I T L S

WORKING PAPER
ITLS-WP-06-11

Influence of Vehicle Occupancy on the Valuation of Car Driver's Travel Time Savings: Identifying Important Behavioural Segments

By

David A Hensher[‡]

May 2006

ISSN 1832-570X

INSTITUTE of TRANSPORT and LOGISTICS STUDIES
The Australian Key Centre in
Transport and Logistics Management

The University of Sydney

Established under the Australian Research Council's Key Centre Program.

NUMBER: Working Paper ITLS-WP-06-11

TITLE: Influence of Vehicle Occupancy on the Valuation of Car Driver's Travel Time Savings: Identifying Important Behavioural Segments

ABSTRACT: Studies that develop estimates of the value of travel time savings (VTTS) for car travel typically assume that the VTTS of the driver is the only relevant measure of the worth of time savings. Although there is a recogntion that the presence of passenger's may condition the driver's choice of route and VTTS, the evidence is somewhat limited on the impact that the number of passengers has on the driver's VTTS. This is especially problematic when evaluating the role that policy instruments such as HOV lanes might play in delivering travel time savings for a specific occupancy, as well as the growing opportunities to have differentiated congestion charges and tolls according to occupancy. This paper investigates the role that the passenger plays in the VTTS of the non-commuting car driver. We find that the overall mean VTTS varies across the number of passengers (from $19.99 to $13.22 per person hour), declining as the number of passengers increases; however this is largely attributable to the decreasing mean VTTS for slowed down time in contrast to a 'flat' mean free flow time. The implications on travel time benefits ignored (through simple averaging) in previous studies, especially tollroad studies, and hence the impact on infrastructure justification, is potentially profound, given the important role played by VTTS and its variation over the number of passengers.

KEY WORDS: ***Car passengers, value of travel time savings, choice models.***

AUTHORS: David A Hensher

CONTACT: Institute of Transport and Logistics Studies **(C37)**
An Australian Key Centre
The University of Sydney NSW 2006 Australia

Telephone: +61 9351 0071
Facsimile: +61 9351 0088
E-mail: itlsinfo@itls.usyd.edu.au
Internet: http://www.itls.usyd.edu.au

DATE: May 2006

Acknowledgement: This research was partially funded by a University of Sydney 2006 R and D grant. The comments of John Rose and Stephane Hess (ITLS colleagues) and three referees are greatly appreciated.

1. Introduction

Public agencies spend funds on transport infrastructure in the expectation of providing opportunities for faster, more efficient movement, and therefore the amount of resource worth spending to make a unit saving in travel time has always been an implicit or explicit issue in transport policy (Gunn 2000). There are many empirical studies on the estimation of values of travel time savings (VTTS), with varying degrees of data and modelling rigour and relevance, mostly based on the observation that travellers are prepared to spend money to save time. These values are applied both to forecasting the effects of speed changes on behaviour, and also to estimation of the social benefit of such savings, in order to calculate value for money of spending public funds on transport investments.

In recent years, an increasingly important application has been to calculate the potential revenue from tolled roads, and networks with user charges, which offer higher speeds at a higher price: here the important issue is not hypothetical willingness to pay, but the actual money which will be handed over. This changes the focus from hypothetical to *bankable* values of travel time savings (Hensher and Goodwin 2004)[1].

All studies (almost without exception, see Accent and HCG 1999 and MVA *et al*. 1987) that develop estimates of the value of travel time savings for car travel, assume that the VTTS of the driver is the relevant measure of the worth of time savings. If a car has multiple occupants, the passengers are not allowed for in an explict way in the valuation. This is especially problematic when evaluating the role that policy instruments such as HOV lanes might play in delivering travel time savings for *a specific occupancy*, as well as the growing opportunities to have differentiated congestion charges according to occupancy[2]. Behavioural responses through VTTS can provide one important input to assist in determining price differences. This study investigates the role that the passenger plays in the VTTS of the car driver's trip, using mixtures of random parameters and error components in a mixed logit model to establish sources of observed and unobserved random and systematic taste heterogeneity, in order to obtain occupancy-profiled VTTS distributions[3]. The context

