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AN EXAMINATION OF BICYCLE USE SENSITIVITIES OVER TIME USING STATED PREFERENCE

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An Examination of Bicycle Use Sensitivities Over Time Using Stated Preference

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Abstract

This paper describes an experimental investigation of the influence of various factors on bicycle use for a set of cyclists in Edmonton in Canada, including an examination of how these influences have changed over time. The relevant data were collected in 1994 and 2005, two points in time separated by 11 years. A stated preference technique was used, with the same survey instrument was applied at both points in time, facilitating a more controlled comparison of the differences in the results for the two points. The results indicate, among other things, that time spent cycling 'in mixed traffic' is more onerous than time spent cycling on 'bike lanes' or 'bike paths'; that secure parking is more important than showers at the destination; that cycling times on roadways tend to become less onerous as level of experience increases; and that the indications are broadly very stable across the two samples collected at different points in time separated by 11 years. Some of these results are novel and others are consistent with findings regarding bicycle use in work done by others, which is seen to add credence to the approach being used here

Key Words

cycling; bicycle route choice; stated preference; logit choice modelling; temporal stability of sensitivities

Introduction

Forecasting with models requires assumptions about the stability of the model parameter values in the future. This assumption almost always goes untested.

The intention in the work reported here is to examine the extent of the changes in certain model parameters over time. The opportunity to conduct such an examination arose with the application of the same stated preference experiment with the same survey instrument in both 1994 and 2005, in the development and updating of travel demand models incorporating representation of the nature of various influences on bicycle use in Edmonton in Canada. With the same instrument used in both cases, some of the sources of distortion in such a comparison are removed, allowing for somewhat less qualified findings to be obtained.

In the fall of 1994, a total of 1128 stated preference questionnaires were completed and returned. In the fall of 2005, a total of 473 were completed and returned. Each questionnaire presented a pair of possible bicycle use alternatives to a current cyclist and asked the cyclist to indicate which alternative was preferred for travel to a hypothetical all-day meeting. Alternatives were described by specifying the amounts of time spent on three different types of cycling facility and whether or not showers and/or secure bicycle parking were available at the destination. This forced the respondent to trade off among conditions regarding these attributes. Indications of socio-economic character and levels of experience and comfort regarding cycling were also collected, although some of the questions posed in 1994 were not posed again in 2005. The stated preference components in 1994 and 2005 were identical, the only differences concerned the omission of questions seeking household income and bicycle purchase cost in 2005.

This paper presents, in order:

- Review of previous work concerning cycling choice behaviour, with a focus on route choice behaviour;
- Description of the method used in this work, including the design and implementation of the data collection and the modelling framework and associated estimation framework;
- Presentation of the estimation results and discussion of the implications of these results; and
- Offering of some conclusions arising from the work.

Review of Previous Work

Previous work on factors affecting bicycle use and bicycle route choice behaviour in particular is reviewed below in order to outline its influence on the selection of factors to consider in this work in particular.

Factors having influence on bicycle use

A wide range of factors have been identified as having an influence on bicycle use in previous studies. Table 1 (included at the end of the paper)) summarizes these factors along with indicating the corresponding sources. The list in Table 1 draws only from studies with a direct focus on cycling behaviour where some form of empirical approach was used in analysis or verification.

The type of cycling facility and the nature of the shared roadway and the vehicle traffic using it seem to have received the most attention, leading to their more frequent identification as behavioural influences. Three broad categories of cycling facility that influence preferences are:

- 'in mixed traffic', where cyclists share the full roadway with other traffic without any longitudinal separation;
- 'bike lane', where cyclists use the roadway with other traffic but have a separate lane that is longitudinally separated from the other traffic lanes and is exclusively for cyclists; and
- 'bike path', a separate facility that is typically much narrower than a roadway that cyclists use exclusively or share with other non-motorised traffic.

Some work has been done developing and supporting the idea that there are different types of cyclists with different perceptions and preferences regarding different types of facilities and treatments (Axhausen and Smith 1986; Epperson *et al* 1995; Forester 1986; Sorton and Walsh 1994). Income, age, level of cycling experience and trip purpose have all been proposed as the basis for categorisations intended to capture these differences.

Cycling safety – real or perceived – is an emotional issue that has received considerable attention in the literature (Forester 1986; Wilkerson *et al* 1992). Various opinions and positions regarding both the influence of different factors on real and perceived safety and the accuracy of generally-held perceptions about safety have been forcefully argued. One particular 'lightning-rod' has been the relative accuracies of perceptions regarding safety across different levels of cycling experience and training. Some contend that cycling on 'bike paths' and 'bike lanes' is actually less safe in general than cycling 'in mixed traffic' – at least for cyclists who understand basic driving rules and practice so-called 'effective cycling' – which contradicts conventional perceptions (Forester 1986; St Jacques and DeRobertis 1995). The influence of safety on cycling behaviour, either directly with regard to perceived conditions or via the factors that affect either actual or perceived safety, has also received some attention and been found to influence behaviour.

