Investigation of Cycling Sensitivities

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Abstract

This paper describes the design and implementation of an innovative stated preference survey for cyclists, undertaken to quantify attitudes and references, together with selected results.

The City of Calgary is upgrading its travel forecasting model. Planned improvements include the explicit inclusion of non-motorized modes, walk and bicycle, for all trip purposes. A scheduled traditional household-based activity survey was not expected to give sufficient numbers or detail about the revealed choices made by cyclists, who represent only a small proportion of all trips made for personal travel on a typical fall day. Additional data was needed to provide information, in a quantitative manner, on the existing attitudes and preferences of cyclists, particularly in relation to route choice and facility use.

Cyclists were asked to imagine making a particular bicycle trip for a specified purpose, length of the activity, familiarity with the destination and outside temperature. For this trip three different randomly generated cycling options were described, in terms of travel times on different types of cycling facilities (roadways and pathways), and type and price of facilities available at the destination.

Respondents were asked to rank their unique set of options in order of preference. The resulting respondent rankings were analysed with a logit model, which establishes a utility function measuring the attractiveness of a cycling option based on its characteristics.

Results show the relative values of different types of cycling facilities and trip destination facilities. Cyclists are attracted to shorter journeys, but are also willing to travel substantially further to ride on specific types of routes; and / or to destinations with specific destination facilities. Numerical measures of the influence of each facility type in the overall attractiveness of cycling are given. Their relevance in the design, implementation and calibration of transportation demand simulation models is also discussed.

Introduction

The City of Calgary, as part of its transportation planning model update, undertook a survey to understand cyclists' preferences for different types of infrastructure. The primary purpose of the survey was to understand cycling route choice preferences so that a computer simulation model can:

- assign cyclists to routes,
- calculate the attractiveness of cycling between various places,
- predict the number of cyclists,
- measure the influence of cycling on accessibility in general, and
- provide an understanding of the overall influence of cycling on the entire multimodal transportation and land-use system.

To represent other modes in travel demand models, specific parameters are usually estimated from a home interview survey of travel behaviour. These data describe the travel choices people have made, and the computer representation of the transportation system is used to describe the attributes of their chosen option and also to enumerate and describe some (or all) of the available but unchosen options. The resulting dataset describes a rich variety of choices suitable for analysis. For cycling, this procedure does not provide as rich of a dataset. Cycling usually consists of a smaller number of trips and a lower proportion of longer trips than either driving or transit. This reduces the number of observed zone-pairs for which trips are observed and makes it more difficult to extract the reasons cyclists choose to make the trips they do. Further, this estimation procedure requires a computer representation of the network of facilities available to cyclists. The less developed understanding as to what is important to cyclists means there is less consensus as to how to create the computer representation of cyclists' facilities required for such estimation. An initial understanding of cyclists' relative preference for different facilities can guide the decisions on *how* to code a cycling network, and whether it is important to distinguish between different types of facilities in the computer abstraction of the physical system available for cyclists.

A Stated Preference Survey measures preferences by asking respondents to make hypothetical choices. A hypothetical situation is described with a number of options, and respondents are asked to indicate which option they would choose. The options are described in terms of a number of attributes, each of which are thought to contribute to the overall attractiveness of the option. The attributes can be varied approximately independently, to avoid correlations that cause difficulty when analyzing observations of choices in real situations. The range of options can thus reflect a wide variety of potential future situations, including situations that currently do not exist (at all or in substantial quantity) because of policy consistency and historical demand and supply. The hypothetical nature of the options makes it unnecessary to measure current situations, reducing the cost of data collection substantially.

Responses from a stated preference survey can be analysed together with observations of actual behaviour. Prior studies that have shown the value of such joint analysis have also shown that the relative marginal values of specific attributes that are established by analysing stated preference data alone are rarely contradicted when stated preference data are analysed together with observations of actual behaviour.

This paper describes a Stated Preference survey of cyclists in Calgary that was designed to help understand cyclists' preferences for modelling purposes. The survey results are a preliminary input into the modelling process, but also provide particular insight into how important various facilities are to different cyclists in different situations. This paper describes the survey, the influence of the survey results on the modelling process, and the relative marginal values of specific attributes.