[1]The central question is: will the willingness to pay we have assumed in the model, be converted into cash in the bank? This question converts into a sensitive and growing list of implementation tasks that are necessary to satisfy the private sector ventures preparing bids to be short listed, and subsequently to win the right to enter into a contractual arrangement with government to build, own, operate and maintain infrastructure. Conversely, public agencies themselves need confidence that the risk sharing arrangements, based on market assumptions, will not be in danger of rapid collapse or embarrassing renegotiations, or public discontent about unexpected fortunes and accusations of monopoly profits. Trujillo *et al*. (2002) provide a very useful overview of these issues in the context of strategically (i.e. intentionally!) over- and under-shooting travel demand. Incorrect use of values of travel time savings may cause serious distortion of investment priorities, and potentially financial stress serious enough to call the viability of a company, or the sustainability of a risk-sharing agreement, into question. An additional dimension is that any errors are likely to become apparent not in thirty years (by which time the issue will be confused and of minority interest) but within the first year or two of operation, with intense public and private interest.

[2] Especially given the new technological opportunities to monitor, in real time, vehicle occupancy in the vehicle. An effective on-board Occupancy Monitoring System (OMS) would allow the tracking and citation of 100% of HOV facility violators (including freeway *and* arterial HOV lanes, plus carpool lots and other HOV facilities). It would be invaluable in identifying HOVs in a High Occupancy Toll (HOT) lane, and would allow HOT lane operation in a non-barrier-separated environment. Over and above the HOV and HOT lane applications, an automated OMS offers the potential to contribute "added value" in numerous areas of urban transportation: Managed Lanes, Value Pricing, and Congestion Pricing, Interoperability with "Standard" tolling, General HOV Monitoring (off HOV lanes), Data Collection, Vehicle Identification, and Use of HOV Facilities by Non-HOVs. See MRC (2004) for details.

[3] Hensher and Rose (2006) investigate the VTTS for the passenger per se.

will be the Sydney road network in which one can choose between tolled and non-tolled routes, with varying toll levels and travel times.

2. What Role might the Passenger play?

Road traffic studies, including toll road patronage studies, are traditionally interested in the vehicle and not the occupant, since the outlays of time and money of interest, including a toll, is per vehicle. However the behavioural response of switching routes, such as to the toll road, is a decision of an individual, typically the driver of a car.[4] Patronage forecasts of toll road use typically use the VTTS for the car driver only. While, for cars it is often suggested that occupant's other than the driver might play a role in the establishment of an appropriate VTTS for the vehicle trip as a whole, a search of the published literature reveals a notable dearth of consideration of this issue. The one exception is a study on VTTS in the UK (Accent and HCG 1999) that established car driver VTTS in the presence of passengers as well as a number of passenger values. However the authors indicate (on page 169) that they had a relatively small amount of passenger data, which by implication precluded any serious assessment of the role of the passenger in influencing the driver's VTTS.

The empirical study carried out by MVA *et al.* (1987) attempted to separate values of time savings for passengers and drivers, or to establish values related to vehicle occupancy, and came to the conclusion that most of the evidence suggested that the values of time savings of passengers were discounted by drivers (who in effect were making the choices). Although passengers might indeed be valuing their own time savings, there seemed to be little evidence of a 'market' which allowed these fully to enter the choice process. One explanation was that car sharers might be a special group of the population with lower than average VTTS and another was that application of economic willingness to pay ideas did not represent the sociology of car sharing. The authors speculated that 'If tolls were charged on the basis of occupancy rather than per vehicle, some more explicit trading might be done'. The study by Accent Marketing *et al.* (1999) reported that their model results indicated that 'driver's value of time increases as the number of passengers…increases', but less than proportionately – i.e., their results were also consistent with the idea that passengers' values were discounted.

This discussion suggests a number of issues for further investigation. Does the car passenger(s) presence, influence the time-cost trade-off of the driver and hence the route chosen? Another way of stating this is: would the driver's time-cost trade off and hence VTTS be different in the presence or absence of passenger(s)? It seems reasonable to speculate that the driver's marginal disutility of travel time might be lessened in the presence of passengers who they can chat to (or even share some of the monetary costs).

