TEST AND APPLICATION OF STATED PREFERENCE AND MIXED LOGIT MODELLING TECHNIQUES FOR TRAVEL BEHAVIOUR RESEARCH IN A RURAL CONTEXT

CHRISTO VENTER and ANAND VENKATESH[1]

Department of Civil Engineering, University of Pretoria, Pretoria, 0002,
Tel (012) 420-2184, Fax (012) 362-5218. christo.venter@up.ac.za
[1] University of Pretoria, and Institute of Rural Management, Anand, India. anand@irma.ac.in

ABSTRACT

Traditional qualitative approaches to understanding rural travel behaviour can usefully be complemented by more quantitative modelling techniques, especially for *ex ante* appraisal and market estimation of new rural transport services. The paper reports on a case study undertaken in an isolated rural area within Limpopo Province in South Africa, aimed at exploring the adaptation and application of choice modelling techniques under severely constrained conditions typical of rural contexts. We describe the combined use of qualitative participatory approaches with conventional travel diary and stated choice surveys. A mixed logit model of combined mode and time-of-day choice is successfully calibrated, showing that rural travellers exhibit rational compensatory decision making behaviour when faced with real alternatives. The model is applied to estimate the demand for a service innovation using cellphone-enabled pre-booked taxi services.

1. INTRODUCTION

Research on rural travel and transport employs mostly qualitative and descriptive techniques using small-sample studies. These techniques are invaluable when the need is to explore and understand the linkages between access, mobility, demographics, household production, and rural livelihoods (e.g. Barwell 2002; Fernando and Porter 2002; Mashiri et al. 2008), and to support the design of effective rural transport interventions. However, the rural development agenda is becoming more mainstream, wide-ranging, and programmatic[1], and one of its aims is to assist private sector roleplayers in improving the sustainability of rural services. In order to assess the design parameters, market potential, and financial suitability of such services, there is a need for more quantitative techniques to forecast the likely demand for planned services or improvements *before* their implementation. While quantitative techniques can not replace qualitative approaches during the early stages of problem identification and programme design, they might provide a useful complement during later stages of programme evaluation (both *ex ante* and *ex post*) and implementation.

In the transport arena the toolbox of procedures available for modeling rural travel demand derives almost entirely from the urban and intercity domains. Conditions in rural areas (especially poor areas) raise specific challenges to the application of these methods. The challenges are twofold: firstly with regard to collecting reliable data for modelling, and secondly relating to the relatively more restricted travel environment and its effects on choice behaviour and attempts to model it.

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[1] See for instance the active involvement of institutions like the World Bank (http://go.worldbank.org/AP2H2Z0M60) and the International Road Federation (www.irfnet.org) in rural transport development, as well as the renewed emphasis placed on rural development by the SA government (www.ruraldevelopment.gov.za; DOT 2007).

Data collection problems revolve firstly around problems encountered when surveying less educated, illiterate, or multicultural populations (Van der Reiss and Lombard 2003). The data required for estimating travel demand models can be complex, especially when it involves choice modelling, with its needs to elicit relatively detailed and precise information on unchosen alternatives and preferences, in either experienced or hypothetical situations. Previous experience in cities has shown that less literate respondents may have problems responding to questions presented in certain formats (such as tabular (Behrens 2003)). In addition, practical and logistical issues related to survey execution across large geographical spaces, sampling in the absence of sampling frames, and linguistic problems add to the difficulty (Morris and Van der Reiss 1980). Experiments in stated preference (SP) techniques have, however, found literacy to be not much of a barrier in the ability to respond consistently and accurately to hypothetical questions (Del Mistro and Arentze 2002) – legitimising the now more widespread use of SP techniques among urban poor populations in developing countries (e.g. Van Zyl et al. 2001; Dissanayake and Morikawa 2002). The experience suggests, however, that special care has to be taken when designing choice experiments and, especially, survey instruments, to ensure clarity and consistency of communication between the researcher and respondent.

