TRIP UTILITY AND THE VALUE OF TRAVEL TIME SAVINGS (VTTS) FOR COMMUTER TRIPS: CRITIQUE AND RECENT ADVANCES

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ABSTRACT

In South Africa, Random Utility Maximisation (RUM) econometric theory based on the weighted linear addition of attribute vectors has been used in commuter trip choice models since the early 2000's. The application of this theory assumes rational choice behaviour by the user, and requires the identification and quantification of the trip choice attributes and their relative weightings, as well as the specification of the random (error) component of the utility equation. One of the important derivatives of this approach is the value of travel time savings (VTTS), i.e. the monetary value a commuter is willing-to-pay to save a specific amount of travel time. However, VTTS and willingness-to-pay are still the subject of extensive research, controversy and debate internationally. In South Africa several attempts have been made to quantify the VTTS for various commuter modes since 2000, and this paper reviews the evidence of VTTS obtained from these studies. The large variation in values reflects a diversity of projects, modes, locations, and the use of a range of estimation methodologies. However not all the variation is explicable by these factors, raising questions about the appropriateness of using such values for demand forecasting and economic benefit estimation. This paper identifies promising advances in choice model specification, relating to the incorporation of commuter travel budgets (time and cost) and unobserved heterogeneity which might help to improve VTTS estimation and the performance of toll and public transport demand models in South Africa.

1. BACKGROUND

In the commuter transportation planning environment, the introduction of discrete choice models (DCM) as part of the conventional four-step system modelling process was made during the 1960's. These were typically simplified binary models where traveller choice was between private and public transport, based on trip attributes such as travel time and/or trip cost.

During the 1970's and 1980's market research techniques such as Stated Preference (SP) experiments were introduced, and enabled the development of more advanced mode choice models using RUM. These models took into account the traveller choice between several (discrete) modes (existing and proposed), and the quantification of trip utility with the inclusion of time and non-time related mode attributes, as well as a random error attribute to represent the unobserved (behavioural) component of choice preference.

Non-time related cost attributes included petrol, tolls, parking and fares while the time related attributes included walking, waiting, in-vehicle & transfer times. The attribute weightings reflected the average commuter's relative perceived importance of the attributes, and the costs were thus termed perceived generalised costs.

The remainder of the paper discusses the concept of commuter trip utility and the derivation of the value of travel time savings (VTTS) from this. An insight into the application shortcomings of random utility maximisation (RUM) is provided, together with an insight into recent choice modelling research focus areas. The paper ends with conclusions in regard the status of trip choice modelling in South Africa.

2. COMMUTER TRIP UTILITY

The concept of utility to quantify subjective expressions of benefit or dis-benefit is well grounded in economic theory. This postulates that consumers will make choices that maximise their perceived utility, and random utility maximisation is the utility concept derived for application in DCM's. The most commonly applied DCM is the multinomial logit (MNL) model. However, to avoid violating the assumptions of this model, care must be taken in their application (Train, 2009).

Because the time and non-time related costs alone cannot properly account for mode choice behaviour, another 'random' attribute or disturbance term is necessary to explain this behaviour. The random term of the utility equation cannot be directly measured and reflects the unobserved heterogeneity associated with the traveller's choice preference, and can reflect for example, taste factors and the underlying latent variables such as attitudes and perceptions.

Trip utility is commonly defined as the linear sum of the weighted trip attributes (i.e. linear-in-parameters). Thus the utility equation for mode m with k attributes is of the following form (Hensher, Rose, & Greene, 2010):

Utility of mode m = $\mu_m = \sum_{n=1}^{k}(\beta_n X_n) + \varepsilon_m$ where:

- β_n is the attribute coefficient (or weighting) of attribute n;
- X_n is the generalised cost attribute (time or non-time related);
- ε_m is the random error (or disturbance) component for mode m;
- k is the total number of modal attributes.

The VTTS estimate for in-vehicle time is calculated as the ratio of the in-vehicle time and fare coefficients for public transport users. For car users, the VTTS estimate is calculated from the ratio of in-vehicle time coefficient and the vehicle running cost coefficient (keeping all else constant).