Imagine the situation where the driver talks a great deal with a passenger, which tends to pass the time quicker (and may make the slower free road more tolerable). Also there may be a feeling that the toll is yielding a benefit to more than one person and so, regardless of who is paying, there is a greater benefit to all occupants than to the driver.

[4] In the case of trucks and some light commercial vehicles, a mix of the driver and the person(s) in an organisation responsible for transport services.

Thus the time-cost trade-off may involve a reduced marginal utility from a time saving but an increased marginal utility for the toll paid. These adjustments would tend to lead to an increase or decrease in VTTS depending on the relative change in the respective marginal utilities.

Another way of looking at the VTTS associated with the car passenger, assuming it has no impact on the car driver or that in any sample of drivers the incidence of passengers is somehow internalised in the driver VTTS (without knowing its contribution in the upwards or downwards direction), is to treat their VTTS as a positive contribution to toll road time savings benefits. This is essentially the implicit outcome of most procedures adopted by toll road patronage forecasting studies. Only by making the driver's VTTS a function of occupancy might this be established. If we can show that the VTTS per vehicle is proportional to occupancy, this would give an overoptimistic assessment of revenue, and correspondingly underestimated assessments of toll-avoiding behaviour.

3. Empirical Context

The data used to establish the role of car occupancy is drawn from a study undertaken in Sydney in 2004, in the context of car driving non-commuters making choices from a range of level of service packages defined in terms of travel times and costs, including a toll where applicable. The sample of 222 effective interviews, each responding to 16 choice sets, resulted in 3,552 observations for model estimation.

To ensure that we captured a large number of travel circumstances, that will enable us to see how individuals trade-off different levels of travel times with various levels of tolls, we sampled individuals who had recently undertaken trips of various travel times (called trip length segmentation), in locations where tollroads currently exist. To ensure some variety in trip length, three segments are investigated: no more than 30 minutes, 31 to 60 minutes, and more than 61 minutes (capped at two hours).

A telephone call was used to establish eligible participants from households stratified geographically, and a time and location agreed for a face-to-face computer aided personal interview (CAPI). A stated choice (SC) experiment offers the opportunity to establish the preferences of travellers for one existing and two new route offerings under varying packages of trip attributes. The statistical state of the art of designing SC experiments has moved away from orthogonal designs to D-optimal designs (see below and Rose *et al.* 2005, Kanninen 2002); and the behavioural state of the art has moved to promoting designs that are pivoted around the knowledge base of travellers, in recognition of a number of supporting theories in behavioural and cognitive psychology and economics such as prospect theory, case-based decision theory and minimum-regret theory (Starmer 2000).

In determining the most statistically efficient design, the literature has tended towards designs which maximise the determinant of the variance-covariance matrix, otherwise known as the Fisher information matrix, of the model to be estimated. Such designs are known as D-optimal designs. Such designs require explicit incorporation of prior information about the respondents' preferences into the design. In determining the D-optimal design, it is usual to use the inversely related measure to calculate the level of D-efficiency, that is, minimise the determinant of the inverse of the variance-covariance matrix. The determinant of the inverse of the variance-covariance matrix is known as D-error and will yield the same results maximising the determinant of the variance-covariance matrix. The formal derivation is given in Bliemer *et al.* (2006)

The two SC alternatives are unlabelled routes. The trip attributes associated with each route are free flow time, slowed down time, trip travel time variability, vehicle running cost (essential fuel) and the toll cost. These were identified from reviews of the literature and through the effectiveness of previous VTTS studies undertaken by Hensher (2001). In addition, previous studies were used to establishing the priors (i.e., parameter estimates associated with each attribute) for designing the experiment. All attributes of the SC alternatives are based on the values of the current trip. Variability in travel time for the current alternative was calculated as the difference between the longest and shortest trip time provided in non-SC questions. The SC alternative values for this attribute are variations around the total trip time. For all other attributes, the values for the SC alternatives are variations around the values for the current trip. The variations used for each attribute are given in Table 1. For example, given the free flow time for a current trip (e.g., 30 minutes), if in a specific SC alternative in the SC choice set the level of free flow determined by the D-optimal design is -20%, then the free flow time listed is 24 minutes.

