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Consumer preferences for on-demand transport in Australia

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ABSTRACT

On-demand transport (ODT) refers to adaptive transport services that use a fleet of vehicles to provide shared flexible transport to consumers, when and where they need it. This study surveyed 3,985 geographically and demographically representative Australians nationwide, to understand consumer demand and willingness to pay for ODT in Australia. Our analysis finds that the current market for ODT services in Australia is small. For example, for an ODT service that costs roughly the same as UberX's ridesharing service, and offers comparable level-of-service, our analysis predicts that only 17 per cent of the Australian population can be expected to use the service a few times a week or more. However, shared electric autonomous vehicles could significantly change the business case for ODT services, by enabling on-demand door-to-door transport services at a fractional cost of similar existing services. Our analysis finds that while consumers are willing to pay, on average, 0.28$/km more to avoid sharing a vehicle with other passengers, 0.17$/km more for door-to-door service, and 0.10$/km to be able to book the service in real time, cost is the most important determinant of ODT use (of the service attributes included in our analysis). For an ODT service that provides the same level-of-service as UberX, but at a fractional cost of $0.30 per km, 31 per cent of the Australian population can be expected to use the service a few times a week or more. And this figure is likely to be larger once we account for more long-term changes in lifestyles that might accompany the introduction of these services. We find that frequency of ODT use is strongly correlated with age and lifecycle stage: young individuals who are employed full-time are likely to use ODT most frequently; older adults who have retired from the workforce and whose children have left home are likely to be infrequent users. Overall, our analysis indicates that ODT services have the ability to both increase public transport use among existing public transport customers, and to draw new customers to public transport services.

1. Introduction

On-demand transport (ODT) refers to adaptive transport services that use a fleet of vehicles to provide shared flexible transport to consumers, when and where they need it. ODT has existed in one form or another since the earliest days of urbanization, and has included such diverse modes of transport as horse-drawn carriages, cycle rickshaws, and modern-day taxicabs. Recent advances in information and communication technologies have enabled newer forms of ODT, such as ridesharing, that aim to remove some of the pain points associated with older ODT services (Rayle et al., 2016), often referred to in the literature as Demand Responsive Transport (DRT) or more recently Flexible Transport Services (FTS) (e.g. Nelson and Wright, 2012). The imminent introduction of autonomous vehicle (AV) technology is expected to further ease the provision of these services, and increase their appeal to consumers (Haboucha et al., 2017; Krueger et al., 2016).

ODT has attracted considerable attention from both the public and private sector, within Australia and globally. Public authorities are exploring the ability of ODT to plug service gaps within existing public transport networks, as reflected for example by ongoing ODT trials in the states of Queensland and New South Wales in Australia (O'Sullivan, 2018). Private corporations are viewing the point-to-point transport market as an increasing source of future revenue, in light of both the success of existing ridesharing service providers, such as Uber, DiDi and Ola Cabs, and the expected arrival of AV technology (Ridester, 2018).

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The objectives of this paper are two-fold: (1) to explore Australian consumer preferences for ODT; and (2) to support the development of suitable ODT services for the Australian community. In service of these objectives, we surveyed 3,985 Australians nationwide in March 2018 on their attitudes and opinions towards different ODT services, and their willingness to pay for use of these services. This study reports some of the key findings that emerged from our analysis of this data.

We make two major contributions to the literature on the consumer demand for ODT and related services. First, we test the influence of ODT service attributes that have been overlooked by previous studies, but are essential to understanding how these services should be designed in practice. For example, how do consumer preferences for door-to-door ODT services compare with ODT services that stop at designated points but have flexible routes that change based on real-time demand, not controlling explicitly for differences in travel time? How much are consumers willing to pay to be able to book ODT services in real time? Second, we have a much larger sample than previous relevant studies on the subject. Consequently, our analysis is able to offer richer insights on the geographic and demographic determinants of consumer demand. In particular, we are able to identify multiple niche segments in the market that ODT service operators should target to maximize patronage.

The remainder of the paper is structured as follows. Section 2 reviews the literature on ODT services, with an emphasis on the Australian context. Section 3 describes the survey instrument that was used to collect consumer data. Section 4 undertakes a descriptive analysis of our sample, and their attitudes and opinions towards ODT services. Section 5 presents the methodological framework underlying our more detailed econometric analysis of the consumer data; and Section 6 reports estimation results for the framework. Section 7 draws out some of the key findings from our analysis for transport practitioners and policy-makers interested in the design, provision and regulation of ODT services. Finally, Section 8 concludes with a discussion of key findings and directions for future research.

2. Literature review

This section reviews studies that have examined the demand for different variants of ODT services. As mentioned previously, ODT services have existed under different names since the earliest days of urbanization. We use the term ODT as a generalization for any public transport service that does not operate on fixed routes and fixed schedules. The term has been adopted by industry and government in Australia as a descriptor for flexible route and/or flexible schedule public transport services currently being trialled across the nation (e.g. KD, 2018). As our sample is drawn from Australia, and findings from our analysis are likely to prove most useful to Australian practice and policy, we have adopted the term as well for our study.

Note that Nelson and Wright (2012) introduce the closely related term Flexible Transport Services (FTS) as "an emerging term in passenger transport which covers a range of mobility offers where services are flexible in one or more of the dimensions of route, vehicle allocation, vehicle operator, type of payment and passenger category…This encompasses traditional dial-a-ride/paratransit services which have existed for over 40 years, more recent telematics-based Demand Responsive Transport for the wider public, taxis, and informal transport solutions mainly associated with developing countries. Importantly the definition of FTS also includes car sharing and lift sharing services." Based on this broad definition, ODT services may be considered as a specific form of flexible transport service.

Section 2.1 reviews studies that have examined the demand for ODT and related flexible transport services that have typically been offered by the public sector as a way of increasing accessibility for those underserved by more traditional fixed route and fixed schedule services. Section 2.2 reviews studies that have examined the demand for taxis and ridesharing services, such as Uber, which represent more commercially oriented versions of ODT services that are operated by the private sector based on profit maximizing principles. And finally, Section 2.3 reviews studies that have examined the demand for shared autonomous vehicles, which are likely to represent the future of ODT services.

2.1. On-demand and related flexible transport services contracted by the public sector

Historically, the public sector has contracted flexible transport services as a means of offering greater transport access and mobility to individuals living in exurban and peri-urban areas that do not have population densities that are high enough to support comprehensive public transport network coverage, and individuals unable to access and use conventional means of public transport services due to physical barriers, such as older adults and individuals with physical disabilities (Logan, 2007). Consequently, in some cases access to these services may not be available to everyone, but limited to specific population sub-groups, based frequently on age, disability status, and place of residence (e.g. community transport services in Australia; QG, 2016). For an excellent collection of academic research on flexible transport services, including but not limited to on-demand and related services contracted by the public sector, the reader is referred to Nelson and Wright (2012).

Flexible transport services have been adopted in many parts of Europe and the US, but have struggled to find traction in the Australian market (Daniels and Mulley, 2012; Mulley et al., 2012). In general, the commercial viability of these services has been a major impediment to greater adoption (e.g. Ryley et al., 2014; Currie, 2007). However, experiences in Europe indicate that at least in some cases, flexible transport services contracted by the public sector have lower subsidy costs per trip than scheduled services (Mageean and Nelson, 2003; CfIT, 2008). In places where flexible transport services have been successful, strict market regulation has been viewed as an important contributing factor. For example, in their analysis of demand responsive transport (DRT) services in Europe, Mageean and Nelson (2003) write, "In terms of the relationship between DRT and scheduled and other public transport, experience shows that the more regulated the environment (e.g. Belgium, Italy), the less conflict there is between DRT and other public transport modes making DRT strategically more easy to implement. Operators with a monopoly can plan services as they see fit, which should lead to a service without duplication, gaps and the fear of losing customers to competitors… However, an innovative authority is required, taking a long-term view of the service. If only a short-term view is taken… DRT is unlikely to be implemented." Studies that have examined consumer preferences for flexible transport services report greatest demand in areas with low car ownership, low population density, and high levels of social deprivation (e.g. Wang et al., 2014).

More recently, public sector organizations are leveraging advances in information and communication technologies to improve the provision and operation of flexible transport services. It is under this general context that the term 'on-demand transport' has been introduced in Australia, to distinguish them both from flexible transport and related services that are accessible only to limited sections of the population, such as community transport, and from bus services that operate according to fixed routes and fixed schedules. Ongoing ODT trials in metropolitan Sydney and regional New South Wales offer potential passengers the option of booking services through a smartphone app (O'Sullivan, 2018). Some of these services offer door-to-door pick-up and drop-off within pre-specified catchment areas, typically of the size of a few square kilometres, others pick-up and drop-off passengers from designated stops that change in real time. Rides are currently charged at flat fares (roughly between $2 and $4) that are not adjusted for distance. And finally, the majority of these services can be booked in real-time (up to 5–10 min before pick-up).

