APPLICATION OF USER PREFERENCE CHOICE MODELS IN THE CITY OF JOHANNESBURG DEMAND MODEL

E ROUX and T LAMPRECHT

Tolplan (Pty) Ltd, P O Box 14791, Hatfield, 0028
Tel: 012 369-7600; Email: tlamprecht@tolplan.co.za

ABSTRACT

Transport models and choice models are often developed in isolation without the benefit of combining it into a single dynamic model. This paper aims to demonstrate that, based on the City of Johannesburg (CoJ) Model, choice models developed from stated preference surveys can be even more valuable when designed to be incorporated into a transport model. This paper describes how the choice models, developed from the stated preference data, supported with reveal preference data from the Household Travel Surveys, was applied in the CoJ Model. The mode choice model includes the intrinsic characteristic of city travellers which are either captive to public transport, mainly due to affordability, or to private transport, mainly due to lifestyle perceptions. An iterative procedure is used whereby mode-specific performance statistics on in-vehicle travel time, walking time, waiting time, travel cost, number of transfers and seat availability from the spatially represent transport model is used to calculate modal splits which can be assigned to the transport network. The transport model allows for the following modes; namely private vehicles, taxis, buses, Bus Rapid Transit (BRT) buses, rail (Metrorail) and Gautrain. The paper shows outputs from hypothetical scenarios based on road tolls, fuel price, BRT headways, and rail improvements to demonstrate the sensitivity in modal shift.

The authors acknowledge the City of Johannesburg - Transport Department who commissioned the original study.

1 BACKGROUND

The City of Johannesburg (CoJ) Model was updated in 2014 as part of the Integrated Transport Network Project. Stated preference (SP) surveys were carried out as part of the project which, together with revealed preference (RP) data from the CoJ Household Travel Surveys 2013 (HTS), were used to develop logit-based user preference choice models. Although these choice models focused on the then already operational Bus Rapid Transit (BRT) services, it included all the main motorised modes in Johannesburg as well. The choice models assisted in understand modal preferences in the city, but was also incorporated in the transport model. This paper describes how the choice models were applied in the CoJ Transport Model.

This paper focusses on the application of the choice models in the transport model, and the detail of the choice models. The extent of the SP surveys, as well as the exact coefficients and calibration statistics of the choice models are well documented (Venter, 2016).

2 MODEL DESIGN

The CoJ Model is based on the classic 4-step modelling process, i.e. trip generation, trip distribution, mode split and assignment (WIllumsun & Ortuzar, 2005). The design of the model was sensitive to data available during the updating of the model. The original CoJ Model, based in EMME2 software, was available to the project team, but this model was not supported with interactive trip generation and modal split processes. The original transport model, the HTS data and SP survey data (2014) were the main sources of data considered in the design.

The modal split process is dependent on the data available from the trip generation and trip distribution process, which necessitate some explanation on how these processes were designed.

2.1 Trip generation and distribution

The trip generation process is dependent on detailed land use information on a zonal system covering the complete CoJ area. Person trip generation rates, derived from available data such as the HTS, was used to calculate trip productions and attractions for each zone for the following five demand strata for low medium and high income persons, i.e. :

- home-based-work;
- home-based-education;
- home -based-shopping;
- home-based-other; and
- non-home-based.

The trip distribution process converted the 15 sets of trip production and attraction totals to complete zonal matrices, making use of trip-length-frequency distributions, derived from the original model and the HTS. The 15 demand matrices were used as input into the modal split process.

2.2 Mode choice process design

The mode choice process design was guided by the structure of the calibrated user preference models.

2.2.1 Calibrated user preference models (Venter, 2016)

The calibrated user preference models allowed for captive users and choice users. Modal captivity is defined as a condition of having only one travel mode (or a subset of modes, such as public transport only) to use.

