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# COMBINING STATED AND REVEALED PREFERENCE SURVEYS IN STRATEGIC TRANSPORT MODELS

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## Abstract

Stated preference (SP) surveys are often undertaken to investigate behaviour to support a particular decision -- e.g., implementing a bus-way -- or as academic exercises to understand decision processes. It is less common for stated preference to be integrated into a citywide household travel survey, but that is what is being considered by the WA Department of Transport for the next Perth and Regions Travel Survey (PARTS-2016). This paper contains a number of detailed recommendations for integrating a stated preference component with a household travel survey.

## 1 Introduction

The upcoming household travel survey for Perth and Regions (PARTS 2016) will include a stated Preference (SP) component. Its primary purpose is to improve the mode choice component of Perth's strategic models. The need for the improvement was the outcome of the Transport Modelling Review commissioned by the Main Roads WA (MRWA), the Department of Transport, the Department of Planning, the Public Transport Authority and Treasury. In that report it was noted that mode choice models based on revealed preference RP data only often have insignificant parameter estimates (gaps in the model) or parameters that are lower in absolute value than the prevailing evidence:

> *"To achieve a fully responsive choice model it will also be necessary to model additional factors. Travellers are increasingly sensitive to crowding on public transport, to highly variable road travel times and to parking availability. Thus a satisfactory mode choice module should contain parameters reflecting responses to these factors, as well as the time and cost parameter estimates already included".* (Taplin *et al.*, 2014, p.48).

PARTS 2016 is planned to be a multi-day household travel survey. The survey collects Revealed Preference (RP) travel data. However, RP attributes often exhibit little variability or are collinear and it is difficult to determine their contribution to choice. Stated preference SP will provide more robust parameter estimates than can be uncovered using only RP data. SP is the appropriate tool to address the gaps in the strategic models, but it needs to be integrated with RP. This paper contains a number of practical recommendations for integrating a stated preference component with a household travel survey, with the aim to obtain the best quality data in the most cost effective manner.

These recommendations are discussed at large in the paper. Following a literature review on RP and SP surveys and a framework for their combination in Section 2, Section 3 discusses the types of experimental designs, the challenges associated with them and the practical advantage of efficient designs when considering large-scale representative samples. Section 4 suggests ways for integrating SP experiments into travel surveys that address both the ongoing support of strategic models as well as addressing identified policy areas and Section 5 addresses the organisational challenges of embedding a SP instrument in a household travel survey.

# 2 Review of principles and methods to integrate Revealed (RP) and Stated Preference (SP) Data

This section provides a review of the literature related to integrating stated and revealed choice data. Along with section 3, the section provides the evidence base support to the recommendations made later in the paper.

## 2.1 Benefits of SP combining SP and RP data

In transport modelling, revealed preference, RP, data refers primarily to *ex post* information, i.e. trips or actions already undertaken by individuals. These data may be recorded by way of a household survey. Stated preference, SP, is based on *ex ante* information, as the choice under investigation (and for which the subjects indicate the potential response) may occur in the future. Whist not observing the choice in the market place, SP surveys observe *"data consistent with economic theory, from which econometric models can be estimated, which are indistinguishable from their RP data counterparts"* (Louviere *et al*., 2000, p.21).

This is an important distinction that needs to be made, as the benefit of SP lies primarily on exploring new responses in hypothetical situations (new services, new markets), whereas RP's strength is in describing real state of affairs or options). Although RP has strong face validity (it describes the real state of affairs), it has numerous limitations (Louviere *et al*., 2000):

- RP cannot be used to examine the transport impact of new alternatives;
- Lack of reliability when there is insufficient variability in the attributes;
- Highly collinear attributes make it difficult to determine the marginal utility ( also known as the taste parameter) of each attribute;
- Other noise around the elements that may have contributed to the selected course of action.

Conversely, SP offers a systematic fashion of manipulating experimental conditions (similar to lab experiments), it eliminates noise on attribute levels, leads to more significant parameter estimates, as well as multiple observations per respondent.

