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Constraints affecting mode choices by morning car commuters

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Abstract

In New Zealand as elsewhere, there is an increasing interest in alleviating congestion on the road transport network to improve economic productivity, reduce pollution, and to use the transport network more effectively. Governments enact various policies to encourage car drivers to change their behaviour, but often find that the full impact is not reached. We propose that car drivers have constraints influencing their mode choice for the morning peak period trip (e.g. needing to transport children, needing a car for work during the day). A stated preference experiment conducted in the three largest New Zealand urban areas not only quantifies the likely impact of a wide range of policy tools (both 'sticks' discouraging car use, and 'carrots' encouraging alternative modes) for each area, but also identifies many significant constraints.

Keywords: Driver behaviour; Travel behaviour; Stated preference; Constraints; Peak period; Mode choice; Urban; Policy; Demand management

1. Introduction

In New Zealand, as elsewhere internationally, there is an increasing interest in alleviating congestion on the road transport network, thereby improving economic productivity (by reducing the amount of productive employee time spent sitting in traffic), reducing air pollution, particularly carbon monoxide and CO_2 emissions, lessening noise and water run-off impacts, and making more efficient and effective use of the road network. The New Zealand Government has recently announced policy changes to expand public transport services and encourage public transport use, developing a walking and cycling strategy (aiming to increase both activities), allow more tolling of roads and to introduce electronic road user charging (Ministry of Transport, 2002). The Government announced it would investigate further the option of congestion charging based on time and location of travel. To impose tolls or congestion pricing, regional councils in Auckland, Wellington and Christchurch have previously identified where a cordon could be placed around the central city areas in their respective regions.

But how well will proposed policy changes meet their objective of alleviating congestion by reducing car use? Changes in transport policy or the conditions of a public transport service may not have their expected impact because policy makers do not understand the constraints affecting an individual's travel choices. The need for research to understand the impact of policies has been recognised by organisations such as the European Commission (1994), the US General Accounting Office (1996) and researchers (see for example, Rosenbloom, 1998).

As part of a larger research programme entitled 'Identifying Factors to Change People's Transport Use', carried out by Pinnacle Research and its collaborators and funded by the Foundation for Research Science and Technology in New Zealand (described at www.pinnacleresearch.co.nz/main_survey.htm), we have undertaken stated preference (SP) experiments in Auckland, Wellington and Christchurch to explore the potential effect of several different policy measures on the respondent's decision to choose to drive a car to work or their own place of study in the morning peak period (before 10 a.m.). At the same time, we collected information on various factors that we

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Table 1
Key facts about urban areas

	Auckland	Wellington	Christchurch
Cities included	Auckland, North Shore, Waitakere, Manakau	Wellington, Lower Hutt, Upper Hutt, Porirua	Christchurch
Topography	Mixed	Hilly around main CBD; flat in Hutt Valley	Distinctively flat
Population[a]	1,074,507	339,747	334,104
Travel to work[a]:			
Drove private vehicle	52%	41%	52%
Public bus	5%	9%	3%
Train	0.5%	6%	<0.1%
Bicycle	1%	2%	6%
Proportion of jobs in CBD[b]	15%	22%	19%

[a] Population and travel to work figures from the 2001 Census (Statistics New Zealand, 2003). Travel to work figures are the main means of travel to work as a percentage of employed residents aged 15+ .
[b] 1991 result from Laird et al. (2001), p 55.

considered might influence mode choice, such as vehicle ownership, gender, age, use of car during the working day, household composition, and so on.

SP experiments present a 'choice setting' in exactly the same way as the individual currently sees it (in this case, the usual morning journey to work or place of study) but alters some of the conditions (by introducing one or more of the policy measures) under which the choice is made, thereby allowing us to observe the potential effect of the policy measure (see Louviere et al., 2000). Beaton et al. (1998) cited two studies showing reasonable external validity in predicting mode choice. In addition, they demonstrated good external validity for predicting switching from single occupant vehicles to a new public transport service in their own small study. There is also a substantive body of social psychology literature demonstrating the link between stated intentions and actual transport behaviour (refer to Baldassare et al. (1998) for additional references).

Multinomial logit and nested logit models are estimated that incorporate the attributes of the stated choice experiments as well as contextual effects (external factors) influencing choice. The resulting models are not used to predict demand but instead allow us to identify the variability in mode share of a range of policy scenarios.

2. Survey design and methodology

2.1. Stated preference experiment design

We conducted our SP experiment in the three main urban areas in New Zealand: Auckland, Wellington and Christchurch. These three areas differ substantially in several ways important for transport: Auckland is the least centralised, with a relatively low proportion of jobs in its CBD; Wellington is the least car dependent, with commuters making greater use of public transport; and Christchurch retains a visibly higher rate of bicycle use (see key background facts in Table 1). Consistent with common use we often refer to each urban area as a city, despite the Auckland and Wellington areas concerned formally including four cities each. Standard random household sampling techniques were used to find car drivers who drove to their workplace or their own place of study before 10 a.m. at least twice a week (in fact, 81% drove to work at least four days in the previous week). Respondents were interviewed face-to-face. The Auckland and Wellington interviews were conducted in mid-1999, while the Christchurch ones were conducted in mid-2001.