The second issue relates to the relatively more restricted choice context typically found in rural areas, as compared to urban areas. Rural travellers often face more restricted mode choice sets – often limited to walking and perhaps one motorised option – due to income constraints, limited private vehicle ownership, long travel distances, and few public transport options. Spatially framed alternatives, in terms of possible routes or destinations, also tend to be more constrained in the rural environment due to a restricted opportunity set. Temporal constraints might include the exclusion of travel at night due to lack of lighting and safety concerns. Constraints on rural travel behaviour may affect both the internal validity (i.e. goodness of fit) and the external (i.e. predictive) validity of choice models, unless they are considered carefully during the design of the choice experiment and the subsequent application of the model.

This research attempts to push forward in this direction by testing and refining methodologies for travel behaviour data collection in rural areas – including the combined use of participatory techniques and stated choice experiments – and by developing a quantitative model of mode and time-of-day choice for longer-distance travel under conditions of mode captivity. The question is firstly methodological: can conventional data collection and modeling techniques successfully be adapted and employed in a rural context? As an illustrative application, the model is then used to forecast the demand for a cellphone-linked transport intervention in the case study area. Beyond methodological insight, the research also offers substantive insights into the constraints and determinants of rural travel demand in the case study community itself, as well as potential implications for rural transport development at large.

2. CASE STUDY AREA: AN OVERVIEW OF KGAUTSWANE

The study area is the Kgautswane rural area in the Limpopo province of South Africa. This area was part of the former Sekhukuneland homeland. It is composed of 18 villages of scattered homesteads with a population of around 150,000. The sole access to the surrounding area is via an unpaved road linking the villages to the nearby towns of Burgersfort, Ohrigstad and Lydenburg between 15 and 40 kilometers away. These towns are major sources of employment, shopping, and services as very few amenities (apart from small spaza shops run from homes) are located within Kgautswane itself. Unemployment is widespread, commercial farming is nonexistent, and crops like *mealies* (maize) are grown by villagers for their subsistence needs. Water is scarce, although

boreholes and rivers are within walking distance of all villages. About 70% of Kgautswane remains unelectrified.

Given the isolated location and poor road infrastructure, accessibility and mobility are considered as serious problems by many residents of Kgautswane. Car ownership is extremely low. The main motorized modes of public transport are buses, minibus taxis and "bakkies" (open pickup trucks operated illegally for passenger transport). Buses are reliable (running on a published schedule), though infrequent, running to Burgersfort twice in the morning and back during late afternoon. Taxis are relatively more frequent during the peak hours of 6-8am and 3-5pm, but difficult to avail during the off peak times. The hostile terrain makes it impossible for buses and taxis to operate in all villages, creating a niche for bakkie operators who penetrate to all villages in Kgautswane. The infrequent and unreliable nature of public transport often force people to walk for relatively long distances as not doing so could imply waiting for long and uncertain amounts of time for the motorized mode.

3. METHODOLOGY AND DATA COLLECTION

The research team employed a mixed-mode approach, combining qualitative with quantitative data collection procedures in a relatively novel way.

3.1 Exploratory work using participatory survey methods

Exploratory research techniques were used to get a general sense of the types of issues governing mobility patterns in the area; to assess the overall levels of captivity in travel; to isolate the key variables or attributes to be investigated further; and to ascertain the range of levels that could be assigned to each in the stated choice model. Several barriers related to linguistic and cultural differences, varying levels of awareness in the community and so forth had to be addressed. Key in doing so was the cultivation of a sound local research base comprising of local resource persons intimately familiar with conditions, and a team of surveyors drawn directly from the community. The local resource persons were two "infopreneurs" in Kgautswane, local residents providing entrepreneurial knowhow to the community.

The resource persons facilitated the identification and training of eight young persons from the area under the supervision and guidance of the researchers, to be deployed as surveyors in the community.