Combining both sources of data is expected to increase reliability of modelling by taking advantage of the best features of both approaches.

## 2.2 Methods to combine SP and RP data

There are two main approaches for achieving this integration: basic and advanced data enrichment.

### *2.2.1 Data Enrichment*

**Data enrichment methods** make use of SP data is used to improve the parameter estimates for attributes where RP provides insufficient variation or exhibits some other problem as outlined above. Morikawa (1989) and Ben-Akiva and Morikawa (1990) pioneered the enrichment methodology by assuming the taste parameters are the same for both RP and SP choice models, but the scale parameter may differ. The **basic enrichment** model estimates common parameters for two multinomial logit, MNL, choice models allowing for a separate scale parameter to account for the different variances in the unobserved utilities. However, variations are possible. Hensher (1998) allowed the scale parameter for each alternative within each data set to be estimated freely, by way of the heteroscedastic extreme value (HEV) choice model. Yañez *et al.* (2010) modelled SP-RP models but considered the possibility that the underlying structure for each data set was nested. In summary, the base model for each data set can be any flexible choice model, but a scale parameter adjustment is the way in which the data is pooled into a single modelling exercise.

Basic data enrichment key points that emerge are:

- Forecasts are based on RP data set, SP data is used to modify the parameter estimates (Cherchi and Ortúzar 2011);
- Household surveys record the attributes of the observed trip. A RP choice observation, requires attribute measurements for the alternate but non-chosen modes of travel;
- The purpose of data enrichment is to provide robust estimates of trip parameters, RP and SP data must have attributes in common.
- SP observations do not need to have similar attribute levels to RP data, but it makes sense to calibrate the attribute levels to RP. For example if the current trip time is 20 minutes then the SP trip time should be anchored by that value.
- When multiple SP observations are used, weighting is required, to give RP and SP equal importance. For example if four SP observations are collected to enrich one RP observation, then a weighting ratio of 1:4 is applied.

**Advanced data enrichment** takes into account the panel data effects (i.e. all SP observations from one person are in some way related). The basis of the technique is to allow the scale parameter to vary. Brownstone *et al.* (2000) estimate a RP-SP choice model using mixed-logit structure, which accounted for error correlation due to “repeated choices”, preference heteroscedasticity, and scaling difference. Two estimation methods were proposed: 1) estimate the SP scale parameter using a basic enrichment technique and pre-multiply the SP variables by the estimated scale parameter; 2) estimate the taste parameters and the scale parameter in a full information maximum likelihood (FIML) model. Bhat and Castelar (2002) extended the joint RP and SP enrichment modes by:

- Accommodating inter-alternative error structure (e.g. A nest logit, NL, type models for each RP and SP sample);
- Accounting for the scale parameter difference between data sets;
- Estimating random parameters to capture preference heterogeneity;
- Accounting for state dependence (the tendency to choose the current RP mode among the SP alternatives) as well as heterogeneity in the state dependence.

The use of mixed logit models (random parameter logit, RPL or an error components model, ECM) represented a significant advance in combining RP and SP data, because the choices made by each individual are treated as unique to that individual, i.e. correlation between the unobserved components of the utility is accommodated. Hensher (2008) and Hensher *et al*. (2008) compared the results from an ECM and the NL and concluded that advanced models explain the choices to a greater degree than basic enrichment models.

Advanced Data Enrichment Additional Points:

- Advanced data enrichment models inherit the first four key points from basic data enrichment;
- Weighting the importance of RP and SP is not mentioned in the literature. However, it still may play a role and should be investigated;
- The choice data for each individual is modelled using a panel data choice model. Any specification of choice heterogeneity is consistent across all SP and RP observations;
- The correlations between alternatives are modelled using an ECM rather than NL model.

#### *2.2.2 Using RP to Ground the SP Attribute Levels*

The section outlines a number of techniques used to ground the SP attribute levels in existing market conditions.