We had a total of 732 completed valid questionnaires, fairly equally divided between the three urban areas (Table 2 shows the gender, age and household type for each urban area). Close to 1400 households were classified as 'ineligible' and the refusal rate averaged about 40% in the three cities. Despite this refusal rate, our sample composition proved broadly similar with respect to gender, age, and household type when compared to the New Zealand Travel Survey (NZTS), an official nationwide travel study with a high response rate[2]. The largest difference is that our sample had fewer respondents than expected in the 15–29 year-old age group (21% compared with 31%). This difference probably reflects the general tendency of this age group to be underrepresented in most surveys (we have not adjusted our results for this under-representation, whereas the NZTS statistical weights increase this age group upwards from 25% to 31% using Census results).

[2] The Land Transport Safety Authority's 1998/99 New Zealand Travel Survey (NZTS) which had over 14,000 respondents nationwide. NZTS results are weighted statistically, to reflect Census results for gender, age, and region. The response rate for the NZTS is a remarkably high 74.9% (only counting households where all eligible respondents responded in full), and hence it can provide a useful check on response bias. For the comparisons with our survey, we used results from the 976 respondents in Auckland, Wellington, or Christchurch urban areas who drove to work or their education before 10 a.m. on a weekday.

Table 2
Demographics: gender, age, household type, employment

		Auckland	Wellington	Christchurch	All 3 areas	NZTS
Unweighted count		$n = 247$	$n = 233$	$n = 252$	$n = 732$	$n = 976$
		%	%	%	%	%
Gender	Male	59	51	50	53	57
	Female	41	49	50	47	43
Age	15[a]–29	22	21	20	21	31
	30–39	28	25	25	26	25
	40–49	30	26	33	30	25
	50–59	15	20	18	18	16
	60+	5	7	4	5	2
Household type	Single	7	12	10	10	6
	Defacto/married couple	22	20	21	21	23
	Single adult with other adults	10	14	12	12	9
	Family (incl. extended) with children under 18	39	37	40	39	40
	Married with children over 18	17	11	11	13	14
	Single adult, children under 18	5	4	6	5	3
Paid employment	Self-employed	13	18	9	13	–
	Full-time salary/wage	59	64	60	61	–
	Part-time salary/wage	17	13	18	16	–
	Student	9	4	12	8	–
	Other	2	1	1	1	–

Note: Components may not always add to 100% exactly because of rounding.
[a] In New Zealand, 15 year-olds are entitled to get a driving licence and to drive on public roads.

The SP experiment had 11 policy tools which, when in place, could affect the decision to drive a car to work or study. As can be seen from Table 3, five of these policy tools could be considered to discourage car use directly, five could be seen as promoting or encouraging public transport use, and the remaining one as encouraging cycle use. Ten of the 11 policy tools were presented in each city—Auckland and Wellington had all of the car use and public transport tools, while Christchurch respondents were presented with the cycling option and only four of the five public transport attributes. Each policy tool had three levels (see Table 3). The levels used in Auckland and Wellington were higher than in Christchurch for three of the car use tools, reflecting the fact that parking is currently much less expensive in Christchurch and because the traffic congestion problems in Christchurch are much less significant than in the other two cities (hence lower cordon tolls would be appropriate). The 10 and 30 c/km proposed vehicle registration surcharges are identical for all three cities both because such a scheme might well require nation-wide implementation and also because this tool targets all driving, not just urban congestion.

Thus, the SP design for each city had ten attributes each of three levels. A full factorial design (i.e. all combinations) produces 59,049 possible combinations (3^{10}). A fractional factorial design was used to create 81 scenarios in which all ten main effects were independent and orthogonal. SP designs are typically defined as a fractional factorial in order to preserve as much as possible of the statistical variability offered by the full factorial while recognising the practical necessity of having the exercise manageable by respondents (Louviere et al., 2000). The design does not permit two-way interactions between design attributes without creating some amount of correlation. Interactions between design attributes and contextual variables are permissible. The 81 scenarios were randomly ordered and then equally divided into nine separate booklets.

Each respondent was presented with 9 different scenarios and asked 'if all these changes were in place on that day, how would you have travelled to work or your place of study?' An example of an SP choice scenario is shown in Fig. 1. 'That day' refers to a day in the previous week for which the respondent had been asked to provide trip diary details. The interviewer coded the open-ended response on the survey form. In the analysis, we coded seven 'mode' choices for each trip:

1. drive a car (Drive)
2. become a passenger in a car (Passenger)
3. arrange carpooling (Carpooling)
4. walk and catch public transport (walkPT)

Table 3
Eleven policy tools and their respective levels as used in stated choice experiment (levels in parentheses are those used in Christchurch survey)

	Level 1	Level 2	Level 3
Tools to reduce car use			
Extra daily parking charge on car park buildings and lots	None in place	$5/day ($2.50/day)	$10/day ($5/day)
Restricting on-street parking to ≤2 h within a nominated radius of work/study place	No change	Within 0.5 km = ≤ *P*120	Within 1.5 km = ≤ *P*120
Converting all on-street parking within a 1 km radius of work/study place to metered parking	No change	$2.50/h ($1.25/h)	$5.00/h ($2.50/h)
Cordon charge to enter central city before 10 a.m.	None in place	$5 each entry ($2.50 each entry)	$10 each entry ($5 each entry)
Vehicle registration surcharge/km driven	None in place	10¢/km	30¢/km
*Tools to increase public transport use*s			
Improved frequency of services during peak hours	No change	50% more often	Twice as often
Lower public transport fares	No change	25% decrease in cost	50% decrease in cost
Improved/shortened trip times of services (e.g. through ticketing improvements, preferential bus treatment at intersections, etc)	10% better	25% better	35% better (including HOV lane)
Improved route coverage of services	No change	Bus stops within 400 m of home and work place	Bus stops within 800 m of home and work place
Increased off-peak services (Auckland and Wellington only)	No change	Services every 15 minutes during off-peak	Services every 30 minutes during off-peak
Tools to increase cycle use			
Cycle lane availability (Christchurch only)	No change	Along 50% of route to work/study	Along 100% of route to work/study

5. drive, park and ride public transport (drivePT)
6. cycle (Cycle)
7. other (including walk, work from home for some or all of the day, taxi, change time of trip).