Exploratory work took the form of in-depth interviews conducted with members from various sections of the rural community, as well as a number of "Participatory Rural Appraisals (PRAs)". The PRA is a well-known tool used in rural research, akin to a customized focus group discussion, that depends on graphical depiction and interaction to elicit certain responses from a small group (Mukherjee 1993). For the purpose of this study we focused on what is known as a "mobility map". Facilitated by the resource persons, various groups from the community were encouraged to graphically describe the journeys they typically make outside of their village. This enabled the research team to better understand the rationales for choice of destination, modes used for various journeys, reasons for travel, problems associated with travel in Kgautswane and the like. It also provided valuable information on the ranges of travel time, fares and so on currently experienced.

3.2 Sampling

For the quantitative phase of the data collection, a stratified random sample was selected so as to capture as much variation as possible in population and spatial characteristics. The researchers randomly selected two to three villages to be surveyed with either high, medium, or low levels of relative access to the main road and its public transport services. Twenty respondents were randomly selected from each village, across a spread of gender and age groups.

A key screening criterion that was adopted for respondent selection was that the respondent should have made at least one trip outside of his or her village during the last 48 hours. This was to ensure that the trips described in the travel diary (see below) were fresh in the respondent's mind and to eliminate problems with memory recall.

3.3 First-stage survey: two-day travel diary

The stated choice survey was undertaken in two stages. The first stage involved requiring sampled respondents to fill out a travel diary for all journeys undertaken by them *outside of their village* during the past 48 hours. It was decided to focus on trips made outside of the village only, as it was observed that, within villages, people tend to make numerous short journeys on foot (such as for visiting or to fetch water) that are difficult to describe in detail due to the absence of addresses and the shortness of the trips. In addition to the standard origin, destination, mode, and time/cost information of their journeys, respondents also had to furnish information on alternative (but unused) modes available for each trip, and reasons why the chosen mode was indeed used. Walk-only trips outside of their village were also considered.

3.4 Second-stage survey: stated choice experiment with reference alternative

In the second stage, respondents were assisted in completing a stated choice questionnaire. The researchers picked one trip from each respondent's first-stage travel diary to act as a "reference alternative", which was used as a constant alternative in the stated choice design, thus allowing the experiment to pivot off the existing situation. The wording used was something like "if I offer you another different way of doing the same trip… tell me whether you would have preferred to travel this way or preferred to travel the way you did earlier." The advantages are two-fold: firstly, it uses the respondent's own knowledge base to construct the stated choice experiment, ensuring the levels presented in the experiment are realistic (Hess and Rose 2009). Secondly, it preserves the choice context in which the original choice was made – together with all its personal and spatial-temporal constraints that might be obscure to the experiment designer. This is thought to improve experimental realism – especially in situations like these where the choice context might be relatively complex and not well understood – as long as the obvious correlations between treatments with identical reference alternatives are explicitly captured during the modeling process through use of the mixed logit or similar formulation (Hess and Rose 2009).

Respondents from the first stage were revisited at a predetermined place and time. Surveyors lost a few respondents in this process but managed to recover 112 out of 140 respondents, or around 80% of the original respondents. This innovative two-stage travel diary-pivot stated choice procedure has to our knowledge not been reported in the literature before, and allowed the calibration of a high quality model (as reported below).

The findings from the qualitative research enabled the researchers to identify salient trip attributes most relevant to mode choice, to include in the stated choice experiment. The seven attributes were:

- Mode (bus, taxi, bakkie, walk)

- Walktime (time to walk to the vehicle)

- Waittime (time spent waiting for the vehicle)

- Fare (Rands per trip)

- Time-of-day (peak 6-9am; off-peak after 9am)

- Frequency (number of vehicles of that mode plying in the area during that time)

- Certainty (level of certainty that user associates with the availability of the vehicle at that time; options are "certain" (for scheduled and reliable service) and "uncertain" (unsure of when vehicle will come, like for taxi or bakkie service)

For attributes like walking time, waiting time and fare, the levels used in the design corresponded to (1) the value reported by the respondent in their reference journey; (2) a better level; and (3) a worse level than the reference one. A fractional factorial design was used, based on standard experimental design procedures for stated choice experiments (see Louviere et al. 2000). Each respondent was given a set of six choice experiments, and asked to indicate their preferred alternative in each case.

