ENCOURAGING SUSTAINABLE COMMUTING BEHAVIOUR THROUGH SMART POLICY PROVISION – A STATED PREFERENCE MODE CHOICE EXPERIMENT IN THE GREATER DUBLIN AREA

Páraic Carroll

PhD Researcher

Trinity College Dublin

Brian Caulfield

Associate Professor

Trinity College Dublin

Aoife Ahern

Senior Lecturer

University College Dublin

Abstract

This paper explores the results of a stated preference (SP) experiment used to test the impact of policy incentives on commuting modal choice in the Greater Dublin Area (GDA). As a method of encouraging 'car-shedding' behaviour, various policy tools that improve the time, cost and convenience trip attributes of carpooling and car-sharing are examined. These measures are assessed in the literature as an empirical strategy of influencing a shift from single occupancy vehicle (SOV) use to more sustainable usage of the private car, such as carpooling and car-sharing. The SP experiment acts as an effective policy appraisal tool by analysing the behavioural responses to hypothetical choice scenarios and identifying the impact of policy incentives on modal share and choice probabilities. As a result of the analysis presented in this paper, an indication of the potential levels of 'car-shedding' in the GDA is determined. The discrete choice multinomial logit (MNL) findings suggested that a reduction in the modal share of SOVs of up to 8% could be realised given the policy implementation recommended. In addition to this, a 1% change in the time, cost and convenience attributes dictated an increase of up to 0.34% in the probability of carpooling and car-sharing being chosen. This paper provides weight to the argument that additional funding assigned to policy incentives alone is an effective strategy in reducing the number of commuters driving alone to work or education.

1. Introduction

Many tools have been devised to encourage travel behaviour change, such as travel plans, travel demand management (TDM) or mobility management (MM), yet much of the focus in the literature centres on internalising these costs in the form of road pricing and parking charges [1, 2]. This paper offers a new approach, '*car shedding'*, which incentivises alternative modes whilst not penalising car owners. Car-shedding is the approach of encouraging the reassessment of the need to drive a private car for certain trip purposes, accordingly reducing utility through selling or forfeiting ownership of a vehicle in exchange for more sustainable means of transport [3]. Car-shedding will be referred to throughout this paper, thus, all references to this term will be in relation to this definition. This paper presents the results of the SP survey, which was conducted in March 2017. The survey was designed to gauge the behavioural response of a sample of commuters to a range of policy incentives intended to attract commuters to travel by carpooling and/ or car-sharing. The paper will also consult relevant literature in this field of research, in addition to delineating the experimental design and survey creation process used. This study contrasts to other empirical work in this area as it focuses exclusively on policy incentives rather than proposing disincentives or pull measures on car users. The paper is organised into the following sections: Section 1 has introduced the context for the paper; Section 2 includes a brief literature review of comparable studies in this area; Section 3 examines the methodology and theoretical foundation for SP surveying and discrete-choice modelling; and Section 4 presents the data analysis and modelling findings from the study.

1.1 The Greater Dublin Area

The GDA has recently witnessed a surge in the numbers of commuters taking sustainable transport modes to work and education. The total number of people commuting to work in the GDA increased from 1.13 million in 2011 to 1.17 million in 2016, representing a 3.8% rise [4]. In 2016 an extra 15% of commuters (9,264 people) travelled by bus, rail and light rail services to work and education in the GDA. Moreover, the numbers of those cycling displayed the most impressive growth across all modes, with an increase of 38.5% [4] within this region. Within Dublin city alone, the number of cyclists entering the city increased by 74.5% between 2010 and 2014 [5, 6]. Yet private cars are still prevalent, as those driving to work in the GDA increased by 11,545 to 441,147 in 2016, with a mode share of 37%. However, the number of people stating to be car passengers decreased by 3.4%, resulting in a mode share of 15% [4].