Considerations in survey design

There has been a growing body of literature describing the preferences of cyclists. The range of approaches and findings are described by Hunt and Abraham, 2001. After reviewing the literature, Hunt and Abraham conducted a stated preference survey asking cyclists in Edmonton in 1994 to consider two hypothetical route options for a journey to an "all day meeting". The route options differed in terms of:

- time spent cycling on roads with mixed traffic,
- time spent cycling on designated bike lanes on roads,
- time spent cycling on bike paths shared with pedestrians,
- availability of showers at destination, and
- availability of secure parking at destination.

The Edmonton survey was extremely valuable in showing the importance of secure parking and the high value that cyclists place on designated cycling facilities. The survey allowed an objective submodel of the attractiveness of cycling to be included in the Edmonton Transport Analysis model. Particular results included:

- having "secure parking" available is as important as saving a cyclist 26.5 minutes "in mixed traffic", and
- if a dedicated linear facility ("bike lane" or "path") is provided then most cyclists will use that facility, even if it is up to 3 or 4 times slower than a more direct route on roads "in mixed traffic".

These results serve to illustrate that a specific model of the attractiveness of differing cycling facilities is necessary before a transportation demand model can be expected to reasonably predict the number of cycle journeys or the attractiveness of cycling in scenarios with differing cycling infrastructure.

The Edmonton survey provided insight regarding the average cyclist's attitudes to facilities, and showed how the impact of cycling facilities on future behaviour can be modelled. The survey results have been discussed at length, with many cyclists comparing the average values measured in the survey with their own route choice preferences. Because of this, new questions have arisen, including:

- Attitudes may vary with trip type. For example, it was suggested that the phrase "all day meeting" (used in the Edmonton survey) could imply time flexibility to some respondents.

- The strong preference for "secure parking" suggests that further work should be undertaken to understand how people value different types of bicycle parking facilities.
- The large differences in disutility associated with time spent cycling on different type of facilities suggests that further exploration is appropriate. A more comprehensive list of different facilities could further distinguish how the type of facility influences the attractiveness of cycling.
- Benefit analysis requires people's willingness to pay for facilities. Including an attribute with a money cost associated with it can provide a measure of willingness-to-pay.

Survey Design

The Calgary survey was designed to measure attitudes to cycling in Calgary, to allow the incorporation of the bicycle mode of travel in the Calgary Regional Transportation Model. The specific design of the Calgary survey built on the strengths of the Edmonton survey, but measured attitudes more specifically for more accurate modelling.

The INVIEW software (Hunt *et al*, 1995) was used to randomly generate three unique sets of alternatives for each respondent. Each set described a hypothetical trip to a hypothetical destination. The first set was described as a commute trip, the second as a meeting trip, and the third as a shopping trip. For each set, an outside temperature was randomly generated between 0 and 25 degrees Celsius. Respondents were told to imagine making the trip by bicycle under the specified conditions, and were asked to rank in order of preference each of the three alternatives for the trip.

The alternatives for the trip varied in their attributes values. The values for each attribute in each option were randomly selected from distributions that were, for the most part, uniform and independent. Certain dependencies were introduced to reduce the complexity of the survey or to maintain essential relationships between two or more attributes. Table 1 shows the attributes, their possible values and dependencies, and the rational for including the attribute. Figure 1 shows an example of one sheet describing a hypothetical commute trip and presenting three different alternatives for that commute trip.

A definitions sheet was included to define the terms "arterial road", "residential road", "wide curb lane", "bicycle lane", "bicycle pathway", "bicycle route", "bike enclosure", "individual bike locker", "clothes lockers", "change room with lockers" and "showers". This was to reduce ambiguity about what type of facility was being described.