**Pivoting**: Individuals use availability and familiarity in their decision-making processes, thus it is considered more appropriate to design surveys that are close to respondent's actual choices (DeShazo *et al*., 2009). Pivoting the SP attribute levels means that the SP levels are proportions of the current RP choice, i.e., +25% or -25%. Pivoting can be around a reference alternative (the levels of the current choice by the respondent remain fixed) or an experienced alternative (the levels of the current choice by the respondent form part of the experimental design):

> **A reference alternative** – the respondent's current RP choice may be used. The reference alternative *maintains the same attribute levels for every scenario*. The choice task becomes one of 'would you switch?' This is valuable when exploring the uptake of a new alternative (i.e., toll road or light rail) the reference alternative approach is appropriate (Hensher, 2010).
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> **An experienced alternative**[1] - A less strict form of referencing is to pivot all SP attribute levels around an experienced alternative. This differs from the referenced alternative approach because the attribute levels of the experienced alternative are included in the design. Basing the range of attribute levels around the respondent's experience reduces cognitive biases and improves design efficiency (Rose *et al*., 2008).

**Conditioning:** It is useful when RP observations are not collected as part of the survey, or that the RP data is collected for one sample and the SP data is collected for another (nevertheless, it is expected that both samples are in the same study area). Pivot designs present attributes that are centred on the attribute levels for each individual. It is also possible to condition the attribute levels on a reasonable expectation of what the attribute levels may be for an individual.

> If there is **no related RP data collection**, conditioning SP attributes would be based on network data. This a similar approach to the way in which the attribute levels are specified for non-chosen RP alternatives whereby the levels are inferred from road network conditions or public transport schedules. The analyst must decide the degree of disaggregation. A set of network attributes could be calculated for each household identified in the SP survey or some geographical boundary may be used, such as the suburb.
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> When **RP data is collected for a different sample,** the attribute levels for the SP sample are conditioned on averages from the preliminary RP data collection. One-off SP surveys are often based on the strategic model's estimates of travel time and costs. These values are estimates based on earlier household travel surveys. Despite of not being data enrichment, conditioning may improve the face validity and forecasting capacity of a stand-alone SP survey.

**Pivoting on Market Segments:** Hybrid pivoting and conditioning may be used to increase the relevance of conditioned attribute levels. The respondent's current alternative (car, public transport alone and park-and-ride) appears in each choice set, but with attributes conditioned by the average levels for commuters with similar trip lengths (short, medium and long) or from a similar geographical location. In this way, subjects respond to choice sets that include their current alternatives, but with attribute levels centred on an average, rather than their own experienced levels. The strategy requires more than one experiment to be designed,

[1] The literature does not make the distinction between a referenced alternative (fixed attribute levels) and an experienced alternative (attribute levels are part of the experimental design). It should.

being far less than one design for each respondent, but more realistic than ignoring the respondents current choice and context.

### 2.3 Inclusion of Attitudes in Choice Models

Substantial scholarly work has shown that inclusion of attitudes in discrete choice models (hybrid choice models) explain better individual decisions of mode (Ben-Akiva *et al*., 2002; Schwanen and Mokhtarian, 2005; Vredin Johansson *et al.*, 2006; Ettema *et al.*, 2011; Prato *et al.*, 2012; Atasoy *et al.*, 2013; Van *et al.*, 2014) and relocation choice (Walker and Li, 2007; Walker *et al.*, 2011; Olaru *et al.*, 2011b), among others. The evidence indicate it is not only the attributes of the modes (cost and time) that are relevant to models of choice, but also the decision *baggage* that individuals bring along when making a choice. Attitudinal constructs, expressed as latent variables, could be tested as covariates inside the utility functions for the discrete choice models.