These seven mode choices later became the basis for our multinomial logit and nested logit modelling.

2.2. Contextual factors in the survey

In addition to the trip diary for one day and the nine stated choice scenarios, demographics and background information about car use (and cycling in Christchurch) was sought. Thus, the SP data was enriched with other covariates that were not part of the stated choice experiment but which may be important influences or constraints on mode choice.

Some of these contextual effects directly reflect travel needs and associated costs or constraints:

- car use for work-related trips during the business day
- transporting children to school
- trips/stops before work (other than transporting children to school)
- whether the journey was discretionary (i.e. could have been postponed or cancelled—without getting someone else to drop off passengers)
- parking costs in the past week
- car ownership
- roundtrip distance, from home to work and/or study place to home (estimated using geo-coding).

Other contextual factors are simply demographics (which may indirectly reflect constraints on mode choice):

- driver's age and gender
- household type
- employment status
- household income (Christchurch only).

The demographics are largely summarised already in Table 2. Table 4 shows contextual variables directly related to transport. Note that these show few striking differences between the three cities. Parking is the exception: Auckland respondents more commonly had parking provided by employers or the place of study, and Wellington respondents more commonly paid for parking.

2.3. Mode choice modelling

The modelling task was to model mode choice, taking into account both the responses to the SP scenarios and the information collected on the contextual effects. In order to make comparisons between the three urban areas, we developed three separate models for choice of mode. Initially, we derived multinomial logit models for each city, then we attempted to improve on these by constructing

PARKING …	
1. Extra charge in a car park lot / building (one where you already pay)..............	$5 extra per day
2. On-street availability..................................	no change
3. On-street charges	all on-street parking within 1.0 km of your work/study place costs $2.50/hr and strictly enforced
PRIVATE VEHICLE …	
4. Registration increase	10c/km (= $1000 per 10,000 km driven)
5. Fee to enter central city up to 10AM..........	none in place
PUBLIC TRANSPORT (trains/buses/ferries) …	
6. Frequency…..	runs twice as often
7. Fares…………	costs half as much
8. Trip time changes	shorten bus trip time by 25% (e.g., priority signalling, quicker ticketing, fewer stops)
9. Route coverage..	no change
10. Hours of operation....................................	service runs at least every 15 minutes during off-peak hours up to 10pm

Fig. 1. Example of stated preference scenario (Auckland and Wellington).

nested logit models. In the case of Wellington and Auckland, the final models are multinomial logit models. The Christchurch model is a nested logit model, chosen from a number of tree structures. It has one branch consisting of the Drive, walk and catch public transport (walkPT) and Cycle mode choices whereas the other branch incorporates the Carpooling, (car) Passenger, drive-park-and-ride (drivePT) and 'all other' mode choices. The nested logit model has inclusive value parameters lying in the 0–1 range, thus meeting the condition for consistency with utility maximisation (Louviere et al., 2000).

3. Results

3.1. Mode choice and mode share

As indicated previously, we had 732 respondents in Auckland, Wellington, and Christchurch who each responded to 9 scenarios. This provided 6581 cases for analysis (7 cases were deleted because a clear choice of a single mode was not made).

Nearly one-half (48%) of the respondents always chose to continue to drive their car (Drive) in response to the scenarios presented them. These respondents were very evenly distributed among the three cities. Those who always chose Drive were more likely to be male, self-employed (students were more likely to switch modes), drive a company or business vehicle, and to use their car during working hours for business-related trips. Note that this common choice of the Drive throughout occurred despite the levels of extra cost involved with some of our policy tools being sufficiently high as to provoke extreme concern and even anger that such options might be being considered. Spontaneous respondent comments recorded at the end of the interview included:

> I am disgusted and appalled at the prospect of the possibility of being charged exorbitant fees to enter the city.
> - I think the government needs a bullet for even considering introducing schemes like this.
> - Paying to get into city is ridiculous.—They' should be shot for even thinking about it.
> - Registration fee is too much.
> - The fee to enter the central city is completely unreasonable.