The user preference models identified four market segments, namely:

- Car captives: People with only the car mode available for a specific trip. Car captives were further divided into two subgroups:
  - Lifestyle car captives: People whose car captivity is due to personal, life cycle or activity-related factors – for instance, a worker who needs their car at work every day, or a parent whose trip patterns are too complex to undertake with public transport (PT); and
  - Availability car captives: People whose car captivity is due to the current unavailability of public transport alternatives, but who might be willing to switch to public transport in future, should an acceptable option become available.

- Public transport captives: People with one or more public transport options available but no car available for a specific trip at a specific time;

- Choosers: People with both a car and at least one public transport option available for their trip.

Based on the four market segments, three interlinked logit-based models were calibrated. These models can be described as follows and are also shown graphically in Figure 1:

- The primary captivity model models the proportion of all trips that are classified as car captive, PT captive, and chooser trips, as a function of personal (trip maker) characteristics, trip-specific characteristics (e.g. time of day), and area characteristics (e.g. general availability of public transport).

- The secondary captivity model divides car captive trips into lifestyle captive and availability captive trips, using similar variables as in the previous model.

- The primary mode choice model applies only to choosers and public transport (PT) captives, and models the main mode used by people who have a choice of different transport options available, with or without the car as an alternative. The model captures choices across both current (RP) and hypothetical (SP) modes, to capture the potential for switching to new (currently unavailable) modes.

It should be noted that the models were calibrated for the motorised modes as main modes, and excluded the non-motorised modes. The models were also consistent with the three income levels (low, medium and high) used in the transport model's trip generation and trip distribution processes. The same variables were used, but alternative coefficients were calibrated for each income level.

The variables used in each model, and the extent to which it was incorporated into the mode choice process of the transport model is discussed on the following subsections.

