

Stated Preference Examination of Factors Influencing Residential Attraction

J.D. Hunt

Abstract The City of Edmonton in Canada conducted a stated preference survey where over 1,200 respondents were asked to consider tradeoffs involving a wide range of elements of urban form and transportation, including mobility, air quality, traffic noise, treatment of neighbourhood streets, development densities and funding sources such as taxes. Respondents were to imagine moving to a new home location and to indicate preferences among hypothetical alternatives for this new location, with these alternatives described in terms of attributes related to the elements of interest. The observations of choice behaviour thus obtained were then used to estimate choice model parameters indicating the sensitivities to these attributes. As such, these parameter estimates provide indications of the relative importance of the corresponding elements and they also provide insights into the influences of the specific home location attributes considered. It is these insights into the influences of home location attributes that is of particular interest in this book presenting a collection of modelling treatments of household behaviour.

1 Introduction

The City of Edmonton in Canada developed a long-range transportation masterplan in the mid-1990s, encompassing a wide range of elements of urban form and transportation, including:

- Mobility
- Air quality
- Traffic noise
- Treatment of neighbourhood streets

J.D. Hunt

Department of Civil Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB, T2N 2N4, Canada

e-mail: jdhunt@ucalgary.ca

- Development densities and
- Funding sources such as taxes

The study described here was conducted as part of the development of the plan, in order to improve understanding of the relative importance placed on these elements by the population and thereby obtain some guidance concerning some of the tradeoffs to be made in the plan. The intention in this study specifically was not to consider what would be best for the population; but, rather, to consider the sensitivities of the population to a specific set of elements addressed in the plan.

A stated preference approach was used, where each of a sample of respondents in the population was asked to imagine moving to a new home location and to indicate preferences among hypothetical alternatives for this new location, with these alternatives described in terms of attributes related to the elements of interest. The observations of choice behaviour thus obtained were then used to estimate model parameters indicating the sensitivities to these attributes. As such, these parameter estimates provide indications of the relative importance of the corresponding elements, as required. But they also provide insights into the influences of the specific home location attributes considered. It is these insights into the influences of home location attributes that is of particular interest in this book presenting a collection of modelling treatments of household behaviour.

This chapter is organised into four sections after this introduction covering survey, analysis approach, results and conclusions.

The analysis approach involved the use of the standard logit model in the estimation of the indications of sensitivities. This particular form of mathematical model of discrete choice behaviour enjoys widespread use throughout the modelling of household behaviour. Consequently, it is appropriate to include in this first chapter (of a book about the modelling of household behaviour) a description of the standard logit model and its application – which is done within the section covering the analysis approach.

2 Survey

2.1 Survey Interview Design

The hypothetical new home location alternatives considered by respondents were described in terms of the following attributes:

- Auto drive time to work
- Operating cost for auto trip to work
- Parking cost for auto trip to work
- Transit ride time to work
- Walking distance to bus stop for trip to work
- One-way fare for transit trip to work

- Auto drive time to shopping
- Operating cost for auto trip to shopping
- Parking cost for auto trip to shopping
- Transit ride time to shopping
- Walking distance to bus stop for trip to shopping
- One-way fare for transit trip to shopping
- Housing type
- Change in housing taxes or rent relative to existing level
- Frequency of noticeably bad air quality
- Nature of traffic noise and disturbance arising from it
- Walking time to local elementary school
- Type of transportation facility to be crossed as part of walk to local elementary school and nature of any provision for that crossing and
- Type of street in front of dwelling and nature of any traffic calming measures in street

In order to remove other elements from consideration and thereby negate their potential impacts, each respondent was also told to assume that all other aspects of the alternative new home locations were the same as their existing home location. That is, for example, the respondent was to imagine that each alternative new home would have the same floor area and money value as the respondent's existing home location.

The descriptions of the hypothetical new home alternatives presented to respondents were developed by randomly varying the condition regarding each of the considered elements, with some degree of control on possible combinations of conditions in order to avoid inconsistent descriptions. That is, each specific hypothetical home location alternative was created by "bundling together" a randomly selected drive time to work, a randomly selected money cost for the auto trip to work, a randomly selected housing type, etc. An example of one restriction on the possible combinations was that a description could not have both a "collector road" in front of the dwelling and "none" for the level of traffic noise. Another was that parking charges remained the same across alternatives in a given interview, reflecting the invariance of work destinations.

Additional materials were presented to each respondent as part of the interview in an effort to establish a consistent understanding of the (sometimes fairly "jargony") terms being used. Separate single pages of point-form notes were used to indicate what was meant by the terms "shopping trip for groceries" and "noticeably bad air quality". Photographs (sometimes with additional point-form notes) were presented depicting the different housing types and indicating the meaning of local road, collector road, crosswalk, pedestrian bridge, block (as a distance measure), speed bump, and chicanes.

In each interview, the respondent was asked to participate in four separate stated preference "games", with four different hypothetical home location alternatives considered in each game. In a given game, the respondent was to establish his or her ranking of the alternatives in order from most to least preferred – which in general

forced the respondent to make tradeoffs among the more and less preferable attributes and thereby provide data indicating the relative influences of these attributes. The descriptions of the alternatives were printed on separate sheets of paper, one for each alternative. Figure 1 shows an example sheet presenting an alternative.

31401	2
Walk to local elem school:	10 minutes using crosswalk on collector road
Local air quality:	noticeably bad 1 day per year
Municipal taxes or rent:	up \$125 per month (up \$1500 per year)
Street in front of dwelling:	local road
Trip to work: By car:	20 minutes in vehicle \$2.00 per day for parking \$0.75 for fuel & user charges (fuel taxes, road tolls)
By transit:	45 minutes in vehicle with no transfers 4 block walk to bus stop \$1.25 fare each way
Trip to shop: By car:	15 minutes in vehicle \$0.50 for parking \$2.00 for fuel & user charges (fuel taxes, road tolls)
By transit:	30 minutes in vehicle with no transfers 1 block walk to bus stop \$1.25 fare each way
Traffic noise:	constant faint hum
Dwelling type:	single family

Fig. 1 Example sheet showing a hypothetical alternative. The respondent was asked to indicate preferences among four such alternatives for a new home location in each game by both ranking the alternatives in order of preference and also rating each alternative on a 0 to 10 scale

In the first three games the sets of four descriptions were selected randomly from the full set of available combinations of conditions. In the fourth game a fixed set of four pre-specified descriptions with specific themes was considered, with the same fixed set of four considered in all interviews. These four pre-specified descriptions embodied specific themes emphasizing mobility, money costs, the environment and children as areas of general concern and had the most attractive conditions for the relevant elements in each case.

In each game, the four sheets containing the descriptions of the alternatives were literally set out before the respondent and the descriptions were reviewed by the interviewer using the point-form notes and photographs as appropriate. The respondent was then left to consider and physically move around the sheets as part of the determination of the order of preference among the four alternatives. When the respondent finally settled on an order of preference, he or she was then asked to rate each hypothetical alternative on a whole number scale from 0 to 10, where 0 represents “terrible”, 5 represents “neutral” and 10 represents “excellent”. This acted to confirm the indicated order of preference: if any inconsistency arose between the indicated order of preference and the 0 to 10 scores, where an alternative with a higher ranking got a lower score, then the order of preference and the scoring were revisited until the inconsistency was eliminated. After the four games of ranking were completed, the respondent was then asked to indicate which one of the elements had the greatest influence in the ranking process.

It would be a very complex and demanding task to consider and compare conditions regarding 19 elements across four alternatives. A significant proportion of respondents might find such a task too difficult and either give up or simply provide incomplete responses, significantly reducing the accuracy of the results obtained. In anticipation of this potential difficulty, the number of elements varying in each of the first three games was reduced by organizing the elements into eight related groups and holding the conditions for four of these groups constant across all alternatives. The four groups of elements to be held constant in a given game were selected randomly as part of the development of the interview. This effectively eliminated these four groups of elements from consideration in that game, and thereby simplified the ranking task to a manageable level. All 19 elements were still printed on each sheet so that the full context was still indicated, and thus could influence the 0 to 10 rating scores. The four groups of varying elements were presented in bold print in order to allow them to be identified more easily.

The order of presentation of the elements could influence respondents, where elements at the top of a sheet might receive more attention than those further down because of respondent fatigue. In order to avoid this effect biasing the results, the order of presentation of both the groups of elements and the elements within the groups was selected randomly for each interview.

As part of the interview, the respondent was also asked to provide the following socioeconomic information:

- Nature of household tenure (own or rent)
- Taxes or rent paid

- AGE, gender, drivers license status, employment status, workplace location, frequency of travel to work and mode usually used for travel to work for each person in the household as appropriate
- Frequency and location of grocery shopping and mode usually used for travel to grocery shopping as appropriate
- Total number of private vehicles owned by household
- Present dwelling type
- Total household income and
- Nature of any mobility, sight/reading and/or hearing disabilities that might have influenced the responses provided

2.2 Conducting the Survey

A random listing of 6,000 households in Edmonton was selected from the publicly-available directory of residential telephone numbers. Several attempts were made to contact and recruit persons in these households for the survey. In the end, a total of 1,277 “face-to-face” interviews were successfully completed and the resulting information coded for analysis.

2.3 Resulting Sample as Representation of Population

In Fig. 2 the sample distribution of household sizes is compared with the corresponding population distribution – as observed in a 100% sample obtained in 1993 (City of Edmonton 1993). In Fig. 3 the sample distribution of dwelling types is similarly compared with the corresponding 1993 population distribution.