This study was commissioned in part due to the increasing interest from the public sector in the provision and operation of smartphone-enabled ODT services, as a way to plug gaps within existing fixed schedule fixed route public transport services, and to offer similar levels of flexibility as traditional community transport services to the general public. In particular, service providers and regulators are interested in understanding what services to design, and who to target. Previous studies have examined related questions in the context of ridesharing and shared AV services (these studies are reviewed over following subsections, for the sake of completeness). However, these questions have not been addressed before in the specific context of smartphone-enabled ODT services. As mentioned previously, our analysis builds on this previous body of work in two key ways. First, our analysis quantifies the relative influence of service attributes that have been overlooked by previous studies, such as the importance of route and schedule flexibility (not controlling explicitly for differences in travel times), or the ability to book travel in real time. And second, our analysis identifies market segments that service operators should target to maximize patronage. Many of the geographic and demographic determinants of these high demand segments, as uncovered by our analysis, are consistent with analogous findings reported by studies on ridesharing and shared AV services. However, due to our significantly larger sample size, we are able to uncover multiple niche segments that have been missed by previous studies.

2.2. Taxis, ridesharing and other on-demand transport services not contracted by the public sector

If different ODT services were plotted along a spectrum that represents varying degrees of route and schedule flexibility, then conventional public transport services that operate along fixed routes and adhere to fixed schedules would represent one end of the spectrum, and taxis and ridesharing services that offer flexible point-to-point transportation would represent the other end. Taxis have existed in different forms since the earliest days of urbanization, from the horse-drawn for-hire hackney carriage services that began operating in London and Paris in the early 17th century, through to the modern engine-powered for-hire car services currently operating in most major metropolitan regions across the world.

Ridesharing services represent a more recent phenomenon that has been enabled in large part by advances in information and communications technologies. However, early precursors to modern day rideshare services include more informal arrangements, such as carpool clubs and 'slugging' (Wilson, 2013). For example, in many American cities with high occupancy vehicle (HOV) lanes on freeways, solo car drivers may pick up additional passengers from designated stops, as part of a non-monetary transaction that gains the driver access to the faster moving HOV lane, and gives the passengers a free ride. The term 'ridesharing services' has been used in particular to refer to transportation network companies (TNCs) that use smartphone applications to match individuals wishing to make a trip from a specified origin to a specified destination with individuals willing to drive them there in their personal cars (Rayle et al., 2016). These services have also been referred to as 'ridesourcing' services (e.g. Shaheen and Cohen, 2018) and 'ridehailing' services (e.g. Circella and Alemi, 2018), which are perhaps more accurate descriptors for these services. However, in Australia, these services continue to be referred to as rideshare, and that is the term that we persist with as well.

Like taxis, ridesharing services offer point-to-point transportation. However, there are some key differences between the two: (1) individuals wishing to request or provide rides must register with the ridesharing service before they can use it; (2) rides are crowdsourced from a pool of available drivers that consists largely of part-timers, usually not licensed to drive commercial vehicles, looking to supplement their incomes from other jobs (e.g. Berger et al., 2018); (3) the ridesharing service employs location-based smartphone technology and data mining algorithms to reduce waiting times, increase reliability and adjust fares in real-time; (4) payments for each trip are processed online using billing information provided at the time of registration by the individuals requesting and providing the ride; and (5) after the trip, the individual who requested the ride can leave feedback about the individual who provided the ride, and this information is visible to other users of the service.

These differences independently may appear marginal at best, but together they have helped create a new paradigm for transportation. Uber, DiDi and Ola Cabs have emerged perhaps as the preeminent ridesharing services currently operating in the world: at the time of writing, Uber offers ridesharing services in 633 cities worldwide; DiDi in 400 cities across China; and Ola Cabs in 110 cities in India. Both DiDi and Ola Cabs have plans for expansion into overseas markets, with the latter having recently launched in Australia. Traditional taxi and ODT services are adopting some of the same service-based principles championed by ridesharing services. As mentioned previously, ongoing ODT trials in New South Wales offer potential passengers the option of booking services through a smartphone app (O'Sullivan, 2018). Similarly, apps like GoCatch and InGoGo allow users to make taxi bookings through smartphone interfaces that are similar to those used by ridesharing services (Mannix, 2016). Conversely, in some cases, rideshare services too have been forced to adopt more traditional technologies. For example, Uber drivers accept cash payments in many parts of Latin America, and the strategy has been key to the company's success in the region (Rochabrun, 2018). Increasingly, the boundaries between ridesharing, taxi and on-demand transport services are becoming less clear.

The competition between traditional taxi services and newer ridesharing services has prompted several academic enquiries. Most studies agree that ridesharing services have had the greatest impact on existing taxi services. For example, Nelson (2016) finds that the annual number of taxi trips in Los Angeles declined from 8.4 million in 2013 to 6.0 million in 2015. Similarly, Hu (2017) reports that, "for the first time, more people are using Uber in New York than the city's fabled yellow cabs. In July [2017], Uber recorded an average of 289,000 rides each day compared with 277,000 taxi trips." Some studies have found that ridesharing services have also been used to substitute trips that would otherwise have been made using public transport services or privately-owned cars. For example, Rayle et al. (2016) find in their survey of 380 intercepted rideshare users in San Francisco that at least half of the ridesharing trips were replacing modes other than taxi, including public transport and driving. By and large, studies have found that users of rideshare services tend to be young, well-educated, high-income, employed individuals, with low levels of car ownership, living in dense urban environments (e.g. Alemi et al., 2019, 2018; Dias et al., 2017).

2.3. Shared autonomous vehicles: The likely future of on-demand transport services

In many ways, the end game for most existing providers of on-demand transport, particularly those from the private sector, is the provision of these same services through autonomous vehicles. For example, both Uber and Lyft are heavily subsidized by investment funding, and both services have failed to make profits since they first started operation (McArdle, 2019). Concurrently, both services are investing heavily in driverless car technology (Conger, 2018; Somerville, 2018). The cost of labour is roughly 50 per cent of the total cost of a taxi ride (e.g. OTER, 2013), and the same fraction likely applies to rideshare services as well, given their close similarity. If rideshare services can eliminate the driver through AV technology, they could potentially cut their operating costs by 50 per cent. Consequently, the long-term commercial viability of rideshare services depends on the availability of AV technology. The technology could enable on-demand door-to-door transport services as a new form of micro public transport, which combines the benefits of existing mass public transport services and private modes of motorized transport, but does not suffer from the same drawbacks (Wong et al., 2017). Compared to mass public transport services that require large catchment areas and/or high densities in order to be feasible, and consequently suffer from first and last mile connectivity problems, micro public transport can offer door-to-door services. Compared to private modes of motorized transport, where high parking costs and frequent congestion can limit access and use, micro public transport is expected to be cheaper, faster and more convenient (Milakis et al., 2017).

The turn of the twenty-first century has seen suggestions of "peak car" (Goodwin and Van Dender, 2013), with stagnant or declining levels of private car ownership and use across much of the developed world, including Australia. AV technology, in conjunction with shared mobility services, could accelerate this shift further, helping households transition from owning two cars to one car, and potentially even to no cars (Fagnant and Kockelman, 2015, 2018; Boesch et al., 2016). Traditional automotive manufacturers are looking to replace potential revenue lost because of reduced car sales by taking on the role of transport service providers themselves. For example, BMW already operates carsharing services in North America and Europe (Korosec, 2018), and General Motors plans to commence its own ridesharing services in 2019 using self-driving cars developed in house (Reader, 2018). Concurrently, and as mentioned previously, shared mobility service providers, such as Uber, are investing heavily in the development of AV technology, to hold on to their current advantage within the point-to-point transport market. The technology is currently being trialled all across the world, including Australia, both on public roads and more controlled, 'closed-loop' conditions, such as university campuses and retirement villages (e.g. McLean, 2019). The first commercially available fully autonomous car is expected to be available by 2020 (Walkers, 2019). For a recent and comprehensive review of the current state of shared AV services, the reader is referred to Stocker and Shaheen (2017).

