0.60	-AU$0.92
Daytime 30-min time window [b]			
- if safe place available	AU$0.22	AU$0.29	AU$0.44
- if no safe place available	AU$1.06	AU$1.40	AU$2.12
Daytime 1-hour time window [b]			
- if safe place available	AU$0.27	AU$0.36	AU$0.54
- if no safe place available	AU$1.11	AU$1.47	AU$2.22
Daytime 2-hour time window			
- if safe place available	-AU$0.45	-AU$0.59	-AU$0.90
- if no safe place available	AU$0.39	AU$0.52	AU$0.78

[a] Since the normalised constant for locker is confounded with the locker-specific attribute levels for delivery method and time window. [b] The main effect was not statistically significant in Table 4, hence these values are less reliable.

With respect to delivery method, consumers in our study are willing to pay a modest amount for leaving the parcel in a safe place relative to leaving it at the front door but are willing to pay up to

AU$6.69 for a high value parcel if they do not have a safe place for postie. Further, they are willing to pay up to AU$2.22 for selecting a specific delivery time window if they do not have a safe place available at their home address. Finally, our data suggests that consumers are willing to pay up to AU$10.92 more for delivery by postie if they do not have a safe place available for drones, while they are prepared to pay up to AU$11.29 less for postie delivery of high value parcels if they do not have a safe place available for postie.

Market share simulation

In this section we present market share simulations based on expected choice probabilities in the ECL model given certain choice scenarios, attribute levels, and market segments, taking different price elasticities into account for parcels of different size and value. We were interested to see what happens to market shares of postie and drone under different costs for drone delivery.

To illustrate the computation of expected choice probabilities, consider the example choice task in Figure 1, and assume the situation that a consumer has a delivery of a small parcel with high value content (>AU$100) and this consumer has a safe place for postie but does not have a safe place for drone. Then based on Table 4 the systematic utilities can be computed based on attribute levels presented in Figure 1 and utility functions in Appendix B:

$$\begin{aligned}
V_{\text{postie}} &= \underbrace{1.049}_{\text{delivery mode}} && \underbrace{+0.893}_{\text{delivery speed}} && \underbrace{+0.256}_{\text{delivery method}} && \underbrace{-0.175}_{\text{delivery time window}} && \underbrace{+14\cdot(-0.381+0.191)}_{\text{delivery cost}} \\
V_{\text{drone}} &= 0.146-2.133+0.957 && +0.297 && +0 && +0.103+0.320 && +8\cdot(-0.381+0.191) \\
V_{\text{locker}} &= 0+0.642 && +0.502 && && && +6\cdot(-0.381+0.191)
\end{aligned} \tag{3}$$

which results in $V_{\text{postie}} = -0.637$, $V_{\text{drone}} = -1.830$, and $V_{\text{locker}} = 0.004$. For each value of the error components, choice probabilities can be computed via Equation (1). Using Monte Carlo simulation with 1,000 quasi-random draws for error components $\eta_{\text{postie}} \sim N(0, 2.192)$ and $\eta_{\text{drone}} \sim N(0, 2.419)$, the expected choice probabilities for postie, drone and locker are 37%, 19%, and 44%, respectively.

Building on Nguyen et al. (2019), we specify four realistic baseline scenarios tailored to our Australian context to then forecast potential market shares, varied by size/weight of the parcel (small up to 1kg versus large 1-5kg) and considering both express delivery (assumed to be next business day delivery) and standard delivery (assumed delivery in three business days). Associated baseline prices (since we now take the perspective of a logistics service operator it is no longer appropriate to refer to costs) for postie and locker are based on April 2020 average prices with Australia Post, namely AU$10.58 for standard small, AU$13.83 for express small, AU$16.83 for standard large and AU$22.43 for express large parcels. In all scenarios, we consider the status quo of parcel deliveries during daytime where no time window can be chosen.

For each baseline scenario, we computed expected choice probabilities of postie, drone and locker where we varied delivery price for drone from AU$2 to AU$24. For each price level we then considered 12 market segments based on availability of a safe place for postie (80% in our sample), availability of a safe place for drone (68% in our sample), and parcel content value (37%, 27%, and 36% of our sample ordered parcels of low, medium, and high value, respectively). For each baseline scenario and price level, we computed the expected market share via a weighted average over all market segments using the above observed segmentation fractions, which required 576 separate Monte Carlo simulations (4 baseline scenarios, 12 price levels, 12 market segments) each with 1,000 quasi-random draws for the two error components.