### 2.4 Forecasting using RP-SP Models

The golden rule of forecasting with RP/SP enrichment models is that the forecast is to be based on RP shares and attribute levels. Enriched parameter estimates (i.e. whereby the same parameter is estimated from both SP and RP data, taking into account scale differences) are preferred, but if not possible, SP parameters conditioned on RP should be used in forecasts.

The usual forecasting exercise is to examine what are the behavioural responses to a travel demand or supply policy instrument. The basis of such a forecast must be the current conditions, found in the RP data. However, three issues may arise in RP/SP collection and modelling, indicating that the forecast cannot strictly be based on RP:

- If a new alternative or untested policy is introduced into the experiment, the market shares and any alternative specific parameter related to the new alternative are unknown. The alternative specific constant (ASC) estimated on the SP data is rescaled (multiplied by the scale parameter) and the alternative is added to the RP data (Louviere et al., 2000).
- Should one or more of the RP and SP parameters to be significantly different, a partial enrichment model is specified, such that not all parameters are common across both sources of data. This leaves the decision maker with a choice on which parameter to use for forecasting. Conventional wisdom says that the RP parameter estimates take precedence (Cherchi and Ortúzar 2011).
- The systematic or random heterogeneity structure of the RP and SP components of the model differs. The choice forecasting model is largely a decision to be made by the analyst. Cherchi and Ortúzar (2011) suggest testing the integrity of the forecasting estimates. For example, the marginal utility of travel time is expected to be negative. The choice on whether the RP or SP attribute levels should be selected may be guided by the percentage of respondents for which the computed marginal utility is positive, which should be minimal.

## 3 Experimental Design

An experimental design starts with identifying the relevant characteristics/attributes of the alternatives that will be compared in the scenarios. Then the number of levels and ranges of variables are set for each alternative, keeping in mind attribute level balance, the possibility of dominance (a bundle that is always better than the others), or that some combinations of attribute levels may be unrealistic (e.g., low fuel consumption and large engine size) or the combinations of levels give rise to higher order correlations (A statistical property that may confound the analysis). Next, combinations/bundles of attributes are selected for each alternative and mixed into scenarios (also called stimuli or games) that will be shown to the respondents. The manner in which these combinations are built is the focus of the design of experiments.

At the outset, the preparation of the experiment requires that the analyst explore the context of the decision and determine relevant alternatives, attributes and levels on which the models will be based. When the context is not well understood, a preliminary qualitative study, in the form of a focus group discussion or an administered questionnaire, is required. The aim of the preliminary inquiry is to identify the relevant choice alternatives and the factors considered influential on the choice decision.

SP experiments *extend* reality and it is important to work out how far the design can push the limits. The preliminary inquiry should determine what is reasonable in the minds of the decision makers. Whilst it recommended that the range of attributes be wider as it helps achieve efficiency (Rose and Bliemer, 2009) this range should not extend beyond credibility. In the market place, the level of service or quality of the alternative is linked to its price. SP experiments need to suspend this relationship, as the aim is to identify the part-worth of each quality feature, as well as the decision maker's responses to pricing. This is not possible when quality and price are perfectly correlated. The preliminary inquiry seeks to understand the degree in which the price-quality relationship can be suspended before the alternative appears 'too good to be true'.

In designing choice experiments, the analyst is looking to find the smallest possible sample that achieves a specified accuracy of an unknown population parameter. The experimental design population is the universal set of possible tasks – a full factorial design, and the design specification refers to selecting the combinations that minimise errors at the lowest cost.

At the stage of generating designs the analyst needs to consider:

- the model to be estimated;
- the number of parameters;
- whether the model will include interactions between attributes;
- whether the alternatives should be labelled (car, bus or train) or should be presented as unlabelled collections of attributes (alternative 1 and alternative 2).

The size of the experiment (number of scenarios shown to respondents) is problematic because the universal set can be quite large. Recent designs completed by the authors include universal sets of size 172 million (Olaru *et al*., 2011a) and $5 * 10^{17}$ (Jabeen *et al*., 2012). Even when fractional (part of the full set of treatments) sets are chosen to maintain the principle of orthogonality (independent attribute levels), the resulting design is far too big to administer to respondents. The solution has been to optimise efficient designs.