Table 5 reveals that, in all three cities, the primary alternative mode chosen was walk and catch public transport (walkPT). Beyond this, however, there was no consistent pattern of mode choice, reflecting the differing nature of the alternatives to car driving available in the three cities. In Wellington, the alternative mode most preferred after walkPT was to drive, park and ride public transport (drivePT). In contrast to Auckland and Christchurch, the drivePT option is widely available (at commuter rail

Table 4
Contextual variables directly related to transport

		Auckland	Wellington	Christchurch
Unweighted count		$n = 247$	$n = 233$	$n = 252$
		%	%	%
Whose vehicle did you use?	My own	84	83	84
	Other vehicle owned by your family/household	4	4	6
	Vehicle owned by another family/household	0	1	1
	Company/business	11	12	9
Used car for work that day	Yes	22	24	21
Trips before work that day	None	70	74	75
	Drove child to school	17	16	14
	Other pre-work trip	13	10	11
Was journey discretionary (i.e. if vehicle had been unavailable, would have postponed or cancelled the journey)?	Discretionary	9	10	8
In the last month, where did you mainly park your vehicle there?	Off-street—resident or business	11	10	8
	Car park provided by employer or place of study	63	47	54
	Paid—public car park building/lot	7	12	4
	Paid on-street parking	1	6	1
	Free on-street parking	15	23	30
	Other	3	3	2
In the past week, how much did you personally pay for parking?	Nothing	76	58	73
	Up to $10	13	25	22
	$10.01–$20	1	9	3
	More than $20	5	8	2
	No response	4	0	0

Note: Components may not always add to 100% exactly because of rounding.

stations) in Wellington and there is clearly a reasonable level of awareness of it. In Christchurch, with its flat terrain and wide streets, choosing Cycle is a much more viable option than in the narrow, winding and hilly streets of Wellington or the much more traffic-congested streets of Auckland. In Auckland, reflecting the generally lower levels of public transport service provision, busier streets and more dispersed population, more car drivers viewed Carpooling with someone else as a viable alternative to driving their own car or using public transport.

The small number of respondents choosing some modes meant that we had insufficient data to estimate the utility function for that mode in detail (i.e. beyond simply fitting a constant). This was the case for the following modes:

- drivePT in Christchurch and Auckland
- Cycle in Auckland and Wellington
- Carpooling/ride sharing in Wellington and Christchurch
- Passenger (in a private or company vehicle) and 'All other [modes]' in all three cities.

An exception was made for carpooling in Auckland, because we found a significant design variable (bus and HOV time 35% better). Unlike contextual variables, such design variables vary within the nine choices made by each respondent.

3.2. Mode choice modelling: design variables

As can be seen at the top of Table 6, all five of the policy tools designed to directly affect car driving are significant in all three cities, albeit only marginally significant in Auckland for on-street parking meter changes. (Note that t-values with absolute values of 1.96 or greater reach the conventional 5% significance level.) Better model fit was obtained by using somewhat different utility functions for different cities. For example, a single dummy variable was used to reflect extra charges in car park lots/buildings in Auckland and Christchurch because overall model fit was not significantly improved by using variables which reflected different levels of the extra charges, whereas in

Table 5
Mode chosen (by city) in response to scenarios

	Auckland	Wellington	Christchurch	All 3 areas
Total number of choices	n = 2219	n = 2094	n = 2268	n = 6581
	%	%	%	%
Drive car	72	64	66	67
Become a car passenger	2	2	2	2
Carpool	2	1	0.5	1
Walk and catch PT	18	24	22	21
Drive, park and ride PT	2	7	1	3
Cycle	2	0.2	6	3
Other (taxi, walk, work from home, change trip time, etc)	4	2	3	3

Note: Components may not always add to 100% exactly because of rounding.

Wellington significantly better model fit was obtained using a variable reflecting the level of the extra charges in dollars (labelled '$5 or $10/day' in Table 6).

Note that the fifth policy tool listed is not simply 'cordon toll cost' but also 'if crossed into toll area before 10 a.m.'. That is, we only attempted to model an impact of cordon toll costs if the respondent actually crossed into the toll area on the day in question. This is important, not only because it results in better statistical fit, but also because the size of the cordon areas differed substantially between the three cities. In Wellington and Christchurch the cordon areas were largely limited to the CBD, but in Auckland the unusual geography (an isthmus) means that the local body responsible for strategic transport planning was most interested in a cordon area much wider than the CBD.

The impact of policy tools improving public transport services was often not detectable to a statistically significant extent. All the public transport design variables were tested in the appropriate utility functions, but only the following tools showed a significant impact on choice (and thus only these ones were retained in the final models shown in Table 6):

- in Auckland and Christchurch, the provision of a bus/high occupancy vehicle lane to reduce trip times by 35% ($t = 2.4, 2.6$ respectively)
- in Wellington, increasing frequency of services in the peak period ($t = 2.9$)
- improving the routing of services in Auckland (to within 400 m of the home and work/study place; $t = 2.2$).

Reducing public transport fares and increasing the frequency of services in the off-peak period were not significant in any city. In a UK study of car drivers and possible policies to attract them out of their cars for short trips, Mackett (2001) found that only 1% of car drivers wanted public transport to be made less expensive in order to get them to use it. The main actions required to increase use of public transport were to improve the routing of services and the frequency.

In Christchurch, the possible increase in provision of cycle lanes did not have a significant effect in encouraging car drivers to switch to Cycle (hence that design variable does not appear in Table 6). This result is not surprising given the experience of both Germany and the Netherlands over the period from 1976 to 1995. During this time, the Netherlands effectively doubled the length of its cycle paths and lanes from 9282 to 18,948 km while Germany almost trebled its network from 12,911 to 31,236 km. These dramatic changes in the network resulted in cycling simply maintaining its (admittedly high) 'market share' of all trips by all modes (27%) in the Netherlands while the German share increased from 7 to 12% (Pucher and Dijkstra, 2000). Mackett (2001) had findings similar to ours: only 2% of UK drivers said they would cycle if improvements to cycle facilities were made. Possible improvements to cycling facilities included more cycle lanes, street lighting and showering facilities at work.