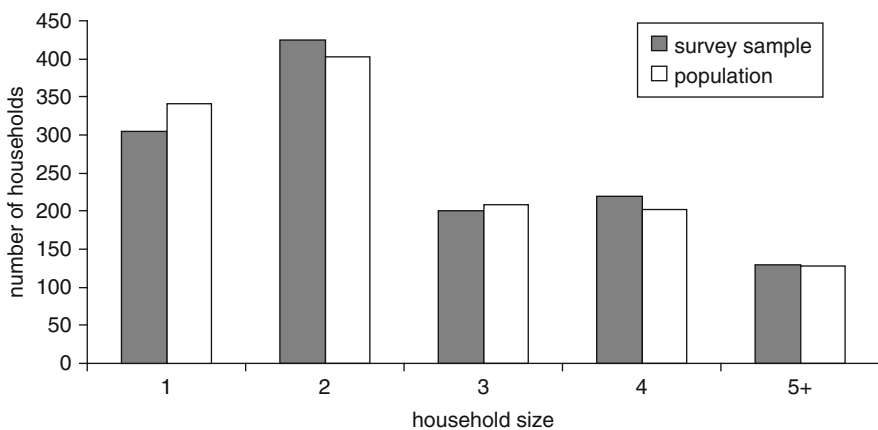


Fig. 2 Comparison of household size distributions in survey sample and population. The survey sample distribution is close enough to the population distribution in this regard to suggest that the sample can be taken to be representative of the typical Edmonton resident

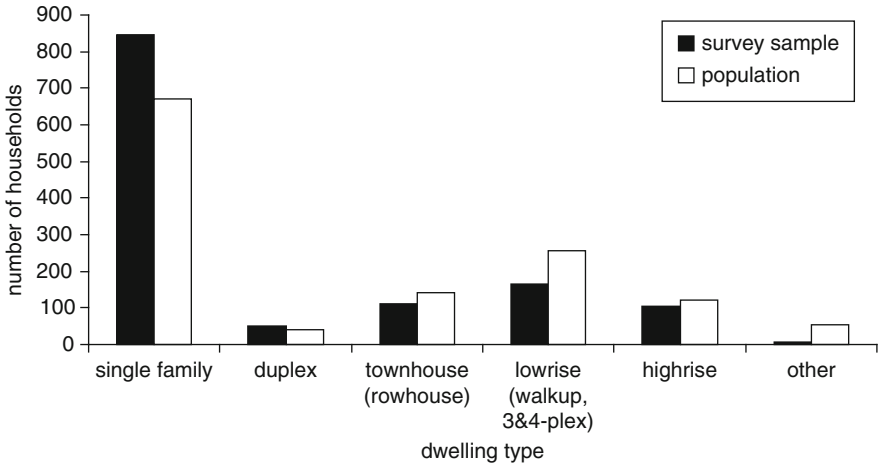


Fig. 3 Comparison of dwelling type distributions in survey sample and population. As above, the survey sample distribution is close enough to the population distribution in this regard to suggest that the sample can be taken to be representative of the typical Edmonton resident

These comparisons indicate that there is a reasonable match between the sample and the overall population regarding these distributions, with some relatively minor differences, suggesting that the sample can be taken to be reasonably representative of the population in discussions of the analysis results.

3 Analysis Approach

Indications of the influences of different attributes for specific groups of households were established by estimating standard logit models for those households using the observations obtained in the survey. The resulting parameters estimates for the logit model indicate the influences of the attributes. This is described below, covering the basic form of the logit model along with the estimation of the parameter values and the interpretation of the results.

3.1 Logit Model Form and Statistics

The logit model is a mathematical model that represents the behaviour of individuals trading off among the attributes of alternatives when selecting one alternative out of a set of available discrete alternatives (McFadden 1974). It has the following form for the choice situation considered here:

$$P_{i^*} = \frac{\exp(U_{i^*})}{\sum_i \exp(U_i)}, \tag{1}$$

where:

i	index representing new home location alternatives,
i^*	a particular new home location alternative,
P_{i^*}	probability that new home location alternative i^* is selected,
U_i	utility value associated with new home location alternative i , expressed in (implied) hypothetical units called “utils”.

The utility function that ascribes utility values to the new home location alternatives has the following general, linear form:

$$U_i = \phi_1 X_{1i} + \phi_2 X_{2i} + \dots + \phi_n X_{ni} + \dots, \quad (2)$$

where:

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

The mathematical form of the logit model is relatively simple and convenient to work with when using empirical data to estimate the values for the parameters, ϕ_n , in the utility function. The statistical properties of the resulting estimates are “well behaved” (McFadden 1974). Consequently, this formulation is a very attractive one for modelling choice behaviour and it continues to enjoy widespread use (McFadden 2007; Train 2003). Variations of this formulation providing more complex treatments have also been developed (Agresti 2007; Hensher and Green 2003; Koppelman 2006).

When values for the utility function parameters have been estimated, the relative influences of factors can be determined using ratios among the resulting coefficient values. For example, if for a given sample the parameter estimate associated with auto drive time is -2.00 utils per minute and the parameter estimate associated with transit ride time is -1.00 utils per minute then an increase in auto drive time is twice as onerous as an equal increase in transit ride time, indicating that auto drive time has double the impact and that a minute of auto drive time is worth 2 min of transit ride time for the typical household in the sample.

The significance of differences among estimates can be considered using standard t-statistics and t-ratios, with the t-ratio being the t-statistic for the estimate’s difference from 0. When a t-statistic or t-ratio has a value greater than 1.96 in absolute magnitude, this indicates that there is a less than 5% chance that the associated difference is due to random effects only (Ang and Tang 1975), and the difference is said to be “significant”.

The overall model goodness-of-fit can be considered using a goodness-of-fit index as follows (Ben-Akiva and Lerman 1985):

$$\rho^2(0) = 1 - \frac{L(*) - k}{L(0)}, \quad (3)$$

where:

K	number of coefficients in estimated model,
L(0)	log-likelihood for model with zeros for all coefficients,
L(*)	log-likelihood for model with estimated coefficients.

This $\rho^2(0)$ index is analogous to the R^2 statistic for linear regression in that it ranges from 0 to 1, with larger values indicating a better fit. It also takes into account the number of parameters used in the model, favouring more parsimonious model specifications (Ben-Akiva and Lerman 1985). Note that in this work specifically the k is omitted from the index as it is a constant across estimations.

A modified form of this goodness-of-fit index, that uses the model with just a full set of alternative specific constants as the point of comparison, is also often used. It has the following form:

$$\rho^2(C) = 1 - \frac{L(*) - k}{L(C)}, \tag{4}$$

where:

L(C)	log-likelihood for model with just a full set of alternative specific constants and zeros for all other coefficients.
------	---

This modified form provides further indication of the fit of the estimated model, in this case relative to a more informed point of comparison. The model with a full set of alternative specific constants uses the observed aggregate share selecting each alternative as the choice probability for the alternative. This is a more informed model that the one with zeros for all coefficients, which uses the inverse of the number of available alternatives as the choice probability for each alternative. Reports of estimation results sometimes include just one or both of $\rho^2(0)$ and $\rho^2(C)$. In cases where a model with a full set of alternative specific constants is not applicable, as is the case with the generic hypothetical alternatives considered in the first three games in the survey conducted for this work, then $\rho^2(0)$ is undefined and thus not reported. Other modifications to these indices are possible when the results of logit model estimations are reported: for example, the number of parameters, k, may not be included in the calculation of the index value, as is the case in this chapter.

The ALOGIT software package (ALOGIT 2007; Daly 1992) was used to estimate the parameters in this work. The “exploded logit” (Chapman and Staelin 1982) version of the estimation process was used, consistent with the use of a ranking process (rather than a single choice process) in the interviews. This “exploded logit” version makes full use of the ranking indications by attempting to predict the full ranking of the alternatives in an observation – not just the single, most preferred alternative.

The indication of the influence of a given attribute that is provided by the corresponding parameter estimate is a value that applies for the typical household for the sample being used. In this sense it is an average or “compromise” value that expresses a general tendency. The sensitivities of specific households in the sample to the attribute will most certainly differ from this compromise value. The variation in sensitivity may be very large – and specific households may feel very differently than the typical household. Therefore, the indications that are provided should only be applied in the consideration of general tendencies for large numbers of households.

4 Results

4.1 *Presentation Format*

Logit models were estimated for the entire sample and for various different subsamples from the survey. The results for some of these estimations are discussed below, with the numerical values shown graphically in figures included in the text and also listed in tables included in an appendix.

4.2 *All Households*

The estimation results for the full sample of all households are shown in Fig. 4 and also listed in the first column of results in Table 1 of the Appendix.

Figure 4 shows the estimation results using a particular format, grouped and shaded by the categories of attributes considered. Working from left to right, these categories are: housing type, air quality, traffic noise, treatment of street in front of the dwelling, travel conditions to work, travel conditions to shop, and walking conditions to local elementary school. The bars for the groups show what the estimation results indicate would be the changes in utility occurring with the corresponding changes in attributes as either (a) increases (labelled “inc”) or (b) switches from the relevant reference cases (the ones with zero values listed in the left-most position for each group).

In Fig. 4, utility values become more negative going up the page, indicating reductions in attractiveness. Thus, reading some examples from the figure: switching from “single family” to “duplex” for the dwelling type has about the same (or perhaps a slightly greater) negative impact on the attractiveness of an alternative as either changing the frequency of bad air from “never bad” to “bad 1 day per week” or increasing auto cost for travel to work by about \$6 (6 times the bar for “\$1 auto cost inc”).

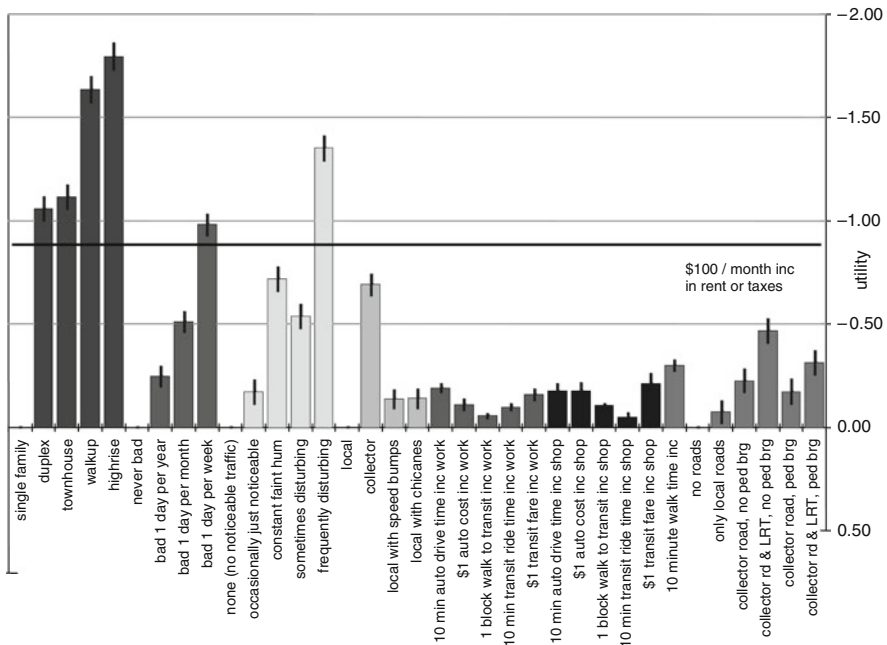


Fig. 4 Estimation results for sample of all households (1,277 households). The bars show the changes in utility that would arise with the indicated changes in attributes, with the change for a \$100 per month increase in rent or taxes shown as a line to provide a reference. Changes in dwelling type away from single family have the greatest impact, followed by increases in traffic noise away from none, and then increases in the frequency of bad air quality away from never. Increases in travel times and costs to work and to shopping have comparatively modest impacts: the time to drive to work would have to increase by almost 60 min in order to have the same negative impact as a switch from single family to duplex dwelling type

The small thin vertical line at the top of each bar in Fig. 4 indicates the standard error for the statistical estimator of the value of the corresponding bar, thereby providing an indication of this aspect of the precision of the estimate. The impact of a \$100 per month increase in taxes or rent is shown using a horizontal line rather than a bar in deference to its potential role as a basis for converting the shown changes in utility into corresponding changes in money amounts. As such, the particular format used for Fig. 4, along with the other similar figures included below, provides a useful graphical depiction of the indications regarding sensitivities provided by the estimation results.