In terms of presentation, the survey instrument may apply: "choose one", "choose the best and the worst alternatives", "rank" the alternatives and/or variations. The designs should take into account the type of response variable.

## 3.1 Efficient Designs

Experimental designs for SP surveys evolved to match the complexity of recent advances in discrete choice modelling. The current state-of-the-art design principles have moved away from the standards of orthogonality, balance and without dominance, in favour of efficiency (Bliemer *et al*., 2009a, b). Efficient designs aim to produce stable and reliable parameter estimates in a fractional design setting, i.e. using only a sample of the possible combinations of attribute levels (Ryan *et al*., 2007). This is achieved by minimising at least one property of the asymptotic variance–covariance (AVC) matrix: determinant, trace, or variances. The AVC matrix depends on the type of choice model used for estimation, thus the model has to be considered at the time when the SP survey is designed. Rose and Bliemer (2005a, b) and

Bliemer *et al.* (2009a) confirmed that efficient designs have more reliable parameter estimates than orthogonal designs for some variants of the discrete choice model.

One of the challenges present at the design stage of SP is the requirement for a known or previously estimated vector of parameters (priors) when deriving the AVC. A less efficient alternative is to base the design on a set of null parameters (i.e. all equal to zero) or to base the design on the researchers' intuition. However, obtaining reliable prior estimates helps considerably in the design process, because a misspecification leads to losses in efficiency (Kessels *et al*., 2008; Bliemer *et al*., 2009b). Priors may be obtained from literature reviews or pilot studies. Even if the literature matches the research question, it will almost always refer to a different setting. Pilot studies have the advantage of reviewing the survey instrument as well as providing the prior estimates.

Currently, the most widely used approach is to maximise statistical efficiency by minimising the standard errors on the anticipated parameter estimates; labelled D-errror because the objective function is the smallest determinant of the error-covariance matrix (Rose and Bliemer, 2009). As indicated, this approach requires that both the model (Ryan *et al*., 2007) and the parameter estimates (e.g., Ferrini and Scarpa, 2007) are known before the SP survey is designed. In applied work, MNL or nested logit are the most commonly assumed choice models (Kaninen, 2002; Bliemer *et al*., 2009a; Goos *et al*., 2010) with very few exceptions (e.g., Sándor and Wedel, 2005).

Numerous algorithms to obtain and implement optimal designs have been examined. Ferrini and Scarpa (2007) and Bliemer *et al.* (2009a) described the construction of various types of experiments including the systematic row- and column-based algorithms (modified Fedorov) and the RSC (relabelling, swapping, and cycling) algorithms. These algorithms start either with a large number of choice sets generated from full or fractional factorial designs, then combinations with lower D-errors are retained (row-based algorithms), or with a randomly generated design in which the levels within each column are changed in order to achieve more efficient designs (column-based); a combination of both strategies such as RSC has also been prevalent. Alternatively, heuristics such as genetic algorithms may be applied. In this case, the chromosomes are the stimuli or choice set elements (combinations of attribute levels across the alternatives), which are combined through various "genetic" operators to obtain the choice sets that minimise D-error (Olaru *et al*., 2011a).

More recently, Bayesian designs have emerged on the arena of experimental designs (Kessels *et al*., 2008). Bayesian approaches go beyond the appealing assumption of fixed known parameters and take into account their uncertainty. This is in response to acknowledged difficulties to obtain quality priors for the experimental designs. Bayesian designs are also more robust.

Irrespective of their type (fixed priors or Bayesian), the practical advantage of efficient designs is that reliable parameter estimates are made using lower sample sizes. In a regime that intends to embed stated preference into the ongoing travel behaviour surveys, this issue is paramount. The SP section of the survey is a smaller cost component, which can assist with balancing out the high prices of RP (travel diary or GPS tracking budget are generally considerable). However, despite the advantages of efficient designs, the notion of representativeness cannot be overlooked.

