The Use of Discrete Choice Models in the Determination of Community Choices Towards Sub-Arterial Traffic Management Schemes

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Abstract:

Responsible local governments are increasingly recognising the need to be sensitive to the local environmental implications of the planning. Rather than rely on the pressures of lobby groups to direct government behaviour in relation to community concerns, a preferred strategy is to identify the preferences and choices of the community as a whole and to use information from a representative cross-section from the community to aid in making environmentally-linked decisions which maximise the benefits to the affected community. This paper demonstrates how discrete-choice models can be used to identify community choices between alternative traffic management schemes designed to improve the traffic impacts of government decisions such as the location of factories, offices and retail outlets. We also indicate the loss of orthogonality which is unavoidable when discrete-choice models are estimated on disaggregate data as distinct from grouped data

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Introduction

More and more local Governments in Australia are becoming increasingly sensitive and responsive to community concerns Often the concerns expressed by community groups are strongly influenced by a vocal minority who may not represent the views of the silent majority. While recognising concerns expressed by lobby groups, it is important to establish the extent to which such views are associated with the views of the community as a whole. One way to establish symbiosis is to develop a set of procedures to determine the preferences and choices of a representative sample of community members with respect to the issue(s) of concern

The purpose of this paper is to show how discrete-choice models can be combined with stated choice data obtained from a sample of community residents to identify community choices between alternative ways of improving the traffic on sub-arterial roads which pass through local areas. Such traffic is attributable to decisions regarding the location of offices, factories and retail outlets The approach represents an appealing method to assist local government in responding to the complaints of the vocal minority so that effective decisions on environmental matters will be consistent with the needs and concerns of the population as a whole.

The paper is organised as follows. We begin with a brief outline of the empirical context in order to establish an appreciation of a typical public issue which should concern local government This is followed by the development of a stated choice experiment and some comments on the interface between choice experiments and discrete choice models estimated on individual-level data. The empirical survey instrument is discussed in the context of data collection and followed by the econometric results. The major outputs of the approach are documented to highlight information which governments can use to make environmentally responsible decisions which impact on communities.

Community input into local government related environmental issues

Shopping centres and industrial parks are major generators of traffic. When major arterial roads become inadequate to efficiently handle such traffic, there is greater use of local and sub-arterial roads to move predominantly through traffic. Residents are naturally disturbed by such developments which bring increased exposure to risk, higher noise levels and deterioration in quality of residential life. In response to neighbourhood protests a number of local governments have implemented road closures and/or local traffic management measures such as speed humps, small roundabouts, mid-block islands and thresholds These strategies are designed to encourage through traffic to stay on relatively-heavily congested arterial roads.

There are many examples of traffic build up on local and sub-arterial residential roads throughout the world which is directly attributable to decisions made by local governments in support of an application to establish a major shopping centre or industrial complex. Businesses increasingly are being asked to consider the traffic implications of their development proposals and to finance suitable traffic management schemes to ensure that the local residential environment is not disadvantaged by the attraction of non-local traffic.

To allow for new traffic attributable to an investment, the local government needs to establish what strategies would be the most successful from a community perspective to ensure that local communities are not disadvantaged. Rather than propose and implement solutions in anticipation of acceptance, it is desirable to recognise the role that local communities can play in the design of community-supported traffic management strategies. This approach enables local government to claim awareness of local community concerns and provides an opportunity for them to plan with, rather than simply for, the local community. The savings in scarce dollars and image are potentially quite substantial.

The empirical study is set in Australia, where many sub-arterial roads in major metropolitan areas are predominantly residential streets. Typically levels of traffic on many sub-arterial roads normally would be associated with major arterial roads (including freeways). Some locations around major shopping complexes and industrial parks have reached such unacceptable levels of exposure to accident risk that some local governments are considering extending local area traffic management to sub-arterial roads. Sub-arterial traffic management (SATM) presents a new challenge because not only is there a desire to improve the safety of sub-arterial residential streets, but this should not be achieved at the expense of filtering current traffic onto local residential streets. The idea of SATM is to improve the safety of sub-arterial roads with measures that lower maximum speeds along roads and reduce the variability in speeds along these roads. Both dimensions are known sources of exposure to accidents.