In light of these developments, a number of studies in recent years have examined the latent demand for shared AV services. Most studies agree that early adopters of shared AV services are likely to be young, employed and highly educated individuals (e.g. Lavieri et al., 2017; Targhi, 2017; Krueger et al., 2016). In terms of service attributes, Krueger et al. (2016) report that travel time, waiting time and fares will be the most significant determinants of shared AV use. In terms of individuals' willingness to share trips with strangers on AVs, Lavieri and Bhat (2019) find that "the travel time added to the trip to serve other passengers may be a greater barrier to the use of shared services compared to the presence of a stranger". Several studies have also examined the trade-offs consumers are willing to make between private ownership and shared access with regards to AVs (e.g. Nazari et al., 2018; Pakusch et al., 2018; Haboucha et al., 2017; Hao and Yamamoto, 2017; Lavieri et al., 2017; Bansal et al., 2016). Most of these studies find that consumers are still hesitant to embrace shared AVs. For example, Bansal et al. (2016), in their survey of 347 residents of Austin, Texas in the United States, find that only 13 per cent of survey participants would be willing to give up personal vehicles and rely exclusively on shared AVs that cost roughly $1/mile, and at least 35 per cent of survey participants would be unwilling to use shared AV services at all, regardless of their costs. Similarly, Haboucha et al. (2017), in their survey of 721 individuals living across Israel and North America, find that even if shared AV services were completely free, 25 per cent of their sample would still be unwilling to use the service. For more comprehensive reviews of studies that have examined consumer preferences for AV technologies, the reader is referred to Gkartzonikas and Gkritza (2019) and Becker and Axhausen (2017). For an excellent collection of research on all matters related to AV technology, the reader is referred to Meyer and Beiker (2018).

To summarize, most academic research on the demand for shared AV services finds that significant proportions of the general population are hesitant to use these services. However, lack of consumer interest may be attributed to both the uncertainty that still surrounds AVs (in terms of the technology itself, the supporting infrastructure, and the regulatory framework) and consumer unfamiliarity (consumer surveys have repeatedly found that significant proportions of the general population are unfamiliar with AV technology and how it will likely function; see, for example, Schoettle and Sivak, 2014). Consequently, any research on the potential demand for shared AV services has had to be, by necessity, somewhat speculative, and predicted adoption rates from these studies might change as the technology matures and as consumers become more familiar with corresponding services.

3. Survey instrument

To measure Australian consumers' preferences for ODT systems and services, a consumer survey was designed following a three-stage process. First, we reviewed the existing literature to identify relevant determinants of ODT use, based on which we formulated a first draft of the instrument. Second, we undertook extensive consultations with project stakeholders from Transport for New South Wales, Transport for Victoria, Queensland Department of Transport and Main Roads, Department of Transport in Western Australia, Royal Automobile Association of South Australia, MaaS Australia, Keolis Downer, and Transdev Australasia, where we amended the instrument to reflect their insights and experiences. And third, the survey instrument was reviewed and approved by experts at the Bureau of Infrastructure, Transport and Regional Economics. The final instrument comprised five sections:

Section I – Current travel behaviour: Respondents were asked about their car and motorcycle ownership; frequency of use of different transport modes; dependence on mobility devices; and household monthly travel expenditure.

Section II – Preferences for on-demand transport (ODT) services: Each respondent was presented four different scenarios, such as the one shown in Fig. 1. Respondents were asked to imagine that they have access to the hypothetical ODT service described in the scenario in terms of four attributes: price, vehicle sharing, booking, and route information. The attributes were varied systematically across scenarios and respondents, and could take any of the values listed in Table 1. An orthogonal main effects plan (OMEP) was generated using SPSS (given both our large sample size and the absence of appropriate priors for many of the model parameters, an orthogonal design was preferred to an efficient design). The OMEP selected an orthogonal fraction of a $5 \times 4 \times 3 \times 2$ factorial design to generate twenty-five profiles in total. Respondents were randomly allocated to four profiles with counterbalancing to control for ordering and blocking effects. Given the length of the survey, respondents were given four scenarios to keep cognitive burden reasonable. For each scenario, respondents were asked to indicate how frequently they would use such a service, and for what kinds of trips.

Section III – Preferences for Mobility-as-a-Service (MaaS) schemes: Respondents were asked about their awareness of and familiarity with MaaS. Each respondent was presented four different scenarios, where they were presented two different hypothetical MaaS schemes. Respondents were asked to indicate which scheme they prefer, if they would purchase the preferred scheme if it were available in the market today, and for what kinds of trips would they use the scheme. We exclude more details on this section of the survey, as it is not directly related to ODT and not relevant to the present study's objectives[1].

Section IV – Attitudes: Respondents were asked to state their level of agreement or disagreement with statements measuring their attitudes towards driving, car ownership, public transport, carsharing, ODT, MaaS, and new technologies and services in general.

Section V – Demographics: Respondents were asked about their age, gender, education, employment, place of residence, household size and structure, and income.

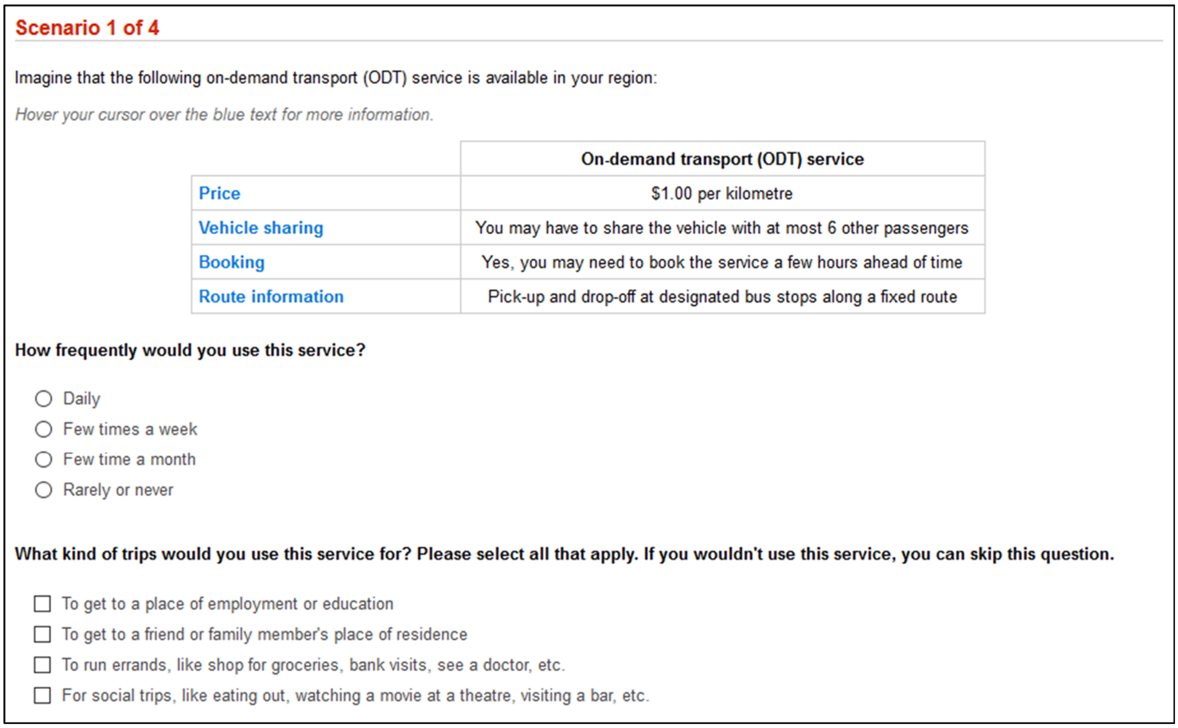
The survey concluded with an open text question to elicit any feedback from respondents about the survey itself. Respondent feedback was largely positive, and specific comments indicated a high level of engagement.

4. Sample characteristics

We recruited 3,985 Australians nationwide through an online consumer panel maintained by the market research company Survey Sampling International in March 2018 to give their responses to the web-based survey described in the previous section. Survey respondents were drawn from New South Wales, Victoria, Queensland, South Australia, Western Australia and the Australian Capital Territory, in rough proportion to the population of these states and territories. We did not recruit respondents from Tasmania and Northern Territory (NT) because we did not have project funding partners from these states.[2] 80 per cent of the sample was drawn from major metropolitan areas, and the remaining 20 per cent was drawn from regional and remote areas, based on the 2016

[1] MaaS systems offer consumers access to multiple transport modes and services, owned and operated by different mobility service providers, through an integrated digital platform for planning, booking and payment. Many actors in industry and government view ODT services as stepping stones to the development of full service MaaS systems. In particular, both ODT and MaaS aim to remove some of the pain points currently experienced by public transport customers through the use of new information and communication technologies. However, they should not be confused with each other. MaaS systems may or may not include access to these additional ODT services, just as they may or may not include access to mass public transport services or point-to-point transport services. MaaS, as it has been broadly defined by the academic and grey literature, does not view access to a particular mode of transport as essential.