An intercept survey of downtown commuter cyclists had recently been completed. This survey asked questions about the nature of the cyclist, the nature of the cycling trip, and the general cycling behaviour and preferences of the cyclist. Of the 2470 cyclists who were observed and intercepted 1434 responded, and 975 of these provided contact information and were willing to be further questioned. Of these, 845 provided email addresses. After checking contact information, 934 were selected for the stated preference survey.

Attribute	Possible values	Rational
total cycling time including stops at red lights and stop signs	5 to 60 minutes for commute trips, 5 to 25 minutes for other trip types	Providing mobility is an essential element of transportation policy.
time on arterial roads	The total cycling time (above) is divided into the times on each of these specific types of facility. For each trip scenario, five of these are first randomly selected to have a value of zero. The total travel time is divided among the remaining two types of facility. The attributes with zero values are not presented to the respondent. Thus for each hypothetical trip respondents only see alternatives made up of, at most, two different types of travel time.	Each of these represents a type of linear facility important in cycling policy, and a critical aspect of the route. Having only two presented values for each respondent avoids overwhelming respondents. "Pathways alongside arterial" is separated from "pathways in park area" to distinguish most current pathways (in linear parks) from potential future pathways (which would mostly be built in non-park settings, since most linear parks in Calgary already have pathways)
time on arterial roads with wide curb lane		
time on arterial roads with bicycle lane		
time on residential roads		
time on bike route consisting of residential roads		
time on bicycle pathways alongside arterial road		
time on bicycle pathways in park area		
Parking facility available at destination	nothing provided, standard bike rack, bike enclosure, individual bike locker	A measure of the attractiveness of each type of possible parking facility was desired.
Cost for parking facility	$0 to $15 for commute trips, $0 to $1.25 for other trips (always $0 for "nothing provided" or "standard bike rack")	A monetary measure of willingness-to-pay for facility was desired for economic analysis of policy alternatives.
Other facilities available at destination	nothing provided, clothes lockers (no change room), change room with lockers, showers and change room with lockers	End of trip facilities can be encouraged by policy. Providing a variety of end-of-trip facilities can help establish willingness-to-pay.
Cost for other facilities	$0 to $15 for commute trips, $0 to $1.25 for other trips (always $0 for "nothing provided")	A monetary measure of willingness-to-pay for facility was desired for economic analysis of policy alternatives.

Table 1: Attributes used to describe cycling alternatives

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Scenario 1 - Commute trip

Imagine that you have recently moved to a new location in the city, and you have also changed your job. You are making a regular commuting trip by bicycle from home to your new job, where you stay a number of hours. You are familiar with the possible routes between your home and your work location.

Please imagine this trip is necessary and the following 3 options are the only ones available to you. Everything not specified below is the same for all three options. Assume the temperature outside is **18°C**.

The differences between the options are in **bold type**. Please rank the options in order of preference, by telling us which is the most attractive, which is the second most attractive, and which is the least attractive.

Option F	
– Total cycling time including stops at red lights and stop signs	**9 minutes**
Which is made up of:	
time on bicycle pathways alongside arterial road	**8 minutes**
time on bike route consisting of residential roads	**1 minutes**
– Parking facility available at destination	**standard bike rack**
Cost for parking facility	**no charge**
– Other facilities available at destination	change room with lockers
Cost for other facility	**$11.00 per month**
Option O	
– Total cycling time including stops at red lights and stop signs	**32 minutes**
Which is made up of:	
time on bicycle pathways alongside arterial road	**7 minutes**
time on bike route consisting of residential roads	**25 minutes**
– Parking facility available at destination	**individual bike locker**
Cost for parking facility	**$2.00 per month**
– Other facilities available at destination	change room with lockers
Cost for other facility	**$14.00 per month**
Option G	
– Total cycling time including stops at red lights and stop signs	**21 minutes**
Which is made up of:	
time on bicycle pathways alongside arterial road	**13 minutes**
time on bike route consisting of residential roads	**8 minutes**
– Parking facility available at destination	**bike enclosure**
Cost for parking facility	**$10.00 per month**
– Other facilities available at destination	change room with lockers
Cost for other facility	**$1.00 per month**

Figure 1: Example of one trip scenario for one specific respondent

Surveys were randomly generated for each of the 934 potential respondents, and most were sent by email. Two attachments were sent with each email message, each containing the same content but differing in format. The first attachment was in HTML (Hypertext Markup Language) format for easy viewing in most email programs and web browsers. The second attachment was in PDF (Portable Document) format for proper printing with Adobe Acrobat or an equivalent program.