There has been little consideration of route length or the directness of the trip as influential factors. This is surprising given that time and directness are seen to play such pivotal roles in route choice behaviour for other modes (Ortúzar and Willumsen 1994). There has been very little evaluation of the tradeoffs that cyclists might be making between the relative directness and pleasantness of different routes. It is possible that efforts to make cycling safer or more pleasant would lead to longer trips and greater delays for both cyclists and motorists (Forester 1996). More importantly, if special accommodations are provided for cyclists at only some locations or parts of networks then at least some cyclists would have to go out of their way in order to enjoy these accommodations. It follows that an understanding of cyclist attitudes regarding tradeoffs between directness and pleasantness would help in the design and evaluation of cycling facilities. Notwithstanding, it should be noted that in some cases where trip length has been considered it has not emerged as an important and significant variable (Axhausen and Smith 1986; Aultman-Hall 1996).

There does not appear to have been any work examining the temporal stability of influences on cycling behaviour specifically.

Ramifications for this research

The potential importance and policy relevance of trip length, together with the lack of agreement regarding it in previous work led to it being selected as one of the factors to be considered in this work. Different cycling facilities and both showers and secure parking were also selected for consideration because of their policy relevance in Edmonton.

The 'in mixed traffic', 'bike lane' and 'bike path' categories for cycling facility were adopted in this work, in part to be consistent with previous work and with designations in Edmonton; but also because it was felt that more detailed categorisations would be too unwieldy given the survey method chosen.

Method

Components of the investigation method are described below, including the survey to collect SP observations of cycling influences and the specific modelling framework used together with the associated setup for estimation of both joint and separate model coefficients using datasets from different points in time.

Bicycle attributes and issues considered

It is important to keep the descriptions of alternatives in stated preference experiments relatively simple, otherwise some respondents may find the task too complicated and thus not try to be accurate (Bates 1988; McMillan et al, 1997). Accordingly, consideration was limited to those attributes and factors identified to be of specific interest in the light of the literature review. The result was a set of specific attributes as follows:

- time spent cycling on roads in mixed traffic: values selected randomly from 0 to 60 minutes, rounded to the nearest 5 minutes;

- time spent cycling on designated bike lanes on roads: values selected randomly from 0 to 60 minutes, rounded to the nearest 5 minutes;
- time spent cycling on bike paths shared with pedestrians: values selected randomly from 0 to 60 minutes, rounded to the nearest 5 minutes;
- availability of showers at destination; with 2 values considered: 'showers are available' and 'showers are not available'; and
- availability of secure parking for bicycles at destination; with 2 values considered: 'secure parking is available' and 'secure parking is not available'.

Descriptions of the hypothetical alternatives were developed by randomly selecting values for the attributes listed above (in all cases from uniform distributions) and combining these selected values into a bundle representing a complete bicycle use alternative. For a given alternative, first one of the three types of time was randomly selected for omission, so that the alternative would include only two types of time and thereby be somewhat less complicated. Then the value for the total travel time was selected and split randomly into the other two types of time, with a 60 minute maximum value for the total time. After that the values for the facility conditions regarding showers and secure parking were randomly selected as indicated. Thus, one alternative might be to cycle for 15 minutes on roadways in mixed traffic and 20 minutes on bike paths shared with pedestrians, with showers but no secure parking at the destination. Another might be 30 minutes on bike paths, with secure parking but no showers at the destination.

Survey instrument

In both surveys a self-completion, mail-back survey questionnaire form was prepared. It contained various questions about actual bicycle use and also presented the SP exercise.

The SP portion of the form occupied about half of one page of the form, including instructions and the presentations of two hypothetical alternatives. The instructions guided the respondent through the process, first setting the context by instructing the respondent to imagine that he or she was travelling from home to an all-day meeting by bicycle, then displaying a randomly selected pair of hypothetical bicycle use alternatives and asking the respondent to indicate which of these alternatives was preferred. An example of this SP portion of the form is provided in Figure 1.

The questionnaire form also contained questions about personal conditions and attitudes as follows:
- gender;
- age, using specified ranges;
- household income, using specified ranges – but only in 1994;
- bicycle purchase price – but only in 1994;
- level of experience with cycling in mixed traffic, using a Likhert Scale with a 'highly-moderately-moderately-highly' sequence of adjectives; and
- level of comfort with cycling in mixed traffic, using a Likhert Scale with a 'highly-moderately-moderately-highly' sequence of adjectives.

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In this section we would like you to play a small game that is designed to indicate how cyclists in Edmonton feel about certain aspects of cycling. Please imagine you have to make a trip by bicycle to an all-day meeting that you must attend. If you are employed, imagine that you must attend this meeting as part of your work responsibilities. Consider the following two options for the trip. They have conditions as indicated and are identical in all other aspects. Please check the box corresponding to the option you most prefer.

Option A: [__]		Option B [__]	
* showers for cyclists at destination	**yes**	* showers for cyclists at destination	**yes**
* secure bicycle parking at destination	**yes**	* secure bicycle parking at destination	**no**
* total cycling time:	**40 minutes**	* total cycling time:	**30 minutes**
which is made up of		which is made up of	
time on bike paths shared with pedestrians	**15 minutes**	time on bike paths shared with pedestrians	**20 minutes**
time on roadways shared with cars	**25 minutes**	time on roadways shared with cars	**10 minutes**

Figure 1: Two randomly generated hypothetical cycling options for a trip to an all-day meeting; respondents were asked to choose between two such options.