[2] While the exclusion of residents from Tasmania and NT does bias our sample geographically, it is not a source of major concern. All samples are biased to some extent. Tasmania and NT together comprise only 3 per cent of the national population. Furthermore, of the five states that we did include in our sample, we have done a state by state comparison for the benefit of our regional funding partners. Controlling for demographic and geographic characteristics, we find no notable differences between ODT consumer preferences across these five states. While some caution is warranted in extrapolating findings from this study to Tasmania and NT, this should not mean that the study can offer no insights on potential preference for ODT in these regions.


Scenario 1 of 4

Imagine that the following on-demand transport (ODT) service is available in your region:

Hover your cursor over the blue text for more information.

	On-demand transport (ODT) service
Price	$1.00 per kilometre
Vehicle sharing	You may have to share the vehicle with at most 6 other passengers
Booking	Yes, you may need to book the service a few hours ahead of time
Route information	Pick-up and drop-off at designated bus stops along a fixed route

How frequently would you use this service?

- Daily
- Few times a week
- Few time a month
- Rarely or never

What kind of trips would you use this service for? Please select all that apply. If you wouldn't use this service, you can skip this question.

- To get to a place of employment or education
- To get to a friend or family member's place of residence
- To run errands, like shop for groceries, bank visits, see a doctor, etc.
- For social trips, like eating out, watching a movie at a theatre, visiting a bar, etc.

Fig. 1. Example screenshot of hypothetical scenario to elicit consumer preferences for different ODT services.

Table 1
ODT service attributes that were systematically varied across scenarios and respondents.

Attribute	Value
Price	$0.5 per km
	$0.7 per km
	$1.0 per km
	$1.2 per km
	$1.5 per km
Vehicle sharing	You have the vehicle all to yourself
	You may have to share the vehicle with at most 3 other passengers
	You may have to share the vehicle with at most 6 other passengers
	You may have to share the vehicle with at most 10 other passengers
Booking required	Yes, you may need to book the service a few hours ahead of time
	No, you can request a vehicle to pick you up in real-time (when you need it)
Route	Pick-up and drop-off at designated bus stops along a fixed route
	Pick-up and drop-off at designated bus stops, but the route may change in real-time based on passenger demand
	Door to door service

Australian Statistical Geography Standard (ASGS) classification. All survey respondents were 18 years or older, with a good spread over all age groups, including older adults (18 per cent of the sample is 65 years and older). In terms of other demographic characteristics, such as gender, education, employment, household size and structure, and income, the sample is roughly representative of the national population. However, compared to the national population, our sample is more urban, more likely to be unemployed, and more educated. Table 2 summarizes the comparison between our sample and the national population.

Any differences between the sample population and the national population have been controlled for in our analysis through reweighting. Iterative proportional fitting was used to impute the joint probability distributions across our sample and the national population for different categories of the following demographic variables: state of residence, ASGS classification, gender, age, education level, employment status, household size, household structure, and household income. For each individual in our sample, the weighting factor was calculated by taking the ratio of the probability of observing the individual's demographic characteristics in the Australian population to the corresponding probability for our sample.

In terms of transport mode use, Fig. 2 plots average use of different modes across the sample. As one would expect, driving, walking and public transport are the most popular transport modes. Of particular relevance to the present study's objectives, use of existing ODT services, namely taxis and rideshare services, is relatively low. Of our sample, 19 per cent indicated using taxis at least a few times a month, and 12 per cent indicated using rideshare services at least a few times a month. Car rental, carshare and bikeshare

Table 2
Summary of sample characteristics and how they compare with the national population.

Variable	Category	Sample	2016 Census
Area of residence	Major cities	80.5%	71.2%
	Regional areas	18.7%	26.7%
	Remote areas	0.8%	2.0%
Gender	Male	48.6%	50.1%
	Female	51.2%	49.9%
Age	18–39 years	38.0%	40.0%
	40–64 years	43.6%	40.5%
	65 years and older	18.4%	19.6%
Employment status	Employed	59.0%	56.1%
	Unemployed	9.6%	4.1%
	Not in the labour force	31.4%	39.8%
Highest level of education	Bachelor's or higher	39.8%	24.7%
	Diploma or certificates I-IV	29.8%	32.8%
	Year 12 or below	30.3%	42.5%
Average household size		2.6	2.5
Average household income		$1,550 per week	$1,736 per week

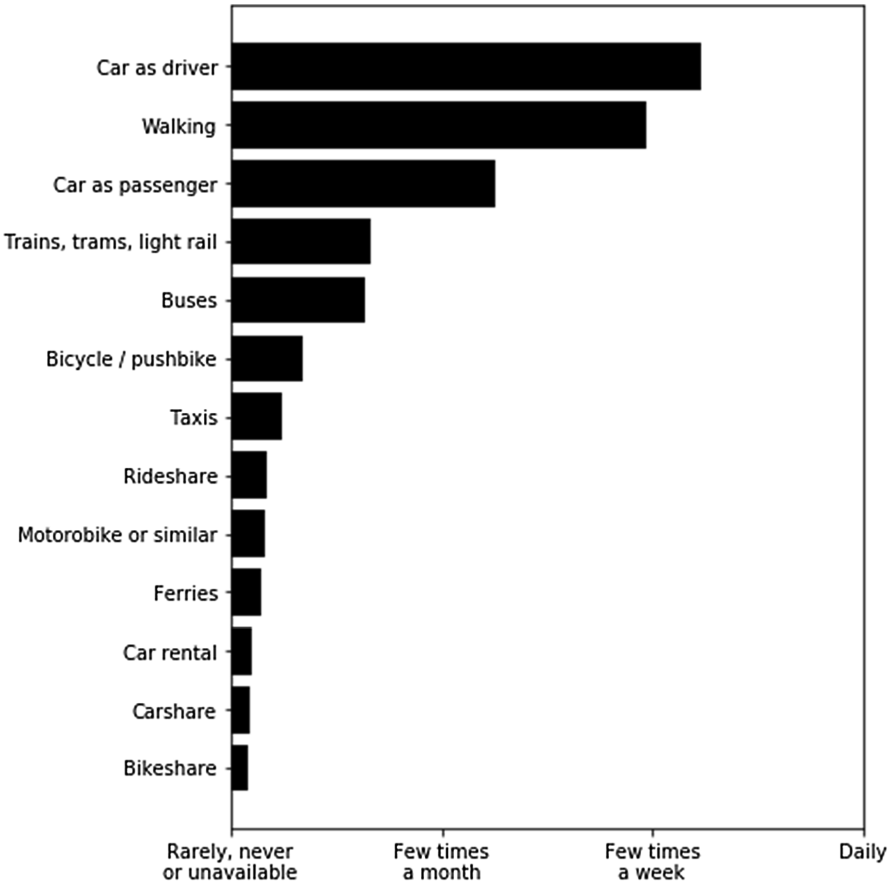


Fig. 2. Average transport mode use across sample.

services were the least popular transport modes, with very low levels of reported use across the sample population.

For each of the ODT scenarios, we asked respondents how, if at all, they would use different ODT services shown to them across scenarios. Fig. 3 plots the proportion of scenarios where respondents indicated that they would use the shown ODT service for different trip purposes. ODT use is greatest for one-off social trips, like eating out, watching a movie, visiting a bar, etc., indicating that ODT too could help plug current gaps in public transport services. ODT use is relatively similar across other trip purposes, with respondents indicating for roughly one in five scenarios that they would use the service to commute to a place of employment or education, to visit their friends and family members, and to run errands.

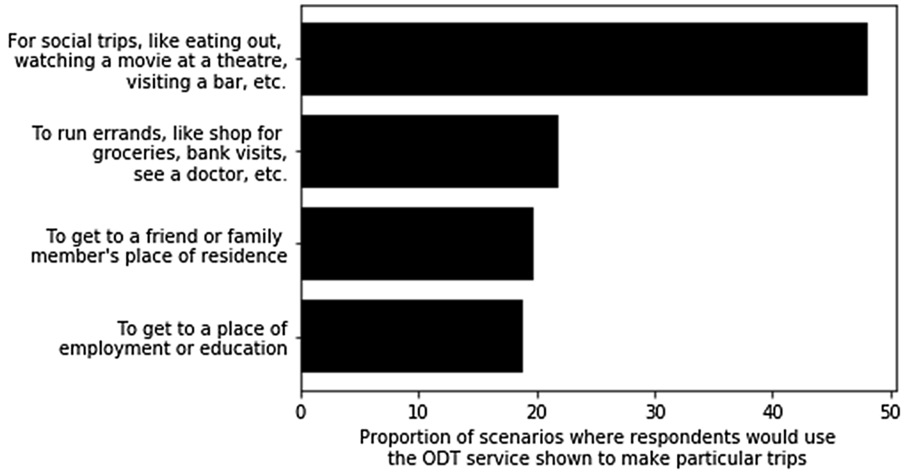


Fig. 3. ODT use by different trip purposes.