The information describing the individual and their typical cycling behaviour had already been collected in the Calgary Downtown Intercept survey. Thus, respondents only had to indicate, for each of the three scenarios, three code letters in the order that corresponded to the relative attractiveness of the alternatives. Respondents entered these into a normal (text) email message and sent them back to the City of Calgary, where they were matched with the records describing the alternatives that were randomly generated for that respondent.

Individuals who were emailed the survey and who provided phone numbers were given approximately 1 week to respond to the survey before they were phoned to ask if they had received the survey and if they were planning on responding, and whether they had any difficulties with their email and whether they would prefer to be sent a copy by regular post.

Individuals who had given a street address but not an email address were sent a copy of the survey by regular post. Individuals who were sent a survey by email but had not responded after ample opportunity, and who had given their postal address, were also sent a copy by regular post.

547 responses were eventually received, each with three sets of three ranked alternatives.

Results and Discussion

The choices made by the respondents were analysed with a logit model, which predicts the probability that a respondent will choose one option over other available options given the attributes of each option. The probabilities are based on the differences in the "representative utility" between options, which are the attractiveness of each option to an average respondent. The form of the utility function (the calculation of the representative utility) is specified by the analyst, and the coefficients of the utility function are estimated so that the resulting logit model is more likely to predict the observed choices than other logit models using the same utility function form.

All of the forms investigated in this paper are linear-in-parameters functions, $U_j = \sum_i \beta_i X_{ij}$, where U_j is the (representative) utility of alternative j, $_i$ is the parameter associated with attribute type i, and X_{ij} is the value of attribute i for alternative j. The parameter values $_i$ are estimated, and they show how a particular value of an alternative's attribute influences the overall attractiveness of the alternative.