Table 1: Profile of the Attribute range in the SC design

	Free-flow time	Slowed down time	Variability	Running costs	Toll costs
Level 1	- 50%	- 50%	+ 5%	- 50%	- 100%
Level 2	- 20%	- 20%	+ 10%	- 20%	+ 20%
Level 3	+ 10%	+ 10%	+ 15%	+ 10%	+ 40%
Level 4	+ 40%	+ 40%	+ 20%	+ 40%	+ 60%

The experimental design has one version of 16 choice sets (games). The design has no dominance given the assumptions that less of all attributes is better. The distinction between free flow and slowed down time is designed to promote the differences in the quality of travel time between various routes – especially a tolled route and a non-tolled route, and is separate to the influence of total time. Free flow time is interpreted with reference to a trip at 3 am in the morning when there are no delays due to traffic.[5] An example of a stated choice screen, for the current trip (or reference) alternative and two design –generated combinations of actual attribute levels (based on a percentage variation from reference alternative from the set in Table 1) is shown as Figure 1.

[5] This distinction does not imply that there is a specific minute of a trip that is free flow per se but it does tell respondents that there is a certain amount of the total time that is slowed down due to traffic etc. and hence a balance is not slowed down (i.e., is free flow, like one observes typically at 3am in the morning).

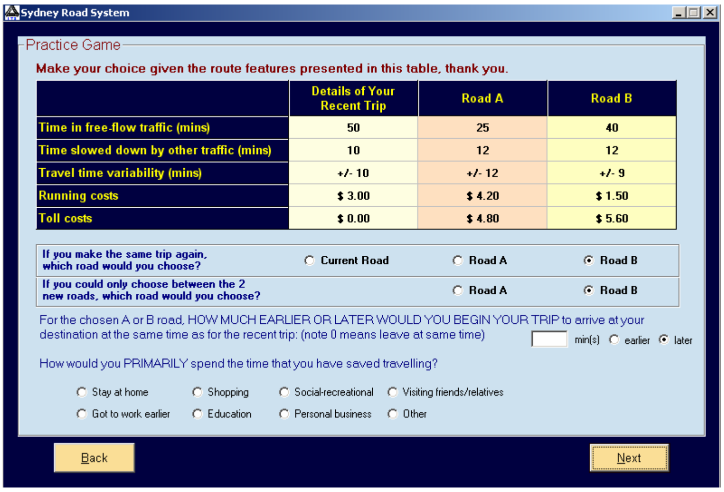

Figure 1: An example of a stated choice screen

4. The Evidence

To establish the influence of the number of passengers in the valuation of travel time savings for car drivers, we estimate a mixed logit model. The specific form of the mixed logit model being used is capable of establishing a number of sources of preference heterogeneity across a sampled population. These are (i) random preference heterogeneity associated with specific attributes induced by an analytical distribution; (ii) systematic sources of preference heterogeneity through making the standard deviation of a random parameter a function of explanatory variables that are individual-specific; and (iii) preference heterogeneity that is associated with alternatives in a choice set in contrast to attributes, referred to as error components for alternatives and nests of alternatives. Greene and Hensher (in press) derive the fully specified model, summarised in equation (1)[6].

$$\text{Prob}_{q,t}\,[j|\,\mathbf{X}_{q,t},\boldsymbol{\Omega},\,\mathbf{h}_q,\mathbf{v}_q,\mathbf{W}_q\,] = \frac{\exp(\boldsymbol{\beta}_q'\mathbf{x}_{q.j.t} + \Sigma_{m=1}^{M} c_{jm}W_{mq})}{\sum_{j=1}^{J}\exp(\boldsymbol{\beta}_q'\mathbf{x}_{q.j.t} + \Sigma_{m=1}^{M} c_{jm}W_{mq})} \qquad (1)$$

Where

$$U_{q,j,t} = \boldsymbol{\beta}_q'\mathbf{x}_{q,j,t} + \varepsilon_{q,j,t} + \sum\nolimits_{m=1}^{M} c_{j,m}W_{q,m}$$

$$\boldsymbol{\beta}_q = \overline{\boldsymbol{\beta}} + \boldsymbol{\Gamma}_q\mathbf{v}_q$$

$$\text{Var}[v_{q,k}^*] = [\sigma_k \times \exp(\boldsymbol{\eta}_k'\mathbf{h}_q)]^2$$
$$\text{Var}[W_{m,q}] = [\theta_m \exp(\boldsymbol{\tau}_m'\mathbf{h}_q)]^2$$

[6] We set out only the features that might be parameterised in the empirical study. Other elements of the model are given in Greene and Hensher (in press).