After the ODT scenarios, we asked survey respondents to indicate their overall attitudes towards ODT, and its potential impact on car ownership. Fig. 4 plots average attitudes across the sample; many of these statements have been adapted from Kamargianni et al. (2018). On average, respondents are slightly sceptical about the ability of ODT to impact their decisions related to car ownership. However, as mentioned previously, most respondents in our sample have little to no real-life experience with ODT services, and it is possible that their attitudes might shift over time as ODT becomes more widely available in Australia.

5. Econometric framework

Data from the hypothetical scenarios, such as the one shown in Fig. 1, were used in conjunction with other geographic and demographic information collected as part of the survey to estimate latent class choice models (LCCMs) of consumer preferences for ODT. Latent class choice models (LCCMs) are finite mixtures of discrete choice models. They were first developed in the field of marketing sciences as tools to identify relatively homogenous consumer segments that differ substantially from each other in terms of their behavior in the marketplace (Kamakura and Russell, 1989). They have since emerged as a very popular form of discrete choice model, finding application in a wide variety of disciplines, including but not limited to transportation. In our case, LCCMs allow us to identify segments in the population that differ in terms of their preferences for different ODT services.

LCCMs comprise two components: a class membership model and a class-specific choice model. The class membership model formulates the probability that a decision-maker belongs to a particular segment, or class, as some function of the characteristics of the decision-maker. Conditioned on the class that the decision-maker belongs to, the class-specific choice model formulates the probability that the decision-maker chooses a particular alternative as some function of the attributes of all of the alternatives in the

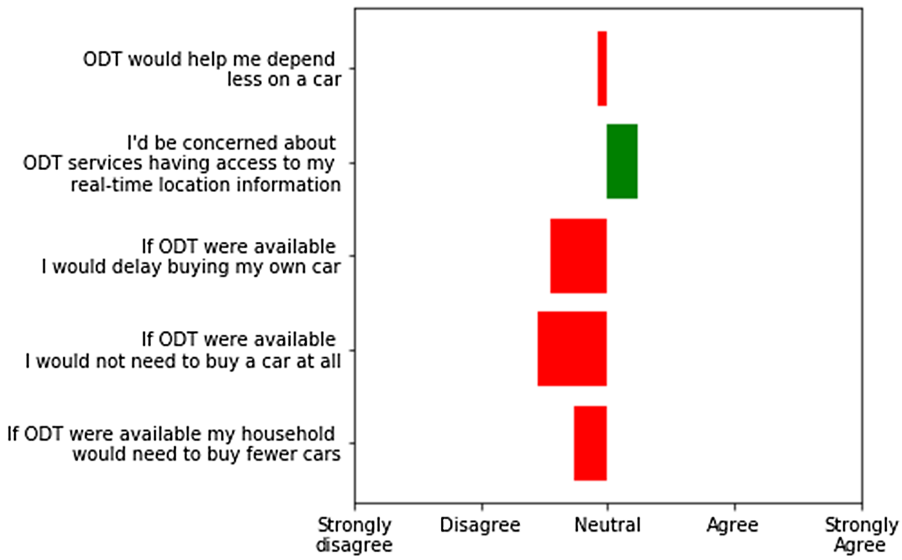


Fig. 4. Average consumer attitudes towards ODT.

choice set.

We begin with a description of the class membership model, formulated in our case as the multinomial logit function:

$$P(q_{ns} = 1) = \frac{\exp(\mathbf{z}_n' \boldsymbol{\gamma}_s)}{\sum_{s'=1}^{S} \exp(\mathbf{z}_n' \boldsymbol{\gamma}_{s'})} \tag{1}$$

where q_{ns} equals one if decision-maker n belongs to class s, and zero otherwise; $\mathbf{z}_n$ is a vector of decision-maker characteristics, such as age, employment and household income; $\boldsymbol{\gamma}_s$ is a vector of class-specific parameters denoting sensitivity to the decision-maker characteristics; and S is the total number of classes.

Next, we describe the class-specific choice model. Recall that each decision-maker is shown four different scenarios, where each scenario presents a hypothetical ODT service. The decision-maker is asked to indicate how frequently they would use the service if it were available in the market today, where the respondent must choose from one of four options: (1) rarely or never; (2) few times a month; (3) few times a week; and (4) daily. Therefore, for a given decision-maker n and scenario t, the class-specific choice model predicts the probability that the respondent chose option j, where $j = 1, \cdots, 4$.

Let $u_{nt|s}$ be the utility of the ODT service for scenario t and decision-maker n, conditional on the decision-maker belonging to class s, specified as follows:

$$u_{nt|s} = \mathbf{x}_{nt}' \boldsymbol{\beta}_s + \varepsilon_{nt|s} \tag{2}$$

where $\mathbf{x}_{nt}$ is a vector of ODT service attributes, such as cost and vehicle sharing; $\boldsymbol{\beta}_s$ is the vector of class-specific parameters denoting sensitivities to these attributes; and $\varepsilon_{nt|s}$ is the stochastic component of the utility specification, assumed for the sake of mathematical convenience to be i.i.d. logistic with location zero and scale one across scenarios and decision-makers. Heterogeneity in the decision-making process is captured by allowing the taste parameters $\boldsymbol{\beta}_s$ to vary across classes. The class-specific probability that option j is selected is given by the familiar expression for an ordered choice model:

$$P(y_{ntj}=1|q_{ns} = 1) = P(\tau_{j,s} \geq u_{nt|s} \geq \tau_{j-1,s}) = P(u_{nt|s} \leq \tau_{j,s}) - P(u_{nt|s} \leq \tau_{j-1,s}) = P(\varepsilon_{nt|s} \leq \tau_{j,s} - \mathbf{x}_{nt}' \boldsymbol{\beta}_s) - P(\varepsilon_{nt|s} \leq \tau_{j-1,s} - \mathbf{x}_{nt}' \boldsymbol{\beta}_s)$$
$$= \frac{1}{1 + \exp(\mathbf{x}_{ntj}' \boldsymbol{\beta}_s - \tau_{j,s})} - \frac{1}{1 + \exp(\mathbf{x}_{ntj}' \boldsymbol{\beta}_s - \tau_{j-1,s})} \tag{3}$$

where y_{ntj} equals one if option j is selected, and zero otherwise; and $\tau_{j,s}$ are the class-specific threshold parameters to be estimated, such that $\tau_{j,s} \geq \tau_{j-1,s}\ \forall\ j = 1, \cdots, 4$, $\tau_{0,s} = -\infty$ and $\tau_{4,s} = \infty$. Eq. (3) may be combined iteratively over scenarios to yield the following class-specific probability of observing the vectors of choices $\mathbf{y}_n$:

$$P(\mathbf{y}_n|q_{ns} = 1) = \prod_{t=1}^{T} \prod_{j=1}^{4} [P(y_{ntj}=1|q_{ns} = 1)]^{y_{ntj}} \tag{4}$$

where $\mathbf{y}_n = \langle y_{n11}, \cdots, y_{nT4} \rangle$; and T is the number of scenarios shown to a single decision-maker, equal to four in our case. Eqs. (1) and (4) may be combined and marginalized over classes, to yield the unconditional probability of observing the vectors of choices $\mathbf{y}_n$, which in turn may be combined iteratively over decision-makers to yield the following likelihood function for the data:

$$L(\boldsymbol{\beta}, \boldsymbol{\tau}, \boldsymbol{\gamma}; \mathbf{y}, \mathbf{x}, \mathbf{z}) = \prod_{n=1}^{N} \sum_{s=1}^{S} P(\mathbf{y}_n|q_{ns} = 1) P(q_{ns} = 1) \tag{5}$$

The unknown model parameters $\boldsymbol{\beta}$, $\boldsymbol{\tau}$ and $\boldsymbol{\gamma}$ may be estimated by maximizing the likelihood function. All models for this study were estimated using the software package PythonBiogeme (Bierlaire, 2016).

6. Estimation results

We estimated a number of different model specifications, where we varied the explanatory variables, the functional form of the utilities, and the number of classes. All models were estimated using data from 3,985 individuals, each of whom were observed to make four hypothetical choices. The final model specification was determined based on a comparison across different measures of fit, such as the Akaike and Bayesian information criteria, and behavioral interpretation.