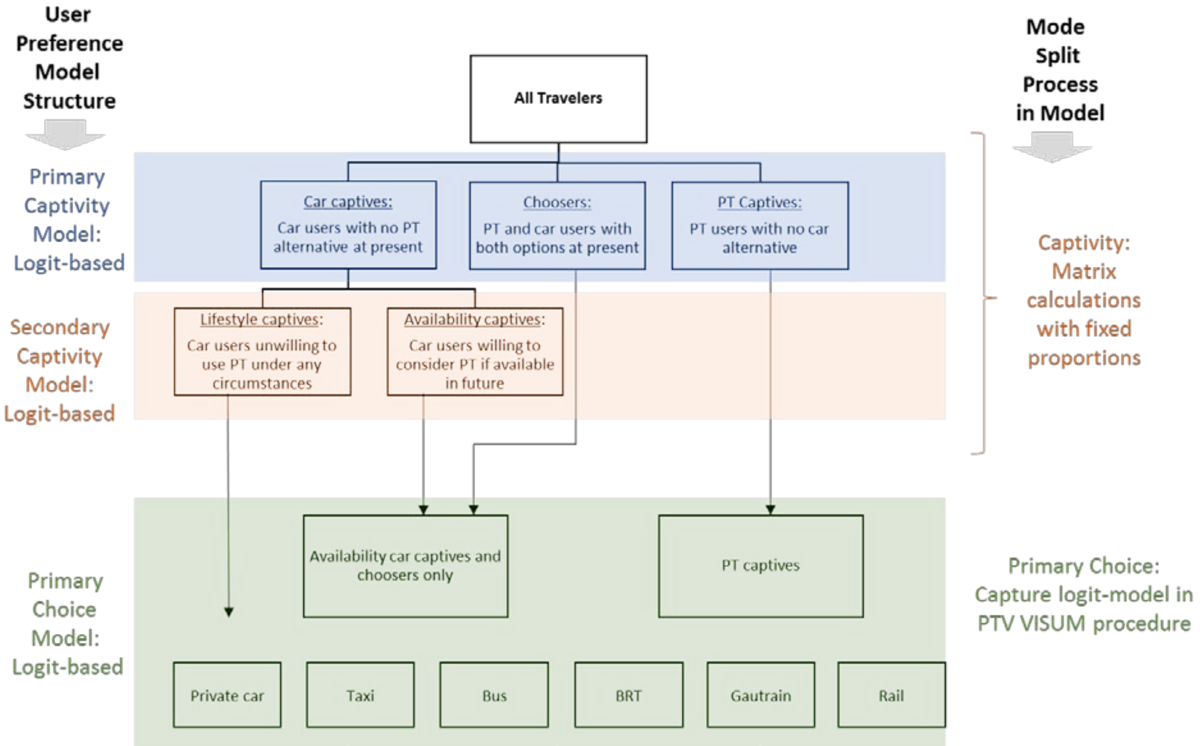

Figure 1: Relation between user preference model and modelled mode split

2.2.2 Mode captivity in the transport model

The primary and secondary captivity models were dependent on a combination of variables. Binary logit models were estimated for both the captivity models.

The significant variables which were included in the models are shown in Table 1 and Table 2 for the primary and secondary models.

Table 1: Variables Included in the primary captivity model

Type of information	Variable	Included	
		Car captive	**PT captive**
Modal access variables	Taxi available within 5 minutes' walk from home	✓	✓
	Bus available within 10 minutes' walk from home		✓
	Train available within 5, 10 and 30 minutes' walk from home		✓
	Respondent does not know how far is nearest PT from home	✓	
Household/ personal variables	Tripmaker age: 35 or more	✓	
	Household size (Medium income households only)		✓
	Tripmaker gender (male) x car ownership		✓

	Tripmaker gender (female) x car ownership		✓
	Tripmaker has tertiary education		✓
Trip-specific variables	Trip purpose (work trip)	✓	
	Time of travel (AM peak)	✓	
	Origin and/or destination of trip is in CBD		✓
	Tripmaker is satisfied or very satisfied with the mode used for this trip	✓	✓
Constants	Constant	✓	✓

Table 2: Variables included in the secondary captivity model

Type of information	Variable
Modal access variables	Bus available within 10 minutes' walk from home
	Respondent does not know how far is nearest PT from home
Household/personal variables	Reason for not using public transport = "I get to work etc. on time with my car"
	Household income is Medium
	Tripmaker is unemployed
	Tripmaker has tertiary education
Trip-specific variables	Origin and/or destination of trip is in CBD
Constants	Constant

Owing to the difficulty to forecast some of the variables, such as the personal variables, the primary and secondary captivity models were represented by fixed proportions in the transport model. The fixed proportion for each income level were derived from on the data used in the based-year captivity models. The average of the proportions across the zones are shown in Table 3

Table 3: Average proportion of captives applied in the transport model

Income level	Car captive (Lifestyle)	PT captive	Choosers (Availability)	Choosers	Total
Low	9.5%	64.6%	9.9%	16.0%	100.0%
Medium	12.6%	56.4%	10.5%	20.6%	100.0%
High	21.4%	37.8%	11.2%	29.6%	100.0%

The matrix calculation feature of PTV VISUM were used to multiply the captivity proportions to the total income-based person trip matrices to calculate private vehicle captive travellers, public transport captive travellers and choosers.

2.2.3 Primary mode choice

The complete primary mode choice model was incorporated into the transport model's mode choice procedure. The primary mode choice model modelled the primary mode choice made by tripmakers when choosing between two or more available modes. The model was only based on the main mode used per trip, so the dependent variable was defined as the mode used for the longest part of the journey, excluding any walk components at the start or end of each trip. The model was applied to PT captive, availability car captive, or choosers calculated from the captivity models. The lifestyle car captives made no conscious choice between car and other modes for their last trip, and were not willing to select BRT in any SP game, so they were excluded from the mode choice dataset.

Two models were developed, one was applied to the public transport captive users and the other to the availability car captives and choosers. The variables which were used in each of the models are shown in Table 4. Like the captivity models, separate models were developed for low, medium and high income users. The same variables were used for the three income groups, but with different mode constants and coefficients.