3.3. Mode choice modelling: contextual variables

The results show that many factors sway mode choice for the trip to work or study in the morning. These reflect important constraints on mode choice.

We found that employment practices strongly influenced mode choice. In particular, increases in the probability that the respondent would choose Drive regardless of how much the cost was increased (to the levels used in this design) were associated with:

- provision of company-owned vehicles ($t = 4.6$, 6.2, 2.5 in Car driver part of model for Auckland, Wellington, and Christchurch, respectively; as well as $t = -3.0$ in the walkPT part of the Christchurch model)
- need to use a car during the day for work-related business ($t = 4.9$, 6.0, 4.7 in Car driver part of model for Auckland, Wellington, and Christchurch, respectively)

Table 6
Final mode choice models: parameter estimates (*t*-values in parentheses)

	Type of model	Auckland Multinomial logit	Wellington Multinomial logit	Christchurch Nested logit
Car driver (drive)				
Extra charge in carpark lot/building	$5 or $10/day		− 0.0560 (− 4.8)	
	Dummy (1 = $2.5 − $10/day)	− 0.3566 (− 4.1)[s]		− 0.7495 (− 4.7)†
On street parking availability restricted to < 2 h (0.5 or 1.5 km)		− 0.3566 (− 4.1)[s]	− 0.2629 (− 2.3)	− 0.5597 (− 2.8)
On street parking metered within 1 km of work/study	$2.50 or $5.00/h		− 0.0560 (− 4.8)	
	Dummy (1 = $1.25 − $5.00/h)	− 0.2258 (− 1.95)		− 0.7495 (− 4.7)†
Registration surcharge/km	10¢ or 30¢		− 0.0110 (− 2.6)	
	Dummy (1 = 10¢ or 30¢)	− 0.4907 (− 4.2)		
	Dummy (1 = 10¢)			− 0.639 (− 2.8)
	Dummy (1 = 30¢)			− 1.1664 (− 4.8)
Cordon toll cost—if crossed into toll area before 10 a.m.	$5 or $10	− 0.1261 (− 7.4)		
	Dummy (1 = $5)		− 0.9631 (− 6.8)	
	Dummy (1 = $10)		− 1.2762 (− 9.0)	
	Dummy (1 = $2.50 or $5)			− 1.3924 (− 6.3)
Drove company vehicle		1.0975 (4.6)	1.4988 (6.2)	1.2971 (2.5)
Drove other family/household vehicle			− 0.6742 (− 2.7)	
Drove own vehicle [base for comparison]				
Used car for work that day		0.7764 (4.9)	0.9083 (6.0)	1.3809 (4.7)
Parking costs in last week (log[$ + 1])		− 0.1858 (− 3.5)		
Mainly park on-street—free and no time limit		− 0.5995 (− 4.0)	− 0.3848 (− 2.9)	
Mainly park on-street—paid			− 0.5904(− 2.6)	
Mainly park off-street (employer, place of study, residential, other business)				1.2445 (5.7)
Mainly park elsewhere		1.0381 (2.6)		
Roundtrip distance in km (≤ 10.5 km)				0.2599 (4.9)
Roundtrip distance in km above 10.5 km				0.0032 (0.3)
Roundtrip distance in km (< 20.5 km)		0.0462 (4.6)		
Trips before work, not children to school		0.7894 (4.3)		
Are trips discretionary?			1.3348 (4.2)	
Full or part-time student		− 0.8883 (− 3.6)		
High school children in household		− 0.6118 (− 4.2)		
Single adult with children under 18		1.0592 (3.6)		− 1.0228 (− 2.9)
Group of adults living together		0.9102 (2.5)		
Single member household		− 0.9389 (− 3.2)		1.1372 (3.3)
Extended family, children under 18				− 1.9845 (− 3.7)
Couple (de facto/married)			0.5226 (3.6)	
Age 30–49				1.3573 (6.1)
Age 40–49			0.5509 (4.3)	
Passenger (in a car/private or company vehicle)				
Constant		− 3.5243 (− 11.7)	− 4.2999 (− 18.9)	− 1.336 (− 1.9)
Are trips discretionary?			2.5660 (6.7)‡	
Male		− 2.2173 (− 7.8)♪		− 2.656 (− 2.9)
Carpool/ride share				
Constant		− 3.0517 (− 9.2)	− 5.1694 (− 16.9)	− 3.2542 (− 2.7)
Bus and HOV time 35% better		0.2871 (2.4)◆		
Roundtrip distance (Dummy 1 = < 20.5 km)		− 1.3831 (− 3.5)		
Male		− 2.2173 (− 7.8)♪		
Walk and catch PT (walkPT)				
Constant		− 2.2703 (− 8.7)	− 2.2307 (− 10.9)	− 3.9645 (− 4.4)
Bus and HOV time 35% better		0.2871 (2.4)◆		0.5748 (2.6)

(*continued on next page*)

Table 6 (*continued*)