The final model specification identified five distinct segments, or classes, in our sample that differ in terms of their preferences for ODT services. The model has a McFadden's adjusted R-squared of 0.169. The class membership model included various geographic and demographic characteristics as the explanatory variables $\mathbf{z}_n$, and the corresponding estimates for the model parameters $\boldsymbol{\gamma}_s$ are enumerated in Table 3. Note that the parameters corresponding to each of the demographic characteristics are significant at the 95% level across at least one of the classes. The parameters corresponding to the geographic characteristics were not found to be statistically significant, but we have retained them in the final specification for the sake of completeness. The class-specific choice models included each of the service attributes listed in Table 3 as explanatory variables $\mathbf{x}_n$, and the corresponding estimates for the model parameters $\boldsymbol{\beta}_s$ and $\boldsymbol{\tau}_s$ are enumerated in Table 4. Note again that the parameters corresponding to most of the ODT service attributes are significant at the 95% level across at least one of the classes. The only exception is the service attribute denoting route flexibility. From a policy standpoint, lack of statistical significance in this case is a useful finding, as it indicates the consumers do not currently value adaptive routes if these services still pick-up and drop-off passengers at designated bus stops. In other words, potential

Table 3
Class membership model.

Variable	Class I: Innovators		Class II: Early adopters		Class III: Potential early majority		Class IV: Potential late majority		Class V: Potential laggards	
	est.	t-stat	est.	t-stat	est.	t-stat	est.	t-stat	est.	t-stat
Class-specific constant	0.000	–	1.338*	2.08	3.095*	5.07	1.625*	1.96	4.657*	8.96
Inner city resident	0.000	–	0.628	1.11	−0.025	−0.05	0.611	1.03	−0.391	−0.91
Inner regional resident	0.000	–	0.737	1.24	−0.062	−0.11	0.365	0.52	0.024	0.05
Under 30 years	0.000	–	−0.175	−0.73	−0.941*	−3.58	−1.395*	−4.39	−2.09*	−9.37
Over 65 years	0.000	–	0.057	0.16	1.261*	4.76	1.348*	2.03	1.597*	7.95
University educated	0.000	–	−0.004	−0.02	−0.461*	−2.62	−0.498	−1.89	−0.855*	−6.11
Employed full time	0.000	–	−0.788*	−3.13	−0.958*	−4.04	−0.92*	−2.34	−1.232*	−6.25
Employed part time	0.000	–	−0.502*	−2.07	−0.654*	−2.86	−0.385	−0.98	−0.743*	−4.02
Male	0.000	–	−0.172	−0.91	−0.632*	−3.67	−0.581*	−2.24	−0.617*	−4.47
Have children living at home	0.000	–	−0.188	−1.02	−0.647*	−3.54	−0.463	−1.87	−0.571*	−3.88
Weekly household income ($1,000)	0.000	–	0.114	1.15	0.317*	3.53	0.343*	2.05	0.317*	4.32
Income not disclosed	0.000	–	−0.106	−0.33	0.098	0.35	0.525	1.12	0.82*	3.57
Have mobility disability	0.000	–	−0.494	−1.66	−1.612*	−5.18	−1.26*	−3.51	−1.701*	−7.12

The reader should note that Class 1 was selected as the base.
* Significant at the 5 per cent level.

ODT service providers should either provide door-to-door service or stick with fixed routes. Therefore, we have retained that variable in our final specification.

We summarize key differences across the five classes identified by the final model specification in Table 5. The classes have been ordered in terms of their decreasing stated frequency of ODT use, and their increasing dependence on the private car. Estimation results for the class membership model and the class-specific choice models provide information on how the classes differ from one another in terms of the kinds of decision-makers that belong to each class (γ_s), the relative importance that they attach to different ODT service attributes (β_s), and their frequency of ODT use in general (τ_s). To further underscore behavioural differences across classes, we calculate posterior class membership probabilities for each decision-maker in our sample, based on their indicated choices to each of the four scenarios, and reweight them to adjust for geographic and demographic differences between our sample and the Australian population. These weighted probabilities are used to characterize additional differences across the classes, in terms of travel behaviour, demographic characteristics and attitudes towards ODT, through a process of sample enumeration.

As mentioned before, the classes have been ordered such that the average frequency of ODT use decreases in going from Class 1 to Class 5. These probabilities were calculated as follows: We enumerated all possible ODT services using the attributes and levels defined in Table 1, resulting in 120 schemes in total. For each scheme, we used the discrete choice model to predict the probability that a particular respondent would use the scheme if it were available today. These probabilities were averaged over all ODT services, and reweighted to adjust for differences between our sample and the Australian population, to arrive at the mean predicted usage frequency for an Australian belonging to the class or market segment.

In going from left to right across Tables 3–5, there are several general trends to be observed. In particular, frequency of ODT use is correlated with age and life cycle stage. Young and middle-aged individuals who are either single or married, with or without children at home, are far more likely to use ODT services frequently. In contrast, ODT use for older individuals whose children have left home is likely to be more infrequent. Education and employment are strongly correlated with frequency of ODT use as well, with more educated and employed individuals being more likely to use ODT more frequently.

Our findings differ from previous studies that have examined consumer preferences for more traditional ODT services (e.g. Wang et al., 2014), which find demand to be greatest in regions with low population densities and high levels of social deprivation. However, our findings are consistent with previous studies that have examined consumer preferences for modern rideshare and shared AV services (e.g. Alemi et al., 2019, 2018; Dias et al., 2017; Lavieri et al., 2017; Targhi, 2017; Krueger et al., 2016; Rayle, 2016). Together, these differences and similarities indicate that the market for ODT might differ significantly from the market for more traditional flexible transport services that are typically operated by the public sector. In fact, ODT services might be in direct competition with taxi, rideshare and other related services that are typically operated by the private sector.

Our model is able to identify several niche markets for ODT services that early trials should target, and the service attributes that they are more likely to value. For example, Class 1 comprises 3 per cent of the national population, and is likely to use ODT services most frequently: 65 per cent of the individuals belonging to the class indicated that they would, on average, be willing to use ODT services daily, and an additional 23 per cent would be willing to use ODT services at least a few times a week. These individuals care most about having door-to-door service: they are willing to pay $0.58 per km for door-to-door service, compared to $0.22 per km to avoid sharing a vehicle, and only $0.10 per km to be able to book the service in real-time. ODT use is likely to be greatest for commute travel: 65 per cent of these individuals indicated they would use ODT to get to a place of employment or education. Individuals most likely to belong to this class include employed working men who regularly commute by public transport; motorcycle owners, who likely use their motorcycles as a cheap and convenient substitute to both public transport and private car ownership;

Table 4
Class-specific choice models.

Variable	Class I: Innovators		Class II: Early adopters		Class III: Potential early majority		Class IV: Potential late majority		Class V: Potential laggards	
	est.	t-stat	est.	t-stat	est.	t-stat	est.	t-stat	est.	t-stat
ODT service attributes										
Cost of ODT service ($/km)	−1.134*	−2.54	−1.718*	−7.91	−2.823*	−10.35	−2.493*	−3.22	−1.990	−1.11
Ability to book service in real time	0.116	0.50	0.154	1.35	0.584*	5.98	0.353	1.44	0.046	0.09
May have to share vehicle with other passengers	−0.251	−0.91	−0.614*	−4.56	−0.969*	−8.20	−0.376	−1.43	−0.192	−0.21
Pick-up and drop-off at designated bus stops, but the route may change in real-time based on passenger demand	0.252	0.95	0.153	1.27	−0.184	−1.72	0.361	1.24	0.756	0.61
Door-to-door service	0.652	1.67	0.258	1.59	0.314*	2.04	0.416	1.39	1.378	1.09
Threshold parameters										
Rarely or never – Few times a month	−4.097*	−5.27	−4.781*	−12.44	−2.851*	−13.05	−5.626*	−4.30	3.520	1.06
Few times a month – Few times a week	−3.073*	−4.56	−2.875*	−10.07	−0.020	−0.07	0.549	0.67	4.817	1.82
Few times a week - Daily	−1.638*	−2.70	0.588	1.93	2.194*	5.69	3.280*	2.92	5.426	1.91

* Significant at the 5 per cent level.

Table 5
High-level summary of different market segments, or classes.