The linear-in-parameters form of the utility function is very convenient for estimation purposes, and has been the basis of all transport MNL applications in South Africa to date. However, it imposes constraints on the model which reduce its ability to capture actual human choice behaviour. Key among these constraints is its compensatory nature – the assumption that a decrease in one attribute can always be offset by an increase in another – and that the marginal rate of substitution (e.g. VTTS) remains constant across the whole range of attribute values. This has important implications for VTTS estimation.

3. APPLICATION SHORTCOMINGS OF RANDOM UTILITY MAXIMISATION

Globally, multinomial logit models (MNL) based on linear RUM specifications are most commonly used in transport mode choice simulations, including in South Africa. The shortcomings of these models when applied to actual demand forecasting and economic evaluations have been highlighted by many researchers (Harrison, 2014).

In terms of local practice, some of the most pertinent concerns include:

i. The assumptions of MNL models that place important constraints on their use. The key constraints are (Train, 2009):
    a. The assumption that the random error attributes are independently and identically distributed (IID). Logit models can represent systematic taste variation (i.e. taste variation that relates to the observed characteristics of the decision maker), but not to random tastes variation (i.e. taste variation that is not linked to observed characteristics);
    b. The IID equivalent behavioural assumption of the independence of irrelevant alternatives (IIA). This states that the probability ratio of any two alternatives should be preserved despite the presence or absence of any other alternative within the set of alternatives in the mode;
    c. MNL are appropriate if the unobserved characteristics are independent over time in repeated choice situations. If they are correlated over time, MNL are not appropriate;

ii. The compensatory utility maximisation approach does not inherently recognise the issue of income constraint, i.e. choice affordability (Bain, 2015). Individuals can only make actual choices based on what they can afford (money and time-wise). This is particularly important when faced with trade-offs between trip cost (e.g. due to tolls), and trip time that may be excessive on alternative routes;

iii. The estimates of trip utility are quantified based on individual survey responses, but are applied in an aggregate manner on a traffic zone basis. Choice preference heterogeneity is an important consideration in the South African commuter environment;

iv. Furthermore, the application of an average VTTS value to all commuters is inherently risky. This is especially so in socio-economic environments where there is choice preference heterogeneity;

v. The linear combination of weighted utility attributes is an assumption that is often made to simplify model estimation during the analysis of an SP data set. In reality non-linear relationships may give better model fit;

vi. The use of average attribute coefficients is not strictly appropriate to estimate willingness-to-pay measures such as VTTS, as each coefficient has a distribution of values reflecting the variation in user perceptions. Mixed logit models (ML) and hybrid choice models (HCM) can be used to take into consideration differing consumer tastes by allowing the introduction of random coefficients in the specification of the utility attributes (Sillano & de Dios Ortuzar, 2005). Classical and Bayesian simulation techniques have been developed to provide random draws of the attribute coefficients with each successive iteration improving the fit of the model to the observed individual choices (Tudela & Rebolledo, 2006), (Sillano & de Dios Ortuzar, 2005);
vii. The RUM approach assumes the consistent and objective rationality of decision makers, and the random error term in the utility equation is interpreted as explaining any non-rational behaviour. However, research in cognitive psychology and sociology has shown that individuals regularly violate all the assumptions of rationality. Decomposition of the random error term incorporating non-rationality effects have been shown to produce better model fit (Ortuzar, Cerchi, & Rizzi, 2014).

4. THE VALUE OF TRAVEL TIME SAVINGS (VTTS)

A key objective in the use of DCM's is the derivation of measures to determine the amount of money individuals are willing to pay in order to derive some benefit. These measures are commonly called willingness-to-pay (WTP).

The VTTS is one such WTP measure, and is defined as the monetary value a commuter is willing to outlay for a specific saving (i.e. a reduction) in their travel time. VTTS is commonly used in road and public transport pricing and transport related economic analyses.

Because time saving benefits typically make up a significant proportion of the overall economic benefits of transport schemes in urban areas (Mackie, Jara-Diaz, & Fowkes, 2002) the accurate estimation of the non-work related VTTS is important in evaluating the overall economic feasibility of a transport initiative.