Type of model	Auckland Multinomial logit	Wellington Multinomial logit	Christchurch Nested logit
PT service operates within 400 meters of home/work place	0.274 (2.2)		
PT frequency in peak increased (Dummy, 1 = 50% or 100%)		0.3410 (2.9)†	
Are trips discretionary?	−0.8237 (−3.0)		0.9544 (2.2)
Made trips before work, not children to school			0.6114 (1.7)
Drove child to school			−1.4399 (−3.8)
Parking costs in past week (log[$ + 1])		0.3801 (8.5)♣	
Drove company vehicle			−6.9338 (−3.0)
Self − employed	−0.5884 (−2.6)	−0.7817 (−4.2)	−2.5688 (−4.3)☺
Full or part-time student	0.5121 (2.1)	0.6784 (2.5)♥	
Part-time employed			−0.9542 (−2.9)
Full-time employed and other [base for comparison]			
Income total for household (Christchurch only; log)			0.541 (3.3)
Age 15−39			1.9549 (5.2)
Age 20−29		0.7248 (5.1)	
Age 40−49			3.2257 (7.0)
Age 50 + [in base for comparison]			
Group of adults living together	1.8765 (5.1)		
Single member household	0.9671 (3.3)		
Primary school children in household		−0.4910 (−3.1)	
High school children, not primary, in household		−0.8637 (−3.6)	
Drive, park and ride PT (drivePT)			
Constant	−3.3942 (−11.4)	−3.764 (−16.7)	−1.96 (−2.1)
PT frequency in peak increased (Dummy, 1 = 50% or 100%)		0.3410 (2.9)†	
PT service operates within 400 m of home/work place		−0.5109 (−2.4)	
Parking costs in last week (log[$ + 1])		0.3801 (8.5)♣	
Full or part-time student		0.6784 (2.5)♥	
Drove child to school		1.0415 (5.3)	
Male	−2.2173 (−7.8)♪		−2.656 (−2.9)
Bicycling (cycle)			
Constant	−4.3204 (−14.4)	−6.4912 (−12.3)	−5.642 (−4.4)
Self-employed			−2.5688 (−4.3)☺
Roundtrip distance in km (≤10.5 km)			−0.0847 (−0.8)
Roundtrip distance in km (above 10.5)			−0.2498 (−3.1)
Christ church cycle in good working order (Chirst church only)			4.8592 (6.2)
Male			1.6367 (3.5)
All other			
Constant	−3.4901 (−12.9)	−4.4123 (−19.0)	−1.4396 (−2.2)
Are trips discretionary?		2.5660 (6.7)‡	
Inclusive values for nested logit			
Drive, walk and catch PT, bicycle	–	–	0.5111 (8.2)
Other four alternatives	–	–	0.8953 (2.7)
Model fit indicators			
Log-likelihood at zero (MNL)	−4317.97	−4074.74	−4413.32
Log-likelihood constants only (MNL)	−2088.25	−2134.40	−2315.03
Log-likelihood at convergence (MNL)	−1789.68	−1768.38	−1929.12
Adjusted pseudo-R^2 (MNL)	0.141	0.170	0.164
Log-likelihood at convergence (nested)	–	–	−1917.38
Adjusted Pseudo-R^2 (nested)	–	–	0.170
Sample size	2219	2094	2268

Note: some variables have shared parameters (marked [s] ◆ ‡ ☺ etc) resulting from the quality constraints— the shared value has been in entered in both or all three of the cells. A more detailed description of each variable is available from www.pinnacleresearch.co.nz.

- employer-provided parking[3] (regardless of whether or not some of the costs of parking were met by the employee).

It is possible that respondents felt that their employer would absorb the increased operating or parking costs, or perhaps would not be affected by it.

Where a respondent was already paying for parking, whether on- or off-street, they were more likely to choose not to Drive (Auckland, $t = -3.5$) or to choose walkPT (Wellington, $t = 8.5$). In Auckland and Wellington, car drivers who parked for free on the street (15 and 23%, respectively) were more likely to choose not to Drive when faced with increased car costs ($t = -4.0, -2.9$, respectively).

Employment status also influences mode choice. In contrast with full-time employees, in Auckland and Wellington, students were less likely to continue to drive, choosing to use public transport instead ($t = 2.1, 2.5$; the Wellington result applying also to drivePT)[4]. We suggest that the typically lower incomes for students and their greater flexibility with respect to time may contribute to this difference. Part-time employees were less likely than full-time to choose public transport in Christchurch ($t = -2.9$).

Self-employed people were less likely than full-time employees to choose to use public transport in all three cities ($t = -2.6, -4.2, -4.3$), or to cycle in Christchurch ($t = -4.3$). Of course, self-employed people also differ in several other ways: 76% are male (c/w 50% of the other respondents), only 8% are under 30 years old (c/w 23%), 22% classified the journey as discretionary/able to be postponed or cancelled (c/w 7%), and 38% drove the car for work purposes during the day (c/w 20%). It is difficult to definitively quantify the relative impact of such correlated variables; but do note that these four variables are present in the models to varying degrees (and when not present, were trialled but were either found not to add significantly to explanatory power or to result in a model with less explanatory power than when using the parameters in Table 6). We speculate that the differences relating to the self-employed derive from things not measured and hence not in the models such as greater perceived time-pressure and/or greater value placed on independence and control. In addition, a long list of reasons for not using public transport (which we did not try to include in the choice models) shows that the self-employed more commonly gave as a main reason 'Car is needed to carry things' (19 c/w 3% of other respondents).