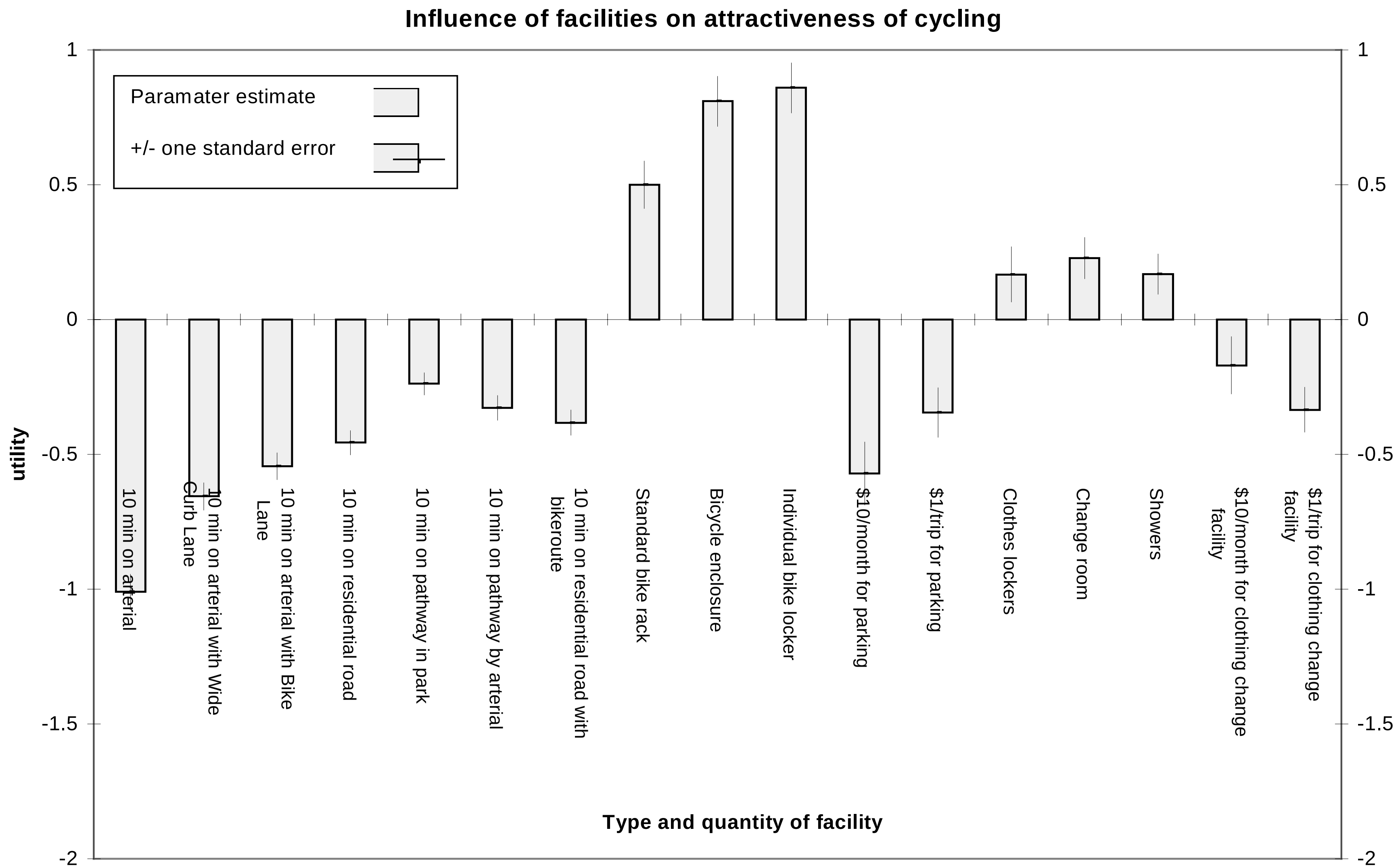

Figure 2: Influence of facilities on the attractiveness of cycling

Figure 2 shows a graphical plot of the parameter values estimated for the full set of all respondents and choices. The bars in the graph show the coefficient values $_i$ in the utility function, and hence show how the attributes of a trip influence the overall attractiveness of that cycling trip. For instance, the first bar on the left has a large negative value. This shows that every 10 minutes on an arterial road detracts significantly from the attractiveness of cycling for a transportation trip.

Trade-off rates can be calculated by comparing the lengths of the bars. The second and third bars from the left show that bicycle facilities along arterial roads can reduce significantly the disutility associated with travel time and hence make longer journeys more attractive (less unattractive). Travelling along an arterial roadway with a bike lane along it is about half as onerous as travelling for the same amount of time along an arterial without a bike lane. An arterial with a wide curb lane is also less onerous than travelling on an arterial without a wide curb lane.

Residential roads are significantly less onerous then arterials, and the addition of a bike route along a residential road further reduces the disutility associated with travel time. Travel time along pathways has the lowest disutility, with a pathway in a park area being less onerous yet again than a pathway alongside an arterial.

The comparison between the largest and smallest coefficients associated with travel time indicate that time spent riding along an arterial roadway is 4.2 times as onerous as time spent riding along a pathway in a park area. Another pair of coefficients indicates that time spent travelling on a residential roadway is 1.9 times as onerous as time spent riding along a pathway in a park area. These can be compared with the results from the Edmonton survey, where cycling "in mixed traffic" was found to be 2.8 times as onerous as travelling along a pathway. This suggests that attitudes are roughly similar between the two cities. The Calgary survey thus reinforces and adds detail to the results from Edmonton. The Calgary survey, by specifying the facility type more exactly, allows a more detailed understanding of how facility types can influence the willingness of people to cycle further and undertake longer cycling trips.