A review of the economic appraisals of two significant Gauteng transport projects has revealed that this is indeed the case, viz.:

i. The economic analysis carried out in 2002 for phase 1 of the Gautrain Rapid Rail system (Gauteng Province, 2002) estimated that the project net present value (NPV) without the time saving benefits was R2.27 billion, but with time savings included was R6.61 billion (2001 Rand), i.e. the inclusion of trip time savings benefits nearly tripled the project NPV. In the analysis, non-work related (commuter) time savings for passenger cars were assumed to be 60% of the total time savings, and passenger cars were estimated to make up 75% of the total 2002 average daily traffic (ADT) mix. The value of non-work related travel time savings used in the analysis was estimated as R32.00/hour for white commuters and R27.00/hour for previously disadvantage individuals (PDI) (2001 Rand);
ii. For the Gauteng Freeway Improvement Project (GFIP), the economic analysis showed that the project NPV ranged between R239.6 billion to R248.0 billion,

depending on the toll tariff per kilometre used (2010 Rand) (SANRAL, 2010). The value of commuter car non-work related time was based on the World Bank recommended value of one third of hourly income, and was estimated at R44.43/hour/vehicle (2010 Rand). The total time saving component (i.e. work and non-work related time savings) of the total passenger car benefits amounted to 29% of the total economic savings, with the balance being made up of vehicle operating costs and accident savings.

iii. The estimation of VTTS has been ongoing since the 1960's, so one would imagine that the estimation of VTTS would be well understood, easily quantified and possibly standardised, especially in developed economies. However, this is not always the case and the estimation and application of the VTTS is still the subject of extensive research, controversy and debate (Metz, 2008).

This is also evidenced by the UK Department for Transport's (UK Department for Transport, 2015) recently published VTTS guidelines for application in economic analyses for both business and non-business related trips (both commute and other non-work related trips). The revised values were based on 11,500 SP surveys and are specified by mode for business related trips. Work is continuing on the implementation of the results and additional research into aspects such as distance based VTTS variation; variation with traffic conditions (e.g. congested versus free flow conditions based on evidence from Australia (Zhang, Xie, & Levison, 2009)); the application of VTTS to take account of car occupancy; and VTTS sensitivity testing amongst others.

4.1 VTTS Estimation in South Africa Since 2000

In the South African context, there have been a number of studies that have estimated the VTTS, especially since the early 2000's. Stated preference (SP) experiments have been the most common approach for estimating these values, although in some instances revealed preference (RP) data has also been used. In a limited number of cases both SP and RP data have been used in combination. However, these studies have typically been for specific transportation projects; were based on small samples; are project, mode and location specific; and their wider application was neither verified nor appropriate.
A review of the VTTS estimates derived from several public transport and toll road projects in Gauteng Province since the year 2000 has revealed a wide variation in values. Table 1 shows the original VTTS estimates together with updated estimated 2015 values.

The following observations are made:

- The range of VTTS values for commuters is significant:
  - For public transport users, between R4.16/hour (low income) and R41.58/hour (high income);
  - For car users, between R16.98/hour (Ekurhuleni) and R126.00/hour for the average non-business car user for the 2004 Gautrain study in the off-peak period;
- There have been several attempts to segment the values by income and by mode (i.e. car and public transport), depending on the type of project under consideration;

- For car commuters, the average 2015 VTTS is approximately R58.10/hour, and for PT users the average value is approximately R12.50/hour, suggesting that both the current mode experience and income might affect VTTS;
- Studies completed since 2010, i.e. the Tshwane, Ekurhuleni and Johannesburg SP surveys have revealed lower VTTS than previous studies. However, note must be taken of the travel market segments that were surveyed, and the purpose for which the surveys were conducted.

The significant variation in derived VTTS values, even within the same geographic context, is not in itself problematic – in fact it accords with the notion of VTTS as being context and traveller dependent. One would hence expect to see variation in VTTS values derived from actual data. However, to be meaningful, such variation should be systemic and not purely random. Unfortunately, in our case the underlying reasons for these variations are not adequately known (beyond simplistic mode and income descriptions).