Household composition, in particular whether or not there are children under 18 living in the residence, affects mode choice. It greatly reduces the likelihood of choosing walkPT, which is variously expressed in the three models as 'drove child to school', making trips before work (but not driving a child to school), household type that excludes children, and/or the presence of children in the household. In Wellington, where drivePT is more commonly a useful option because of the commuter train network, car drivers who drove children to school were far more likely to choose this alternative when faced with increased car operating costs ($t = 5.3$). Thus, the converse is true, particularly in Auckland: adults living independently (either in a single member household, or as a group of non-related adults) without children are more likely to switch to using public transport ($t = 5.1, 3.3$). There is one exception, in Christchurch, where single member households were more likely to choose Drive ($t = 3.3$), and the presence of children under 18 (in households with single adults) was associated with a propensity to switch modes ($t = -2.9$).

Age was not an overly significant factor influencing mode choice, given the other variables already in these models (several of which are closely related to age, e.g. driving children to school). However, the tendency to keep using a car (choosing Drive) is perhaps at a maximum around the age of 40 (as shown by the last parameter estimates in the Car Driver utility function for Wellington and Christchurch). This reflects perhaps the stage of life many people experience then, with children at home beginning to be more independent and the movement of at-home parents back into the workforce (also feeling perhaps a little old to cycle while still more pressured for time than older people approaching or in retirement).

The round-trip distance (home–work/study–home) was not as significant a factor in mode choice as we had expected, and despite a wide range of recorded distances (around 20% were less than 8 km/5 miles, and 20% were 32 km/20 miles or more). Distances did not feature at all in the Wellington model (despite extensive investigation), and in a limited way in both the Auckland and Christchurch models. In Auckland, Drive is more attractive for longer trips, although there is no additional effect above the distance of around 20 km ($t = 4.6$). Also in Auckland, Carpooling was less common with trips of 20 km or less ($t = -3.5$). Not surprisingly, Cycle is less and less attractive the longer trips become (although choices of Cycle were only common enough to model in Christchurch). However, up to a round-trip distance of 10 km no

[3] This is shown by the high positive t-value of 5.7 in the Car driver part of the Christchurch model associated with 'Mainly parked off-street', which contrasts with the implicit values of 0 for the other three parking possibilities. Less obvious is the evidence for this in the implicit value of 0 for the same parameter in the Auckland and Wellington models, which contrasts with the negative t-values for on-street parking in those areas. (The significant positive t-value of 2.6 for 'Mainly parked elsewhere' in the Auckland model is relatively trivial as it concerns only 2.8% of respondents in Auckland; similarly, the absence of a significant negative parameter estimate for paid on-street parking in Auckland is not important because this parking type was only used by 0.8% of respondents in Auckland (see Table 4).

[4] In Christchurch, one might suspect that a difference between students and full-time employees does not emerge because we can include income in the model for that city; however, the parameter estimate associated with students remains not significantly different from 0 when the income variable is removed. The same is true when the age variables, also likely to be correlated with student status, are removed as well.

Table 7
Marginal effects of policy tools on mode choice

	% Shifted from drive		
	Auckland	Wellington	Christchurch
Off-street parking charges			
Surcharge \$5/day in car park buildings/lots		3.5	
Surcharge \$10/day in car park buildings/lots		7.5	
Surcharge \$5–10/day	3.6		
Surcharge \$2.50–\$5.00/day			4.8
On-street parking restrictions/charges			
Availability restricted to $<$ 2 h (0.5 or 1.5 km)	3.6	3.3	3.5
Metered within 1 km of work/study (\$2.50–\$5.00/h)	2.2		
Metered within 1 km of work/study (\$1.25–\$2.50/h)			4.8
Metered within 1 km of work/study \$2.50/h		1.7	
Metered within 1 km of work/study \$5/h		3.5	
Registration surcharge/vehicle-kilometre			
10¢/km		1.3	4.0
30¢/km		4.1	8.0
10¢/km or 30¢/km	5.1		
Toll Charges before 10 a.m.			
\$2.50–\$5.00			4.5
\$5.00	1.8	7.9	
\$10.00	4.5	11.0	
Changes in public transport services			
Bus and HOV time 35% better	1.9		2.3
PT frequency in peak increased by 50% or 100%		3.6	
PT service operates within 400 m of home/work place	1.6		

significant effect of distance was found ($t = -0.8$; this non-significant t-value was retained to clearly demonstrate the piecewise linear terms being used). Drive is (relatively) more attractive for longer trips, but this effect plateaus at around 10 km in Christchurch ($t = 4.9$ for distances up to 10 km, $t = 0.3$ for extra distance above that)[5], given that the declining attractiveness of Cycle above 10 km is modelled separately ($t = -3.1$).

3.4. Car driver responsiveness to the policy tools

The marginal effects identify the practical consequence of each policy tool (attribute) used in the stated choice experiment and are, thus, more informative from a policy perspective than simple interpretation of the parameter estimates associated with each attribute. A marginal effect may be defined as the average change in the probability of choosing Drive resulting when a policy tool (such as \$5 parking surcharge or cordon charge) is applied, compared to the status quo, where none of the policy tools is applied.

Overall, the measures designed to reduce car use (by either increasing car driving costs or reducing access to parking) have higher marginal effect values than changes in public transport services. The ranking of the measures varies between the three cities: for example, in Wellington the cordon charge (\$5–10) and the \$10 surcharge on car parking buildings or lots have the greatest effect on shifting car drivers to another mode, while in Christchurch and Auckland the registration surcharge (10–30¢/km) has the greatest potential effect.