Simulated market shares are presented Figure 3, noting that they do not add up to 100% since the remaining market share is for parcel locker. The results suggest for all baseline scenarios that if drone delivery has the same (baseline) price as postie and locker, then postie is preferred over drone. Considering a standard small parcel in that situation (with baseline price AU$10.58), postie would have a roughly 20% points higher market share than drone and the highest market share drones achieve in our forecast is 52% at the AU$2 price level. For express large parcels, drones can reach up to 83%

market share if they are priced at AU$2 per delivery, although this may not be commercially feasible given the higher cost of large/bulky deliveries.

Further, we observe for standard small parcels that drones become the preferred option once the drone delivery price falls below AU$6.50, while for express small parcels drone delivery price needs to fall below approximately AU$10. For standard large parcels drones are preferred once the drone delivery price falls below approximately AU$13, while for express large parcels the drone delivery price would need to fall below AU$18.50. While postie is preferred over parcel lockers at the same price level, lockers could still have a market share around 40% if the drone delivery price is very high.

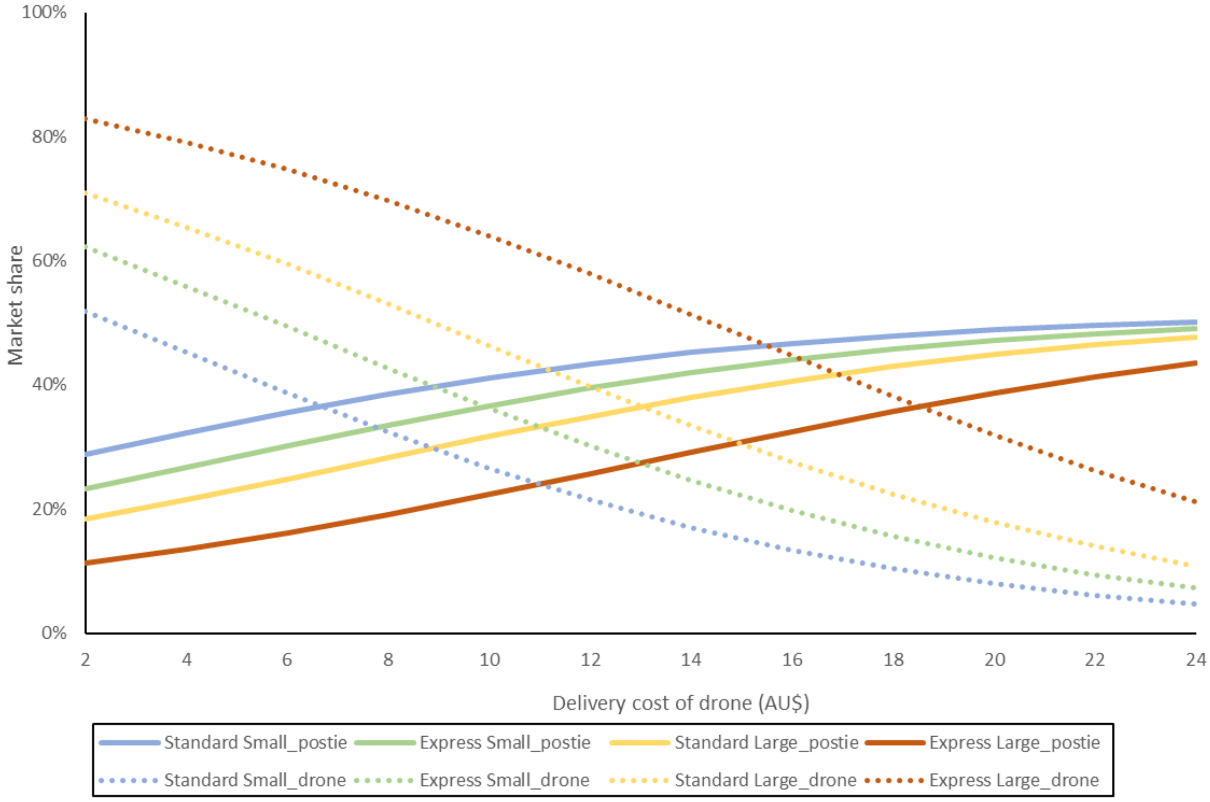


Figure 3. Market shares for postie / drone at different drone delivery prices

Conclusions

By developing a stated choice experiment based on random utility theory and deploying it to the last-mile parcel delivery context, we identified that despite the boom in e-commerce and technological advancements, traditional postie services are still the preferred option compared to aerial drones and lockers for consumers in Australian urban areas. That said, our market share simulations indicate that different to the niche market offerings they aspire today, aerial drones can become the preferred delivery mode with market shares up to 83%. Aerial drone operators can achieve that if they deliver at a low price, but more than free of charge, as proposed by Buldeo Rai et al. (2019), which in turn gives rise to logistics service provider opportunities. We further show that situational context – parcel value, availability of a safe place for delivery – moderates preferences for delivery modes and WTP for add-on services, such as signature on delivery. Especially our finding related to the availability of a safe place introduces a new dimension to the discussion in the literature, that of situational context and infrastructure at the receiving end of physical distribution and innovative last-mile parcel delivery.