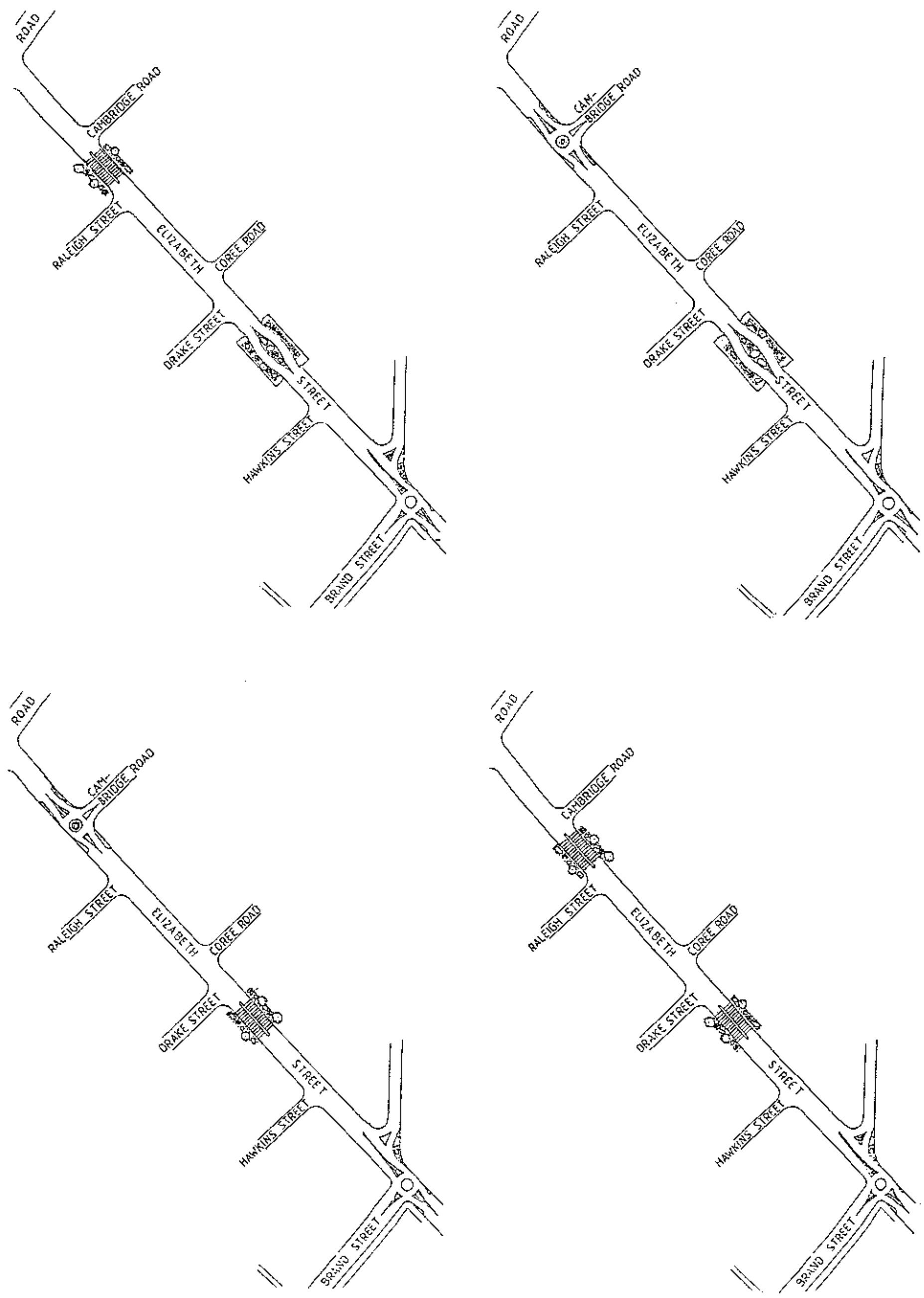
The stated choice experiment

Any plan to improve local traffic consequences requires careful assessment of both benefits and costs. Benefits are primarily reductions in mean speeds, variability of speeds along the road, and reductions in noise levels. The main costs are actual outlays on installation and maintenance. A number of well-tested traffic management devices can combine to define a SATM scheme, each of which has different speed, noise and cost implications. Our task is to establish a mechanism for measuring preferences of the affected communities and, hence their choices in relation to alternative device schemes.

The devices considered by local government traffic engineers are small roundabouts, mid-block islands and thresholds. Four combinations of the three types of devices were pre-determined to recognise road geometry constraints on the placement of devices along roads in the study location. The four schemes are depicted in Figure 1.

The four SATM schemes were proposed for a busy sub-arterial road in a suburb 12 kilometres from the centre of Sydney, Australia. We sought to measure community preferences for these schemes using a survey instrument in which residents evaluated different schemes. A rating scale was used to obtain a metric measure of relative utility.

Figure 1 Pictorial representation of the alternative schemes administered to respondents



This scale can be transformed into a choice index in a number of ways. Ratings can be approximated by rankings (including ties), treated as ordinal categories, and/or the highest actual or predicted rating treated as a first preference choice. These alternative ratings transformations can be analysed at individual or group levels. The former generates choice probabilities, the latter generates choice proportions. In this paper we illustrate the use of the highest rating treated as the first preference choice, and use multinomial logit techniques to model these preferences.

We designed a stated choice experiment in which four attributes were used to define each traffic management scheme. The attributes were 1) traffic speed at the device, 2) traffic speed between devices, 3) noise level at each device, and 4) the source of funds to pay for the facility. Each of the attributes had three levels; a full factorial would require 81 combinations of attribute levels per scheme. We used an orthogonal, main effects fraction to generate a sample of 6 alternative combinations per