2. Literature Review

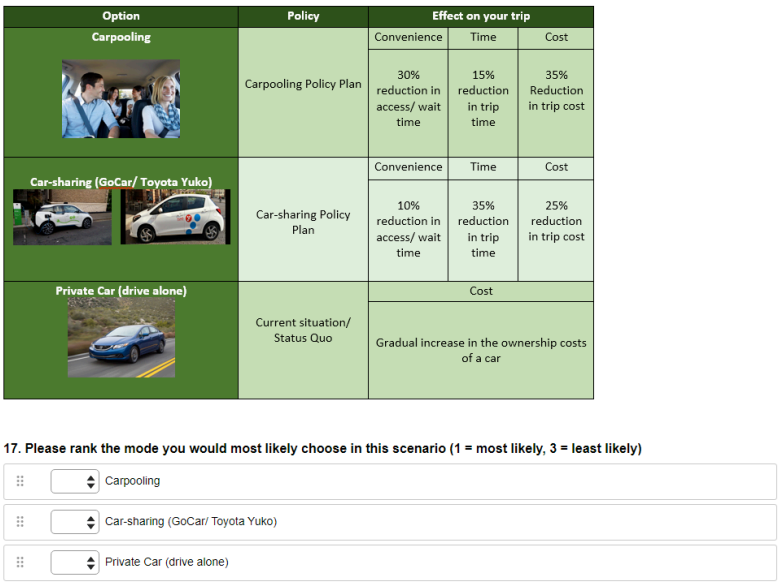
A review of literature from various international case studies on the incentivisation of alternative modes of transport as a means of reducing car use or ownership was conducted. Yet, much of this literature focuses on dis-incentivising private car travel through fees and charges such as: parking fees, tolls and fuel price increases [1; 2; 6; 9; 10], in addition to flat and time-differentiated kilometric charges and cordon charges [11; 13; 14], as methods of placing an extra financial burden on car users. Whereas other work [14; 15; 16; 17], centres on providing time and cost etc., incentives to users of alternative modes to encourage a modal shift. From their analysis, O'Fallon [9] explained that policy tools are most effective when in 'packages, so policymakers can choose the tools that are suited to the constraints of the car driving population'. In addition to this, they identified that improvements to alternative modes should not be overlooked in the event that car usage is discouraged through fees and charges. As a result of this, it was decided that the policies offered in the SP scenarios in this study, would be presented in the form of policy packages or plans that are linked to the modes attributes, which will be discussed in the next section.

3. Survey design and methodology

In the study reported in this paper, respondents were prompted to choose one option from a set of three. These three options or alternatives were: (i) Carpooling, (ii) Car-sharing, (iii) Car (drive alone/ SOV). The private car (drive alone) option was incorporated as a constant or 'no choice' / 'status quo' option with no attributes associated with it. This decision was made, firstly, as there was a reluctance to put-off likely respondents by applying disincentives to the car. Secondly, it is held in the literature that including a base alternative or 'current choice' option, leads to more realistic and accurate market predictions, as well as better mimicking consumer choices [18; 19; 20]. This produces better model parameter estimates and more precisely estimates modal choice changes in the population. Principals of SP experimentation require the analyst to provide respondents with scenarios in which they are prompted to make a trade-off by considering alternative-specific attributes. The alternative-specific attributes for carpooling and car-sharing in this study were considered in reference to the literature (12; 19). From this it was identified that the main attributes affecting mode choice behaviour for carpool and car-share were: Convenience (10%, 30%, 50% reductions in access/wait time); Travel Time (15%, 25%, 35% reductions in trip time); Cost (15%, 25%, 35% reductions in trip cost). These attributes were delivered on three attributes levels, representing low, medium and high attribute strength.

A fractional factorial design was then generated using IBM SPSS software, producing 27 individual choice combinations that were 'blocked' into 9 versions to allow for the 9 SP scenarios to be assigned evenly, as outlined in Hensher, et al. [22]. Blocking variables reduce the number of SP scenarios that each respondent is required to answer, lowering the effects of survey fatigue. The nine versions of survey were then randomly assigned to the respondents to minimise the influence of learning [23]; using the Qualtrics survey flow randomiser function [24].

The SP survey, conducted online in March of 2017, was circulated to a sample resident and working/ studying in the GDA, and was organised into 4 sections: (1) Introductory questions; (2) Perceptions of policy measures; (3) Stated preference scenarios; (4) Demographic characteristics. The introductory section was used to determine revealed characteristics such as mode of choice, distance, time and costs of their commute. Section 2 explored attitudes to measures such as in work cycling facilities, carpool/ car-share assistance, the provision of timetabling information, financial incentives and the availability of the option to telecommute to determine the support for such policies. The main module of the survey was included in Section 3 - the SP choice scenarios, and the final section included a number of socio-demographic questions. The policy package incorporated into the scenarios was included in the brief prior to commencing the SP component of the survey. The policies presented were: Free-on street and private parking for high occupancy vehicles (HOVs) and car-share members; Availability of HOV lanes; Exemption of road tolls; Guaranteed ride home for carpoolers and car-sharers; and cost subsidies. The context for the hypothetical mode choice was then delineated, as the respondents were informed that they had been offered a job in a new location and that they would need to decide on how they would travel to work based on new trip characteristics. For instance, if their trip became 35% cheaper and 15% quicker by carpooling to work/ education relative to their current trip, as shown in Figure 1, owing to various policy tools being implemented, would this encourage them to switch to carpooling or would they simply continue with their current mode of choice (i.e. no change)? Figure 1 displays an example of a SP scenarios included in the survey.