	Class I: Innovators	**Class II: Early adopters**	**Class III: Potential early majority**	**Class IV: Potential late majority**	**Class V: Potential laggards**
Share of the Australian population	3 per cent	10 per cent	9 per cent	20 per cent	58 per cent
ODT use	Daily; for all travel, especially commuting	Few times a week; for all travel	Few times a month; for mostly social trips	Few times a year; for mostly social trips	Rarely or never
Sensitivity to service attributes	High willingness to pay for door-to-door service ($0.58 per km)	High willingness to pay for avoiding sharing a vehicle ($0.36 per km)	Not very sensitive to any service attributes	High sensitivity to costs	High willingness to pay for door-to-door service ($0.69 per km)
Attitudes towards ODT	ODT could help reduce car dependence and car ownership		ODT could help reduce car dependence, but not car ownership		ODT unlikely to affect car dependence or ownership
Geography	Proportionally spread across metro, regional and remote areas				Regional and remote residents more likely to belong to this persona
Demography	Young; highly educated; employed; male; have children at home; low income; disabled; residents of outer regional and remote areas	Young; highly educated; male; have children at home; low income; disabled	Middle aged; residents of inner city areas; high incomes	Do not have children at home; young; median incomes; residents of outer regional and remote areas	Old; retired; empty nesters; not college educated; high incomes
Current travel behavior	High motorcycle ownership rates; high dependence on use of mobility devices; high public transport use		Low motorcycle ownership rates; low dependence on use of mobility devices; low public transport use		

and mobility device users, who are likely dependent on others to fulfill their mobility needs, and would potentially welcome the independence offered by ODT services.

Similarly, Class 2 comprises 10 per cent of the national population, and is likely to use ODT services less frequently than Class 1 but more frequently than the other classes: while only 9 per cent of the individuals belonging to the class indicated that they would, on average, be willing to use ODT services daily, 62 per cent would be willing to use ODT services at least a few times a week. These individuals care most about not having to share a vehicle: they are willing to pay $0.36 per km to avoid sharing a vehicle, compared to $0.15 per km for door-to-door service, and only $0.09 per km to be able to book the service in real-time. Frequency of ODT use is evenly spread across different trip types, including both commute and non-commute travel. In terms of individuals most likely to belong to this class, there is considerable overlap with Class 1. A key difference between the two classes is with respect to the effect of employment: individuals that are not currently in the labour force are more likely to belong to Class 2.

This information could be used by a potential ODT service provider or regulator to design two separate services: one for commuters that prioritizes door-to-door service (or at least home pick-up), and one for non-working people that prioritizes private access. The same vehicles could potentially be spread between the two services by time of day. More vehicles can be allocated to the commuter service during peak hours, when commute travel is expected to be greatest. And more vehicles can be allocated to the non-commuter service during off-peak hours, when non-commute travel is expected to be greatest.

Finally, the size of the five classes is remarkably consistent with the size of different adoption cohorts as described by the innovation diffusion process (Rogers, 2010; Bass, 1969). For reference, Fig. 5 shows the different cohorts. In particular, the size of the first two ODT personas is almost identical to the Innovators and Early Adopters cohorts. As the ODT market evolves, and as more ODT services become available to consumers, it is likely that the other cohorts too will emerge from the remaining ODT personas identified by our analysis. Our findings should serve as a positive reminder that while a large share of the national population may not yet be willing to use ODT, as the technology adoption cycle for other innovations has demonstrated in the past, they too could be persuaded to use ODT in time.

7. Policy implications

In this section, we explore some of the policy implications of our model results. Table 6 lists average consumer willingness to pay for different ODT service attributes. Consumers are willing to pay most to avoid sharing a vehicle with other passengers: 0.28$/km. Recall that the ODT scenarios varied the potential number of other passengers between 0 and 10. However, our model did not find consumers to be sensitive to the number of passengers, only whether they have or do not have to share the vehicle with other passengers. Our finding is in disagreement with studies conducted by Queensland TMR, following ODT trials in the state, that found consumers to be most sensitive to the potential number of other passengers that they might have to share the service with (as that number serves as a proxy for level of service, in terms of door-to-door travel times). Note however that most individuals in our sample have no prior experience with ODT services, and their sensitivity to particular service attributes might likely change once they have

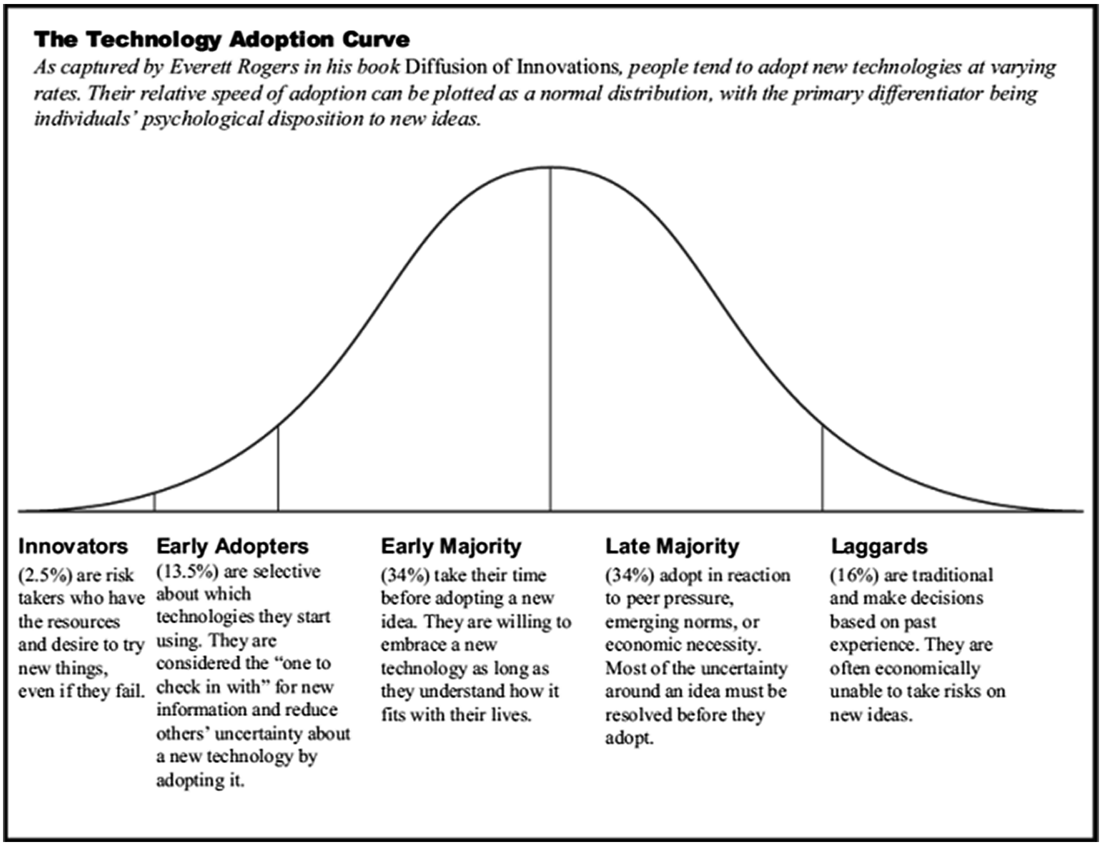


Fig. 5. The innovation adoption curve, first defined by Ryan and Gross (1943), follows a normal distribution for people and time; all new ideas, products, services, and technologies can be viewed as going through an adoption process (Source: Canada et al., 2016).

Table 6
Consumer willingness to pay for ODT service attributes.

Willingness to pay to be able to…	Amount	Comments
Book ODT service in real time	$0.10 per km	–
Have door-to-door service	$0.17 per km	No preference between fixed route fixed schedule services and flexible route flexible schedule services
Avoid sharing a vehicle	$0.28 per km	Number of passengers that the vehicle is shared with did not have a statistically significant effect

actually used an ODT service.

Consumers are willing to pay 0.17$/km for door-to-door service. However, we did not find the willingness to pay for flexible routes and/or flexible schedules to be statistically significant for any of the classes or the sample as a whole. Again, we speculate this may be due to consumer inexperience with ODT services, and that the value of flexible routes and schedules might only become apparent to consumers once they have actually used an ODT service. Finally, consumers are willing to pay a nominal 0.10$/km to be able to book the service in real time, as opposed to having to book the service several hours in advance.

Table 7 enumerates usage rates across the national population, as predicted by our model for different potential ODT services. For an ODT service that costs roughly the same as UberX's ridesharing service, and offers comparable level-of-service, 17 per cent of the national population can be expected to use the service a few times a week or more. For an ODT service that costs roughly the same as public bus services, and offers comparable level-of-service, 15 per cent of the national population can be expected to use the service a few times a week or more. Note that our model predicts relatively similar levels of usage for UberX-like ODT services and public bus-like ODT services. Superficially, the finding corroborates evidence from other studies that indicate that rideshare services such as UberX are viewed by consumers as substitutes for traditional public transport services, and not necessarily complements.