Data collection

Edmonton is the principal metropolitan centre in the central and northern portions of the Province of Alberta in Canada. In 1994 the population of the Edmonton metropolitan (Census) area was approximately 866,000 (Edmonton 1995). Edmonton has a connected network of designated bicycle routes and trails. In 1993 there were (Edmonton 1993):

- 47 kilometres of bicycle paths, for use by cyclists and pedestrians exclusively, called 'Class 1 Routes';
- 3 kilometres of bicycle lanes, where a longitudinal portion of a roadway is designated for use by cyclists exclusively, called 'Class 2 Routes'; and
- 96 kilometres of bicycle routes, where cyclists are provided with a signed route through the roadway network but share the road with motorized vehicles, called 'Class 3 Routes'.

In addition, there were at least 55 kilometres of multi-use recreational trails in the City river valley park system (Edmonton 1993).

In both surveys, questionnaire forms were handed to cyclists, left at cycling shops and attached to parked bicycles throughout the Edmonton area. In 1994, after the removal of unusable and inconsistent forms, the result was a data set of stated preference choice observations for a corresponding sample of 1128 individual cyclists. In 2005, with a more modest initial distribution, the result was a similar data set of stated preference choice observations for a sample of 473 individual cyclists. These two datasets were used to estimate the coefficients in different utility functions.

Modelling and associated estimation framework

The logit model has the following form for the choice situation concerning two hypothetical bicycle use alternatives as considered in this research:

$$P_a = \exp(\lambda U_a) / (\exp(\lambda U_a) + \exp(\lambda U_b))$$

where:

P_a	=	probability that bicycle use alternative a is preferred;
U_a	=	utility value associated with bicycle use alternative a;
U_b	=	utility value associated with bicycle use alternative b; and
λ	=	dispersion parameter.

The utility function that ascribes utility values to the bicycle use alternatives has the following general, linear form:

$$U_i = \phi_1 * X_{1i} + \phi_2 * X_{2i} + ... + \phi_n * X_{ni} + ...$$

where:

n	=	index representing attributes
X_{ni}	=	value of attribute n for alternative i
ϕ_n	=	utility function coefficient associated with attribute n.

In the estimation of the utility function coefficients using empirical data, the dispersion parameter, λ, is effectively factored in with the utility expression. The result is that the utility function considered is:

$$\lambda U_i = \lambda\phi_1 * X_{1i} + \lambda\phi_2 * X_{2i} + ... + \lambda\phi_n * X_{ni} + ...$$

The implication is that values of the estimated coefficients include the dispersion parameter and thus are $\lambda\phi_1$, $\lambda\phi_2$, … , $\lambda\phi_n$ and not simply ϕ_1, ϕ_2, … , ϕ_n. The estimation process cannot discern the specific value of λ separate from the utility function coefficients and it is the values of the utility function coefficients factored by λ that are reported in the results. However, it is possible to obtain indications of the relative values of λ in different but related choice situations. This is done here for the relative values of λ for the two sets of observations, one collected in 1994 and the other collected in 2005, with these two λ denoted λ_{1994} and λ_{2005} respectively.

The utility function coefficients for the two sets of observations are estimated simultaneously, with both joint and separate coefficients included, facilitating a more complete comparison. This is done using a nested logit configuration as shown in Figure 2. For each individual observation only one branch or the other is available, corresponding to the year of the observation. But certain coefficients are the same across branches.

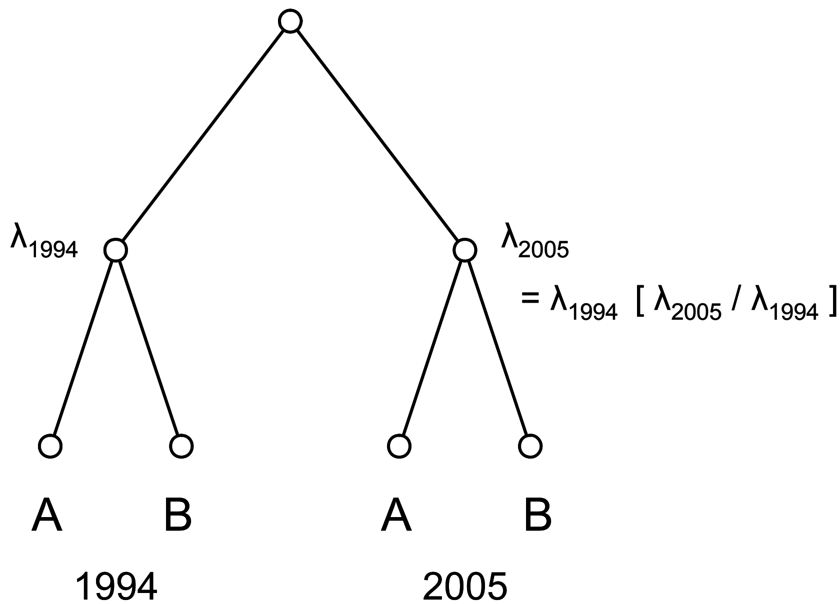

Figure 2: Nested logit model structure for simultaneous estimation of utility function coefficients for 1994 and 2005 observations.