There is a significant risk in applying VTTS estimates derived under one set of circumstances in another unrelated situation. This could give rise to erroneous results and invalid conclusions. The implications for the accuracy of mode choice models and economic analyses may therefore be severe, as illustrated by a number of recent cases.

Since 2000 there have been a number of high profile transport initiatives where the modelled patronage has not materialised after project implementation. These include the City of Johannesburg Phase 1a and 1b Rea Vaya Bus Rapid Transport (BRT) project (Steyn, 2014) and the first phase of the Gautrain Rapid Rail system (Steyn, 2013).

Strong public opposition to the introduction of freeway tolls as part of the Gauteng Freeway Improvement Project (GFIP) since its implementation in 2012 has also highlighted the issue of trip utility quantification, and its application in willingness-to-pay environments.

The findings of the Gauteng Premier's Panel on the socio-economic impacts of GFIP and e-tolls (Gauteng Premier Advisory Panel, 2014) suggested that willingness-to-pay resistance might be partly related to differences between the range of travel time benefits as perceived by commuters; the average VTTS values used in the determination of the toll tariffs; the effect of congested versus free-flow conditions on VTTS; and the variation in commuter trip length on the freeways, i.e. the effect of cumulative tolls, both on an individual trip basis as well as over prolonged periods of time, e.g. a month.

Table 1: Values of Travel Time Savings for Several South African Transport Projects (Rand/hour)

Project	Application	Date of Development	Time Period Modelled	Market Segment	Value of Travel Time Savings (Rand/hr)	Estimated 2015 Value of Travel Time Savings (Rand/hr)	Comment
Gauteng Province GTS2000 EMME Model	Gauteng Strategic Planning Model, 2000	Jul-00	Weekday AM Peak Hour	Car: HBW Low Income Car: HBW Middle Income Car: HBW High Income PT: HBW Low Income PT: HBW Middle Income PT:HBW high Income	25.00 25.00 42.00 2.00 12.00 20.00	51.97 51.97 87.31 4.16 24.95 41.58	SP Studies
Gauteng Toll Model	Gauteng EMME Model for Freeway Tolling Evaluation	Jun-00	All Periods	Car Users	20 to 70	42 to 146	SP and RP Surveys
N4 Platinum Toll Road (*Not strictly urban)	Toll modelling for N4 toll road bidding process	Jun-00	All Periods All Periods	Commuters Non-PDI Commuters PDI	50 to 60 30 to 50	104 to 125 62 to 104	SP and RP Surveys SP and RP Surveys
Gautrain Phase 1: Park to Hatfield (Commuter)	Gautrain Commuter Ridership: Public Sector Comparitor	Jul-01	Weekday AM Peak Hour	Average Car Commuter	41.24	81.65	Derived from SP Surveys
Gautrain Phase 1: Park to Hatfield (Commuter)	Gautrain Commuter Ridership: Gauliwe Consortium Bid Gautrain Commuter Ridership: Gauliwe Consortium Bid	Sep-04 Sep-04	Weekday AM Peak Hour Weekday Off-Peak Hour	Average Car Commuter Average Car Commuter	54.00 74.00	92.36 126.57	Derived from SP Surveys
Gautrain Phase 1 Economic Analysis	Provincial Economic Analysis	2001	Weekday AM Peak Hour	White Car Commuter PDI Car Commuter	32.00 27.00	63.36 53.46	Estimated from SP Survey
Gauteng Freeway Improvement Project (GFIP)	SANRAL GFIP Economic Analysis	2010	Weekday AM Peak Hour	Average Commuter Car User	44.43	56.71	World Bank Recommendation
City of Tshwane BRT Project	BRT Ridership Study: Existing Public Transport Users BRT Ridership Study: Existing Car Users	Sep-10 Sep-10	Weekday AM Peak Hour Weekday AM Peak Hour	Average PT User Average Car User	5.00 25.50	32.55 5.00	Derived from SP Surveys
N1 and N2 Winelands Toll Study	Bidder Demand Model Bidder Demand Model	Jan-10 Jan-10	Weekday AM Peak Hour Weekday AM Peak Hour	Business Car User Non-Business Commuter	98.45 39.81	125.65 50.81	Wage based estimate Origin Uncertain
City of Ekurhuleni BRT Project	BRT Ridership Study: Existing Public Transport Users BRT Ridership Study: Existing Car Users (Tembisa)	Jul-13 Jul-13	Weekday AM Peak Hour Weekday AM Peak Hour	Average Car Commuter Average PT Commuter	5.40 15.40	16.98 5.95	Derived from SP Surveys
Gauteng Integrated Transport Masterplan 25	GITMP25 EMME Model	Nov-13	Weekday AM Peak Hour	Low Income All trips Middle Income All Trips High Income All trips	4.50 34.52 55.96	4.96 34.52 55.96	Estimated from GTS2000 values
City of Johannesburg SP Study	Development of Up-dated Metropolitan Transportation Model	2014	Weekday AM Peak Hour	PT Captives Low Income PT Captives Middle Income PT Captives High Income	8.89 6.00 3.43	8.89 6.00 3.43	SP / RP Derived Values
				Car Captives & Choosers: Low Inc Car Captives & Choosers: Mid Inc Car Captives & Choosers: High Inc	12.31 6.60 5.23	12.31 6.60 5.23	SP / RP Derived Values