Returning to the estimation results specifically, all the parameter estimates have signs consistent with expectations, and all are significantly different from zero except for those concerning (a) the sensitivity to the “only local roads to cross” condition regarding the walking trip to the local elementary school and (b) the set of three constants related to the four specific themes considered in the fourth game of each interview.

The ratio of the parameter estimate for auto time over the parameter estimate for auto cost is \$0.1732 per minute. This is very close to previous estimates of the value of auto drive time in Edmonton: \$0.1767 per minute from 1995 stated preference carpool use data (McMillan 1996) and \$0.1962 per minute from 1991 revealed preference mode choice data (City of Edmonton 1991). This close match suggests that the value found here is a reasonably accurate estimate of the actual value of drive time to work for the population, which supports the idea that the respondents in this study are reacting to the hypothetical situations in much the same way Edmontonians have previously in other situations, which adds more general credence to the full range of results obtained in this study.

Similarly, the ratio of the parameter estimate for transit ride time over the parameter estimate for transit cost for the trip to work is \$0.0619 per minute, which is reasonably consistent with the corresponding indications obtained in previous work.

The ratio of the parameter estimate for auto ride time to work over the parameter estimate for transit ride time to work is 1.94. This indicates that for the typical Edmonton resident a reduction in auto travel times to work has almost twice the impact on the attractiveness of residential locations as does an equivalent reduction in transit ride times to work. A value of 1.54 was obtained for this ratio in a previous study in Edmonton using revealed preference mode choice data (Hunt et al. 1998) and has been confirmed in later work (Hunt 2003). Values for this ratio of around 2 are not uncommon in work done elsewhere. Again, this reasonable match between behaviour in a real situation and behaviour in the corresponding hypothetical situation considered in this study adds credence to the results obtained in this study.

Respondents were told as part of the interview that it took 1 min to walk 1 block. This allows the estimation result for the walk to transit for the trip to work expressed in an amount per block to also be expressed as an amount per minute as required. The same applies for the result for the walk to transit for the trip to shopping.

The ratio of the parameter estimate for transit walk access to work over the parameter estimate for transit ride time to work is 2.83. This is somewhat higher than the value for this ratio found previously in Edmonton (Hunt 1990), but is similar to typical values found elsewhere (Ortúzar and Willumsen 1994). This may be due to sample error or some systematic distortion regarding the responses to transit walking distances in particular in this study. It is also possible that there are problems with the value found previously in Edmonton. In any case, this difference suggests that there should be some relatively greater concern about the results obtained here and in previous analysis in Edmonton regarding transit walk distances specifically.

The sensitivity to auto ride time for shopping is very similar to the corresponding sensitivity to auto ride time for work, with the work-related value being slightly higher. This is consistent with the idea that there may be additional time pressures arising because of concerns about required arrival times.

In contrast to the case with auto ride times, the sensitivity to auto cost for shopping is almost 60% higher in absolute magnitude than the sensitivity to auto

cost for work, consistent with the notion that shopping travel is relatively more discretionary than work travel in general and therefore likely to exhibit higher cost elasticity.

The ratio of the parameter estimate for auto time over the parameter estimate for auto cost for shopping is \$0.1002 per minute. This is lower than the corresponding value of drive time for the trip to work and is in the range of similar values obtained work done previously, adding yet further credence to the range of results obtained here.

These results for the parameter estimates for auto ride time and auto money cost for both work and shopping together suggest that the difference in value of auto ride time between work and shopping arises because of a difference in the sensitivity to money costs, with the sensitivity to drive time remaining comparatively similar.

The ratio of the parameter estimate for transit walk access to shopping over the parameter estimate for transit ride time to shopping is 5.86. This is much higher than the corresponding value of 2.83 found for travel to work as indicated above. The type of shopping trip being considered likely had a substantial influence on this value in particular. In the interviews, respondents were told to consider a shopping trip for a week's worth of groceries for the household. Carrying these groceries for the walking component of the transit trip would make the corresponding walking distance or time relatively more onerous, contributing to the higher value obtained. This implies that the respondents made an effort to follow the interview instructions, at least in this respect, and that in general they behaved consistently, which is encouraging. It also means that the values associated with transit walk for shopping in particular must be interpreted carefully and applied elsewhere with caution.

The ratio of the parameter estimate for auto ride time over the parameter estimate for transit ride time for shopping is 3.74. This compares with a ratio of 1.94 for the analogous ratio for travel to work, suggesting that travel time to shopping has comparatively little impact on the attractiveness of home locations. This may arise because respondents are less likely to see transit as a viable alternative to auto for travel to shopping for a week's worth of groceries as defined for the shopping trip, and are therefore less concerned about the associated transit travel times. In any case, it follows that auto travel times for shopping have a much greater influence on the attractiveness of residential location than do transit travel time for shopping.

The ratio of the parameter estimate for transit ride time over the parameter estimate for transit cost for travel to shopping is \$0.0223 per minute. This is a relatively low value, consistent with expectations for this segment of travel, reflecting the comparatively higher sensitivity to money costs for shopping in general together with the reduced sensitivity to transit travel times for this situation in particular as discussed above.

The ratio of the parameter estimate for walk time to the local elementary school over the parameter estimate for walk time during the transit trip to work is 0.56. This lower sensitivity for the trip to school is expected to arise because trips to work are made by adults whereas trips to elementary school concern younger children with reduced time pressures generally. Respondents were told the walk time to the

school was for a healthy adult, with the implication that the walk times for children would be somewhat greater and to the extent that the respondents took this into account it would act to make the sensitivity to walk time for the trip to school for children even lower than the value obtained in the estimation. Travel times for trips to the local elementary school may also have less influence generally because for many households there are few relevant work locations and many potential school locations spread throughout the region, reducing distances to schools generally and thereby making them less important when considering home locations. In any case, the travel times for trips to work have a much greater impact on the attractiveness of residential locations – for perhaps a range of reasons.

It is perhaps notable that substantial concerns about risks to children in the neighbourhood could have produced a high level of sensitivity to walk time for the trip to school – but that this did not happen. It may be that the typical Edmonton resident does not feel that such risks are significant in Edmonton generally. However, it may also mean that those respondents in households where such concerns are prevalent tend to drive children to school and therefore are relatively unconcerned about walking distances for the trip.

The estimation results for the “walking conditions to local elementary school” category of attributes indicate the influences (in terms of the differences in utility) associated with the types of roads or transportation corridors to be crossed and the facilities provided at the crossing points for the walking trip to the local elementary school. These differences in utility are expressed relative to the “no roads to cross” case, which has a fixed utility of zero.

The parameter estimates for all the other crossing situations are negative, indicating that any switch from having no roads to cross reduces the attractiveness of the residential location.

The t-ratio is only 1.4 for the parameter estimate for the “only local roads” condition for the walking trip to school. This suggests the need to cross some local roads, as opposed to no roads at all, on the way to school has a comparatively weak and dispersed impact on the attractiveness of residential locations.

The parameter estimate is -0.2251 utils for the “collector road, no pedestrian bridge” crossing on the walking trip to school. The ratio of this parameter estimate over the parameter estimate for walk time to school is approximately 7.5 min per trip, indicating that adding a collector road crossing on the walk to school has the same impact on the attractiveness of a home location as adding of 7.5 min to the walk itself. The ratio of this parameter estimate over the parameter estimate for money cost for the auto trip to work is approximately \$2.06 per trip. These ratios indicate there is a comparatively strong negative impact on the attractiveness of home locations, perhaps resulting from the perception of increased inconvenience and exposure to danger arising with the need to cross a collector road. The respondents were told that all such crossings without a pedestrian bridge were at painted crosswalks with pedestrian-actuated overhead flashing lights. It is expected that crossings without such facilities would be seen as even more onerous and have a correspondingly greater negative impact on the attractiveness of residential alternatives.

The ratio of the parameter estimate for “collector road with LRT, no pedestrian bridge” over the parameter estimate for walk time for the trip to school is approximately 15.6, indicating that adding a collector road with LRT crossing on the walk to school has the same impact as adding 15.6 min to the walk itself. This is an increase of 8.1 min, or more than double, relative to the collector road only condition; again, with a painted crosswalk. The implication is that the addition of an LRT crossing at grade on the walk trip to the local elementary school has a further large negative impact on the attractiveness of home locations, perhaps because of concerns about safety along with concerns about the impact of a light rail corridor on the sense of neighbourhood integrity.

The impacts of pedestrian bridges rather than painted crosswalks for these crossings on the walking trip to school are indicated with the parameter estimates for the “collector road, pedestrian bridge” and the “collector road with LRT, pedestrian bridge” conditions.

The addition of a pedestrian bridge reduces the negative impact of the collector road, but the differences in utility values are not statistically significant at the 5% level. The implication is that a pedestrian bridge on its own, when introduced over a collector road to be crossed on the walk to school, has a tendency to slightly reduce the negative impact on the attractiveness of residential locations, but that this is not a strong effect.