Theoretical implications

Our key theoretical contribution is the development of a microeconomic model that describes consumer preferences towards parcel delivery by postie, aerial drone, and parcel locker in metropolitan areas. The newly established relationships in this model contain information about the willingness-to-pay for delivery speed, delivery method and delivery time window for parcels of different value, and can be used to predict delivery mode market shares for different types of parcels distinguished by size, weight, and content value. Through the use of D-efficient choice experiment data tailored to the specific delivery environment and context of each respondent, our model is expected to have a high degree of reliability and external validity. Our results confirm broader last-mile delivery studies (Garver et al.; 2012; Nguyen et al.; 2019) for the postie/aerial drone/locker parcel context by showing high preference for cheap and fast deliveries.

Reflecting on Buldeo Rai et al. (2019) and Caspersen and Navrud (2021), who both found that consumers accept increased delivery time in return for reduced emissions, our results suggest that delivery speed is highly valued by parcel delivery consumers. Importantly, both studies did not include aerial drone deliveries but were limited to parcel lockers. Assuming that aerial drones are very carbon emission friendly, our findings suggest that consumers can have both, very fast (within 2 hours) and carbon low parcel delivery. This removes the delivery speed/carbon emission trade-off where aerial drone delivery is available and hence adds to the extant literature on innovative last-mile delivery.

Moreover, preferences for parcel delivery in our utility functions are moderated by situational context and parcel value. First, we show that parcel value positively impacts the preference for lockers and even more so the desire to use drones, relative to postie. In contrast to Gawor and Hoberg (2019), who used cluster analysis and only considered relatively high value parcels (retail price of goods purchased online US$130 to US$1,280)[5], our scope was broader by considering a much wider range of parcel values (AU$5 to AU$5,000 in our sample).

Second, we show that with increased parcel value, customers tolerate much higher delivery cost, which is not something that has been mentioned in the extant literature (e.g., Mittendorf et al., 2017). Indeed, our results contrast Tokar et al.'s (2020) notion of online shoppers not being prepared to pay for superior delivery services and Buldeo Rai's (2019) findings of consumers not being prepared to pay at all for delivery services of low value items.

Third, we empirically confirm McKinnon and Tallam's (2003) notion that consumers may worry about security and illegal intent regarding unattended deliveries to their homes by adding availability of a safe place as a moderator in parcel delivery choice model, impacting not only preferences for mode, making lockers more and drones/postie less desirable, but also delivery method. Whilst previous studies have shown that perceived risk plays a role in the adoption of self-service parcel services (Zhou et al., 2020) and delivery drones (Osakwe et al., 2021), our results suggest that such perceived risks exemplified through a lack of safeguards also moderate consumer preferences in both the aerial drone and traditional postie delivery contexts. By adding the dimension of having a safe place available, especially for high value items, sheds new light on the discussion and highlights the importance of situational context and infrastructure at the receiving end of last-mile delivery. The literature on consumer acceptance of logistics technologies (Cai et al., 2021) may find this of interest. It could be argued that the availability of insurance could help with this, but Garver et al.'s (2012) results suggest relative low utility for insurance availability and our parcel values are on average so low that insurance would not be justifiable. Our results suggest further that requiring a signature on delivery is generally not important to consumers but becomes significantly desirable when a safe place for postie is not available and significantly undesirable during lockdown where physical distancing was obligatory. This shows that there can be a multitude of perceived risks impacting consumer preferences and therefore the value of add-on services such as signature on delivery depends on whether the potential exposure is minimised through contextual risk mitigation.

In terms of WTP, in addition to our revealed same day delivery values (AU$3.38-AU$6.78) relative to delivery within 5 business days, our study offers first evidence on WTP for an even speedier 2-hour delivery (AU$3.75 to AU$7.52). Gawor and Hoberg (2019) is the closest comparator in the extant literature, revealing WTP for same day online shopping delivery ranging from US$2.33 to US$10.79 (relative to delivery in 3–4 days) depending on type of consumer group. At face value our WTP values seem slightly smaller but the relative premium/value for speedy delivery is much higher considering that parcel values in our study were often less than AU$50. We further reveal WTP of up to AU$2.22

[5] The US$/AU$ exchange rate as of 7 June 2021 is 1.29. Further note that comparisons with findings in the extant literature are prone to distortions, as the base levels of relative effects usually differ.

for selecting a specific delivery time window and AU$6.69 for signature at delivery if no safe place is available for postie or drones.