## 3.2 Representativeness

Literature in data collection (regardless of the area of interest) is clear about the types or errors affecting representativeness and their magnitude (Richardson *et al.*, 1997). Simply said, a sample is representative of the entire population if: it is "similar" to the population from which is drawn and it covers the population heterogeneity (space, socio-demographics, behavior of interest). This draws attention to the fact that a sample representative for a particular question/matter is most likely not representative for a different question.

Stochastic sampling procedures ensure representativeness, however non-response and response biases can have a large impact on the validity of the questionnaire or survey to which the participant is responding. This is because human subjects do not respond passively to stimuli, but rather actively integrate multiple sources of information to generate their response in a given situation. If they are disengaged with the survey, they may refuse participation (non-response). On the other hand, high involvement with socially and morally charged issues may cause not only self-selection, but also bias in responses (denying undesirable traits, and ascribing to those that are socially desirable). Both sources create a systematic error of the measurement that is sought (Bonsall, 2009).

More recently, representativeness was questioned in relation to the method of data collection. Some deployment techniques are considered more immune to such biases: pencil and paper postal surveys, face-to-face interviews. However, empirical knowledge concerning the validity of data gathered using new digital communication technology approaches (GPS, web surveys), in comparison to more traditional surveys, is still in its relative infancy. This suggests that additional attention must be paid to any link between the survey instrument (including SP), the medium of data collection, and the non-response and social desirability biases. For example, relying solely on socio-demographics for representativeness may obviate obtaining reliable findings if ignoring destination locations for activities or mobility restrictions.

# 4 Recommendations for Including a SP Instrument in a Household Travel Survey

This section summarises the practical considerations for undertaking an SP data collection as part of a Household Travel Survey. The discussion focuses on the gaps identified in Perth's strategic transport model review (Taplin *et al.*, 2014) and make recommendations for the upcoming PARTS 2016 survey. However, for the general audience we have tried to make the recommendations generalizable to other contexts. Details on the designs, sample sizes and cost estimates for the Perth case can be found in Olaru *et al*. (2015).

## 4.1 SP Methodology Relevant to the Household Travel Survey

The primary purpose of the SP survey in this study is to provide parameter estimates for the strategic transport models. In addition, SP offers the possibility of exploring the factors beyond travel time and travel cost:

> *"To achieve a fully responsive choice model it will also be necessary to model additional factors. Travellers are increasingly sensitive to crowding on public transport, to highly variable road travel times and to parking availability. Thus a satisfactory mode choice module should contain parameters reflecting responses to these factors, as well as the time and cost parameter estimates already included".* (Taplin *et al.*, 2014, p.48).

***Recommendation 1:*** A household travel survey can incorporate a **SP instrument to provide robust parameter estimates**. By taking into account the needs of a strategic model, a base experimental design can be developed with the sole purpose of providing parameter estimates for the mode choice models in the strategic transport model.

Commuting (journey to work or education) places the most stress on the transport infrastructure. Significant policy decisions will require the support of a model of travel behaviour for this function more so than other travel purposes. The stated preference collection should look at the commuting mode choice problem. However, the review of Perth's strategic model also identified gaps in the mode choice model for shopping trips (Taplin *et al*., 2014, p.47). The decision on which trip purpose to focus on will be contextual.

Given the expense of such a survey, target policies should be identified and the instrument should address the data needs for these policies. The policies may relate to new pieces of infrastructure, such as a light railway line, or travel demand management instruments, such as high occupancy vehicle lanes.

***Recommendation 2:*** The SP instrument is designed to provide demand insight to support target policies. The number and nature of these policies will be contextual. However, the experiments should be extensions to the base design aimed at supporting the mode choice model to be employed in a strategic transport model.