As shown in Table 7, the size of the potential modal shift (measured as a percentage shift of car drivers to another mode) varies significantly between the cities. The greatest impact of any one measure occurs in Wellington, where approximately 11% of drivers would shift to another mode if faced with a cordon charge before 10 a.m. of \$10; about 8% would shift if a cordon charge of \$5 was in place. In Christchurch, the strongest effect (8%) came from the 30¢/km registration surcharge, while in Auckland, the registration surcharge, of either 10¢ or 30¢/km, results in modal shift from Drive of about 5%.

The difference in the impact of the toll charge and registration surcharge reflects the differing travel habits in the three centres. In Wellington and Christchurch, nearly all (98%) of the respondents lived outside of the cordon area, while in Auckland only 57% lived outside the cordon. (In Auckland, the cordon area of interest to the local council was much broader than the CBD focus of the cordon areas in Wellington and Christchurch.) Approximately one-half of Auckland and Christchurch drivers had not entered the cordon area in the previous week, while 67% of the Wellington drivers had crossed into the cordon area before 10 a.m. in the previous week. Thus, the higher marginal effect for toll charges in Wellington reflects the fact that drivers in Wellington are far more likely to be

[5] Again, this nonsignificant t-value was retained for clarity, to demonstrate the piecewise terms fitted.

affected by a cordon charge than either Christchurch or Auckland. Also, Wellington drivers generally would not have easy alternative routes available if a cordon toll were imposed (because the Wellington cordon area cuts completely across major through-routes and is bounded by the sea and hills) whereas Christchurch drivers would probably find alternative routes more easily (arterial roads lie just outside the cordon area on all sides).

Similarly, differences in parking situations (see Table 4) mean that Wellingtonians would be more commonly affected by proposals to introduce a parking surcharge or tax in car park buildings or lots. Increasing the metered parking costs to $2.50/h within one kilometre of the work or study place resulted in a smaller modal shift in Wellington (1.7%) and Auckland (2.2%) than in Christchurch (4.8%). The doubling of the size of the marginal effect could be explained by the fact, shown in Table 4, that twice as many people in Christchurch parked on-street for no charge (30%) than do in Auckland (15%). In Wellington, approximately 23% of respondents parked on-street for free.

4. Conclusions

The variation in the effects of the policy tools on car driver behaviour across the three main urban centres means that there is no single policy mechanism that will address congestion issues across urban centres in New Zealand. Government policy proposals will be best developed in 'packages', such that implementers can choose the tools appropriate to the constraints their car driving population faces.

Unfortunately, our SP experimental design did not permit us to assess the possible impacts of combinations of specific policy tools—this is an area for further research effort focusing on fewer policy tools. The research here manipulates an unusually large number of policy tools simultaneously: once policy decisions have been made to focus on fewer, it is possible for future research to explore a smaller number of tools more sharply (both by estimating impact of combinations of tools, and also by collecting more detailed contextual information relevant to the reduced number of tools).

The policy tools investigated here include both 'carrots' (measures to improve public transport services or increase the availability of cycle lanes) and 'sticks' (measures discouraging car use). The sticks proved to have a generally greater influence on stated mode choice than the carrots. However, this is not to say that policy makers should ignore the need to improve public transport services, because people encouraged to switch modes need an alternative that is convenient to use. Our results warn that implementing measures to promote the use of alternative modes, such as public transport and cycling, without complementary measures to deter car use might not have the desired effect on traffic growth and congestion. This confirms the previous European finding by Marshall and Banister (2000) based on four case studies of European experience. Anecdotal evidence from Auckland, indicates that although significant increases in public transport usage have been recorded over the past 3 years (approximately 7%/year) due to improvements in trip times and trip frequency, little or no impact has been made on traffic growth in the region.

Although measures to increase the cost or inconvenience of driving a car show the greatest potential in addressing congestion issues, our study reveals a number of constraints that pre-empt drivers from choosing an alternative mode of travel to their work or place of study. In particular, employment practices (such as company-owned vehicles, providing on-site parking, and using the car for work-related trips during the business day) significantly constrain the ability of employees to choose not to drive a car. Likewise, self-employed people were more likely to continue to choose to drive. This result suggests that further investigation into the linkages between employment policies and practices and their influence on mode choice is warranted. For example, we have begun work assessing the applicability of employer travel plans in New Zealand. A better understanding of these linkages will enable policy-makers, employers and employees to better determine the types of policy actions that would generate significant changes in mode usage.

Drivers living in households with children generally felt more constrained to choose to drive than did households comprised of adults only. To some extent, this may well reflect the greater flexibility and convenience of the car compared with public transport for journeys with multiple destinations. However, we have subsequently shown that this type of constraint can be reduced by initiatives such as the 'walking school bus,' which sees the burden of transporting children to and from school shared with other parents (O'Fallon et al., 2002). We have also begun research describing occupancy patterns in detail (much occupancy research simply observes the number of occupants in vehicles on specified routes; our research will profile occupancy in terms of personal and demographic characteristics—especially the distinction between trips transporting children and those transporting other adults).

Students also showed readiness to switch from driving, which is not surprising given the generally lower incomes and greater flexibility with respect to time. Surprisingly, perhaps, we found that age and distance travelled did not impose strong additional constraints on mode choice by such commuters.

Further understanding of the impacts of such constraints might be provided in future by using more recent choice modelling techniques such as latent class models.

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