And

$v_{q,k}$ = a random variable with $E[v_{q,k}]=0$ and $\mathrm{Var}[v_{q,k}] = a_k^2$, a known constant.

Γ_q is the matrix of structural parameters, Γ multipled by a diagonal matrix, say Λ_q which contains the observation specific standard deviations on the diagonals. This is how we build heteroscedasticity in the parameters into the model. The parameters are randomly distributed over individuals, according to a pre-defined analytical distribution, with means and variances that can depend on individual characteristics, $\mathbf{h}_q$. The components of this model are:

$\bar{\beta}_{q,k}$ = fixed mean,

σ_k = fixed part of the standard deviation of the random parameter $\beta_{q,k}$,

$\exp[\boldsymbol{\eta}_k'\mathbf{h}_q]$ = observed heterogeneity associated with the distribution of $\beta_{q,k}$.

$\boldsymbol{\Omega}$. is a parameter set for all the structural parameters, $\bar{\beta}$, $(\sigma_k,\eta_k, k=1,\ldots,K)$.

$W_{m,q}$ are normally distributed effects with zero mean, $m = 1,\ldots,M \leq J$ and $c_{jm} = 1$ if m appears in utility function j. The 'kernel logit' model suggested by Ben-Akiva *et al.* (2001), based on an idea first proposed by Brownstone and Train (1999)[7], incorporates additional unobserved heterogeneity through effects that are associated with the individual's preferences within the choices. Train (2003) provides a discussion of this form of maximum simulated likelihood estimator used to parameterise this model.

The profile of car occupancy (excluding the driver) is given in Table 2, distinguishing adult and children passengers. 83 (37.3 percent) of the 222 car drivers did not have any passengers. For the 62.7 percent who did have passengers, one additional passenger was most common (58 percent of car drivers), with this being an adult 92.5 percent of the time. Although the sample size decreases as the number of passenger's increases, the expansion over 16 choice sets provides a minimum of 128 observations of time-cost trade-offs for trips with four passengers. The proportion of passenger's who are adults, declines as the occupancy level increases as might be expected where the majority of trips involve the immediate family members.

[7] The Ben-Akiva et al. paper was a reaction to the suggestion in Brownstone and Train, pointing out that identification can be difficult to assess in mixed models with these kinds of error components for alternatives and nests.

Table 2: Car Occupancy Profile for Passengers (excluding driver) per car (83 car drivers or 1328 estimation observations exist for car drivers without any passengers).

Passengers/car					Total Sample
Total passengers per vehicle	1	2	3	4	1.08
Average no. of adult passengers per vehicle	0.925	1.393	1.913	1.333	0.852
Average no. of child passengers per vehicle	0.075	0.607	1.087	2.667	0.332
Ratio adults/children	12.33	2.295	1.760	0.500	2.567
Total no. of observations	80	28	23	8	222
Estimation sample (i.e, no. of observations by 16)	1280	448	368	128	3552

The estimated model recognizes and accounts for the correlated structure inherent in 16 choice sets associated with the same individual. Correlated alternatives are induced through the nesting of the error components. The preferred empirical model is presented in Table 3. After extensive assessment of unconstrained and constrained distributions (e.g., triangular, normal, lognormal) we have selected a constrained triangular distribution (in which the spread[8] estimate is constrained to equal the mean estimate[9]) for the random parameters. If the scale equals 1.0, the range is 0 to 2 $ß_1$. This is shown to be an appealing way of capturing the random taste heterogeneity, avoiding the search for such heterogeneity at the extremes of unconstrained distributions. The triangular distribution was first used for random coefficients by Train and Revelt (2000) later incorporated into Train (2003). Hensher and Greene (2003) also used it and it is increasingly being used in empirical studies.