scheme. This design limits us to estimates of main effects. Given that there were four schemes, the number of possible combinations of schemes for choice sets of size four is 6^4 or 1296 total schemes. We proceeded by randomly selecting an alternative combination for each scheme each time a respondent was interviewed. The attribute combinations associated with each scheme are summarised in Table 1.

Each respondent rated each description on a 10 point scale. Some example showcards associated with each scheme are given in Figure 2. The experiment was administered as a personal interview with a sample of residents from the local government area in which the proposed SATM schemes were to be implemented. In order to investigate whether differences in preferences depend on whether a resident lives on the directly affected street, a stratified sample was drawn of close-by streets whose access could be affected, and other streets elsewhere in the local government area (all of which could be affected by the funding decision). The sample consisted of 131 local and close-by residents and 34 other residents.

In addition to the experimental design data, we also obtained information useful for investigating (i) how a resident's role as a car user affected their preferences (ii) how a resident's role as a pedestrian affected their preferences (iii) how a resident's time living in the local government area affected their preferences, (iv) how the schemes affected the resident's access to their own street, and (v) whether the resident's household income had some effect on preference.

Table 1 The SATM schemes derived from a two-stage experimental design

Scheme	Speed at device	Speed between devices	Noise level	Funding
tmr	45	80	same	Council $16,000
tmr	20	55	more	State $16,000
tmr	45	55	less	Rates $7.50 per resident
tmr	20	30	same	Council $16,000
tmr	70	80	more	Rates $8.50 per resident
tmr	20	80	less	Rates $8.00 per resident
rmr	45	80	same	Council $19,000
rmr	70	80	more	State $19,000
rmr	70	80	same	State $19,000
rmr	45	55	less	State $19,000
rmr	20	55	less	Council $19,000
rmr	20	55	same	Council $19,000
rtr	20	30	same	State $18,000
rtr	20	80	less	Rates $8.00 per resident
rtr	45	55	same	Rates $8.50 per resident
rtr	20	80	more	Rates $8.00 per resident
rtr	70	80	more	State $18,000
rtr	45	55	same	State $18,000
ttr	45	80	same	Council $15,000
ttr	70	80	more	State $15,000
ttr	20	55	more	Council $15,000
ttr	20	80	less	Rates $7.00 per resident
ttr	45	55	same	State $15,000
ttr	20	55	less	Council $15,000