Managerial implications

Much of the extant literature offers recommendations for (e-)retailers, such as Tokar et al. (2020) suggesting that customers value enhanced delivery services but are not willing to pay for them or Buldeo Rai et al. (2019) recommending omnichannel retailers to introduce more pick-up and return locations and to rely on slower but free delivery due to consumers being happy to wait and them valuing sustainability. With a focus on last-mile delivery rather than online shopping consumer preferences, our results not only contrast those studies (e.g., speed clearly matters to WTP in the last-mile parcel delivery context) but also extend the previous evidence to consumer preferences associated with delivery modes, including aerial drones, with clear managerial implications for last-mile physical distribution and logistics service providers. For example, Australia Post valued our mode choice findings where postie is on average still being the preferred option, at least in the low value parcel space. Drone preference increases dramatically with parcel value, which is perhaps the most impactful finding from a management perspective, given that current drone delivery applications often focus on small value items such as coffee or pizza. We argue that aerial drone delivery companies should instead focus on more valuable, time critical secure consignments that can demand higher premiums and hence commercially viable operations. Moreover, drones are expected to be competitive in certain markets since they perform strongly on two attributes that were found in our study to be of high relative importance to consumers, namely delivery cost and speed. In the small parcel delivery market drones are competitive from as low as AU$6.50 and AU$18.50 for standard small and express large deliveries, respectively. Those costs are not too far-off today's market cost using traditional delivery options and if drones can deliver faster, it is not implausible that once available to consumers, drone delivery options could quickly gain market share. As such, our findings support the extant literature that talks to various innovative applications of drones as a service (Shahzaad et al., 2019) and provide empirical evidence of considerable market opportunity for aerial drones in the physical distribution context. Put this argument the other way around, for logistics service providers to remain competitive without using drones, they may need to make postie or locker operations more cost efficient and ultimately cheaper to use. As part of this discussion, investment costs for operating an aerial drone delivery network need to be considered, too, but those were not part of the scope of this study.

Our results suggest further that not having a safe place for parcel delivery by postie and drones does not automatically leave parcel lockers as the preferred alternative. Logistics providers may not only be able provide add-on services to compensate for the lack of safe place, such as time specific deliveries and signature on delivery, but also charge for them. Our presented WTP values can be used by logistics service providers, who in today's fast-changing world need to not only make strategic decisions around engaging in aerial drone delivery but also regarding what value-added services to attach to potential drone services or conversely to postie and then how to price them attractively and competitively. Our simulation results, whilst showing that both postie and locker are still enjoying healthy market shares under current operating and pricing conditions, suggest price infliction points and much higher potential market shares for drones than expected. Logistics providers may therefore consider investing into aerial drone technology and commence with a skimming pricing and marketing strategy. Those already invested in locker and/postie assets may want to start thinking about ways that would allow them to price their services much more competitively.

Limitations and future research

A potential limitation of our study is the single mode character of the presented last-mile delivery solutions. While we appreciate that drones can also be used in multi-trip delivery models with trucks (Moshref-Javadi et al., 2020), our focus was on the interface between private consumers and the final leg of delivery. Future research may expand our methodology to multi-modal solutions and other jurisdictions. While we are confident that our results are representative for the urban context, future research should also investigate consumer preferences for parcel deliveries in regional areas. Having regulatory advantages, regional and sparsely populated areas may be the first to experience drone delivery solutions due to reduced complexity and traffic in the regional setting, although such operations may not be commercially viable. We emphasize that our conclusions are drawn purely from a consumer and logistics service provider point of view, clearly regulatory frameworks need to be in place to allow drones to fly safely in urban areas with minimal negative externalities (e.g., noise). While our data is limited to Australia, global consultancy studies have shown that consumer choices around parcel delivery options follow similar trends regardless of the jurisdiction (Joerss et al., 2016). We still recommend future research here, as the situational context, such as availability of a safe place, may differ globally.

In our simulation we were primarily interested in market shares and mode sensitivities to price changes and the results are useful in the context of revenue/demand maximization. Future research should further investigate cost/profit functions of the three modes in the various contextual environments to understand the ultimate choices of logistics service providers, i.e., whether they pass on cost savings, investment cost of building up an aerial drone delivery network, including infrastructure. It would further be worth considering cost-benefit analysis for logistics service providers to invest into safe places to leave unattended parcels in large apartment blocks.

Finally, we note that our data was collected during the COVID-19 pandemic. We expect consumers to prefer cheaper and faster deliveries under all circumstances, but we acknowledge that our measured preferences towards delivery mode and method may have been impacted by the pandemic. It is impossible to say whether long-term preferences are better reflected by data collected during the pandemic, often referred to as the 'new normal' given its expected long-lasting impact, or by data collected prior to the pandemic, i.e., the 'old normal'. As a recommendation for future research, we propose repeating the same choice experiment in a future year to investigate preference stability.

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