The general forms for the utility functions for the four alternatives are:

$$U_{a1994} = \Sigma_{n\varepsilon N1}\phi_{n,joint}*X_{n,a1994} + \Sigma_{n\varepsilon N2}\phi_{n,1994}*X_{n,a1994} + \Sigma_{n\varepsilon N3}(\phi_{n,1994})*X_{n,a1994}$$
$$U_{b1994} = \Sigma_{n\varepsilon N1}\phi_{n,joint}*X_{n,b1994} + \Sigma_{n\varepsilon N2}\phi_{n,1994}*X_{n,b1994} + \Sigma_{n\varepsilon N3}(\phi_{n,1994})*X_{n,b1994}$$
$$U_{a2005} = \Sigma_{n\varepsilon N1}\phi_{n,joint}*X_{n,a2005} + \Sigma_{n\varepsilon N2}\phi_{n,2005}*X_{n,a2005} + \Sigma_{n\varepsilon N3}(\phi_{n,1994} + \phi_{n,\Delta 1994-2005})*X_{n,a2005}$$
$$U_{b2005} = \Sigma_{n\varepsilon N1}\phi_{n,joint}*X_{n,b2005} + \Sigma_{n\varepsilon N2}\phi_{n,2005}*X_{n,b2005} + \Sigma_{n\varepsilon N3}(\phi_{n,1994} + \phi_{n,\Delta 1994-2005})*X_{n,b2005}$$

where:

n = index representing attributes;
U_{a1994} = utility value associated with bicycle use alternative a in the 1994 observations;
U_{b1994} = utility value associated with bicycle use alternative b in the 1994 observations;
U_{a2005} = utility value associated with bicycle use alternative a in the 2005 observations;
U_{b2005} = utility value associated with bicycle use alternative b in the 2005 observations;
$X_{n,a1994}$ = value of attribute n for alternative a in the 1994 observations;
$X_{n,b1994}$ = value of attribute n for alternative b in the 1994 observations;
$X_{n,a2005}$ = value of attribute n for alternative a in the 2005 observations;
$X_{n,a2005}$ = value of attribute n for alternative b in the 2005 observations;
X_{ni} = value of attribute n for alternative I;
$\phi_{n,joint}$ = utility function coefficient associated with attribute n joint for the 1994 and the 2005 observations;
$\phi_{n,1994}$ = utility function coefficient associated with attribute n for the 1994 observations only;
$\phi_{n,2005}$ = utility function coefficient associated with attribute n for the 2005 observations only;
$\phi_{n,,\Delta 1994-2005}$ = additional component of utility function coefficient associated with attribute n for 2005 observations relative to the 1994 observations.

N1 = set of attributes that share the same utility function coefficients across the years of observation;
N2 = set of attributes that have different utility function coefficients across the years of observation; and
N3 = sets of attributes that share a component of the same utility function coefficient across the years of observation (notionally for 1994) and then have an additional different component of the utility function coefficient (notionally for 2005).

The above equations show the different group of terms with utility function coefficients, some the same and some different across the years of observation. The third group of terms, for the N3 set of attributes, facilitates a statistical test of the significance of the difference in sensitivity between 1994 and 2005: by considering the significance of the difference from 0 of the additional different component of the utility function coefficient (for 2005) in a given instance.

With the dispersion parameters included the models are:

for 1994:

$$Pa1994 = \exp(\lambda_{1994}Ua1994) / (\exp(\lambda_{1994}Ua1994) + \exp(\lambda_{1994}Ub1994))$$

where:

Pa1994 = probability that bicycle use alternative a is preferred in a 1994 observation;

and for 2005:

$$Pa2005 = \exp(\lambda_{2005}Ua2005) / (\exp(\lambda_{2005}Ua2005) + \exp(\lambda_{2005}Ub2005))$$

where:

Pa2005 = probability that bicycle use alternative a is preferred in a 2005 observation.

With this setup as it is shown in Figure 2, it is the dispersion parameter λ_{1994} that is effectively factored in with the utility expressions for both 1994 and 2005, along with an additional ratio term $\lambda_{2005} / \lambda_{1994}$ that is also factored in with the utility expressions for 2005. As a result, the model for 2005 is actually:

$$Pa2005 = \exp(\lambda_{1994}[\lambda_{2005} / \lambda_{1994}]Ua2005) / (\exp(\lambda_{1994}[\lambda_{2005} / \lambda_{1994}]Ua2005) + \exp(\lambda_{1994}[\lambda_{2005} / \lambda_{1994}]Ub2005))$$

where:

With this setup, the estimation process can provide a value for the ratio term $\lambda_{2005} / \lambda_{1994}$ along with values of the utility function coefficients, in this case all factored by λ_{1994}. Thus, a value for λ_{1994} cannot be established, but a value for $\lambda_{2005} / \lambda_{1994}$ can be established – and used in the comparison of the estimates arising from the two datasets.

The nested logit model and the estimation of the coefficients in the utility function using empirical data are well-known. See Ben-Akiva and Lerman (1985) for a more general review of the method, issues and interpretation of results with logit choice modelling as used here and Bradley and Kroes (1990), Bradley and Daly (1992), and Morikawa (1994) for more specific descriptions of the use of the nested logit structure with different sets of observations.

Results

Various alternate utility functions were considered using different combinations of function coefficients, including ones that are the same and ones that are different across the 1994 and 2005 datasets.

The definitions of these coefficients are provided in Table 2.