Option	Policy	Effect on your trip		
Carpooling	Carpooling Policy Plan	Convenience	Time	Cost
		30% reduction in access/ wait time	15% reduction in trip time	35% Reduction in trip cost
Car-sharing (GoCar/ Toyota Yuko)	Car-sharing Policy Plan	Convenience	Time	Cost
		10% reduction in access/ wait time	35% reduction in trip time	25% reduction in trip cost
Private Car (drive alone)	Current situation/ Status Quo	Cost		
		Gradual increase in the ownership costs of a car		

Fig. 1 Example of one stated preference scenario

4. Results

4.1. Data collection

A sample size of 385 respondents was estimated to be suitable for the estimation of the survey results, based on a 95% confidence level, 5% margin of error, and the GDA population of 1,907,332. The sample was collected online with the aid of Delve Research, an independent survey research company, who operate panels of respondents nationally. A total of 552 responses were collected, 432 of these were fully completed. The sample showed a gender split of 44.5% male and 55.5% female, which was representative of the Census 2016 GDA population (49% male and 51% female) [4]. It was found that a greater percentage of the sample were aged within the 35-44 and 45-54 age cohorts, with at least a secondary school education, married with no children, an average household income of between €25,000 to €50,000 per annum, living in the inner suburbs of Dublin and working in Dublin city centre. The age, number of children/ dependents, educational attainment, marital and economic status characteristics of the sample were similarly found to be adequate representations of the population of the GDA when compared with the 2016 Census results from the GDA [4].

4.2 Stated preference analysis and model results

An MNL model was found to be the most established method of analysing the relationship of the attributes in a mode choice experiment [22; 25], modelled using NLOGIT discrete choice modelling software [26]. By analysing the choice proportions of the survey, it was found that carpool was the most chosen mode with almost half of respondents (48.41%) opting for this alternative. The remaining two options (Car and Car-share) were shared with 26.79% and 24.80% of the respondents selecting these modes respectively. This provided an encouraging signal that more people could be inclined to make more efficient use of the private car in the GDA by increasing the occupancy levels of cars when commuting.

In modelling the survey results, an attributes-only model was generated first consisting only of the main attributes, attribute levels and alternative-specific constants assigned to each respective alternative. These results displayed in the third column of Table 1, show that all parameter coefficients were statistically significant and the chi-squared probability value of

0.000 was satisfactorily below alpha to warrant a rejection of the null hypothesis that the policy incentives do not increase the utility of the carpool and car-share alternatives. The cost attribute was found to be most significant variable, at the 99% confidence level for carpool and 95% for car-share. These coefficients suggested that as carpooling and car-sharing became increasingly cheaper modes, the utility of these modes increased and the likelihood of individuals choosing them also rose.

The extended model in the final column of Table 1, improved upon the attributes-only model with the inclusion of various socio-demographic variables, listed in column two. The presence of these variables produced a higher pseudo rho-squared value of 0.074, in contrast to the attributes-only model value of 0.014, thus suggesting that the extended model was a more accurate representation of the data. A comparison of the log-likelihood (LL) and Akaike Information Criterion Coefficient (AICc) values support this statement, as the extended model produced a LL figure of -856.938 and AICc of 1773.9, whereas the base comparison LL value of -925.384 and AICc of 2802.8 were considerably higher, signifying that the extended model was of better quality and represented goodness of fit to the data. Table 1 also shows that all the beta coefficients of the extended model were statistically significant to various confidence levels, with the marginal exception of the *Carptime* coefficient. This may suggest that individuals who chose to carpool did not place such an emphasis on the time attribute. The full model output, the model was reduced to exclude non-significant variables. However, various predictors in the model produced significant results with gender, age and education level being significant variables for both the carpool and car-share alternatives. Gender was binary coded (male = 1, female = -1) and as the gender coefficient was found to be negative for both carpool and car-share alternatives, this suggested that females were more likely than males to take these modes. Other significant coefficients suggested that those within higher age cohorts with higher levels of education were more likely to carpool and car-share than younger males with lower levels of education. Those living in areas in the outer suburbs or peripheral locations of the GDA would have higher likelihood of choosing to carpool. In addition to this, single people were distinctly more likely to carpool than married individuals. Yet those working in closer proximity to Dublin city centre in full-time employment would be more likely to car-share. Furthermore, having a driving license and more than one car rather counter-intuitively increased the chances of those commuting by both carpool and car-sharing to work or education.