With the LRT included, the addition of a pedestrian bridge reduces the negative impact by an amount that is statistically significant at the 5% level, indicating that the introduction of a pedestrian bridge over a collector road with LRT does have a much more substantial positive impact. In terms of other factors, it has the same impact as a decrease in walking time of 5.2 min or a decrease in the money cost for auto travel to work of \$1.41 per trip. However, because the parameter estimate for “collector road with LRT, pedestrian bridge”, is still more negative than the corresponding parameter estimate for “collector road, no pedestrian bridge”, the implication is that if LRT is added to a collector road corridor then the further introduction of a pedestrian bridge will not compensate for the addition of the LRT, at least with regard to the impact on the walk to the local elementary school.

The estimation results for the “dwelling type” group of parameters are expressed relative to the “single family” category, which has a fixed utility component of zero.

The parameter estimates for all the other dwelling types are negative, indicating that any switch from the single family dwelling type is undesirable, making the residential alternative less attractive.

The ratio of the parameter estimate for the “townhouse” category over the parameter estimate for auto travel time to work is approximately 58.9 min. This indicates that a switch from a single family dwelling to a townhouse is as onerous as an increase of almost 1 h in the daily trip to work by car for the typical Edmonton resident. The values for various other ratios concerning switches from “single family” can be established in a similar manner. For example, the value for the ratio for the switch from “single family” to “highrise” is nearly 95 min of auto travel time per trip to work.

These ratio values may seem high; but they are within the range of commuting drive times some households in larger cities are observed to accept in order to live in single family dwellings. The results obtained here indicate that the typical Edmontonian in the sample has similar attitudes and would behave the same way if forced to do so – but does not have to because single family alternatives are more generally available nearer to work. They are also very similar to analogous results obtained in a similar study performed in 1994 in Calgary, a comparable city also in Canada about 300 km south of Edmonton (Hunt 1994). Further, these ratios concern components of utility that apply with all other factors held constant. That is, everything else apart from housing category and auto travel time is assumed to remain the same. Various other unattractive aspects associated with being more than 90 min away from work, such as increased travel costs and reduced shopping and entertainment opportunities, can be expected to get mixed in and influence more intuitive attitudes concerning specific amounts of travel time, making these specific time amounts seem more onerous than they are on their own.

The components of utility for the various housing categories are consistently more negative with each increase in associated residential density, suggesting that increasing densities – at least at the micro-scale – act to reduce residential attractiveness. The changes in utility are relatively large, showing the largest changes of any of the groups of attributes, indicating that dwelling type, and all the various things associated with it, have a strong influence on housing preferences.

The estimation results for the “air quality” group of parameters are expressed relative to the “never bad” category, which has a fixed utility of zero. Not surprisingly, the parameter estimates for all the non-zero frequencies of bad air quality are negative and become more negative as the frequency increases.

The frequency of bad air going from “never bad” to “bad 1 day per week” has the same impact as an increase in municipal taxes of about \$122 per month, or as an increase in auto drive time to work of about 52 min per trip.

It is perhaps somewhat surprising to find that there is such a strong feeling about the air being bad 1 day per year rather than never: it has the same impact on residential attractiveness as an increase in auto time to work of about 12.9 min per trip. To some extent it seems more reasonable that such a low frequency of bad air would have much the same effect as the air never being bad. But a similar level of sensitivity to the air being bad just 1 day a year was obtained in the above-mentioned study in Calgary (Hunt 1994). Perhaps the prevailing attitude is that if the air is worse than certain standards 1 day a year then it is likely to be less than ideal a number of times. In any case, there is a clear indication that the typical Edmontonian, like the typical Calgarian, is very sensitive to even very modest changes in air quality.

The estimation results for the “traffic noise” group of parameters are expressed relative to the “none” category, which has a fixed utility of zero. As expected, the parameter estimates are negative for all the cases where there is some degree of traffic noise.

The relative magnitudes of the parameter estimates for the traffic noise cases indicate that a constant faint hum of traffic has a somewhat more negative impact

than does traffic noise that is “sometimes disturbing”, and that “frequently distracting” traffic noise has the greatest negative impact. Going from “no noise” to “frequently distracting” traffic noise has the same impact on residential attractiveness as an increase in the drive time to work of about 71.4 min per day, and an even greater impact than does going from “air never bad” to “air bad 1 day a week”.

At about the time the interviews were being conducted, a new truck route bylaw was being developed for the City of Edmonton. The additional media attention this generated on truck issues, including noise, may have caused some respondents to be somewhat more sensitive to traffic noise issues than is the case normally. The results indicated here should be interpreted accordingly.

Overall, the estimation results regarding the two environmental aspects considered indicate that these aspects can be very important to the typical Edmonton resident in the context of housing location depending on the extent of change involved. The relative levels of impact for the different levels of change considered seem entirely reasonable, which is seen to add further credence to the results.

The estimation results for the “street in front of dwelling” category of attributes are expressed relative to the “local” category (with no traffic calming treatments), which has a fixed utility of zero.

The parameter estimate for the “collector” category is -0.6885 utils, indicating that a change from “local” to “collector” in front of the dwelling has about the same negative impact on the attractiveness of home alternatives as a switch from “none” to “constant faint hum” regarding traffic noise. This impact of roads with a throughput function is perhaps a response to the associated higher levels of possibly faster traffic and corresponding range of adverse factors.

The parameter estimates for “local with speed bumps” and “local with chicanes” are both negative, indicating that the introduction of these treatments reduces the attractiveness of residential locations for Edmontonians. This is perhaps somewhat surprising. It was expected that traffic calming treatments acting to reduce traffic speeds would be appreciated on a local road in front of the dwelling and thus would act to increase the attractiveness of the location; with the general dislike of these treatments emerging only when encountering them while driving elsewhere. It may be that the results obtained here arose because respondents were unable to separate the appeal of such treatments in one context from the dislike of them in another, with the net effect being negative. It is also possible that some respondents may have been able to make such a separation, but saw the interview as an opportunity to send a message regarding these treatments generally. Some may even feel that these treatments alter traffic characteristics in such a way that traffic is no less and perhaps even more bothersome: the increased vehicle braking, accelerating and even bouncing that results from the treatments may be seen to create greater levels of disturbance that are worse than higher vehicle speeds. Additionally, some may feel that child safety concerns are not reduced much by these treatments – in fact there may be increased concerns about greater driver distraction and the potential for children to be hidden from drivers by horizontal obstructions with chicanes. Finally, ease of driving conditions in front of the dwelling may indeed be of more importance than reduced speeds even immediately in front of the dwelling at that

point specifically. In any case, the results suggest that both speed bumps and chicanes on the street in front have a net impact reducing the attractiveness of residential locations.

The parameter estimate for an increase in rent or taxes of \$100 is -0.8033 utils, which is a bit more than the impact of a switch from “none” to “constant faint hum” regarding traffic noise. Other comparisons can be made regarding the impact of tax increases, such as moving from a single family dwelling to a walkup, with a change in utility of -1.6340 , is equivalent to increasing taxes by about \$200.

As indicated above, the estimated values were not statistically significant for the three constants representing the differences in utility among the four pre-specified descriptions considered in the fourth game of each interview. There are only three such constants whose values are estimated because the fourth (arbitrarily selected a priori to be the “money costs” theme) is set to zero. Estimating these sorts of constants is a test of the ability of the full set of estimated parameters to explain the attitudes to a collection of elements altogether. The implication of these values not being statistically significant (that is, of the inability to reject the null hypothesis that they are zero) is that there is no net significance to what is omitted when the rest of the estimated parameters are used to explain attitudes to the collection of elements considered, which adds further credence to the results obtained.

4.3 Relative Influence of Elements for All Households

Based on the presentation in Fig. 4, the set of parameter estimates obtained for the full sample “loosely” suggests that housing type has the greatest influence on residential attraction, followed by traffic noise, air quality and municipal taxes. The nature of the road in front of the dwelling follows these. Then changes in auto travel times to work of 20 min or so – similar to the existing average travel time to work in Edmonton – and similar changes in walking times to school appear to be the next most influential after that, followed by other aspects of the walking trip to school and then by other components of the vehicle trips to work and to shopping.

These rankings of relative influence have an arbitrary component in that they are based on assumed values for various changes, such as the 20 min change in auto travel time used in the previous paragraph. The parameter estimations themselves (as listed in Table 1 of the Appendix) provide much less arbitrary indications – showing the rates at which various changes are valued and at which tradeoffs between different combinations of elements are made. That is, rather than merely indicate that air quality has more or less impact on residential attraction than does auto travel time to work or municipal taxes, these results indicate that completely avoiding bad air 1 day per month has the same impact as a decrease in auto travel time to work of about 27 min per trip or a decrease in municipal taxes of about \$63 per month. This is less arbitrary and more precise. Altogether, these parameter estimates provide utility values for different housing alternatives that can be used to

evaluate conditions more generally and also to forecast the actions of specific people and households in the selection of home locations.

Even with the above, it is still useful in some considerations to have some appreciation of the relative impact of each element independent of its specific condition. An alternative indication of the relative strength of influence of each element is available from the results via the t-ratio of the parameter estimate. The t-ratio provides a rough indication of the relative strength of the influence of the associated element on the utility for the alternative: if an element has a relatively strong influence it will tend to increase the magnitude of the associated parameter estimate relative to its standard error, making the t-ratio greater in absolute magnitude. Other factors also influence the t-ratio, which means that it is not an ideal indication of the relative strength of an element – but there is an overall general tendency for the t-ratio to be larger in absolute magnitude when the influence of the element is greater.

In addition, the interviews also included a direct question asking which element was most influential. Immediately after the ranking of hypothetical home locations, each respondent was asked to indicate which of the elements was the most influential in the ranking process.

Figure 5 is a “tornado diagram” that displays the t-ratio and the relative frequency of being indicated most influential side-by-side for each of the elements. The order of presentation from top to bottom is based on the relative frequency of being indicated most influential.

Generally, dwelling type, traffic noise, and municipal taxes or rent are the most important elements considered, followed closely by air quality and then by a second tier including walking time to school, auto ride time to work and the nature of the street in front of the dwelling. This order is broadly consistent with the order based on the interpretations of the estimation results as presented in Fig. 4 and discussed above. However, there are some differences towards the bottom of the diagram. Both of these measures become increasingly unreliable as relative importance decreases, which means that what can be said about the order of relative importance for the remaining elements below the nature of the street in front of dwelling is less definite, apart from the indication that aspects of the trip to work (beyond auto time) and the walking distance for transit to shopping are the most influential out of this lower tier. Perhaps most notable is the relatively weak influence of vehicle ride times to shopping.