Source: Various Provincial, Metro, Transport Authorities and Own Analysis.

5. RECENT CHOICE MODELLING AND VTTS ESTIMATION ADVANCES

Theoretical and practical developments have significantly advanced choice modelling. These hold promise for improving choice modelling accuracy in local applications.

5.1 Integration of Microeconomic and Psychology Theories: Hybrid Choice Models

The way that consumers make product, service and travel choices is changing. Increasing electronic access to information and social media platforms are providing consumers with new insights into choice options, allowing for better informed and sophisticated decision making.

Utility theory assumes that consumer choice behaviour is made in a rational, considered and objective manner. However, observed choice behaviour regularly violates these assumptions of rationality (Ortuzar, Cerchi, & Rizzi, 2014). The mathematical choice models developed to predict consumer behaviour must therefore take the changing behavioural environment into account, and be adapted to more accurately simulate the demand for goods and services. DCM's such as MNL models are criticized for not being sensitive to taste heterogeneity, i.e. the fact that different people have different sensitivities to the attributes of the alternatives in a choice environment (Train, 2009).

Hybrid choice models (HCM) integrate discrete choice models and behavioural theory (Abou-Zeid & Ben-Akiva, 2014). The HCM is a highly flexible model that can approximate any random utility model. It relaxes the three limitations of MNL models by allowing for random taste variation, unrestricted substitution patterns, and the correlation of the unobserved (or latent) attributes over time.

The advantages of HCM's are:

i. They specifically allow for the modelling of unobserved heterogeneity through the simulation of taste variation by drawing random coefficient values from defined distributions;
ii. They offer improvement in statistical efficiency, transparency and enhanced behavioural realism (i.e. better model fit);
iii. They offer the potential for better and more sensible policy related forecasting accuracy by considering the effect of changing attitudes and tastes over time.

HCM models can be derived under a variety of behavioural specifications, and each derivation provides a particular interpretation. The following figure compares the overall model structure of discrete choice MNL and HCM models.