Table 4: Variables in the mode choice models

Type of variable	Variable
Alternative Specific Constants	• Bus • BRT (Reference category) • Gautrain • Taxi • Train • Car (for a*vailability car captives and choosers only)*)
Service variables	• Travel cost • In-vehicle travel time • Walk time at start of trip • Waiting time • Seat available on BRT • Number of transfers

The mode choice module in PTV VISUM were used to capture the various mode split models. The PTV VISUM software allows for various choice models, including the logit procedure which was used for the CoJ Transport Model. The mode choice module captures the modes, variables, coefficients and mode constants derived from the calibrated logit models.

2.3 First order assignment results for the mode split process

The real benefit of a mode split process incorporated into a transport model is the ability for demand to move between the modes with transport system changes. The first assignment of the transport model provides the service characteristic (skim matrices) to use in the mode split process to calculate the utility for each mode based on the logit function. For the CoJ Transport model, it was found that two assignment iterations were enough to provide acceptable (converging) results for the mode split process.

The mode split process provides for three demand matrices (based on the three income levels) for each transport mode, i.e. private car, taxi, bus, BRT, metro rail and Gautrain. The demand matrices are summed for each mode before it is assigned to the transport network. Private vehicles are assigned with an equilibrium assignment and public transport modes with the headway-based assignment technique.

Any changes to the transport network or services which will cause a change in the variables included in the mode split process (Table 4) will result in changes in the modal split. Such changes include changes in elements such as, user costs, road links, public transport routes, public transport stops or transfer facilities. The CoJ Transport Model is thus very valuable in the sense that, unlike most other city models, the mode split process is sensitive to system changes.

3 MODEL VALIDATION

The private vehicle assignment results were calibrated and validated with peak hour traffic counts which were available from CTO Stations, Johannesburg Road agency and other sources based on international guidelines (Schlaich, et al., 2013) (Pedersen & Samdahl, 1982). However, apart from Gautrain, limited public transport passenger census data was available for services in Johannesburg, which made it difficult to calibrate and validate the public transport assignment results on a detailed level. It would be ideal to have public transport passenger census data for stops, routes and services for each mode during the peak hours.

A comparison of overall mode share data between the CoJ Transport Model and the HTS is shown in Table 5. It is evident from the comparison that the overall mode share is within reasonable accuracy levels for a strategic demand model.

Table 5: Comparison between modelled and HTS modal shares

Mode	CoJ Model Mode Split 2014	HTS Mode Split 2013
Private Car	45.2%	45.2%
BRT	3.0%	1.2%
Bus	14.2%	8.0%
Gautrain	0.6%	0.1%
Taxi	29.2%	38.3%
Train	7.8%	4.8%
Other	0%	2.4%
TOTAL	100%	100%

4 MODEL APPLICATION ON HYPOTHETICAL SCENARIOS

For this paper, the CoJ Transport Model was used to compared four scenarios with a reference scenario to demonstrate the modal split sensitivity of the model. The reference scenarios consisted of an expanded BRT network, limited road network upgrades and the forecasted 2025 morning peak hour demand. In the four scenarios, the networks and demand remained the same as in the reference scenario, while some system characteristic where changed. The following four hypothetical scenarios were analysed:

- Scenario 1: Increase modelled BRT service headway from three minutes to 10 minutes (less frequent services);
- Scenario 2: Increase the Gauteng Freeway Improvement Project (GFIP) toll tariffs with 100%;
- Scenario 3: Increase the fuel prices with 20% without increasing public transport fares; and
- Scenario 4: Change the mode constant of rail (Metrorail) in the mode choice models to be the same as that of Gautrain, thus assuming Metrorail can improve their image in such a way that travellers will perceive the unmeasured variables to be the same as that of Gautrain.