4.4 Low Income Households

The estimation results for the sub-sample of 152 households with annual before-tax incomes less than \$20,000 are shown in Fig. 6 (using the same general arrangement used in Fig. 4) and also listed in the second column of results in Table 1 of the Appendix.

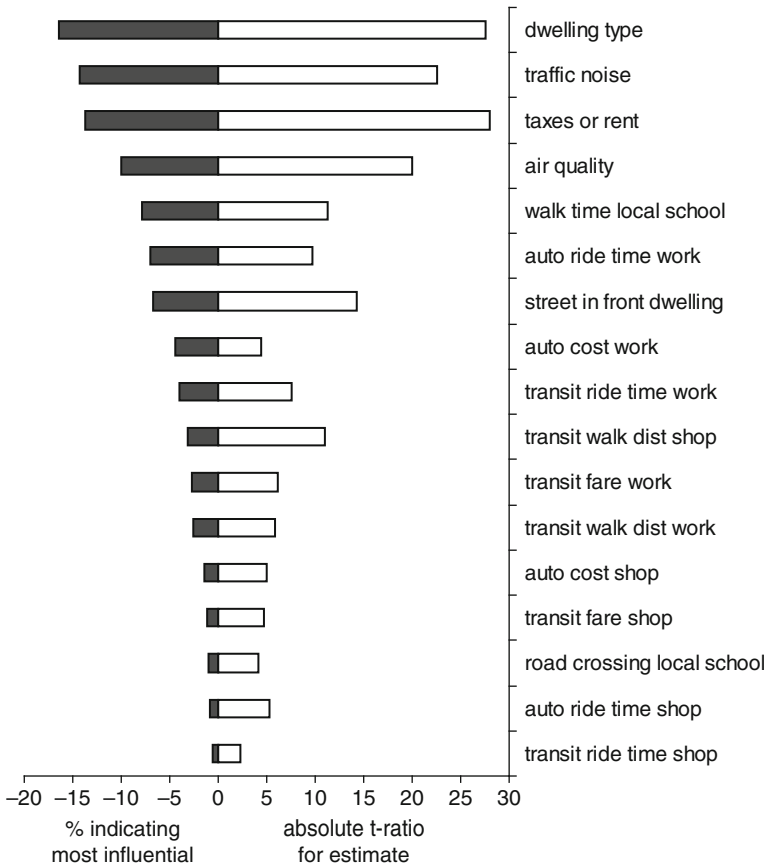


Fig. 5 Tornado diagram comparing t-ratio and percent most influential indications. The bars on either side of the centre line for each element show (*on the left*) the percent of interviews where the element was indicated to be the most influential in evaluating alternatives and (*on the right*) the absolute value of the t-ratio for the related parameter estimate for the element. Dwelling type, traffic noise, and municipal taxes or rent had the greatest influences, followed closely by air quality and then by a second tier including walking time to school, auto ride time to work and the nature of the street in front of the dwelling. Generally, travel conditions for transit and for trips to shopping had comparatively less impact on the attractiveness of home locations

The t-ratios are much smaller for these results than they are for the entire sample, consistent with the much smaller size of this sub-sample and resulting increased standard errors and associated reduced certainty in the parameter estimates.

The impact of auto travel time to work on the attractiveness of home locations is lower for this sub-sample. The ratio of the parameter estimate for auto time over the parameter estimate for auto cost for work is \$0.1363 per minute, lower than the corresponding value of \$0.1732 per minute found for the full sample. Obtaining a lower value for this sub-sample is consistent with the standard economic principle

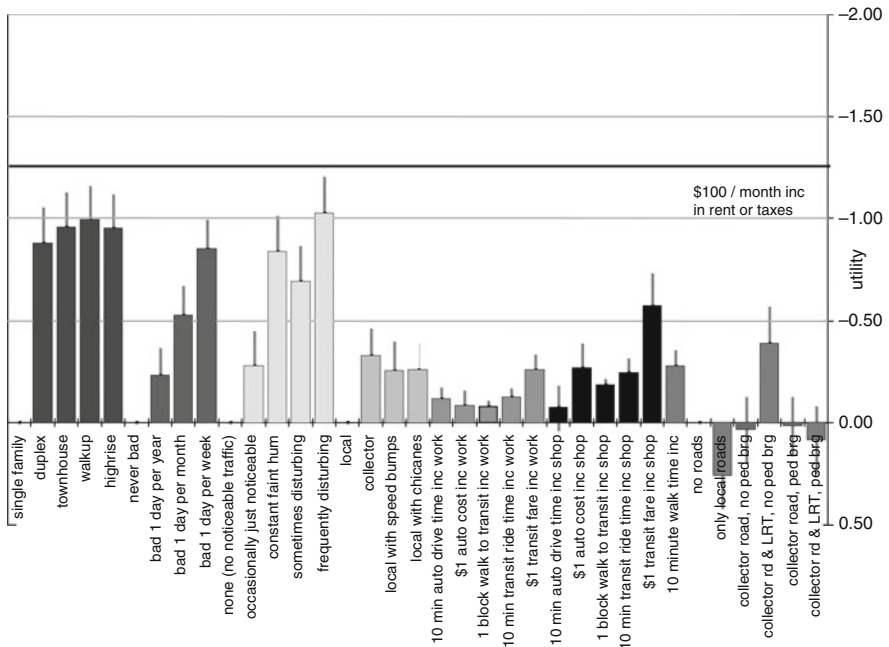


Fig. 6 Estimation results for sub-sample of low income households (152 households). The impacts of money amounts are all much greater than they are for all households, consistent with expectations. There is little difference among the impacts of dwelling types other than single family and road types other than local. The small sample size has likely influenced the results to some extent, with greater standard errors obtained throughout

that households with lower incomes tend to have lower values of time, all other things being equal, adding yet further credence to the range of results obtained here.

The impacts of the money costs of travelling to work and to shopping by transit on residential attraction are much greater for this sub-sample, as is the impact of municipal taxes or rent. This suggests that the typical lower income household tends to be much more sensitive to increases in money costs than does the typical “all-incomes” household, which is to be expected.

The impacts of changes to various housing types other than “single family” are reduced for this sub-sample and all roughly the same across the different types considered. For example, a change from “single family” to “walkup” acts to reduce residential attractiveness about as much as does an increase in transit cost to work of about \$2.00 per trip. The differences in the parameter estimates among the dwelling types other than single family must be viewed cautiously, however, because the standard errors are much larger, indicating that the differences are fairly imprecise values.

The impacts of changes in air quality and traffic noise for this sub-sample are very broadly similar to what they are for the full sample. The nature of the street in front of the dwelling has somewhat less impact and the conditions for the walk to

the local elementary school appear to have slightly greater impacts. The results concerning the impact of the need to cross only local roads is somewhat surprising: the positive estimate for “only local roads” implies that the need to cross some local roads is preferable to the ability to avoid all road crossings on the way to school. It is possible that this reflects concern about the personal security of children along more hidden paths behind houses rather than on the sidewalks of local streets, but it may also reflect a lack of knowledge generally within this sub-group of neighbourhood configurations that allow children to walk to school without crossing any roads. Again, because the standard errors are relatively larger, the values of the parameter estimates must be viewed with more caution.

4.5 High Income Households

The estimation results for the sub-sample of 113 households with annual before-tax incomes more than \$100,000 are shown in Fig. 7 and also listed in the third column of results in Table 1 of the Appendix.

Again, the t-ratios for these results are much smaller than they are for the entire sample, consistent with the much smaller size of this sub-sample.

The sensitivity to auto travel time to work is greater for this sub-sample than it is for the full sample. The ratio of the parameter estimate for auto time over the parameter estimate for auto cost is \$0.2092 per minute, higher than the corresponding value for the full sample, again consistent with the economic principle that those with higher incomes tend to have higher values of time.

The impact of municipal taxes or rent on the attractiveness of home locations is lower for this sub-sample than it is for the full sample, consistent with expectations.

The impact of the cost of travelling to work by transit is about the same for this sub-sample as it is for those in households with incomes less than \$20,000 per year considered immediately above. This is somewhat surprising: it was expected that transit travel costs to work would have much less of an impact for this sub-sample.

The results concerning the cost of travelling to shopping by transit are also surprising: a positive parameter estimate was obtained for this sub-sample, indicating that the typical respondent in this group would prefer to pay more, not less, for transit to shopping. This is surprising, but it is consistent with the results obtained in the above-mentioned study done in Calgary (Hunt 1994) which also obtained a positive coefficient estimate for transit cost to work for the highest income group. It is hypothesized that these results do not arise because these households want to pay more themselves and thus find locations with greater transit costs more appealing; rather they arise because these households want to pay less in taxes. It is expected that these households tend not to use transit themselves, so they are not concerned about higher fares per se, but they are worried about the potential tax implications of higher transit deficits, which leads a significant number of the people in these households to feel that transit fares – non-work ones in particular – should be increased in order to reduce transit deficits. It bears noting that this hypothesis is