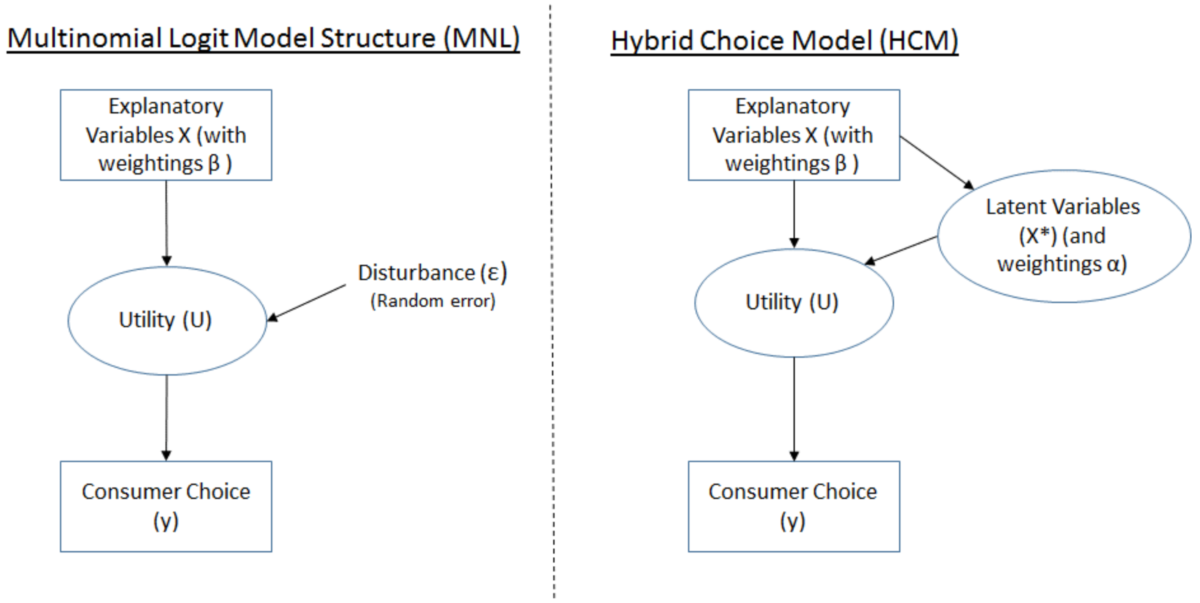

Figure 1: Structure of MNL Model and HCM Model *(Abou-Zeid & Ben-Akiva, 2014)*

The important characteristics of HCM's are:

i. They require the introduction of the utility explanatory latent variables (X*) and their associated coefficients (or weightings) α;
ii. The latent variables are endogenous and are hence dependant on the explanatory variables X. In the model they are defined as a function of the explanatory variables;
iii. The latent variable coefficient distributions may be either discrete or continuous.

No HCM models have been developed and applied in South Africa. Only one application of a mixed logit model has been found – the 2014 City of Johannesburg mode choice model.

5.2 VTTS, Cumulative Tolls and the User Willingness-To-Pay Versus Ability-to-Pay

Sydney has a total of 9 linked toll roads extensively used by commuters, and another five in the planning stage. These linked toll roads, extensively used by commuters, are functionally similar to the tolled GFIP freeway network.

Several well publicised commercial toll road concession projects in Sydney and Brisbane have gone into receivership over the last 10 years due to low actual traffic flows and toll revenues (Grad & Kenyon, 2013). The VTTS used in the traffic models has been highlighted as one possible reason why the modelled flows were so much higher than the actual flows, and in particular the effect of cumulative tolls on the perceived commuter VTTS (Hensher, Ho, & Wen, 2015).

Personal monthly budget constraints and competing demands on disposable income may affect the commuter's ability-to-pay for tolls. Traffic models assume users have the ability to pay the toll tariff on the day, but the affordability of toll payments over a longer period, say a week or month is not considered. Bain refers to this as the *affordability overlay* (Bain, 2015).

Hensher and Bain have determined that dramatic reductions in VTTS occur when the effect of constrained travel budgets and cumulative tolls are taken into consideration. Bain suggests that there is a toll payment saturation level above which the traveller's willingness-to-pay for trip time savings reduces. This results in the commuter either not using the new toll facility beyond the toll saturation point or, if possible, changing travel mode.

The following table shows the modelled magnitude of this decrease defined in four categories, i.e. model without budget constraint, and then with budget constraint based on only the existing tolled route; existing route plus one extra tolled section; existing route plus two additional tolled sections:

Table 2: Effect of Toll Saturation on Commuter VTTS (AU$/person hour)
(Hensher, Ho, & Wen, 2015)

VTTS	Model Without Budget Constraint	Model with Budget Constraint		
		Current Toll Route Only	Current Toll Route Plus 1 Extra	Current Toll Route Plus 2 Extra
Mean VTTS	AU$ 24.24	AU$ 12.04	AU$ 6.09	AU$ 5.70
Standard Error	AU$ 7.09	AU$ 2.94	AU$ 1.60	AU$ 1.52

The net effect of the application of these findings is that when applied in traffic models, the unconstrained VTTS values will produce higher traffic demand and toll revenues, putting at risk the financial viability of the scheme. Hensher estimates that these lower VTTS values explain 33% of the difference between actual and modelled flows.