It was considered prudent to include an additional screening task to identify respondents who provide arbitrary or non-trading responses to the stated choice questionnaire without understanding the task at hand. We thus added an additional profile or treatment to the statistically generated set of six profiles. This profile was deliberately fabricated as an option dominated by the reference alternative, on the hypothesis that rational respondents should always prefer the reference alternative over the offered option. An *a priori* decision was made to exclude respondents who chose the "wrong" alternative. This resulted in the loss of 25 out of 112 administered questionnaires, or 22% of the sample.

4. EMPIRICAL FINDINGS

This section first describes the sample and travel diary findings, and then reports on the results of the mixed logit model calibrated on the stated choice data[2].

4.1 Sample demographics and revealed travel behaviour

The average respondent was female, 25 to 39 years old, had a grade 10 education, unemployed, and earned less than R600 per month. Comparison with census data showed that the screening criterion (that a respondent should have travelled outside of the village during the past 48 hours) biased the sample towards the younger, more mobile part of the Kgautswane population, but that the sample was still broadly representative of the community at large.

The 48-hour travel diaries showed that, in line with the majority of respondents being nonworkers and females, the most common purpose of traveling outside the village was for shopping in nearby towns – accounting for a full third of reported trips. Only 16% of trips were for work. The average walking time to a vehicle was 14 minutes, followed by an average wait of 12 minutes. Most trips occurred during peak times when public transport was most available. The average number of out-of-village trips per day was 0.63 per person (note this applies only to mobile persons, not the entire population).

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[2] For more detail on the sample characteristics, travel diary findings, and model results, see Venter and Venkatesh (2009).

Table 1 shows the distribution in modes used by the respondents. The majority of the respondents chose bakkie as the mode of travel. However, only a third of bakkie users had no other mode available for this trip (third column of table 1), indicating that many people choose to use bakkies, unsafe and uncomfortable as they are, rather than walk longer distances to bus or taxi services (especially when carrying loads). Bus and taxi modes are chosen almost equiproportionately. Those who chose walk as mode of travel generally travelled shorter distances within Kgautswane itself, even though walk times can be as much as three hours one-way; 71% of walkers feel they are captive to the walking mode.

Table 1: Distribution of modes, reasons for choosing mode, and captivity reported by sampled respondents (n=260 trips)

Mode	% of trips by mode	% of mode users with no other mode available for this trip	Reason given for choosing this mode (% of respondents)			
			First vehicle to come my way	Only option available	Low Price	Close to village
Bus	23	48	9	7	8	1
Taxi	26	42	7	7	7	1
Bakkie	35	32	11	5	4	11
Walk	16	71	-	-	-	-
All	100	44	-	-	-	-

Table 1 also provides insight into the reasons respondents cited for choosing particular modes. Interestingly, a very common reason is that it was the first vehicle to appear. This suggests that mode choice for many people might be based not on compensatory rules relating to the quality of the alternatives, but rather that people are so used to having limited choices that simple availability is the overriding factor. This firstly underscores the importance of mode captivity as an issue moderating travel behavior in rural areas. It also suggests that conventional compensatory decision models might not work as well here as in the urban context, and that much further work is required to understand decision processes and how to model them.

4.2 Model estimates for mixed logit model

A discrete choice model of mode choice was calibrated on the stated choice data obtained in the second stage of the data collection as well as certain personal variables. The model was formulated as a mixed logit model, which is an advanced model form in which some or all coefficients are estimated not as fixed point estimates – as in the traditional multinomial logit (MNL) model – but are treated as random variables assumed to follow a normal distribution. The advantages of the mixed logit include its ability to capture taste variations in the population, and to allow correlated error terms across observations such as that which occurs with stated preference data obtained from repeated questions asked of the same respondent[3]. In our model, walking time, waiting time, fare, number of

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[3] In this case, all the observations from a single individual are not independent as they are subject to the same (unobserved) taste variables, and should not simply be pooled together in a MNL model. For more information on the formulation and application of the mixed logit model the reader might refer to Ortuzar and Willumsen (2001) and Hensher and Greene (2003).

vehicles, time of day and uncertainty associated with the mode were treated as random coefficients[4].