It is expected that extending the base SP design to investigate demand for a specific research question poses little risk in undermining the primary purpose of the SP component (robust parameter estimates for the mode choice model). However, Pilot studies should be undertaken using experimental designs to test the parameter consistency across the choice models. If it is found that one or more of the policy specific designs diverge from the base design, either adjustments to the designs is required or a greater sample should be allocated to the base design.

***Recommendation 3***: A **substantial pilot test** should be conducted on the survey instruments to judge the quality and consistency of the designs, due to their strong dependence on prior parameter estimates.

**Data enrichment:** describes the joint estimation of behavioural parameters using both RP and SP observations and the methods of basic and advanced enrichment were detailed in Section 2.2. The modelling strategy should pursue data enrichment to inform the experimental design and setting of attribute levels. Thus, the recommendation is:

***Recommendation 4***: Future mode choice components of a strategic transport model should aim to make the most of **data enrichment** to provide robust parameters.

Data enrichment informs the general principle of grounding SP attributes by the current experiences of the respondents (i.e., RP data). Whilst there are a number of approaches to ground the SP attributes, a practical solution is the hybrid approach to pivoting and conditioning: the respondent’s current alternative (RP) to appear in each choice set, but with attributes conditioned by the average levels for commuters with similar trip lengths (short, medium and long). This strategy requires fewer designs, but it is more realistic by accounting for the respondent’s current choice and context.

## 4.2 Attitudinal Constructs

Individual decisions are driven not only by the alternative attributes and by the decision makers’ characteristics and circumstances. Other motives seem to play an important role in mobility decisions: feelings of power, comfort, social status, restrictions, etc., which implies that the utility functions should embed not only features representing the instrumental value of the alternative, but also attitudes and feelings of the decision maker.

The attitudinal survey instrument depends on the context of the inquiry. For example, attitudes towards the environment may be relevant for the introduction of a new public transport mode, whereas attitudes to risk and uncertainty may be explored when examining congestion management instruments.

Consequently, we propose:

***Recommendation 5***: Both the **RP and SP surveys should make use of attitudinal scales** to improve the estimation of choice parameters and to inform policy. Attitudinal scales enter the choice model as correlates with latent classes (Olaru et al., 2011) or as latent variables (Yañez et al., 2010).

# 5 Implications for integrating with A Household Travel Survey

Given that SP can assist in enriched parameter estimations for strategic transport models, it appears that a full integration with the household travel survey (RP) is necessary. The RP component will be collected by the main survey and a follow-up survey would be administered to a representative sample. Cost implications may mean that only a fraction of the main sample will receive the follow-up SP survey.

An interim level of integration is possible in that the household travel survey attribute levels provide a foundation for future SP exercises. Data collected from a household travel survey provide a range of trip attributes that can at least be considered as reasonable – or likely to have been experienced. A choice model can be undertaken using the RP data (observed trips and imputed attribute levels of the non-chosen modes). The parameter estimates from the RP choice model may provide priors to be used for efficient designs (aimed at saving on sample size requirements). This enables pivoting or conditioning of the SP attributes.

Independent of the deployment method for the RP exercise (mail-out, face-to-face interview that is computer aided, GPS prompted recall, online, etc.), running the SP component separately from the main survey faces the following challenge:

- **Organisational boundaries**. The SP function relies heavily on access to household travel survey and the RP choice models in a timely manner. Cross organisation boundaries will inhibit the sharing of data. The primary surveyor will have a privacy contract with the sample that will require some form of data de-identification to be undertaken before sharing. Along with necessary data cleansing, formatting, this will cause delays particularly because the priorities of the RP data collection agency will focused on the efficiency of its primary function and sharing data will require shifting resources away from its core business. By contracting the same organisation to undertake the RP and SP component it is understood that a number of data analysis functions are necessary to complete the full data collection. However, this poses some risk in finding the right contractor with the capabilities to understand both the RP travel survey data collection and the pre-analysis required to develop and administer deliver an efficient and relevant SP instrument.