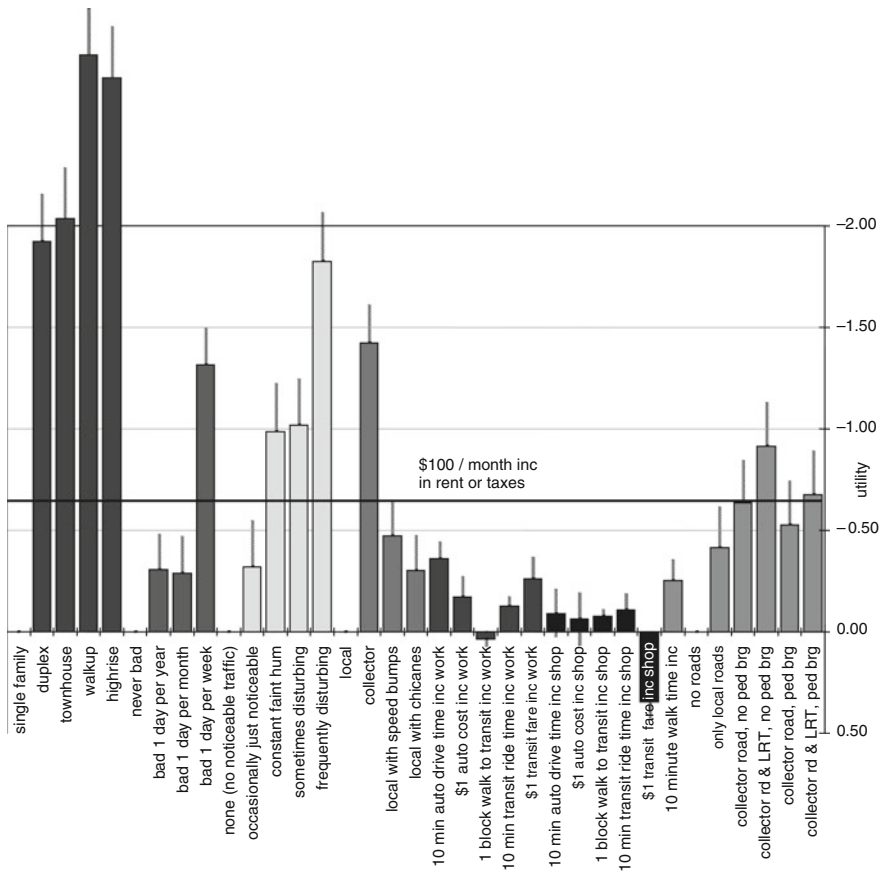


Fig. 7 Estimation results for sub-sample of high income households (113 households). The impacts of money amounts are all lower than they are for the full sample. The impacts of dwelling type, air quality, traffic noise and conditions for the walk to the local elementary school are all greater. The implied values of travel time (to work at least) are greater, consistent with expectations. The impact of the money cost for transit to shopping is positive, suggesting that increasing this fare will act to make housing locations more attractive. This unexpected result is perhaps caused by concerns within this sub-sample about the tax implications of higher transit deficits. Again, the small sample size has also likely influenced the results to some extent

highly speculative, and not based on information beyond that presented in the estimation results.

The impacts of changes to various dwelling types other than “single family” for this sub-sample are more pronounced than they are for the full sample, but they follow the same general pattern in that those types associated with higher densities have a comparatively greater impact. The effect on attractiveness of a change from “single family” to “highrise” is an exception: it is lower than the impact of a change from “single family” to “medium density” for this sub-sample whereas it is higher for the full sample. It may be that a significant proportion of those Edmontonians in

this group imagine luxury-style (perhaps even penthouse) accommodation when considering the “highrise” housing type, which acts to reduce the overall negative evaluation of this dwelling type for this group.

The impacts of poorer traffic noise conditions and of reductions in air quality are generally greater for this sub-sample. This is consistent with the idea that those in this group will be relatively more concerned about these aspects and correspondingly less concerned about money costs overall. Still, the t-ratios for these parameter estimates are not as high as they are for the full sample, indicating that somewhat less confidence should be placed in the values found for these parameters.

4.6 Households with Children Under 18-Years Old

The estimation results for the sub-sample of 450 households with at least one member under 18-years old are shown in Fig. 8 and also listed in the fourth column of results in Table 1 of the Appendix.

The parameter estimates indicate that the attitudes and sensitivities for this sub-sample are fairly similar to those for the full sample.

One difference between this sub-sample and the full sample concerns the impacts of changes in dwelling type from “single family”: types associated with higher residential densities have greater negative impacts for this sub-sample than they do for the full sample. The negative impact of a change from single family dwellings to highrises is particularly dramatic for this sub-sample, which is consistent with expectations for households with children.

Another difference concerns speed bumps and chicanes on the road in front of the dwelling. The parameter estimates for both are very near zero and highly insignificant in this case; whereas they are both negative and significant for the full sample. This suggests that there is some greater level of approval for these treatments in this sub-sample than is the case with the full sample – where those in households with children tend to see these treatments in a somewhat more positive light than do others – such that the net impact of these treatments on residential attractiveness is neutral rather than negative for the sub-sample.

4.7 Other Sub-samples of Households

The estimation results for various other sub-samples of households are shown in Tables 2–4 of the Appendix, as follows:

- In Table 2:
 - Retired households, with all members over 65 years of age and not working (140 households)

- Households where alternative with reduced money cost emphasis most preferred in fourth game (433 households)
- Households where alternative with children emphasis most preferred in fourth game (121 households) and
- Households where alternative with mobility emphasis most preferred in fourth game (270 households)

The estimation results for these other sub-samples are largely consistent with expectations.

For retired households and unemployed households the attributes related to travel to work have comparatively little impact on residential attractiveness, particularly for the auto mode. For households with no private vehicles and for retired households the attributes related to auto travel have relatively little impact – and the corresponding parameter estimates are all insignificant.

The consistency with results for households located in the downtown area tend to display attribute influences consistent with greater preferences and/or tolerances for downtown conditions, such as dramatically reduced aversions to dwelling types other than single family and much greater sensitivities to attributes of transit travel. The same applies broadly for inner city and suburban households. It should also be noted that there is some small amount of overlap between the definitions of inner city and suburban areas, so that the sum of the total number of households for the two corresponding sub-samples is greater than the number for the full sample.

The results for the sub-samples based on the preferences for particular emphases displayed in the fourth game are also consistent with the displayed preferences. But there is an element of circularity in these definitions – where the displayed preference that is the basis for the grouping into a particular sub-sample also contributes to the estimation results – which does reduce to some extent the strength of the indications provided in this regard, but only for these sub-samples.

Overall, the consistency with expectations displayed by these results is seen to provide further credence to the full set of results obtained.

5 Conclusions

5.1 *Validity of Results*

This study has successfully obtained valid indications of the impacts on residential attractiveness of a range of elements of urban form and transportation for various categories of Edmonton residents. The methods applied in the study avoided a

number of anticipated difficulties as intended. The results are consistent with the findings of other work done in Edmonton and with standard economic principles. Furthermore, they match reasonable expectations. All this adds substantial credence to the results.

The sample of respondents interviewed appears to be a reasonable representation of the entire population of Edmontonians in spite of the biases inherent in its selection. There is a fair match between sample and population for some known characteristics and the attitudes of households are broadly consistent among most of the different sub-samples considered. Certainly there are differences among different sub-groups as indicated above – but the overall general pattern in the results remains somewhat the same, which can be expected to reduce the impact of differences between sample and population to some extent. Consequently, the results for the full sample are considered to be reasonably accurate indications of the attitudes for the typical Edmonton household, with the caveat that the sample is not 100% representative and therefore provides indications that could be slightly distorted. Certainly, it appears that the broad trends in the attitudes for the sample can be attributed to the population with reasonable confidence.

It should also be noted, as an additional caveat with regard to representation, that individuals were used to “speak” for households – to respond on behalf of their households. The potential differences between individuals and households and the associated issues regarding the representation of distributions for these two groups were not explored in this work.

As a final general caveat, in all cases the impacts on attractiveness indicated by the parameter estimates are for a “typical” individual as represented by the full sample or sub-sample considered. The sensitivities of specific individuals (or households) will most certainly differ from those determined for this typical individual. In fact, for example, some households even prefer highrise housing to single family housing. The values and tradeoff rates indicated here apply at the overall average level and should in general only be applied in consideration of broader tendencies for large numbers of Edmontonians.

5.2 Principal Findings

Out of the attributes of urban form and transportation considered, housing type, traffic noise and municipal taxes or rent have the greatest impacts on residential attractiveness for the typical household. The preferences for single family dwellings and little traffic noise in particular are very strong and consistent across almost all sub-groups. The typical household is willing to endure large increases in travel times and costs to work and shopping in order to stay in a single family dwelling or maintain low traffic noise, all other things being equal.

The typical household is also very concerned about municipal taxes and rents. The strength of this concern is broadly consistent across all groups considered. There is a much greater sensitivity to money paid in taxes than there is to money paid to travel to work or shopping.

Air quality is another attribute that has a relatively large impact on residential attractiveness. The desire for very low frequencies of bad air quality (according to government standards) is strong enough that the typical resident is willing to trade off substantial increases in municipal taxes and large increases in travel times to work in order to obtain these low frequencies of bad air quality, all other things being equal. This is very consistent across all sub-groups considered.

Walking times to the local elementary school and auto travel times to work have substantial impacts on the attractiveness of home locations. There is some variation in the levels of impacts of travel times and in the corresponding values of time, but overall the time spent travelling to school and work are some of the more influential attributes out of those considered. For the typical resident a decrease in travel time work of 1 min has the same impact on the utility of a residential location as a decrease in municipal taxes of \$2.35 per month, all other things being equal. This provides a standard against which proposed transportation improvements could be assessed.

The nature of the street in front of the dwelling also has some reasonable impact on residential attractiveness for the typical resident. The desire for a local road rather than a collector is reasonably strong and consistent across all the sub-groups considered.

Auto travel times to work have more of an impact on household attractiveness than auto costs or transit travel times and costs to work for the typical resident. The sensitivities to auto travel times to work are roughly twice those to transit travel times to work. This means that the typical resident would get about twice the increase in residential utility with a reduction in auto travel times to work as he or she would with an equivalent reduction in transit travel times to work, all other things being equal. It also means that improvements to transit travel times to work must be roughly twice those to auto travel times to work in order to have the same impact on residential utility for the typical resident.

For the typical resident the money costs for travel to work or shopping have little impact on residential attractiveness relative to the other attributes elements that were considered.

As indicated above, the impacts of attributes on residential utility vary substantially across the population. Different sub-samples of households displayed different sensitivities, broadly consistent with expectations. The practical implication of this variation is that considerations based on a single set of values for the entire population are not going to respect this variation and thus are not going to be as accurate as considerations with different sets of values for different sub-groups of the population.

5.3 Further Work

Much further work could be done following on from the work reported here. Some of the possibilities considered most appropriate are outlined below.

The logit models and associated utility functions whose parameters have been estimated for the different categories of households could be used as models of residential location choice forming the basis of a residential allocation process in a land use model. These models would still have to be calibrated, adjusting the response characteristics and the aggregate shares to match known aggregate targets. This is because it is inappropriate to assume that the stated preference behaviour observed in this work provides valid indications of these aspects. But the trade-off rates among a wide range of elements for a variety of household types established in this work could be used directly.

The utility functions established in this work could also be used as the basis of a framework for policy evaluation. Utility values calculated using these functions could be used to evaluate the total change in satisfaction arising with changes regarding any one or more, and even all, of the housing related attributes considered – for the typical household or even for different types of households. This change in satisfaction can be expressed in dollar equivalents, thereby providing the essence of a cost-benefit analysis for policy evaluation. Such an analysis would include representation of the impacts regarding all of the attributes considered. For example, the impact on residential location utility of an increase in traffic noise in a given neighbourhood arising with the development of a new major road would be combined with the corresponding impact on utility arising with the improved travel times to work for all households. Thus, one of the criticisms of partial cost-benefit analysis is avoided in that these impacts are evaluated and included – at rates based on the indicated preferences of the typical household. Certainly, the changes in utility values for potential alternative plans would provide decision-makers with important numerical information regarding these alternatives, to be considered along with other information in deciding what to do for the future.