Table 2: Definitions of utility function coefficients used in presented results

Coefficient	**Definition**
Road	sensitivity to minutes riding on roadways in mixed traffic for 1994 and 2005 jointly
Lane	sensitivity to minutes riding on designated bike lanes on roadways for 1994 and 2005 jointly
path	sensitivity to minutes riding on bike paths shared with pedestrians for 1994 and 2005 jointly
showers	sensitivity to availability of showers at destination for 1994 and 2005 jointly
parking	sensitivity to availability of secure parking for bicycles at destination for 1994 and 2005 jointly
ASCforB	alternative specific constant for the B option for 1994 and 2005 jointly
$road_{1994}$	sensitivity to minutes riding on roadways in mixed traffic for 1994 only
$lane_{1994}$	sensitivity to minutes riding on designated bike lanes on roadways for 1994 only
$path_{1994}$	sensitivity to minutes riding on bike paths shared with pedestrians for 1994 only
$showers_{1994}$	sensitivity to availability of showers at destination for 1994 only
$parking_{1994}$	sensitivity to availability of secure parking for bicycles at destination for 1994 only
$ASCforB_{1994}$	alternative specific constant for the B option for 1994 only
$road_{2005}$	sensitivity to minutes riding on roadways in mixed traffic for 2005 only
$lane_{2005}$	sensitivity to minutes riding on designated bike lanes on roadways for 2005 only
$path_{2005}$	sensitivity to minutes riding on bike paths shared with pedestrians for 2005 only
$showers_{2005}$	sensitivity to availability of showers at destination for 2005 only
$parking_{2005}$	sensitivity to availability of secure parking for bicycles at destination for 2005 only
$ASCforB_{2005}$	alternative specific constant for the B option for 2005 only
$road\Delta_{1994\text{-}2005}$	additional sensitivity to minutes riding on roadways in mixed traffic for 2005 relative to that for 1994
$lane\Delta_{1994\text{-}2005}$	additional sensitivity to minutes riding on designated bike lanes on roadways for 2005 relative to that for 1994
$path\Delta_{1994\text{-}2005}$	additional sensitivity to minutes riding on bike paths shared with pedestrians for 2005 relative to that for 1994
$showers\Delta_{1994\text{-}2005}$	additional sensitivity to availability of showers at destination for 2005 relative to that for 1994
$parking\Delta_{1994\text{-}2005}$	additional sensitivity to availability of secure parking for bicycles at destination for 2005 relative to that for 1994
$ASCforB\Delta_{1994\text{-}2005}$	additional alternative specific constant for the B option for 2005 relative to that for 1994
$\lambda_{2005} / \lambda_{1994}$	ratio of dispersion parameter for 2005 over dispersion parameter for 1994

The estimation results for a selection of some of these utility functions are displayed in Tables 3, 4 and 5. These results are discussed below.

Results for 1994 and 2005 datasets separately

The estimation results for utility functions considering just the 1994 or the 2005 sensitivities separately are shown in Table 3.

Table 3: Estimation results for 1994 and 2005 datasets separately

Set-Up:	**1994-1**	**1994-2**	**2005-1**	**2005-2**
Estimated Coefficients				
attribute or coefficient	*value (|t-ratio|)*	*value (|t-ratio|)*	*Value (|t-ratio|)*	*value (|t-ratio|)*
$road_{1994}$	-0.05507 (10.4)	-0.05501 (10.4)		
$lane_{1994}$	-0.01347 (3.1)	-0.01374 (3.1)		
$path_{1994}$	-0.01952 (4.5)	-0.01966 (4.5)		
$showers_{1994}$	0.19673 (2.1)	0.20236 (2.1)		
$parking_{1994}$	1.45943 (13.6)	1.45702 (13.5)		
$ASCforB_{1994}$		-0.13425 (1.9)		
$road_{2005}$			-0.07371 (7.7)	-0.07361 (7.7)
$lane_{2005}$			-0.01113 (1.8)	-0.01112 (1.8)
$path_{2005}$			-0.01575 (2.5)	-0.01583 (2.5)
$showers_{2005}$			0.37091 (2.5)	0.37726 (2.6)
$parking_{2005}$			0.97581 (6.4)	0.98042 (6.4)
$ASCforB_{2005}$				-0.08065 (0.8)
Goodness of Fit Statistics				
Number of observations	1128	1128	473	473
Number of parameters	5	6	5	6
Ln-Likelihood(0)	-781.8700	-781.8700	-327.8586	-327.8586
Ln-Likelihood(*)	-620.2747	-618.3946	-272.3956	-272.0938
$\rho^2_{(0)}$	0.2067	0.2091	0.1692	0.1701
Akakie Information Index	0.2003	0.2014	0.1539	0.1518

All of the individual coefficient estimates in these functions considered in Table 3 have high t-ratios, except for the alternative specific constant for option B and this particularly for 2005. This indicates that all of the considered influences are 'significant' (in a statistical sense) and that there was not a substantial bias associated with the order in which the options were presented in either year, perhaps moreso for 2005 than for 1994.

In these results, the coefficients for the road, lane and path components all appear to be fairly stable in the switch from 1994 to 2005. The values for road show an increasing sensitivity and the values for lane and path show decreasing sensitivities, but these all seem to be fairly modest changes. The changes for showers and parking appear to be much more substantial. The coefficient for showers almost doubles and the coefficient for parking drops by a third, in both cases these changes involving large absolute amounts.

However, these comparisons suffer from a lack of indication of the influence of the difference in dispersion parameters from 1994 to 2005, which is unavailable with these separate estimations. They also suffer from a lack of statistical consideration of the estimator variances involved. All this acts to reduce the strength of any findings regarding the changes in sensitivities from 1994 to 2005 arising from these results – and leads to the more complete consideration of simultaneously estimated coefficients described below.