Statistically the mixed logit model is a significant improvement (log-likelihood of -2130.56) over the multinomial logit version whose log-likelihood at convergence is -2733.44. We investigated a number of ways in which car occupancy plays a role in influencing the utility of a specific trip attribute package; and found that interacting a dummy variable for each of the number of passengers (0,1,2 and 3 plus) was preferred to a monotonic specification in terms of the number of passengers. Furthermore we found that the best specification captured the number of passengers through conditioning the standard deviation of each random parameter for free flow and slowed down time, and captured the mix of adults and children through conditioning the standard deviation of the alternative-specific error component for the reference alternative. The positive sign on the parameter estimates for the heterogeneity around the standard deviation of free flow and slowed down time suggests that an increase in the number of passengers, holding all other influences constant, increases the unobserved heterogeneity (i.e. widens the distribution of the parameter space) for free flow and slowed down time across the sample. We were not able to find any systematic sources of decomposition of the mean.

[8] The spread is the standard deviation times $\sqrt{6}$.
[9] For a triangular with mean=spread, the density starts at zero, rises linearly to the mean, and then declines to zero again at twice the mean. It is peaked, like one would expect. It is bounded below at zero, bounded above at a reasonable value that is estimated, and is symmetric such that the mean is easy to interpret.

We have also found that there exists a significant amount of unobserved heterogeneity that is alternative (in contrast to attribute) specific, and that accounting for this as error components for alternatives and nests of alternatives parameters is of relevance. This would normally be assigned to the IID component of the unobserved effects (and/or induce some potential confoundment with the attribute-specific parameters), which would fail to recognise the significantly greater amount of unobserved heterogeneity associated with the reference alternative in contrast to the two experiment design alternatives. Indeed we have also been able to identify systematic variation in the error component variance associated with the reference alternative that is attributed to the proportion of passengers who are adults. Accounting for this increases the standard deviation of the unobserved alternative-specific effect for the reference alternative.

Table 3: Summary of Empirical Results: Non-Commuter Trips
Time is in minutes; costs in dollars ($2004). T-values in brackets)

Attribute	Alternatives	Parameter estimates (t-values)
Random parameters with constrained triangular		
Free flow time	All	-0.1393 (-17.11)
Slowed down time	All	-0.1638 (-14.61)
Toll cost	All	-2.3395 (-27.18)
Running cost	All	-0.6915 (-24.07)
Non-random parameters:		
Reference-alternative specific constant	Reference	-0.9747 (-7.67)
Toll presence constant (1,0)	All	6.3495 (22.75)
Heterogeneity around Standard deviation:		
Free flow time * No passengers	All	0.3751 (1.90)
Free flow time * One passenger	All	0.6027 (5.23)
Free flow time * Two passengers	All	0.5367 (2.70)
Free flow time * Three or more passengers	All	2.3145 (29.5)
Slowed down time * No passengers	All	0.5883 (3.43)
Slowed down time * One passenger	All	0.4489 (2.12)
Slowed down time * Two passengers	All	0.6821 (2.38)
Slowed down time * Three or more passengers	All	2.3301 (28.8)
Error components for alternatives and nests of alternatives parameters:		
Standard deviation	Reference	1.4096 (11.05)
Standard deviation	Experimental Design alts	0.6010 (4.05)
Heterogeneity around standard deviation of error components effect:		
Proportion of passengers who are adults	Reference	0.4483 (2.17)
Log-likelihood at convergence		-2130.56
Pseudo-R^2		0.453

Note: MNL model log likelihood at convergence was -2733.44

The VTTS findings are summarised in Table 4. To calculate the mean VTTS for free flow and slowed down time, we take draws from the estimated distributions which are derived from the parameter estimates given in Table 3, calculate VTTS for each draw, and average the results. We illustrate the form of the empirical specification for the free flow attribute's unconditional distribution and the VTTS formula:

Marginal utility of free flow time (MU_{ff}) = {-0.1393 + 0.1393 x [exp(0.3751*0P +0.6027*1P + 0.5367*2P + 2.3145*3Plus P) x T } where P = passenger, T is the triangular distribution obtained from a standard uniform V =U[0,1] by T= $\sqrt{2V}$ -1 if V<.5 or T=1- $\sqrt{2(1-V)}$

VTTS (free flow) = MUff/((Rcost*(-0.6915 + 0.6915*T) + Toll *(-2.3395 + 2.3395*T})/(Rcost + Toll))

Table 4: Car Driver VTTS Segmented by Car Occupancy Profile for Passengers (excluding driver) $ per person hour. Standard deviation in brackets

Passengers/car	0	1	2	3	4	Total Sample
Free flow	8.818 (5.65)	8.457 (6.23)	8.495 (6.39)	8.393(10.98)	8.975 (7.66)	8.62 (6.16)
Slowed down time	33.67 (17.38)	34.0 (17.4)	24.59 (17.5)	24.10 (22.8)	21.28 (17.1)	31.88 (17.78)
Weight Ave Time	19.99 (11.68)	18.04 (10.1)	14.44 (9.51)	14.72 (12.25)	13.22 (8.48)	18.07 (10.78)

We find that the overall mean VTTS varies across the number of passengers (from $19.99 to $13.22 per person hour), declining as the number of passengers increases, although it is essentially flat for 2 and 3 passengers. This is largely attributable to the decreasing mean VTTS for slowed down time in contrast to a 'flat' mean free flow time (varying from $8.975 to $8.393 per person hour[10]). This does not support the Accent Marketing *et al.* (1999) finding that 'driver's [total] value of time increases as the number of passengers…increases'. The implications on travel time benefits ignored (through simple averaging) in previous studies, especially tollroad studies, and hence the impact on infrastructure justification, is potentially profound, given the important role played by VTTS and its variation over the number of passengers.

We investigated potential sources of systematic variation in VTTS for free flow, slowed down and weighted average overall travel time, in two models, one in which the explanatory variables were the number of adults and the number of children as passengers, and the other where we defined dummy variables for 1,2,3 adults and respectively children (setting four passengers as the base). The dummy coded variable specification found no statistically significant effects, whereas the continuous variable version did, but only for the weighted average travel time (t-values in brackets):

VTTS overall = 20.109 (16.27) -2.553 (-2.25)*number of adult passengers – 1.4171(-1.40)* number of children; (r^2 = 0.036)

Although the overall explanatory power of this simple equation is low, the number of adults passengers has a statistically significant influence.

10 This diference of $0.58 per person hour translates into substantial time benefits for the population as a whole.

5. Conclusions

This research has highlighted the influence that the number of passengers has on the valuation of travel time savings of car drivers. The evidence has important policy implications for innovative ways of growing patronage and revenue for toll roads that is linked to the occupancy status of the car. With advanced intelligent on-board occupancy identification, the technical capability of assessing occupancy-differentiated tolling and congesting charging is very real.

From a policy perspective, HOV lanes are typically introduced to benefit multiple occupancy yet it is the driver travelling without passengers who places the highest value of travel time savings, that are presumably delivered via HOV compared to conventional lanes. What this suggests is that HOV policy is not related directly to time savings per se although it has indirect time benefits to all car users. Revisiting the MVA *et al.* (1987) comment that 'If tolls were charged on the basis of occupancy rather than per vehicle, some more explicit trading might be done', there is mounting evidence herein that this suggestion merits closer attention. This is of particular relevance where savings in slowed down (or congestion time) can be offered relative to savings in free flow time.

References

Accent Marketing and Research and Hague Consulting Group (1999) The Value of Travel Time on UK Roads – 1994, report prepared for the Department of Transport, London.

Ben-Akiva, M, Bolduc, D & Walker, J (2001) Specification, identification and estimation of the logit kernel (or continuous mixed logit) model, MIT Working paper, Department of Civil Engineering.

Bhat, CR (2001) Quasi-Random Maximum Simulated Likelihood Estimation of the Mixed Multinomial Logit Model, *Transportation Research* Part B, 35, 677-693.