tmr	=	threshold	midblock	roundabout
rmr	=	roundabout	midblock	roundabout
rtr	=	roundabout	threshold	roundabout
ttr	=	threshold	threshold	roundabout

Figure 2 Example showcards used to elicit rating responses

CARD No. 101

SCHEME 1	Threshold - Mid-Block Island - Roundabout		
COST	SPEED AT DEVICE	SPEED BETWEEN DEVICES	IMPACT ON NOISE LEVEL
$16,000 paid out of Council Funds	45 kph	80 kph	same noise as before installation

CARD No. 202

SCHEME 2	Roundabout - Mid-Block Island - Roundabout		
COST	SPEED AT DEVICE	SPEED BETWEEN DEVICES	IMPACT ON NOISE LEVEL
$19,000 paid out of Council Funds	20 kph	55 kph	more noise than before installation

CARD No. 303

SCHEME 3	Roundabout - Threshold - Roundabout		
COST	SPEED AT DEVICE	SPEED BETWEEN DEVICES	IMPACT ON NOISE LEVEL
$18,000 grant from State Government	45 kph	55 kph	less noise than before installation

CARD No. 404

SCHEME 4	Threshold - Threshold - Roundabout		
COST	SPEED AT DEVICE	SPEED BETWEEN DEVICES	IMPACT ON NOISE LEVEL
$15,000 grant from State Government	20 kph	30 kph	same noise as before installation

The discrete choice model for scheme choice

The stated choice data were transformed into a first preference response (choice) set with the highest rating assumed to be the most preferred alternative. The unit of analysis is an individual respondent. Each respondent had a choice set of four schemes with 16 choice sets considered by the entire sample. The multinomial logit technique (Hensher and Johnson 1981) was used to obtain parameter estimates for the scheme specific design variables (i.e. speed at and between the devices, noise level and source of funds) and the contextual variables (e.g. car ownership, household incomes, affect on access, etc.) as mentioned above. The most significant results from the model are summarised in Table 2.

Table 2. The discrete choice model results

Variable	Alternative(s)	Parameter Estimate	T-ratio
Scheme-Specific Constants			
tmr	tmr	-0.338052	-0.80
rmr	rmr	0.407803	1.00
rtr	rtr	-0.426389	-1.00
Other Effects			
more noise	ttr	-0.576124	-1.8
less noise	ttr	1.01052	2.3
Council fund scheme	rmr	-1.22295	-2.6
speed between devices interacted with use as pedestrian at least once per day	all	-0.042274	-5.3
local resident	tmr	0.566070	1.93
local resident	rmr	0.663810	1.70
local resident	rtr	0.661558	1.62
Likelihoods			
likelihood at zero	-228.74		
likelihood at convergence	-177.36		
likelihood ratio	0.22		

Multinomial Logit Model: Maximum Likelihood Estimation Scheme shares:
tmr=.1879, rmr= .333, rtr= .1879, ttr= .2909

Discrete-choice methods such as the multinomial logit model estimated on individual data require the differencing on the attributes to be the **chosen alternative minus each and every non-chosen alternative**. Combined with the natural correlation in the real world of certain attributes such as speed at devices, which cannot plausibly be greater than speed between devices, maintenance of design orthogonality is difficult. One tries to minimise correlations resulting from differencing by using fractional factorial designs. Hensher and Barnard (1990) illustrate the difficulty of retaining design orthogonality when **individual choice data** (in contrast to aggregate choice proportions) are used to estimate discrete-choice models. The attribute differencing problem can be circumvented by aggregating data over replications either within or across individuals, and analysing choice frequencies (Louviere and Bunch 1989, Van Berkum 1987, Offen and Little 1987).