5.3 Commuter Perceptions of Time Savings and Willingness-To-Pay

The New Zealand Transport Agency undertook research (O'Fallon & Wallis, 2012) into the validation and verification of the utility of travel time for commuters in Auckland and Wellington, New Zealand in 2012. It was hypothesised that commuters have a (possibly unconscious) 'ideal' or 'minimum' commute time, and when the actual commute time is less than this ideal time, any savings in travel time would be equal to zero (or even negative). If the actual travel time is greater than the ideal time, only the time savings in excess of the ideal time would be of value and hence determine the willingness-to-pay.

An on-line SP experiment was conducted on a sample of 512 commuters across all modes, including NMT modes. In addition to actual and ideal trip durations, mode and other demographic data, a simple stated preference experiment was conducted to estimate travel cost and time sensitivity between their existing mode and three alternative modes.

Several important findings were made:

i. The average commute time was 20 minutes, and most respondents spent more time commuting than they wanted, but only 3% indicated they would prefer zero travel time. There were distinct differences in the distribution of the values of travel time savings between the various modes;

ii. The median *ideal* commute time was 10 minutes, suggesting that commuters were spending 10 minutes more per day (on a one-way trip) than they would like;
iii. Drivers indicated that they derive some utility from commuting, or at least experienced less disutility. Public transport users were twice as likely to want to halve their travel time as other users, including NMT;
iv. For drivers and public transport users a preferred *minimum* travel time of 7 to 8 minutes was identified, and any time savings below this threshold were not perceived as savings;
v. There was a 12% core of 'non-trader' commuters who did not value any savings in travel time no matter how long their commute time. This core selected to maintain their travel time and not reduce it or telecommute;
vi. 40% of workers and 37% of respondents enjoyed the time commuting, with NMT users indicating higher enjoyment than drivers or public transport users. Reasons given for this enjoyment were that it was a transition time; time to think & relax; listen to music/radio and exercise for NMT users. Only 12% of commuters indicated that they worked during their commute.

The conclusions drawn from the study are (O'Fallon & Wallis, 2012):

- Using an average VTTS in demand models and economic analyses is not appropriate for all commuters;
- Time savings for commuters whose actual travel time is less than the ideal minimum value do not value any time savings, and should therefore excluded in an economic analysis. In addition, any other perceived trip cost savings may also be lost;
- In addition, small time savings (for example a minute or two) are meaningless to commuters and should not be included in an economic analysis;
- From the perspective of some commuters, time spent travelling by any mode is not all lost, and SP experiments should take this into account. Some commuters may associate a positive utility from their travel time, considering it as a transition time, time to relax, and for fitness (NMT).

6. CONCLUSIONS

A number of conclusions can be drawn as follows:

i. Transport mode choice modelling to date in South Africa has been based on the simple and robust Multinomial Logit (MNL) model, often using Stated Preference and sometimes Revealed Preference data. Almost all the VTTS estimates have been used in demand forecasting for toll road and public transport projects;
ii. There has been important research undertaken internationally into the design of SP experiments, RUM investigation, and VTTS estimation over the last 10 years. Also, HCM and ML models have become more relevant as a result of the advantages these models have in introducing latent behavioural attributes into the choice environment; improving statistical fit; and forecasting relevance when these behavioural attributes change over time;
iii. Very few of these efforts have found their way into South African transport related choice model research and application. These findings have the potential to explain some of the reasons for the over-estimation of passenger and car

demand and fare and toll revenues for several high profile projects, such as Rea Vaya, Gautrain and GFIP;

iv. Given the wide range of VTTS values estimated in South Africa over the last 15 years, there is potential benefit for the development of ML and HCM. However, only one application of a ML case study was found, and no research into the development and suitability of these models in the South African environment is evident;

v. The South African VTTS estimates derived for transport projects and application in their associated demand models have largely been location, project and mode specific. They are also characterised by small sample sizes, and the use of both stated preference and revealed preference data for utility estimation and choice model calibration has also been limited. This has resulted in a wide range of estimated VTTS values. The reasons for this wide variation are not well understood;