Table 4

Attributes-only and Extended Model Output

Observations N = 1605					
	Variable	Attributes-Only Model		Extended Model	
		Coefficient	Z-stat	Coefficient	Z-stat
Carpconv	Convenience	0.0109***	3.24	0.0131***	3.06
Carptime	Time	0.0128*	1.91	0.0126	1.47
Carpcost	Cost	0.0179***	2.65	0.0246***	2.86
Carpgen	Gender			-0.2023**	-2.23
Carpage	Age			0.3678***	4.68
Carpedu	Education			0.1824***	4.38
Carplive	Living location			0.1904**	2.25
Carpmari	Marital Status			-0.2210**	-2.01
Carplic	Licence			-0.9395***	-3.91
Carpown	Car Ownership			-0.3005***	-2.71
Carsconv	Convenience	0.0131***	3.33	0.0098**	1.97
Carstime	Time	0.0171**	2.18	0.0187*	1.86
Carscost	Cost	0.0192**	2.45	0.0209**	2.07
Carsgen	Gender			-0.3260***	-3.08
Carsage	Age			0.2589***	2.89
Carsedu	Education			0.0836*	1.65
Carswork	Working location			-0.2381**	-2.27
Carsempl	Employment Status			-0.0952*	-1.72
Carschil	No. of Children			0.1786**	2.16
Carslic	Licence			-0.5606**	-2.05

Carsown	Car Ownership	-0.3135**	-2.40
	Attributes-Only Model	Extended Model	
Log Likelihood	-1393.401	-856.938	
Constants only LL	-1414.195	-925.384	
AICc	2802.8	1773.9	
Pseudo Rho Squared	0.014	0.074	
Prob. Chi-squared	0.000	0.000	

* Significant at 90% confidence, ** Significant at 95% confidence, *** Significant at 99% confidence

Various behavioural indicators derived from the choice data, such as elasticities and simulation models were modelled in this study. Transport elasticities are based on either actual (revealed) and/ or SP studies, and are often expressed as the ratio of the proportional behavioural change to the proportional changes in prices, fares or services [6]. Elasticities measure the percentage change in the probability of choosing a particular alternative in the choice set with respect to a given percentage change in an attribute of that same alternative (direct elasticity) or a competing alternative (cross elasticity) [22]. 'What if' simulation models provide the analyst with the capability to use an estimated model to test how changes in attribute value impact upon choice probabilities and market shares for choice alternatives [22; 27]. Using this approach, the analyst can investigate the tactical issues such as service design and pricing strategies through the use of hypothetical simulations of attribute value changes. In this way, the analyst can aid transport planners and support policymakers in the examination of the impact of socio-economic and transport-related variables on future passenger demand for certain modes [28]. This indicator is pertinent to the aims of this study as it acts as a gauge of projected modal shares in future years given new demands for alternative modes.

The modelled elasticities displayed in Table 2, relate to the impact of a 1% change in the three attributes in the model, which translates into a 1% decrease in trip times and costs and a 1% decrease in wait and access times associated with convenience. From this analysis cost was found to be the most statistically significant attribute, displaying a 0.34% increase in the probability of car-sharing being selected and 0.22% for carpooling. However, the cross elasticities produced the expected output, for if this change were applied to either carpooling or car-sharing only, this would negatively affect the likelihood of the mode with no such change. For example, if a 1% decrease in the cost of car-sharing occurred, this would result in a fall of 0.22% in carpooling being chosen, and if the cost of carpooling was altered, car-sharing would experience an 0.11% reduction in the probability, thus negatively effecting its utility overall. Comparable findings are noticed with the time and convenience attributes as increases of 0.27% and 0.18% to the probability of car-sharing and carpooling are recorded for time, and rises of 0.26% and 0.17% from changes to the convenience variable. The results here suggest that the carpool and car-share alternatives are relatively elastic to changes made to the convenience, time and cost attributes, with cost being most significant.