Finally, for an ODT service that provides the same level-of-service as UberX, but at a fractional cost of $0.30 per km, a significantly larger 31 per cent of the national population can be expected to use the service a few times a week or more. The price point for such a service could potentially be achieved through new transport technologies and services, such as shared electric autonomous vehicles. Our predicted adoption rates for such a service serves to underscore that while consumers are willing to pay extra for improved level-of-service, cost is ultimately the most important determinant of ODT use. The reader should note further that these

Table 7
Predicted usage rates of different ODT services.

ODT service	Predicted usage			
	Daily	**Few times a week**	**Few times a month**	**Rarely or never**
$1.15 per km (comparable to UberX prices in Melbourne); no sharing; real time booking; and door-to-door service	5%	12%	23%	61%
$0.70 per km (comparable to bus fares in Sydney); sharing; no real time booking; fixed route fixed schedule	4%	11%	21%	65%
$0.30 per km (comparable to shared electric autonomous cars); no sharing; real time booking; and door-to-door service	11%	20%	18%	51%

Table 8
Predicted usage rates across New South Wales for an ODT service that costs $0.70 per km; vehicles are shared between passengers; the service can be booked in real time; and the service offers flexible routes and flexible schedules, but not door-to-door service.

Region	Predicted ODT service usage				2016 mode share for commute travel	
	Daily	Few times a week	Few times a month	Rarely or never	Private car	Public transport
Greater Sydney						
Baulkham Hills and Hawkesbury	3%	8%	21%	69%	78%	17%
Blacktown	6%	14%	20%	61%	74%	22%
City and Inner South	10%	18%	25%	48%	33%	41%
Eastern Suburbs	8%	18%	32%	41%	51%	36%
Inner South West	4%	16%	27%	52%	64%	30%
Inner West	6%	13%	33%	49%	52%	40%
North Sydney and Hornsby	4%	15%	21%	60%	52%	39%
Northern Beaches	2%	9%	24%	66%	70%	22%
Outer South West	3%	9%	14%	74%	81%	15%
Outer West and Blue Mountains	2%	12%	18%	67%	82%	13%
Parramatta	8%	22%	28%	43%	66%	29%
Ryde	3%	17%	36%	45%	60%	33%
South West	9%	23%	25%	43%	79%	16%
Sutherland	1%	8%	21%	69%	75%	20%
Regional New South Wales						
Capital Region	10%	12%	16%	62%	90%	2%
Central Coast	5%	11%	20%	64%	85%	11%
Central West	4%	11%	18%	67%	90%	1%
Coffs Harbour – Grafton	2%	10%	16%	72%	90%	1%
Far West and Orana	3%	5%	3%	89%	88%	1%
Hunter Valley	2%	8%	18%	72%	92%	2%
Illawarra	3%	7%	22%	69%	87%	7%
Mid North Coast	4%	5%	18%	73%	90%	1%
Murray	2%	6%	10%	82%	90%	1%
New England and North West	12%	15%	20%	54%	89%	1%
Newcastle and Lake Macquarie	5%	13%	22%	60%	90%	4%
Richmond – Tweed	3%	14%	19%	64%	90%	2%
Riverina	1%	4%	11%	84%	90%	1%
Southern Highlands and Shoalhaven	9%	14%	23%	54%	90%	2%

predicted adoption rates may be viewed as short-term measures of demand elasticity. Our model does not account for more long-term changes in lifestyles that might accompany the introduction of ODT services, such as reductions in private car ownership levels or changes in residential settlement patterns, which could potentially increase the use of these services even further.

As mentioned previously, ODT services are currently being trialled across a number of regions across Australia. We use our model to assess how service uptake might vary across different regions within New South Wales, for an ODT service that costs $0.70 per km; vehicles are shared between passengers; the service can be booked in real time; and the service offers flexible routes and flexible schedules, but not door-to-door service. Our example ODT service attributes have been selected to mimic as closely as possible ODT services currently being trialled across New South Wales. Consequently, our model predictions can help identify regions that offer promising markets for these early trials. Table 8 enumerates usage frequencies for the ODT service across different regions in New South Wales, corresponding to the ASGS statistical area level 4 designation. For comparison, we also include private car and public transport mode shares for commute travel across these regions, as recorded by the 2016 Australian Census. In general, predicted ODT usage across regions is strongly positively correlated with existing public transport use, indicating that ODT services are likely to be used by existing public transport customers to plug gaps within extant public transport services. For example, within the Greater Sydney metropolitan area, predicted ODT use is greatest in the inner-city neighbourhoods of City and Inner South and Eastern Suburbs. Both neighbourhoods have high current public transport mode shares. However, there are several exceptions to this trend as well. For example, suburban neighbourhoods such as Ryde, North Sydney and Hornsby have high current public transport mode shares, but exhibit a low willingness to use ODT services. Conversely, across regional New South Wales, Capital Region, New England and North West, and Southern Highlands and Shoalhaven have low current public transport mode shares, but exhibit a high willingness to use ODT services. These findings indicate that ODT services may have the ability to draw new customers to public transport, particularly in regional and remote communities where the provision of fixed route fixed schedule services is especially untenable.

The reader should note however that predicted adoption rates specific to a neighbourhood or region are subject to high standard errors, due to smaller sample sizes: the number of respondents from any one neighbourhood or region in our sample typically varies between 20 and 40. As such, our findings are indicative of potential demand for ODT services across the Greater Sydney metropolitan area and regional New South Wales. However, more data is needed to conclude definitively which neighbourhoods and regions in particular should be selected for early trials.

8. Conclusions

This study undertook an analysis of consumer data collected from 3,985 Australians nationwide on their attitudes and opinions towards different ODT services, and their willingness to pay for use of these services. We find that the current market for ODT services is small. For example, for an ODT service that costs roughly the same as UberX's ridesharing service, and offers comparable level-of-service, our analysis predicts that only 17 per cent of the national population can be expected to use the service a few times a week or more. However, shared electric autonomous vehicles could significantly change the business case for ODT services, by enabling on-demand door-to-door transport services at a fractional cost of similar existing services. Our analysis finds that while consumers are willing to pay, on average, 0.28$/km more to avoid sharing a vehicle with other passengers and 0.17$/km more for door-to-door service, cost is the most important determinant of ODT use (of the service attributes included in our analysis; note that our analysis does not measure the effect of travel times or speeds). For an ODT service that provides the same level-of-service as UberX, but at a fractional cost of $0.30 per km, 31 per cent of the national population can be expected to use the service a few times a week or more. And this figure is likely to be larger once we account for more long-term changes in lifestyles that might accompany the introduction of these services.

We find that frequency of ODT use is strongly correlated with age and lifecycle stage: young individuals who are employed full-time are likely to use ODT most frequently; older adults who have retired from the workforce and whose children have left home are likely to be infrequent users. This is unfortunate, as many studies have argued that ODT services could provide a viable transport alternative for older adults who can no longer drive (e.g. Fagnant et al., 2015). Older adults are typically the slowest to adopt new technologies (Pew Research Center, 2014), and our analysis finds that significant shifts in attitudes and opinions are needed if older Australians are to embrace these new transport service paradigms. Note however that our analysis did not control for differences in activity and travel intensity. It is possible that for some individuals, low stated use of ODT services is not a reflection of lack of interest in using such a service, but a reflection of lower overall travel needs. Future research should strive to decompose these confounding effects.

Finally, our analysis is able to identify several niche markets for ODT services that early trials should target. In terms of demographic characteristics and existing transport use, frequent ODT users are most likely to be employed working men who are regular public transport users, motorcycle owners, or mobility device users. In terms of geography, the results are more mixed. While ODT use tends to be high in inner-city neighbourhoods, our analysis finds equally high demand in suburban and regional pockets across the country as well. In general, our analysis indicates that ODT services have the ability to both increase public transport use among existing public transport customers, and to draw new customers to public transport services.

While our findings offer a useful basis for transport planners and policy-makers to approach the design of potential ODT services in their respective jurisdictions, our analysis is limited by the hypothetical nature of our data. Ongoing ODT trials in Australia offer opportunities for making up for some of the deficiencies of our analysis, through the collection of observational and experiential data from potential consumers who have had the opportunity to use these services in real life. This information could be used to update some of our findings, and inform improvements to the provision and operation of these services in practice.

CRediT authorship contribution statement

Akshay Vij: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Stacey Ryan:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing - original draft. **Spring Sampson:** Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Writing - original draft. **Susan Harris:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tra.2019.12.026.

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