Table 2: Parameter estimates of the mixed logit model

Random Parameters	Coefficient	t statistic
Constant (Non-reference option)	**-0.472**	-2.895**
Bus Mode	**2.169**	3.342**
Taxi Mode	**1.762**	2.56**
Bakkie Mode	**1.360**	2.079**
Walktime	**-0.0333**	-3.631**
Waittime	**-0.0256**	-5.229**
Fare	**-0.089**	-4.824**
Certainty (1 if certain of arrival time)	**0.4513**	2.292**
Frequency of Vehicles	**0.133**	2.667**
Time of day (1 if Peak)	0.15	0.775
Nonrandom Parameters	**Coefficient**	**t statistic**
Bus*Gender	-1.121	-1.456
Taxi*Gender	-0.953	-1.202
Bakkie* Gender	**-1.256**	-1.659*
*Statistically significant at 10% level of significance **Statistically significant at 5% level of significance P^2 (Goodness of fit)=0.258 P^2_{adj} = 0.2360		

Table 2 provides the model output, including the average value of each coefficient and its calculated t-statistic. Almost all the main effects are statistically significant and have the expected signs. Bus is the most preferred mode of transport, relative to walk, while bakkie is the least preferred, corroborating preference findings from the exploratory phase of the study. Walking to the vehicle has 1.3 times higher disutility than waiting for the vehicle, which is indicative of the poor condition of footpaths in the area. The significance of the frequency and certainty coefficients indicates that higher reliability, availability and frequency are indeed valued positively by the community[5].

The constant was a binary variable attached to the non-reference alternative, and was included to capture any bias in the responses towards choosing the reference trip, even while controlling for the service quality attributes as presented. Its negative sign indicates that a bias exists in favour of the current travel option; this can be interpreted as an implicit

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[4] For comparison purposes a conventional multinomial logit model was also estimated on this data. The coefficient estimates were almost identical to those of the mixed logit, but the former provided none of the useful information on taste heterogeneity in the population.

[5] The model also included various cut-off parameters to test aspects of choice set formation, as described in Venter & Venkatesh (2009). These results are not reported in the current paper.

resistance to change. This suggests the existence of conservative behavior on the side of rural consumers towards new products or services.

Various interactions were also tested. The only significant interaction effect was between bakkie use and gender (albeit at a 10% level of significance), indicating that bakkies are relatively less appealing to women as compared to men.

5. ILLUSTRATIVE APPLICATION: DEMAND RESPONSE TO LOGISTICS BROKERING SCHEME

In order to illustrate the usefulness of quantitative demand models such as the one estimated for performing *ex ante* assessments of proposed policy or programme interventions, we applied the model in a typical forecasting exercise. The intervention relates to the establishment of an ICT (Information and Communications Technology) based logistics brokering scheme, described in greater detail by Maritz and Maponya (2010) in another paper at this conference. The scheme aims to address the high level of information asymmetry between demand and supply in the public transport market – taxi operators do not know when there is a demand for travel, and end up underproviding or providing service at the wrong or unpredictable times. The CSIR-developed project allows users to use cellphones to book group taxi trips in advance, thus ensuring better load factors for taxi operators and less uncertainty for users.