Table 5

Elasticities

Convenience	Carpool	Car-share	Car
Carpool	0.173	-0.180	-0.180
Car-share	-0.094	0.260	-0.094
Car	0	0	0
Time	Carpool	Car-share	Car
Carpool	0.185	-0.180	-0.180
Car-share	-0.093	0.272	-0.093
Car	0	0	0
Cost	Carpool	Car-share	Car
Carpool	0.231	-0.228	-0.228

Car-share	-0.118	0.341	-0.118
Car	0	0	0

In order to produce simulations of mode choice share, a number of 'what if' scenarios were conducted (more information see: [27; 28]). It was determined from this analysis that a large percentage of the sample were estimated to switch from driving solo to carpooling and car-sharing given changes made to attribute values in the simulation model. The figures presented in Table 3 show that modifying the cost attribute from an actual value of 35 to 50, would result in 107 individuals switching to carpool and car-share. Of these 107 individuals, 72 would switch to carpool and 35 to car-share, or 5.3% and 2.6% of the sample respectively. Modifications made to the time and convenience attributes also produced noteworthy findings, as 6.49% of the sample are estimated to switch to carpool and car-share when time is also set to a 50% attribute level value, and 6.30% of respondents are predicted to move to these modes as a consequence of changing convenience to a 60% reduction value, from a value of 50. Changes to cost represented the most significant modal shift and resulted in the car (drive alone) alternative having the smallest modal share (18.84%) given the three attribute value changes. This finding supports the premise that car-shedding behaviour can be encouraged in the GDA by presenting attractive incentives to commuters without sacrificing the comfort, freedom and independence benefits of owning a private vehicle. It indicates that if viable alternatives are incentivised to the extent that they offer greater benefits in the form of time and cost savings to the commuter, then sustainable travel behaviour change can be encouraged.

Table 6

Simulation Model of Attribute Level Value Changes

Alternatives	Base Model		Scenario		Choice share changes	
***Convenience* - fixed at new base value of 60% reduction (access + wait times)**						
	N	% Share	N	% Share	N	% Share
Carpool	652	48.40	693	51.41	58	4.32
Car-share	334	24.79	352	26.1	27	1.97
Car	361	26.80	303	22.4	-85	-6.30
***Time* - fixed at new base value of 50% reduction**						
Carpool	652	48.40	710	52.73	58	4.33
Car-share	334	24.79	363	26.95	29	2.15
Car	361	26.80	274	20.31	-87	-6.49
***Cost* - fixed at new base value of 50% reduction**						
Carpool	652	48.40	724	53.74	72	5.34
Car-share	334	24.79	369	27.41	35	2.61
Car	361	26.80	254	18.84	-107	-7.96

5. Conclusions

This study calculated the behaviour impact of a policy plan on the commuting population of the Greater Dublin Area, through a modal choice experiment. An SP survey that incorporated several pull factors for carpooling and car-sharing into hypothetical choice scenarios, was tested to examine the potential for car-shedding shifting behaviour. This was an approach that has, to the knowledge of the author, not been conducted in Ireland to date, which presents a valuable opportunity for further empirical research in this area. The analysis of the survey results provides weight to the statement that individual commuters do need proper inducement to change longstanding and unsustainable commuting habits. It was found that if such incentives result in tangible time and cost savings for the commuter, then this could encourage a shift away from SOV commuting. Based on the MNL results, it was determined that cost was a factor of prime consideration in the decision to carpool or car-share. Thus, as the trips became cheaper, the utility for carpooling and car-sharing rose.

It was also identified that the single women in the middle to higher age cohorts, with a university education and who commute from the outer suburbs to Dublin city for work or education were most likely to carpool or car-share. Those with children would be more likely to car-share than those without and commuters with a driving licence and at least one car available to the household would represent higher likelihood to carpool or car-share. Finally, the analysis determined that significant reductions in the modal share of SOVs of up to 8%, could be attained if policies are put in place to reduce the time and cost attributes of commuting to work by carpooling and car-sharing. In addition to this, a 1% change in the convenience, time and cost attributes yielded a direct elasticity or increase in the probability of carpooling and car-sharing being chosen, of up to 0.34%. Therefore, this study effectively acts as an effective policy appraisal tool for investigating behavioural responses to mode choice decision making that is not revealed in the market [29].

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