vi. The need for research into and a comprehensive review of transported related mode choice modelling practice in South Africa is required, with a view to developing best practice choice modelling guidelines. While this is a large task, it is possible to address this by addressing a few important aspects such as choice model design, SP experiment design, RUM development procedures, and robust trip utility and VTTS estimation;

vii. Enhancements to the specification of trip utility; alternative choice models; inclusion of commuter trip budget constraints and the valuation of short trip benefits have the potential to substantially improve the understanding of choice preference heterogeneity, and the estimation of commuter mode choice and route choice models;

viii. These will also provide substantial improvements to the estimation of VTTS for the various trip market segments.

7. REFERENCES

Abou-Zeid, M., & Ben-Akiva, M. (2014). Hybird Choice Models. In S. Hess, & A. Daly, *Handbook of Choice Modelling* (pp. 383 - 412). Edward Elgar.

Bain, R. (2015, November 8). The Affordability Overlay. *RBconsult*.

de Dios Ortuzer, J., & Willumsen, L. (2011). *Modelling Transport, 4th Edition.* London: Wiley.

Gauteng Premier Advisory Panel. (2014). *The Socio-Economic Impact of the Gauteng Freeway Improvement Project and E-Tolls Report.* Johannesburg: Gauteng Province Government.

Gauteng Province. (2002). *Environmental Impact Assessment: Gauteng Rapid Rail Link, Volume 3: Socio-Economic Environment.* Johannesburg: Gauteng Province.
Grad, P., & Kenyon, P. (2013, July 16). Australia Suffers Toll Concession Failures. *Tunnel Talk*.

Harrison, G. W. (2014). Real Choices and Hypothetical Choices. In S. Hess, & A. Daly, *Handbook of Choice Modelling* (pp. 236 - 254). London: Edward Elgar.

Hensher, D., Ho, C., & Wen, L. (2015). *How Much is Too Much for Tolled Road Users: Toll Saturation and the Implications for Car Commuting Value of Travel Time Savings.* Sydney: Institute of Transport and Logistic Studies, University of Sydney.

Hensher, D., Rose, J., & Greene, W. (2010). *Applied Choice Analysis: A Primer.* Sydney: Cambridge Press.

Mackie, P. J., Jara-Diaz, S., & Fowkes, A. S. (2002). *The Value of Travel Time Savings in Evaluation.* Santiago: University of Chile.

Metz, D. (2008). The Myth of Travel Time Savings. *Transport Reviews Volume 28, No. 3*, pp. 321-336.

O'Fallon, C., & Wallis, I. (2012). *A Wider Look at How Travellers Value the Quality and Quantity of Travel Time.* Auckland: NZ Transport Agency Research Report 469.

Ortuzar, J., Cerchi, E., & Rizzi, L. (2014). *Handbook of Choice Modelling: Transport Research Needs Paper 29.* Edward Elgar.

SANRAL. (2010). *Economic Analysis of the Gauteng Freeway Improvement Scheme.* Pretoria: SANRAL.

Sillano, M., & de Dios Ortuzar, J. (2005). Willingness to Pay Estimation with Mixed Logit Models: Some New Evidence. *Environment and Planning*, 525 - 550.

Steyn, I. (2013, February 8). Gautrain Number Tick Up but below Initial Estimates. *Engineering News*.

Steyn, I. (2014, July 11th). Rea Vaya Battles Low Numbers. *Engineering News*.

Train, K. E. (2009). *Discrete Choice Methods with Simulation.* Cambridge: Cambridge University Press.

Tudela, A., & Rebolledo, G. (2006). Optimal Design of Stated Preference Experiments when Using Mixed Logit Models. *Association for European Transport and Contributors*.

UK Department for Transport. (2015). *Understanding and Valuing Impacts of Transport Investment: Values of Travel Time Savings.* London: UK Department for Transport WebTAG.

Zhang, L., Xie, F., & Levison, D. (2009). Illusion of Motion: Variation in Value of Travel Time Under Different Freeway Driving Conditions. *Transport Research Record: Journal of Transportation Research Board No. 2135*, 34-42.