Bliemer, MCJ, Rose, JM & Hensher, DA (*forthcoming*) Constructing efficient stated choice experiments allowing for differences in error variances across subsets of alternatives, accepted *Transportation Research B*, December 2005.

Brownstone, D & Train, K (1999) Forecasting new product penetration with flexible substitution patterns. *Journal of Econometrics*, 89, 109-129

Burgess, L & Street, DJ (2005) Optimal designs for choice experiments with asymmetric attributes, *Journal of Statistical Planning and Inference*, forthcoming.

Greene, WH & Hensher, DA (in press) Mixed Logit and Heteroscedastic Control for Random Coefficients and Error Components *Transportation Research E*.

Greene, W, Hensher, DA & Rose, J (2006) Accounting for heterogeneity in the variance of the unobserved effects in mixed logit model *Transportation Research* 40B (1), 75-92.

Gunn, HF (2000), An Introduction to the Valuation of Travel-Time Savings and Losses, in *Handbook of Transport Modelling,* Vol. 1, DA Hensher & KJ Button, ed., Elsevier Science Ltd.

Hensher, DA (2001) Measurement of the valuation of travel time savings, *Journal of Transport Economics and Policy* (Special Issue in Honour of Michael Beesley), 35, 71-98.

Hensher, DA (in press) How do Respondents Process Stated Choice Experiments? – Attribute consideration under varying information load, *Journal of Applied Econometrics*

Hensher, DA & Goodwin, PB (2004) Implementation of values of time savings: the extended set of considerations in a tollroad context, *Transport Policy* 11 (2), 171-181.

Hensher, DA, Rose, JM & Greene, WH (2005) The Implications on Willingness to Pay of Respondents Ignoring Specific Attributes *Transportation*, 32 (3), 203-222.

Hess, S, Bierlaire, M & Polak, J (2005) Estimation of value of travel-time savings using mixed logit models, *Transportation Research A (2/3)*, 221-237.

Kanninen, BJ (2002) Optimal Design for Multinomial Choice Experiments, *Journal of Marketing Research*, 39 (2), 214-217.

Louviere, JJ, Hensher, DA & Swait, J (2000) *Stated Choice Methods: Analysis and Applications in Marketing, Transportation and Environmental Valuation*, Cambridge University Press, Cambridge.

MCormick Rankin Corporation (MRC) (2004) *Automated Vehicle Occupancy Monitoring Systems for HOV/HOT Facilities*, Final Report prepared for Enterprise ITS, Ontario, December.

The MVA Consultancy, Institute of Transport Studies University of Leeds, & Transport Studies Unit University of Oxford (1997) *The Value of Travel Time Savings*, Policy Journals, Newbury.

Rose, JM, Hensher, DA & Greene, W (2005) Recovering costs through price and service differentiation: accounting for exogenous information on attribute processing strategies in airline choice *Journal of Air Transport Management*, 11, 400-407.

Rose, JM, Bliemer, MCJ, Hensher, DA & Collins, AT (2005) Designing Efficient Stated Choice Experiments Involving Respondent Based Reference Alternatives, University of Sydney, (submitted to *Transportation Research B*, May 2005).

Rose, JM & Bliemer, MCJ (2005a) Constructing Efficient Choice Experiments with Alternative Specific and Generic Parameter Estimates, Working Paper: ITLS-WP-05-07, Institute of Transport and Logistics Studies, University of Sydney, April.

Rose, JM & Bliemer, MCJ (2005b) Sample optimality in the design of stated choice experiments, Working Paper: ITLS-WP-05-09, Institute of Transport and Logistics Studies, University of Sydney, May.

Starmer, C (2000) Developments in non-expected utility theory: the hunt for a descriptive theory of choice under risk, *Journal of Economic Literature*, XXXVIII, 332-382.

Train, K (2003) Discrete Choice Methods with Simulation, Cambridge University Press, Cambridge.

Train, K & Revelt, D (2000) Customer-specific taste parameters and mixed logit, working paper, Department of Economics, University of California, Berkeley, http://elsa.berkeley.edu/wp/train0999.pdf

Trujillo, L, Quinet, E & Estache, A (2002) Dealing with demand forecasting games in transport privatisation, *Transport Policy*, 9(4), 325-334.