The sub-sample definitions based just on the socio-economic characteristics of the household members are most directly applicable in any further modelling or analysis work. Those sub-sample definitions based on the decisions of households, particularly those regarding location decisions, require the “answer” of the modelling process to be known before the appropriate model for the appropriate sub-group can be identified, which introduces a circularity that is avoided when definitions based just on the socio-economic characteristics of the household members are used.

The survey instrument and analysis used here could be similarly applied elsewhere, perhaps with modifications respecting differences in language and culture as appropriate. This would allow the development of a broader understanding of the sensitivities to attributes of urban form and transportation considered in this

work – regarding how they vary in other settings and even across cultures, and thus the extent of any transferability in the associated parameter values. The use of a common survey instrument and treatment would help remove differences in results related to differences in conditions, and allow a more thorough consideration of the sensitivities themselves. The extent to which the within setting variations (among sub-groups) are greater than the between setting variations could also be considered – possibly helping develop a more complete understanding of the role of supply conditions and of sensitivities and attitudes in the development of urban areas.

The influences of other attributes could also be considered using the process used in this work. The set of attributes considered here is by no means exhaustive. A more complete understanding of the sensitivities of the typical household to a wider range of attributes would further inform both modelling and planning in various areas. For example, the impacts of road surface conditions, frequency of traffic lights along roadways, and safety at LRT stations, as examples within the transportation area, and of different forms of service charges and access to hospitals, libraries and social service programs, as examples within a larger context, could also be examined. Sensitivity to changes in the contribution to aggregate greenhouse gases consistent with the Kyoto Protocol could also be considered. This would provide indications of the tradeoff rates among such attributes. If some of the attributes considered in this work are also considered in any such additional work, then a set of consistent tradeoff rates concerning the combined group of attributes can be developed. This would allow the combined impacts of any one or more, and even all, of the combined groups of attributes to be determined and compared on a consistent basis as described immediately above. Ultimately, this could lead to much more complete and consistent both modelling of behaviour regarding residential location and numerical-based consideration of the preferences of the population and of the quality of life being provided in the planning work that is done.

Acknowledgements The work described here was sponsored by The City of Edmonton. The preparation of this paper was supported by the Natural Science and Engineering Research Council of Canada and by the Institute for Advanced Policy Research at the University of Calgary. This description drew extensively from a previous paper (Hunt 2001). A more detailed description of this work is provided in the project report (Hunt 1996).

Appendix: Estimation Results

See Appendix Tables 1–4.

Table 1 Estimation results for Logit choice models for all households and selected sub-samples of households

Parameters	All households			Incomes below 20 K			Incomes above 100 K			Children under 18 years		
	Estimate	Abs t-ratio		Estimate	Abs t-ratio		Estimate	Abs t-ratio		Estimate	Abs t-ratio	
Dwelling type												
Single family	0	-		0	-		0	-		0	-	
Duplex	-1.0570	18.2		-0.8783	5.1		-1.9220	8.3		-1.1450	11.6	
Townhouse	-1.1130	19.1		-0.9566	5.6		-2.0350	8.2		-1.2880	12.8	
Walkup	-1.6340	26.2		-0.9895	5.9		-2.8410	12.6		-1.8520	17.0	
Highrise	-1.7940	27.8		-0.9514	5.8		-2.7290	11.0		-2.3930	19.5	
Air quality												
Never bad	0	-		0	-		0	-		0	-	
Bad 1 day per year	-0.2446	5.2		-0.2299	1.7		-0.3073	1.8		-0.2681	3.3	
Bad 1 day per month	-0.5092	10.6		-0.5264	3.7		-0.2879	1.6		-0.4741	5.8	
Bad 1 day per week	-0.9796	20.0		-0.8504	6.0		-1.3150	7.4		-0.9824	11.6	
Traffic noise												
None (no noticeable traffic noise)	0	-		0	-		0	-		0	-	
Occasionally just noticeable	-0.1694	2.9		-0.2758	1.6		-0.3192	1.4		-0.2051	2.1	
Constant faint hum	-0.7165	12.4		-0.8354	4.8		-0.9886	4.3		-0.8015	8.0	
Sometimes disturbing	-0.5348	9.3		-0.6934	4.1		-1.0180	4.5		-0.5852	5.8	
Frequently disturbing	-1.3500	22.2		-1.0250	5.8		-1.8230	7.6		-1.5200	14.0	
Street in front of dwelling												
Local	0	-		0	-		0	-		0	-	
Collector	-0.6885	14.1		-0.3307	2.5		-1.4250	7.7		-0.8073	9.3	
Local with speed bumps	-0.1352	3.0		-0.2570	1.8		-0.4735	2.9		-0.0126	0.2	
Local with chicanes	-0.1380	3.0		-0.2594	2.0		-0.3028	1.8		-0.0120	0.1	
Taxes or rent												
\$100 per month increase	-0.8033	28.1		-1.2260	13.5		-0.6665	6.7		-0.6579	13.8	
Travel to work												
10 min auto drive time increase	-0.1890	9.6		-0.1170	2.1		-0.3613	4.4		-0.1756	5.2	
\$1 auto cost increase	-0.1091	4.2		-0.0858	1.2		-0.1727	1.8		-0.1464	3.3	
Travel to shopping												
1 block walk to transit increase	-0.0536	5.5		-0.0780	2.6		0.0340	1.0		-0.0568	3.4	
10 min transit ride time increase	-0.0974	7.2		-0.1253	3.1		-0.1246	2.6		-0.0876	3.9	
\$1 transit fare increase	-0.1574	6.0		-0.2574	3.3		-0.2605	2.5		-0.1625	3.7	
Travel to shopping												
10 min auto drive time increase	-0.1746	4.9		-0.0747	0.7		-0.0918	0.8		-0.1804	3.0	
\$1 auto cost increase	-0.1743	4.6		-0.2706	2.3		-0.0638	0.5		-0.3025	4.6	
1 block walk to transit increase	-0.1022	10.8		-0.1855	6.3		-0.0746	2.2		-0.1026	6.1	

(continued)

Table 2 Estimation results for Logit choice models for selected sub-samples of households

Items Parameters	Retired		No workers		One or more workers		No private vehicles		
	Estimate	Abs t-ratio	Estimate	Abs t-ratio	Estimate	Abs t-ratio	Estimate	Abs t-ratio	
Dwelling type	Single family	0	0	0	0	0	0	0	
	Duplex	-0.8808	5.0	-0.9244	7.1	-1.1070	17.0	-0.6346	3.5
	Townhouse	-1.0350	5.8	-1.0150	7.9	-1.1650	17.6	-0.5522	2.8
	Walkup	-1.3180	6.5	-1.3460	9.7	-1.7380	24.6	-0.6712	3.5
	Highrise	-0.5076	3.0	-1.0750	8.2	-2.0150	26.9	-0.5052	2.8
Air quality	Never bad	0	0	0	0	0	0	0	
	Bad 1 day per year	-0.1564	1.1	-0.1555	1.5	-0.2650	5.0	-0.4114	2.6
	Bad 1 day per month	-0.6202	4.3	-0.5377	5.2	-0.5110	9.4	-0.6081	3.7
	Bad 1 day per week	-0.9169	6.2	-1.0020	9.3	-0.9810	17.7	-1.0480	6.2
	None (no noticeable traffic noise)	0	0	0	0	0	0	0	0
Traffic noise	Occasionally just noticeable	-0.2288	1.4	-0.2649	2.1	-0.1335	2.1	-0.1549	0.9
	Constant faint hum	-0.5896	3.4	-0.7541	5.9	-0.7049	10.9	-0.5723	3.1
	Sometimes disturbing	-0.5223	3.0	-0.6133	4.7	-0.5151	8.0	-0.5636	3.0
	Frequently disturbing	-0.9789	5.6	-1.0330	7.9	-1.4450	20.9	-1.1870	5.9
	Local	0	0	0	0	0	0	0	0
Street in front of dwelling	Collector	-0.5932	4.2	-0.5512	5.2	-0.7360	13.3	-0.1613	1.0
	Local with speed bumps	-0.1478	1.1	-0.2305	2.3	-0.1155	2.2	-0.0058	0.0
	Local with chicanes	-0.3492	2.6	-0.2978	3.1	-0.1089	2.1	-0.0252	0.2
	\$100 per month increase	-0.9242	10.7	-1.0260	15.9	-0.7578	23.6	-1.0110	10.1
	10 min auto drive time increase	0.0418	0.7	-0.0154	0.4	-0.2427	10.8	-0.0221	0.3
Taxes or rent Travel to work	\$1 auto cost increase	-0.1197	1.5	-0.1128	2.1	-0.1057	3.6	0.0196	0.2
	1 block walk to transit increase	-0.0435	1.4	-0.0420	2.0	-0.0566	5.2	-0.0533	1.6
	10 min transit ride time increase	-0.0268	0.6	-0.0538	1.8	-0.1169	7.6	-0.1093	3.7
	\$1 transit fare increase	-0.1727	2.0	-0.2142	3.6	-0.1474	5.0	-0.3336	2.2
	10 min auto drive time increase	0.0679	0.6	-0.0812	1.0	-0.2000	5.0	-0.1069	0.9
Travel to shopping	\$1 auto cost increase	0.0891	0.7	-0.0600	0.7	-0.2008	4.7	-0.1782	1.4
	1 block walk to transit increase	-0.2740	8.2	-0.1913	8.5	-0.0824	7.8	-0.3055	8.5
	10 min transit ride time increase	-0.0304	0.4	-0.0571	1.2	-0.0416	1.7	-0.1507	2.0

(continued)

Table 3 Estimation results for Logit choice models for selected sub-samples of households