Results for 1994 and 2005 datasets simultaneously with joint coefficients

The estimation results for utility functions considering the 1994 and the 2005 sensitivities simultaneously with various sets of joint coefficients are shown in Table 4.

Table 4: Estimation results for utility functions with joint coefficients

Set-Up:	**1**	**2**	**3**	**4**
Estimated Coefficients				
attribute or coefficient	*value (|t-ratio|)*	*value (|t-ratio|)*	*Value (|t-ratio|)*	*value (|t-ratio|)*
road	-0.05943 (13.0)	-0.06104 (12.3)	-0.06096 (12.2)	-0.06098 (12.3)
lane	-0.01239 (3.5)	-0.01291 (3.4)	-0.01307 (3.5)	-0.01288 (3.4)
path	-0.01806 (5.0)	-0.01889 (5.0)	-0.01899 (5.0)	-0.01890 (5.0)
showers	0.22942 (2.9)	0.23525 (2.9)	0.24210 (2.9)	0.23724 (2.9)
parking	1.29269 (14.9)	1.35628 (12.5)	1.35558 (12.5)	1.35755 (12.5)
ASCforB			-0.12757 (2.1)	
$road_{1994}$				
$lane_{1994}$				
$path_{1994}$				
$showers_{1994}$				
$parking_{1994}$				
$ASCforB_{1994}$				
$road\Delta_{1994-2005}$				
$lane\Delta_{1994-2005}$				
$path\Delta_{1994-2005}$				
$showers\Delta_{1994-2005}$				
$parking\Delta_{1994-2005}$				
$ASCforB\Delta_{1994-2005}$				-0.10674 (0.9)
$\lambda_{2005} / \lambda_{1994}$	1 (-)	0.86898 (7.1)	0.87030 (7.1)	0.87030 (7.1)
Goodness of Fit Statistics				
Number of observations	1601	1601	1601	1601
Number of parameters	5	6	7	7
Ln-Likelihood(0)	-1109.7286	-1109.7286	-1109.7286	-1109.7286
Ln-Likelihood(*)	-902.0627	-901.5458	-899.2498	-901.1335
$\rho^2_{(0)}$	0.1871	0.1876	0.1897	0.1880
Akakie Information Index	0.1826	0.1822	0.1834	0.1817

Again, all of the individual coefficient estimates in these functions considered in Table 4 have high t-ratios, in this case including the alternative specific constant for option B when estimated jointly for 1994 and 2005 but still excluding the alternative specific constant for option B when estimated separately for just 2005. This indicates that all of the considered influences are 'significant' (in a statistical sense) and that there may have been some reasonable degree of bias arising with the order of presentation of the options – with the negative value for the constant for option B indicating a tendency to select option A (the one on the left). The implication is that an alternative specific constant (such as the one for option B) should be included in the utility functions in order to take this degree of bias into account in the analysis. But because this result does not remain strong for the 2005 data, the implication is that it is also reasonable to consider utility functions without the constant as part of a larger analysis.

The value of ratio of the dispersion parameters $\lambda_{2005} / \lambda_{1994}$ is held fixed at 1 in Set-up 1, and is estimated with the other coefficients in each of Set-ups 2, 3 and 4. The estimated value remains at about 0.87 in all cases. The implications are that there is a comparatively higher variance in the error terms for the 2005 data (this variance is inversely proportional to the dispersion parameter λ (Ben Akiva and Lerman 1985)) and that the associated sensitivities are not as well represented for 2005. This is consistent with the somewhat lower values for the $\rho^2_{(0)}$ and the Akakie Information Index goodness-of-fit measures obtained for the 2005 data compared to the 1994 data when considered separately as shown in Table 3. However, the estimated value for the ratio of the dispersion parameters is not highly significantly different from 1 (the value associated with the null hypothesis that the dispersion parameters are not different) so the indication regarding the difference in the error term variance is not a strong one.

The estimated values for all of the sensitivities change slightly in going from Set-up 1 to Set-up 2, this occurring with the release of the ratio of the dispersion parameters $\lambda_{2005} / \lambda_{1994}$ to be estimated by the data. The modest degree of change here is consistent with the estimated value for $\lambda_{2005} / \lambda_{1994}$ not being highly significantly different from 1.

Results for 1994 and 2005 datasets simultaneously with coefficients for 1994 and for the addition for 2005 relative to 1994

The estimation results for utility functions considering the 1994 and the 2005 sensitivities simultaneously with various sets of coefficients specific to 1994 and to the change in going from 1994 to 2005 are shown in Table 5.

All of the individual coefficient estimates for the 1994 data in these functions considered in Table 5 have high t-ratios, including the alternative specific constant for option B.

Table 5: Estimation results for utility functions with coefficients specific to 1994 and coefficients for additional sensitivity components for 2005 relative to those for 1994