The design attributes which explained the largest variation in choices between schemes were speed between devices, the level of noise at each device and the source of funds to pay for the scheme. Speed at each device was not statistically significant. Although speed between devices was an important influence, it interacted with use of the affected street as a pedestrian, which was not surprising as 60 percent of the sample use the affected streets at least once per day as pedestrians. The noise dimension was defined by three dummy variables (more than currently, less than currently, and the current level) with one excluded from the model. In individual-level discrete choice models, attributes which do not vary in magnitude across alternatives have to be specified as alternative-specific and assigned to a maximum of J-1 alternatives (where J is the total choice set). The two noise attributes were assigned to three of the schemes, and their parameters were constrained to be equal across all three schemes, and also were allowed to be unconstrained. The only statistically significant scheme-specific noise attributes were those associated with scheme 4 (two thresholds and a roundabout (ttr)). All other things equal, the relative utility associated with scheme 4 is influenced statistically (positively) by a reduction in noise, and negatively by an increase in noise compared with the other three schemes (where the noise parameters were set to zero). This result applies for the total sample of local, close-by and other residents of the local government area. 49 percent of the sample are local residents and 30 percent live in streets close to the SATM streets.

In contrast we found that on average local residents who live on the affected streets prefer schemes 1, 2 and 3 compared to scheme 4. We suspect this is because thresholds (of which there are two in scheme 4) have a desirable overall noise benefit, but are less appealing on other attributes. In particular, the mean parameter estimates for the three scheme-specific dummy variables for local residents suggest that roundabouts are preferred. Speed between devices appears to be a generic effect across all four schemes. The average speed associated with each scheme is respectively 38.9 kph, 36.6 kph, 38.4 kph and 38.8 kph. The mean elasticity of probability of choosing a scheme with respect to the speed between devices conditional on pedestrian use (standard deviation in parenthesis) is : tmr = -1.338 (1.199), rmr = -1.111 (1.032), rtr = -1.345 (1.205), ttr= -1.141 (1.066).

The scheme-specific constants (set to zero for scheme 4: ttr) account for the mean effect of the unobserved influences on scheme choice. Relative to scheme 4, the mean of the unobserved effects exerts a downward bias for schemes 1 and 3 and an upward bias for scheme 2. Overall scheme 2 is the most preferred with a mean probability of choice equal to 0.324. The mean choice probabilities for schemes 1, 3 and 4 are respectively 0.190, 0.183 and 0.303.

Use of the stated choice model for prediction

The results from the stated-choice model can be used to identify schemes which are acceptable to the community as a whole, and the residents in the directly impacted locality in particular. This can be done by determining the probability of choosing a particular scheme by each of the populations. So that the choices of schemes available to the community are realistic we need to select combinations of meaningful ranges of the statistically significant attributes that influence the community's rating, and choice of schemes.

To make the choice simulation manageable, we varied the two significant design attributes: speed between devices and noise level for each class of resident (local vs non-local). By introducing individual difference effects, we allowed for the conditioning that choices have when they are evaluated by the residential population. The selection of the scheme which is to be implemented must be determined by an expectation as to what speed configuration, associated with each scheme, is actually likely to occur if it is installed.

Thus our simulation approach requires us to estimate a table of community probabilities by speed between devices and noise levels at devices for each scheme for each community group. Given site-specific feasible speeds we can apply the estimated model to identify the resident population's most preferred scheme. A summary of choice probabilities for each scheme is given in Table 3.