As in the Edmonton survey, the Calgary survey shows that cyclists place a high value on a place to park their bicycle. In the Calgary results, an "individual bike locker" was valued as highly as saving the respondent 8.5 minutes of their travel time along arterial roadways or 18.8 minutes along a residential roadway. These values, although meaningfully high, are not as high as the 26.5 minutes that Edmonton cyclists were willing to ride in mixed traffic in order to get to a place where "secure parking" was available. In Calgary, the alternative to having a specific parking facility available was "nothing provided", which probably suggested to respondents that they would have to lock their bicycle to a signpost or a tree. In Edmonton, the alternative to secure parking was "secure parking: no" which was meant to suggest the same thing, but some comments received with the Edmonton survey indicated that some respondents interpreted this as an unrealistic situation where there was no place whatsoever to lock up a bicycle. The differences between the results from Calgary and Edmonton may be partially caused by Edmonton respondents interpreting "secure parking: no" in a different way than intended in the survey design.

Approximate values of time can be calculated using the survey results. A comparison of the leftmost 7 bars in figure 2 with the bar for trip parking suggests values-of-time of between $4/hr (for travelling in a pathway in a park) and $17/hr (for travelling along an arterial). These can be used to calculate the benefit of more direct facilities that save time. These values are approximate only, as cyclists were not told to imagine that they *had* to use the supplied parking facility and pay the charge, and some respondents may have considered the time savings on a return trip as equal to the time savings on the outbound (specified) trip. Measuring cycling value-of-time is complicated by the fact that cyclists are not normally faced with out-of-pocket expenses on a trip. This survey was not designed to address this full complexity, but the results do provide approximate guidelines.

The general pattern of preferences was consistent across trip types, but there were certain important and significant differences. For commute trips, cyclists were willing to spend slightly more time cycling (on all facility types) but placed a higher value on end-of-trip facilities (except for a "standard bike rack" which many commuters may feel is inadequate for all-day regular parking). For meeting trips, cyclists were more willing to spend money on parking facilities (perhaps because they imagined being reimbursed by their employer) and placed a higher value on the various clothing change facilities. They did not value travel time at a lower value (contrary to a hypothesis that arose out of discussions regarding the Edmonton survey results). For shopping trips, cyclists found travel time on all on-street facilities much more onerous, placed a slightly higher value on parking facilities, and did not place any value on the various clothing change facilities.

Various socio-economic categorisations were explored to search for differences in attitudes between different cyclists. By and large, no significant differences were discovered. Traditional socio-economic variables do not seem to be adequate for understanding differences in preferences between individuals.

The Calgary Downtown Intercept survey had asked respondents whether they preferred "on-street" or "off-street" facilities or whether they had no preference in this regard. Most cyclists said they preferred off-street facilities. Those who said they preferred "on-street" facilities (or who had no preference) in the Calgary Downtown Intercept survey did not find on-street facilities less onerous in the stated preference survey. Rather, they found "off-street" facilities substantially more onerous. Thus there is some preliminary suggestion that those who prefer to cycle on the streets don't enjoy on-street riding more than the average cyclist; but rather they dislike off-street riding more than the average cyclist. The attitudes of these cyclists may be related to the message of many cycling advocacy groups (based at least partially on analysis of accident records) that pathways provide a false sense of safety and security. The analysis along this dimension is very preliminary; the data collected here is rich enough to support more sophisticated analysis of the differences between those who prefer pathways and those who do not.

Conclusions

The stated preference survey provided numerical indications of how various facilities influence the attractiveness of cycling. These can be used in a number of ways:

- as parameter relationships in the relevant choice models within a transportation demand model,
- as guidance in setting up a computer representation of cycling facilities in a transportation demand model, to support further estimation and calibration from other (observed choice) data sources and to predict cycling behaviour during operation of the model for policy analysis, and

- to directly inform cycling policy.

For a transportation model to be sensitive to cycling policy, it should include a direct representation of various on-street and off-street linear cycling facilities. The quality of end-of-trip facilities (especially bicycle parking) should also be included, although a direct representation is not completely necessary. Without a direct representation, the quality of end-of-trip facilities would end up being included in the "alternative specific constants" for cycling to each destination zone. The numerical values established here could then be used to modify these alternative specific constants for each destination based on the definition of each policy scenario.