Set-Up:	**5**	**6**	**7**	**8**
Estimated Coefficients				
attribute or coefficient	*value (|t-ratio|)*	*value (|t-ratio|)*	*Value (|t-ratio|)*	*value (|t-ratio|)*
road				
lane				
path				
showers				
parking				
ASCforB		-0.11779 (2.0)		-0.13433 (2.0)
$road_{1994}$	-0.05507 (10.4)	-0.05500 (10.4)	-0.05501 (10.4)	-0.05501 (10.4)
$lane_{1994}$	-0.01347 (3.1)	-0.01370 (3.1)	-0.01374 (3.1)	-0.01374 (3.1)
$path_{1994}$	-0.01952 (4.5)	-0.01964 (4.5)	-0.01966 (4.5)	-0.01966 (4.5)
$showers_{1994}$	0.19673 (2.1)	0.20160 (2.1)	0.20263 (2.1)	0.20237 (2.1)
$parking_{1994}$	1.45943 (13.6)	1.45673 (13.5)	1.45702 (13.5)	1.45702 (13.5)
$ASCforB_{1994}$			-0.13425 (1.9)	
$road\Delta_{1994-2005}$	-0.01871 (1.7)	-0.01870 (1.7)	-0.01867 (1.7)	-0.06799 (0.4)
$lane\Delta_{1994-2005}$	0.00233 (0.3)	0.00256 (0.3)	0.00261 (0.3)	-0.00485 (0.2)
$path\Delta_{1994-2005}$	0.00377 (0.5)	0.00374 (0.5)	0.00381 (0.5)	-0.00679 (0.2)
$showers\Delta_{1994-2005}$	0.17438 (1.0)	0.17916 (1.0)	0.17512 (1.0)	0.42797 (0.5)
$parking\Delta_{1994-2005}$	-0.48308 (2.6)	-0.47272 (2.5)	-0.47604 (2.5)	0.18063 (0.1)
$ASCforB\Delta_{1994-2005}$			0.05356 (0.4)	
$\lambda_{2005} / \lambda_{1994}$	1 (-)	1 (-)	1 (-)	0.59873 (0.8)
Goodness of Fit Statistics				
Number of observations	1601	1601	1601	1601
Number of parameters	10	11	12	12
Ln-Likelihood(0)	-1109.7286	-1109.7286	-1109.7286	-1109.7286
Ln-Likelihood(*)	-892.6702	-890.5803	-890.4884	-890.4884
$\rho^2_{(0)}$	0.1956	0.1975	0.1976	0.1976
Akakie Information Index	0.1826	0.1876	0.1867	0.1867

The estimates for the 1994 to 2005 increments (sometimes negative) provide direct indications of the differences between the 1994 and 2005 sensitivities. In many cases these values are not significantly different from 0. The implication is that in these cases the values for the 2005 data are not significantly different from the corresponding values for the 1994 data. In particular, the sensitivities for land, path and showers are all indicated to be not significantly different in 2005 than in 1994. In the results for Set-ups 5, 6 and 7, the value for the road coefficient – concerning the sensitivity to time spent in mixed traffic – shows a fairly significant change from 1994 to 2005: in these cases the coefficient becomes more negative, indicating an increasing adverse sensitivity to time spent cycling in mixed traffic, with a fairly strong t-ratio of 1.7 in all three cases. The value for the parking coefficient also shows a fairly significant change from 1994 to 2005 in the results for Set-ups 5, 6 and 7: the coefficient becomes more negative, this time indicating a decreasing positive sensitivity to the availability of secure parking, with a strong t-ratio of around 2.5 in all three cases.

In Set-up 8, the last shown, the value of ratio of the dispersion parameters $\lambda_{2005} / \lambda_{1994}$ is estimated rather than held fixed at 1 (as it is in Set-ups 5, 6 and 7). The estimated value of approximately 0.6 is not too far from the value of about 0.87 obtained when considering just joint coefficients (in Set-ups 2, 3 and 4). But the corresponding t-ratio is only 0.8, indicating a comparatively low level of confidence in the estimated value is appropriate. The t-ratios for all of the other estimates for the 1994 to 2005 increments are even lower. The overall indication is that the data set of 2005 observations may not be sufficient to support the estimation of Set-up 8.

Conclusions

The work reported here has demonstrated the feasibility of using stated preference surveys with the same instrument at two distinct points to examine the temporal stability of certain choice sensitivities in the form of utility function coefficients. The simultaneous estimation capabilities with the nested logit structure allow more formal statistical testing of the significance of changes in coefficients along with taking into account differences in error structures for the data obtained at the different points in time.

For the specific context considered here – the stability of sensitivities to certain specific factors influencing bicycle route choice between 1994 and 2005 – the indications provided by the work are somewhat mixed. Some of the coefficients did not change significantly from 1994 to 2005, including the ones for time spent cycling in designated bike lanes, time spent cycling on bike paths and the availability of showers at the destination, suggesting that the sensitivities to these have not changed. Others of the coefficients did change significantly (or fairly significantly) from 1994 to 2005, including the ones for time spent cycling in mixed traffic (which showed a fairly significant shift to a more onerous negative sensitivity) and the availability of secure parking for bicycles at the destination (which showed a significant reduction in the positive sensitivity.

A couple of important caveats need to be stated with regard to these results.

First, there is no indication provided regarding the changes occurring in the intervening time between 1994 and 2005. The results are silent regarding whether the changes that did occur were even or whether there were greater swings well beyond the differences arising for the 1994 and 2005 points in particular.

Second, there was no direct adjustment or control applied in the analysis to take into account difference in the samples from the two time period with regard to personal characteristics. Other work done with the 1994 data has shown that there are tendencies for certain sensitivities, including those concerning the availability of showers and the availability of secure parking, to vary with income and bicycle purchase price. It was not possible to adjust for these tendencies in the analysis done here because the income and bicycle purchase price questions were omitted from the survey done in 2005. It may be possible to expand both samples using population age and gender distributions in order to partly control for the differences in personal characteristics, but this is left to future work. Thus, most formally, the differences considered here directly concern only the two samples considered rather than the corresponding populations of cyclists in 1994 and 2005 in Edmonton. It is expected that these two samples are reasonably representative in each case, so there should be some confidence placed in the indications obtained here, but with some reservations.