To estimate the potential demand for a pre-booked taxi service, marginal effects (akin to standard elasticities, except that they relate to categorical rather than continuous variables) were derived from the mixed logit model parameter values. The results showed that a change in the predictability of a service from "uncertain" to "certain" increases its choice probability by 7.6%. Applying this number to the observed taxi share from the travel diary, it is estimated that about 7% of existing taxi trips would be made using the prebooked service, even if all other attributes (such as fare and pickup locations) remain unchanged[6] (table 3). The overall percentage of trips taken by taxi would increase from 26% to 31%, with the majority of these trips coming from current bakkie users. Regardless of the accuracy of this rough forecast, this is a substantial demand. Given the small marginal costs of implementing the prebooking service, it should be an attractive proposition for taxi operators in terms of enhanced profit potential.

Table 3: Estimated impacts of prebooked taxi option

Policy scenario	Mode share of taxi service
As now (from travel diary)	26%
% of current taxi users shifting to prebooked taxi	7%
% of current bakkie users shifting to prebooked taxi	13%
Total mode share for taxi (including prebooked service)	31%

The estimated values of the coefficients (table 2) also allow the analyst to calculate the monetary value attached to various supply parameters. In this case, the ratio of the fare and certainty coefficients indicates that, on average, users are willing to pay a premium of around R5.00 per trip for the benefit of greater certainty. Although this needs further

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[6] For illustration purposes the marginal effects are applied at the aggregate level only; a more accurate forecast would be obtained by assessing individual-specific elasticities and taking choice set constraints into account. Work is ongoing on this topic.

confirmation, is it thus possible that taxi operators might be able to charge a premium fare for the pre-booked taxi service – an even greater incentive for providing it.

6.   CONCLUSIONS: METHODOLOGICAL AND SUBSTANTIVE FINDINGS

In this study we presented a model of travel behavior in an isolated rural area of South Africa. As one of a very small group of studies to date investigating rural travel demand quantitatively, it contributes both in terms of methodological findings, and of providing substantive insights into rural travel in this case study community.

Methodologically, the research confirmed that standard survey and modeling techniques can be adapted for use among less educated, less literate, rural populations that have had little opportunity to engage in survey tasks (especially the more complex ones required in stated choice experiments). Respondents by and large provided data of the expected high quality, allowing the estimation of a solid mode choice/time-of-day model and associated elasticities.   Although data quality did seem to vary somewhat, the incorporation of checking and screening questions in the survey proved useful to weed out erroneous responses.

Other innovations proved useful to tailor the study to the spatial and demographic specificities of the rural environment. These include the use of a mixed-mode approach, applying qualitative exploratory techniques such as Participatory Rural Appraisals (PRAs) in tandem with conventional stated choice experimentation. This enabled the researchers to gain a better understanding of the travel environment and key behavioral aspects before designing and executing the survey components.

In terms of substantive findings around rural travel behaviour in the Kgautswane community – as an exemplar of isolated rural areas in former homelands – both the qualitative data and the quantitative survey results showed that captivity to walking is widespread and problematic. Captivity seems to be caused more by low availability of motorized transport than by affordability constraints. Better frequencies for public transport, especially during the off-peak, would likely be highly beneficial to this community. Travellers seemed to mind waiting for vehicles less than walking long distances to public transport, suggesting that upgrading of footpaths, as well as selected road upgrading to enable the expansion of public transport routes to remote areas, should be a priority. This might benefit especially women, who seem to dislike traveling in bakkies more than men, but often find themselves captive to bakkies in more remote settlements.

A low-cost operational improvement that would benefit many is to improve the reliability of transport services, for instance through implementation of a cellphone-enabled prebooking system for group taxi transport.   Illustrative policy testing of this service using the calibrated mode choice model showed that there is likely to be substantial demand for such a service, and that users are, on average, willing to pay a fare premium of around R5.00 in exchange for greater certainty of supply.

The findings also suggest some directions for further research on rural travel in general. One of the strongest needs to emerge is to investigate the nature and extent of transport captivity in rural areas, and its associated impacts on mobility and livelihoods. The implications of captivity on the modeling and prediction of rural travel behaviour could be severe; some evidence suggests that non-compensatory choice mechanisms might be prevalent. Alternative behavioural paradigms for rural travel behaviour need to be investigated.

ACKNOWLEDGMENTS

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