Socio-economic variables may not be essential for predicting the relative impact of different facilities, even though other surveys have found that socio-economic variables influence the overall tendency to cycle. This is not inconsistent: the survey here was measuring relative attitudes to different facilities, not the overall attitude towards cycling. For relative attitudes to different facilities, it seems more important to consider differences in trip type than differences in socio-economic variables.

Cyclists' willingness-to-pay to reduce their journey time (their "value of time") varies significantly across facility types. The highest estimate, $17/hr for arterial roadways, is higher than values-of-time estimated for other modes using similar methods (see, for example, McMillan *et al*, 1997, which established a value-of-time for carpool vehicles of $9.19/hr by comparing the coefficients of travel time and parking cost from stated preference data collected in Calgary and Edmonton). Thus, if a typical cyclist is using an arterial road without a wide curb lane or bike lane (perhaps because no other route is available), saving her one minute of travel time probably has more social value than saving a transit user or a motorist one minute of travel time. On the other hand, reducing travel time on pathways is only valued at about $4/hr, suggesting that the presence of pathways is more important to the average cyclist than providing high-speed and direct pathways. On street treatments varied in their value. Bicycle lanes and wide curb lanes along arterials are seen as important improvements. Bicycle routes, defined as "A defined route along roads, signed to make it easier to follow, shown on the Calgary Pathway and Bicycle Route Map", are seen as having very little value over and above an unsigned and unmapped route *on the same type of facility*. The survey was designed to distinguish the value of bicycle routes separately from the type of facility along the route; whereas in reality bicycle routes serve to identify time-saving through-routes that connect to pathways, make use of residential roads, and avoid arterial roads with narrow lanes and heavy traffic. This survey suggests that a well-designed bicycle route that guides cyclists quickly to or along desirable facilities will have high value, but that a poorly designed bicycle route that is little more than signs and a line on a map will have low value. Maps and routes are valuable if they identify preferred facilities such as continuous residential roads, pathways, bike lanes, wide curb lanes and bicycle parking facilities.

The sample frame for the survey was existing cyclists to the downtown area who had responded to a previous survey and had indicated they were willing to be re-contacted. Thus there is substantial opportunity for bias due to self-selection and location (downtown area). In general, stated preference surveys are thought to do a good job of measuring the *relative* preference towards different attributes even when the sampling of respondents is biased. Thus the *relative* size of the coefficients in the utility function (indicated by the relative size of the bars in figure 2) is considered valuable, and this paper predominantly reports such comparisons. The strategy for integrating cycling into the overall transportation model is to combine the stated preference results with an analysis of actual choice behaviour collected using the same methods that are applied to other modes. It is expected that the relative size of the coefficients associated with specific cycling facilities will not change much during such analysis, and that the observations of actual behaviour will end up primarily influencing other coefficients, such as the alternative specific constant for cycling.

The widespread availability of email allowed a more automated and efficient data collection. The prior collection of socio-economic information (from a previous survey) and the database identifying the randomly generated alternatives simplified the response, allowing the City to accept free-form text responses. Standalone surveys would require a more sophisticated form-based response to manage the complexity of the socio-economic data and the observed choice data. Nonetheless, it seems that internet based surveying is "coming of age" and that paper survey forms (and regular postal service) may soon be relegated to a backup method for use with individuals who do not have access to the internet.

This survey has confirmed that an average cyclist strongly prefers off-street cycling facilities and low-traffic residential roads. However, this does not contradict the common argument that cyclists only prefer off-street facilities because they are unaware of the true nature of cycling accidents; that if they were educated as to the dangers of cycling and how to avoid them their preference for off-street facilities would disappear. Future surveys might attempt to understand how perceptions of safety influence the preference for off-street facilities. Subjective survey techniques could be used to identify how cyclists understand and communicate risk and safety, and this could lead to a stated preference survey where the safety of each alternative is specifically and clearly described. It may be possible with such a survey to discern the degree to which the preferences for facilities with less auto traffic are based on perceptions of the risk associated with auto-bicycle collisions.

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