Alleviating the problems associated with multiple organisations undertaking the survey suggest that one agency should be responsible for both the household travel survey and the SP survey. This leads to the further advantages of:

- **Cost of administration:** An integrated RP and SP survey undertaken by one agency has the potential to reduce the cost of administrating both survey components. The obvious reason being is only one source of overheads applies to the individual survey components. In this case, given that the data collection agency will need to follow up with households to verify travel diary or GPS records, the potential saving comes from incorporating the SP data collection into the follow up validation process. Moreover, integration may achieve a quick turnaround of the RP data, required to estimate choice models in order to identify priors for the SP designs and for conditioning the choice sets.
- **Continuity of conversation with the respondent:** The respondents will view the whole exercise more favourable if there is a consistent channel of communication. The implication for the administering organisation is that they assign a single person to each household to be the main source of contact. However, from an integration of the SP and RP context, having a single organisation (branding, contact addresses, newsletters, and hearing complaints) is less frustrating to the respondent and will improve the quality of the data.

In addition, to aid the consistency of communication with the respondents, the SP instrument should be **as seamless as possible**, in that it looks and feels part of the main survey The exact method for administering the SP instrument depends the instrument being used to conduct the household travel survey.

# 6 Summary and Conclusion

Our recommendations were clustered into four categories:

**Technical (Sampling and Coverage) -** Efficient experimental designs offer a substantial cost saving in terms of sample size. To optimise this saving it is recommended that the SP component is conducted in a semi-dynamic way. The attribute levels of the SP experiment are pivoted on the RP responses and revealed preference models are used to estimate priors to be used in the design.

Related to sample size, ongoing/continuous surveys are more cost efficient than infrequent big surveys (Raimond, 2009), also providing valuable information on changes in travel patterns. This monitoring of change improves the modelling of responses to socio-economic dynamics and highlights if and when behavioural shifts occur.

**Organisational -** Given the technical approach, the dependence of the SP choice component on the household travel survey is total. The administration of both surveys should be integrated into one organisation for the following reasons:

- Organisational boundaries: The design of SP relies heavily on access to RP data in a timely fashion. Cross-organisation boundaries will inhibit the rapid and efficient sharing of data.
- Cost of administration: An integrated RP and SP survey undertaken by one agency has the potential to reduce the cost of administrating both survey components. Given that the data collection agency would need to follow up with households to verify data (e.g., travel diary, GPS records), the potential saving comes from incorporating the SP data collection into the validation process.
- Continuity of conversation with the respondent: The respondents will view the whole exercise more favourable if there is a consistent channel of communication; having a single organisation (branding, contact addresses, newsletters, and hearing complaints) is less frustrating to the respondent and will improve the quality of the data.

**Behavioural -** In the early days of discrete choice modelling (DCM), taste weights (parameters) were conditioned on social-demographic variables as a possible explanation of preference heterogeneity. Whilst the inclusion of social-demographic variables in mode choice models remains an important tool, more recently preference heterogeneity has been incorporated as a random parameter or as a function of attitudinal and lifestyle variables. Understanding personal attitudes and including them in DCM is essential because often the choice of mode is not so much whether a person is male or of a certain age, but whether they hold certain attitudes about travelling by public transport or towards the environment. Personal attitudes influence how people trade-off the relative cost or time advantages offered by a particular mode. Hybrid choice models fuse a model of a person's attitudes or lifestyle with a model of travel choices (Bolduc and Alvarez-Daziano, 2010). These models are relevant for market appraisals as they help explain the marked differences in choices made by individuals facing similar conditions.

**Identified Policy -** The principal purpose of the SP component is to support parameter estimates for the mode choice components of a strategic transport model (Taplin *et al*., 2014). However, there is the opportunity to provide insight into key policy areas. Starting with a base design to cover the need to parameterise the strategic transport model, a number of modifications were added to explore identified policy areas, such as the implementation of new light rail infrastructure or possible congestion management strategies.

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