Scheme specific mean choice probabilities were calculated by application of the utility expressions for each alternative, as given in Table 2, and the multinomial logit form of the discrete-choice model. For example the utility (U) of the tmr (threshold, midblock, roundabout) scheme is given as:

Utmr = -0.338052 - 0.042274 (speed between devices * pedestrian use dummy) + 0.566070 (local resident dummy variable)

Similarly the utility expressions for the other schemes are given as:

Urmr = 0.407803 - 0.042274 (speed between devices * pedestrian use dummy) - 1.22295 (Council funds pays for scheme) + 0.663810 (local resident dummy variable)

Urtr = -0.426389 - 0.042274 (speed between devices * pedestrian use dummy) + 0.661558 (local resident dummy variable)

Uttr = -0.42274 (speed between devices * pedestrian use dummy) - 0.576124 (more noise than currently dummy) + 1.01052 (less noise than currently dummy).

The probability of choosing scheme i = $\exp(U_i)/(\exp U_{tmr}+\exp U_{rmr}+\exp U_{rtr}+\exp U_{ttr})$

Table 3. Predictions of community choice of schemes

Scheme	Speed between devices (kph)	Noise level for scheme	Probability of choice of scheme	
			Local	Non-local
tmr	40	high	0.238	0.232
	40	low	0.167	0.135
	60	high	0.209	0.207
	60	low	0.153	0.127
rmr	40	high	0.414	0.371
	40	low	0.299	0.222
	60	high	0.486	0.438
	60	low	0.356	0.268
rtr	40	high	0.240	0.212
	40	low	0.168	0.123
	60	high	0.210	0.190
	60	low	0.155	0.116
ttr	40	high	0.107	0.183
	40	low	0.366	0.519
	60	high	0.094	0.164
	60	low	0.335	0.489

The results in Table 3 highlight the importance of contextual effects, especially as regards residential location. For a given speed between devices and a level of noise associated with the devices (treating schemes 1, 2 and 3 as being no noisier than the current levels of traffic), residents living on the directly affected streets have a higher mean probability of choosing schemes 1, 2 and 3 and a lower probability of choosing scheme 4 compared to non-local residents. The level of noise associated with a ttr scheme has a strong influence on scheme choice. For example, if a ttr scheme has a noise level greater than the current traffic level, the probability of choosing it at a mean speed of 60 kilometres per hour (kph) between devices is 0.094 for local residents and 0.164 for non-local residents. If noise levels at the devices are lower than current noise levels, the choice probabilities are 0.335 and 0.489 respectively. Assumptions about noise levels clearly exert a very important influence which impacts on the choice probabilities associated with the other schemes

The above evidence was calculated to reflect the range within which speed and noise is likely to actually occur if a scheme is implemented It is likely that a mean speed close to 60 kph will occur and noise levels at the devices will be lower than currently Under this scenario the scheme most preferred by the local residents is scheme 2 (rmr) with a probability of 0.356. Ttr is a close second (probability 0.335), primarily because of the noise reduction. For non-local residents scheme 4 is a clear winner. This is an intuitively plausible result because non-local residents think thresholds will limit their behaviour less than roundabouts and mid-block islands because the threshold enables a vehicle to continue to travel in a straight line. In contrast, roundabouts and mid-block islands tend to force a slower speed overall and require more competition with traffic entering the traffic stream from other directions However roundabouts and mid-block islands have more beneficial features for local residents.

Conclusions

The choice modelling approach developed in this study provides an appealing framework within which community concerns arising from the actions of local government can be incorporated in the planning process A combination of discrete-choice models and stated choice data at an individual resident level provides a method to identify which traffic management decisions will accord with the greater desires of the community. The approach outlined above is relatively simple to implement and provides intuitive outputs to assist in making effective decisions In ongoing research, we are extending the empirical study to evaluate the temporal stability of community preferences with respect to the choice of devices and schemes.

Acknowledgments

The impetus for this study came from Kam Tara who saw an opportunity to introduce stated choice methods into the evaluation of traffic management schemes. Eugene Smith supported this initiative and invited us to explore the possibility of developing and applying the method in the context of Willoughby Municipality's immediate problem with traffic in three residential streets. We are indebted to Kam Tara, Eugene Smith and Bill Dewer (Municipal Engineer, Willoughby Council). Financial support was given by the Roads and Traffic Authority of New South Wales.

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