Items Parameters	No children not retired			Downtown located			Inner city located			Suburbs located		
	Estimate	Abs t-ratio		Estimate	Abs t-ratio		Estimate	Abs t-ratio		Estimate	Abs t-ratio	
Dwelling type	Single family	0	-	0	-	0	-	0	-	0	-	-
	Duplex	-1.0730	13.5	-0.6198	3.7	-1.0660	14.2	-1.0740	11.4	-1.0740	11.4	-
	Townhouse	-1.0720	13.3	-0.1770	1.1	-1.0360	13.5	-1.2980	13.8	-1.2980	13.8	-
	Walkup	-1.6150	19.2	-0.9345	5.9	-1.5520	18.7	-1.7800	18.1	-1.7800	18.1	-
	Highrise	-1.7930	20.5	-0.3043	1.9	-1.5920	19.4	-2.1770	20.1	-2.1770	20.1	-
	Never bad	0	-	0	-	0	-	0	-	0	-	-
Air quality	Bad 1 day per year	-0.2562	4.0	-0.1625	1.3	-0.2766	4.5	-0.2427	3.2	-0.2427	3.2	-
	Bad 1 day per month	-0.5307	8.0	-0.6702	5.2	-0.6120	9.7	-0.3944	5.1	-0.3944	5.1	-
	Bad 1 day per week	-1.0320	15.4	-0.8823	6.5	-1.0290	16.1	-0.9842	12.3	-0.9842	12.3	-
	None (no noticeable traffic noise)	0	-	0	-	0	-	0	-	0	-	-
Traffic noise	Occasionally just noticeable	-0.1214	1.5	-0.0153	0.1	-0.2240	3.0	-0.0998	1.1	-0.0998	1.1	-
	Constant faint hum	-0.6977	8.9	-0.7601	5.0	-0.6924	9.1	-0.7686	8.3	-0.7686	8.3	-
	Sometimes disturbing	-0.5231	6.7	-0.5371	3.5	-0.6203	8.2	0.4040	4.4	0.4040	4.4	-
	Frequently disturbing	-1.3850	16.9	-1.3430	8.6	-1.3420	16.8	-1.3940	14.3	-1.3940	14.3	-
	Local	0	-	0	-	0	-	0	-	0	-	-
	Collector	-0.6778	10.2	-0.7240	5.2	-0.6785	10.4	-0.7125	9.3	-0.7125	9.3	-
Street in front of dwelling	Local with speed bumps	-0.2041	3.3	-0.1967	1.5	-0.1559	2.5	-0.1128	1.6	-0.1128	1.6	-
	Local with chicanes	-0.1879	3.0	-0.2260	1.8	-0.1879	3.1	-0.0662	0.9	-0.0662	0.9	-
Taxes or rent	\$100 per month increase	-0.9127	22.8	-0.8170	10.7	-0.8503	22.2	-0.7324	16.5	-0.7324	16.5	-
	10 min auto drive time increase	-0.2503	9.2	-0.1968	3.3	-0.2061	8.2	-0.1749	5.3	-0.1749	5.3	-
Travel to work	\$1 auto cost increase	-0.0949	2.7	-0.1418	2.1	-0.1161	3.5	-0.0985	2.3	-0.0985	2.3	-
	1 block walk to transit increase	-0.0528	4.0	-0.0773	3.1	-0.0489	4.0	-0.0577	3.5	-0.0577	3.5	-
Travel to shopping	10 min transit ride time increase	-0.1223	6.5	-0.1490	3.4	-0.0941	5.4	-0.0922	4.1	-0.0922	4.1	-
	\$1 transit fare increase	-0.1551	4.5	-0.2884	3.9	-0.1591	4.7	-0.1521	3.5	-0.1521	3.5	-
	10 min auto drive time increase	-0.2197	4.5	-0.0655	0.6	-0.2017	4.4	-0.1424	2.5	-0.1424	2.5	-
	\$1 auto cost increase	-0.1347	2.6	-0.1738	1.8	-0.1119	2.2	-0.2447	4.1	-0.2447	4.1	-
	1 block walk to transit increase	-0.0746	5.9	-0.1228	5.0	-0.1085	8.6	-0.0964	6.4	-0.0964	6.4	-
	10 min transit ride time increase	-0.0431	1.4	-0.2095	3.2	-0.0704	2.5	-0.0152	0.4	-0.0152	0.4	-

(continued)

Table 4 Estimation results for Logit choice models for selected sub-samples of households

Parameters	Environment emphasis			Finances emphasis			Children emphasis			Mobility emphasis		
	Estimate	Abs t-ratio		Estimate	Abs t-ratio		Estimate	Abs t-ratio		Estimate	Abs t-ratio	
Dwelling type	0	-		0	-		0	-		0	-	
Single family	-1.3880	13.7		-1.1410	11.0		-1.2520	6.4		-0.5749	4.8	
Duplex	-1.3510	13.0		-1.1460	11.3		-1.0970	5.6		-0.8295	6.8	
Townhouse	-1.9100	17.2		-1.7070	15.9		-1.8370	8.8		-1.1330	8.5	
Walkup	-2.0380	18.0		-1.9340	17.3		-3.2020	10.4		-1.0450	8.3	
Highrise	0	-		0	-		0	-		0	-	
Air quality	-0.3828	4.6		-0.1214	1.5		-0.4709	3.1		-0.2390	2.3	
Bad 1 day per year	-0.9812	11.0		-0.3191	4.0		-0.3043	1.9		-0.3780	3.8	
Bad 1 day per month	-1.5320	17.0		-0.7552	9.1		-0.8012	5.0		-0.7623	7.4	
Bad 1 day per week	0	-		0	-		0	-		0	-	
Traffic noise	-0.2156	2.1		-0.1602	1.6		-0.3055	1.5		-0.0712	0.6	
Occasionally just noticeable	-1.0020	9.7		-0.6560	6.7		-0.8228	4.3		-0.4432	3.6	
Constant faint hum	-0.8275	8.1		-0.3692	3.8		-0.7978	4.2		-0.3338	2.7	
Sometimes disturbing	-2.0330	18.0		-1.0340	10.3		-1.5790	7.5		-1.0260	8.1	
Frequently disturbing	0	-		0	-		0	-		0	-	
Street in front of dwelling	-0.8689	10.4		-0.6462	7.5		-0.7689	4.5		-0.5752	5.6	
Collector	-0.2753	3.5		-0.0930	1.2		0.1045	0.7		-0.1238	1.2	
Local with speed bumps	-0.0957	1.2		-0.2545	3.2		-0.1217	0.8		-0.0739	0.7	
Local with chicanes	-0.6660	14.0		-1.0570	20.0		-0.4710	5.2		-0.8631	14.0	
Taxes or rent	-0.1956	5.6		-0.1587	4.7		-0.2448	3.8		-0.2187	5.1	
Travel to work	-0.0653	1.4		-0.1841	4.1		-0.1100	1.3		-0.0778	1.4	
10 min auto drive time increase	-0.0280	1.7		-0.0434	2.5		-0.0480	1.6		-0.1154	5.5	
\$1 auto cost increase	-0.1221	5.0		-0.0721	3.1		-0.0077	0.2		-0.1633	5.5	
1 block walk to transit increase	-0.0881	1.9		-0.2410	5.2		-0.0392	0.5		-0.1946	3.3	
10 min transit ride time increase	-0.1518	2.4		-0.1755	2.8		0.0075	0.1		-0.2781	3.8	
Travel to shopping	-0.1405	2.2		-0.1669	2.5		-0.3645	2.8		-0.1973	2.4	
\$1 auto cost increase	-0.0695	4.3		-0.0979	6.0		-0.0638	1.8		-0.1793	8.4	
1 block walk to transit increase	-0.0108	0.3		-0.0782	2.1		-0.0043	0.1		-0.0564	1.2	
10 min transit ride time increase												

(continued)

References

- Agresti A (2007) Multicategory logit models, Chap. 6. In: An introduction to categorical data analysis, 2nd edn. Wiley, New York
- ALOGIT (2007) Alogit Software and Analysis Ltd, available at the website: www.alogit.com. Accessed 2007
- Ang AHS, Tang WH (1975) Probability concepts in engineering planning and design – vol 1: Basic principles. Wiley, Toronto
- Ben-Akiva ME, Lerman SR (1985) Discrete choice analysis: theory and application to travel demand. MIT, Cambridge, MA
- Chapman RG, Staelin R (1982) Exploiting rank ordered choice set data within the stochastic utility model. *J Market Res* 19:288–301
- City of Edmonton (1991) Calibration of a nested Logit AM peak hour mode split model. Transportation Department, The City of Edmonton, Edmonton AB, Canada
- City of Edmonton (1993) Report of the Edmonton Civic Census for 1993. The City of Edmonton, Edmonton AB, Canada
- Daly AJ (1992) ALOGIT Users' Guide, Version 3.2. Hague Consulting Group, The Hague
- Hensher DA, Green WH (2003) The mixed logit models: the state of practice. *Transportation* 30(2):133–176
- Hunt JD (1990) A logit model of public transport route choice. *Inst Transp Eng J* 60(12):26–30
- Hunt JD (1994) Evaluating Core Values Regarding Transportation and Urban Form in Calgary, BGS:22-10-94. City of Calgary GoPlan Project, Calgary, AB, Canada
- Hunt JD (1996) Evaluating Core Values Regarding Transportation and Urban Form in Edmonton. City of Edmonton MasterPlan Project, The City of Edmonton, Edmonton AB, Canada
- Hunt JD (2001) Stated preference analysis of sensitivities to elements of transportation and urban form. *Transp Res Rec* 1780:76–86
- Hunt JD (2003) Modelling transportation policy impacts on mobility benefits and Kyoto-Protocol-related emissions. *Built Environ* 29(1):48–65
- Hunt JD, Brownlee AT and Doblanko LP (1998) Design and calibration of the Edmonton Transport Analysis model. In: Preprints for the 78th Annual Transportation Research Board Conference. January 1999, Washington DC, USA
- Koppelman FS (2006) Closed form discrete choice models. *Handbook of transport modeling*. Pergamon, Oxford, pp 211–228
- McFadden D (1974) Conditional logit analysis of qualitative choice behavior. In: Zarembka P (ed) *Frontiers in Econometrics*. Academic Press, New York, pp 105–142
- McFadden D (2007) The behavioral science of transportation. *Transp Policy* 14:269–274
- McMillan JDP (1996) A stated preference investigation of commuters attitudes towards carpooling in Calgary and Edmonton. Dissertation, University of Calgary
- Ortúzar JdeD, Willumsen LG (1994) *Modelling transport*, 2nd edn. Wiley, New York
- Train K (2003) *Discrete choice methods with simulation*. Cambridge University Press, Cambridge, UK