The modelled mode split results are shown in Table 6. It is evident from the outputs that the changes are small. This is partly due to the captive travels who are not prepared to switch modes. The increased BRT headway -meaning a less frequent service – resulted in a 2.5% reduction in BRT modal share. Both the increases in toll and fuel price caused a reduction in private car use, 0.5% and 2.7% respectively. The improved Metrorail service resulted in a 2.7% increase in ridership. The nature of the mode split changes appears logical, but appropriate public transport census data, which is historically very limited or absent, is required to validate the extent of these changes.

Table 6: Modelled mode split results of the hypothetical scenarios

Mode	2025 AM BRT Network (Reference)	Increase BRT headway (3min to 10min)	Increase existing GFIP tolls (100% increase)	Increase in fuel price (20% increase)	Improved Metrorail Perception (=Gautrain)
Private Car	49.0%	49.5%	48.5%	46.3%	48.0%
BRT	14.1%	11.9%	14.2%	14.8%	13.5%
Bus	9.3%	9.8%	9.4%	9.8%	8.8%
Gautrain	1.6%	1.7%	1.6%	1.7%	1.6%
Taxi	20.3%	21.1%	20.5%	21.3%	19.6%
Train	5.8%	5.9%	5.8%	6.1%	8.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

5 CONCLUSIONS AND RECOMMENDATIONS

This paper described how user preference choice models, developed from RP and SP data, were incorporated into the mode split process of the CoJ Transport Model. The transport-related independent variables from the choice models are multiplied with modelled mode performance statistics, which provides a tool which dynamically assess the impact of transport system changes on modal split.

This approached is a methodological advance on current practice, such as the previous version of the CoJ Model (Mokonyama, 2004), whereby the mode split step follows directly from the trip generation step – providing for modal split to be dependent on land use and demographic information per zone, rather than the transport system.

The choice models revealed the intrinsic characteristic of some city travellers who are captive to public transport, mainly due to affordability, and some to private transport, mainly due to lifestyle perceptions. The CoJ Transport model encapsulates this characteristic which, if not dealt with properly, can result in an oversensitivity of modal shift.

Due to the nature of some of the independent variables used in the captivity models, the captive proportions of private car and public transport travellers were fixed in the model. This allowed for only part of the generated persons trips to be consider for alternative modes. The captivity part of the model can, however, be improved if the mode access and trip specific variables are incorporated into the model.

The paper shows some outputs from hypothetical scenarios based on road tolls, fuel price, BRT headways, and rail improvements to demonstrate the sensitivity in modal shift. The changes in mode split might appear insignificant, but considering that these percentages are applied to 1.25 million peak hour person trips (2025), the changes can influence the performance and feasibility of a mode.

Transport models and choice models are often developed in isolation without the benefit of combining it into a dynamic model. The CoJ Model demonstrated that SP surveys can be even more valuable when designed to be incorporated into a transport model. The paper highlights the lack of sufficient public transport census data to properly calibrate and validate mode split models. Sufficient public transport census is essential in building credibility of mode split models and the application thereof in an environment where we are making huge investments in a new public transport mode such as BRT. It is also important to continue applying and improving mode split models in our cities to scrutinize it with reality.

6 REFERENCES

Mokonyama, M., 2004. *Overview of the City of Johannesburg strategic transportation modelling framework.* Pretoria, Emme/2 Users Conference.

Pedersen, N. J. & Samdahl, D. R., 1982. *Highway traffic data for urbanized area project planning and design (NCHRP Report 225),* Washington D.C.: TRB.

Schlaich, J., Heidl, U. & Möhl, P., 2013. *Multimodal macroscopic transport modelling: State of the art with a focus on validation and approval.* Riyadh, Saudi Arabia, s.n.

Venter, C., 2016. *Are we giving BRT passengers what they want? User preference and market segmentation In Johannesburg.* Pretoria, s.n.

WIllumsun, L. G. & Ortuzar, J. d. D., 2005. *Modelling Transport: Third Edition.* West Sussex, England: Wiley.