In addition, it became apparent as the work progressed that the data for 2005 in particular could not support some of the desired analysis – as in Set-up 8. The available sample of 473 observations was not large enough.

In the light of the insufficiency of the 2005 dataset, in terms of both sample size and the omitted questions regarding income and bicycle purchase price, it is the intention that additional survey be conducted in 2006 with the required questions restored.

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Table 1: Summary of factors that have been identified as influences on cycling behaviour and cycle route choice in particular, together with references where these factors are identified

Factor	References
Facility Characteristics	
type of cycling facility (whether mixed with traffic, bike lane, or bike path)	Antonakos 1994; Aultman-Hall 1996; Axhausen and Smith 1986; Bradley and Bovy 1984; Calgary 1993; Copley and Pelz 1995; Goldsmith 1996; Guttenplan and Patten 1995; Harris and Associates 1991; Kroll and Ramey 1997; Kroll and Sommer 1976; Landis and Vattikuti 1996; Lott *et al* 1978; Mars and Kyriakides 1986; Nelson and Allen 1997; Sacks 1994; Taylor and Mahmassani 1997
nature of shared roadway, including road class, sight distances, turning radii, lane/median configurations	Aultman-Hall 1996; Calgary 1993; Copley and Pelz 1995; Davis 1995; Denver 1993; Epperson 1994; Landis and Vattikuti 1996; Mars and Kyriakides 1986; Shepherd 1994; Sorton 1995; Sorton and Walsh 1994;
existence of on-street parking	Davis 1995; Epperson 1994; Mars and Kyriakides 1986
pavement surface type and/or quality	Antonakos 1994; Axhausen and Smith 1986; Bradley and Bovy 1984; Davis 1995; Epperson 1994; Landis and Vattikuti 1996
grades	Antonakos 1994; Axhausen and Smith 1986; Davis 1995
intersection spacing and/or configuration	Aultman-Hall 1996; Davis 1995; Epperson 1994; Teichgraeber 1982

Table 1 continued:

cycling treatments at signals, including timing and loop detection	Copley and Pelz 1995
completeness and directness of cycling infrastructure	Ambrosius 1984; Copley and Pelz 1995; Sacks 1994
availability of showers at origin and/or destination	Guttenplan and Patten 1995; Sacks 1994; Taylor and Mahmassani 1997
availability of secure parking for bicycle at origin and/or destination	Calgary 1993; Copley and Pelz 1995; Denver 1993; Guttenplan and Patten 1995; Mars and Kyriakides 1986; Sacks 1994; Taylor and Mahmassani 1997; Wynne 1992
Non-Cycle Traffic Characteristics	
motor vehicle speeds and driver behaviour	Antonakos 1994; Davis 1995; Epperson 1994; Landis and Vattikuti 1996; Mars and Kyriakides 1986; Sorton 1995; Sorton and Walsh 1994
volume or mix of motor vehicle types, including proportion trucks	Antonakos 1994; Axhausen and Smith 1986; Bradley and Bovy 1984; Calgary 1993; Davis 1995; Epperson 1994; Landis and Vattikuti 1996; Mars and Kyriakides 1986; Sorton 1995; Sorton and Walsh 1994
pedestrian interaction	Mars and Kyriakides 1986

Table 1 continued:

Individual and Trip Characteristics

gender	Antonakos 1994; Aultman-Hall 1996; Sacks 1994; Taylor and Mahmassani 1997
age	Antonakos 1994; Aultman-Hall 1996; Sacks 1994; Taylor and Mahmassani 1997; Treadgold 1996
income	Taylor and Mahmassani 1997
level of cycling experience	Antonakos 1994; Axhausen and Smith 1986; Sorton and Walsh 1994
private vehicle ownership	Sacks 1994
concerns about safety	Antonakos 1994; Kroll and Ramey 1997; Kroll and Sommer 1976; Lott *et al* 1978; Mars and Kyriakides 1986
concerns about personal security	Sacks 1994
flexibility of work hours	Denver 1993; Sacks 1994
type of bicycle (whether road bike or mountain bike)	Antonakos 1994; Taylor and Mahmassani 1997
bicycle purchase price	Parajuli 1996; Parajuli *et al* 1996
trip length, by time or distance	Bradley and Bovy 1984; Calgary 1993; Guttenplan and Patten 1995; Parajuli 1996; Parajuli *et al* 1996;

Table 1 continued:

Environment/Situation Characteristics

weather	Calgary 1993
sweeping/snowplowing	Copley and Pelz 1995
nature of abutting land uses	Axhausen and Smith 1986; Davis 1995; Epperson 1994; Landis and Vattikuti 1996
aesthetics along route	Antonakos 1994; Sacks 1994
degree of political and public support for cycling	Clarke 1992; Copley and Pelz 1995; Wynne 1992
level of public assistance for cyclists, including maps, route advice and emergency aid	Denver 1993
education and enforcement regarding cycling	Antonakos 1994; Denver 1993; Wynne 1992
availability of public transport	Denver 1993; Wynne 1992
cost and other disincentives to use other modes	Moritz 1997; Sacks 1994; Taylor and Mahmassani 1997; Wynne 1992