Environmental & Resource Economics (2005) 32: 509–531
DOI 10.1007/s10640-005-7686-7

Households' Willingness to Pay for Water Service Attributes

DAVID HENSHER[1], NINA SHORE[2] and KENNETH TRAIN[3,*]
[1]*University of Sydney, Sydney, Australia;* [2]*NERA Economic Consulting;* [3]*Department of Economics, University of California, 549 Evans Hall 3880, Berkeley, CA, 94720-3880, USA;*
**Author for correspondence (e-mail: train@econ.berkeley.edu)*

Accepted 20 May 2005

Abstract. Water consumption and disposal are often taken for granted as essential services with required levels of service quality, yet little is known about how much consumers are willing to pay for specific service levels. As customers in many countries face changing levels of water availability (especially shortages linked possibly to climate change and limited catchment capacity), the need to assess the value (and hence benefit) to society of varying service levels and prices in an effort to secure the provision of and disposal of water has risen on public agendas. In an attempt to establish how much customers are willing to pay for specific levels of service, we use a series of stated choice experiments and mixed logit models to establish the willingness to pay to avoid interruptions in water service and overflows of wastewater, differentiated by the frequency, timing and duration of these events. The empirical evidence is an important input into the regulatory process for establishing service levels and tariffs, as well as useful planning information for agencies charged with finding cost effective ways of delivering services at prices that customers deem to be value for money.

Key words: mixed logit, waste water, water service

JEL classifications: C13, C25, D12, Q25

1. Introduction

Drinking water and sewage services are generally provided by either a local government agency or a regulated firm. In either case, explicit decisions must be made as to the appropriate mix of service quality and price. Water service interruptions can occur due to unexpected emergencies or system failures, as well as for planned maintenance. The expected frequency, timing, and duration of interruptions can be affected by the capital investments and operations of the supplier, with higher levels of service generally being attainable through higher costs and hence higher prices. For wastewater, the analogous issue concerns overflows: reducing the expected frequency and time to repair overflows incurs a cost, which translates into higher prices for customers. To determine the appropriate level of these service attributes relative to price, information is needed on the value that customers place on each attribute.

There is a long tradition of quantifying the value of reliability and other service attributes for electricity. An overview of the estimates relating to the electricity service is given by Eto et al. (2001). To our knowledge, there have been no previously published studies of the value of service attributes for drinking and wastewater – even though the issues are the same for water as electricity, and the money at stake is often equivalent if not higher in regions where the absence of rain is increasing and catchment infrastructure is (arguably) in need of upgrading.

In this paper we report results from a study of the value that householders place on attributes of drinking water and wastewater service. Our analysis is based on stated choice experiments, similar to those used by Cai et al. (1998) and Goett et al. (2000) for electricity. Louviere et al. (2000) provide a description of stated choice experiments in general and their applications in other areas. Briefly, in a choice experiment, a survey respondent is presented with two or more options for service levels and associated price and is asked to state which option he/she prefers. Different service levels and prices are specified in a number of experiments, to provide the variation that is necessary for identification through estimation of the marginal utilities of each attribute. A series of experiments is presented to each surveyed customer, with the experiments varying over respondents. Respondents' choices reveal their willingness to pay for improved service. Statistical analysis of the responses, using discrete choice models, provides estimates of the willingness to pay.

In the sections below we describe the sample, the choice experiments, the estimation procedure, and the results of the study.

2. Sample

The study was conducted in 2002 in Canberra, Australia's national capital. The supplier of water and wastewater services in Canberra is ActewAGL. Also a supplier of electricity and gas services, ActewAGL was established in October 2000 and is Australia's first utility joint venture between a major private sector group (AGL) and a government owned enterprise (ACTEW Corporation). The water and wastewater assets remain public property, with ActewAGL providing water and wastewater services under a service contract. The Independent Competition and Regulatory Commission (ICRC) regulates rates, access to services and infrastructure, and other matters relating to electricity, natural gas, water and wastewater utilities. The ICRC issues price directions in relation to water and wastewater services, and oversees the quality, reliability and safety of services. Our study was initiated by ActewAGL in response to a request by the ICRC for information on customers' valuation of service attributes, to assess whether the current levels of reliability and other attributes are appropriate.

Prior to designing our survey, we conducted a series of exploratory, qualitative group discussions to identify the salient aspects of the water and wastewater services. Three focus groups were conducted with residential customers, each exploring customers' perceptions and experiences of water and wastewater services. The information that was obtained during the focus groups was utilized to design the choice experiments, including which service attributes were included in the experiments, how the attributes were described, and the levels that each attribute could take.

The survey was conducted in two parts - an initial recruitment interview and a choice experiment task. The sample was randomly generated from the Electronic White Pages (the telephone book). The recruitment questionnaire was designed to target the person in the household who would be responsible for dealing with utility-type decisions such as dealing with supply issues and ensuring that the bill gets paid. Other recruitment criteria were that: (i) participants were to be connected to the water and/or wastewater service; (ii) participants were either to receive a bill directly from ACTEW/ActewAGL or a written notice from their landlord;[1] (iii) participants had to be able to provide a 'ballpark' estimate of their annual water service bill; and (iv) participants were not to be employed in the market research industry, advertising, media or public relations, or by a gas, electricity or water utility (according to standard market research practice). Once the respondent was deemed to meet these criteria, the choice experiments, described below, were mailed out to the respondent. The respondent was then contacted by phone and interviewed about the choice experiments.

A total of 240 respondents were recruited, of which 211 completed the mailed-out choice experiments in a follow-up interview. To obtain the 240 recruited respondents, a total of 486 households were contacted. Of these, 179 refused to be interviewed and another 67 were excluded because they did not meet the criteria listed above. The relevant response rates are therefore: 47 percent of all contacted households, including those that did not meet the eligibility criteria (211/486), 56 percent of contacted households that met the criteria for eligibility (211/380, assuming that those households who refused to be interviewed had the same share that would meet the criteria as those who did not refuse),[2] and 88 percent of households who were mailed the choice experiments (211/240).

3. Choice Experiments

Two sets of experiments were presented to the respondents, one regarding drinking water service and the other for the wastewater service. An example of each is given in the appendix along with the protocol that was used when interviewing the respondents about the experiments. Each experiment listed two service options with their descriptions, and the respondent was asked which of the two service options he/she prefers. Two sets of experiments were presented, one set for drinking water and another for wastewater. The options in each choice experiment were described in terms of the following attributes and levels.

For drinking water, the service options specified the following attributes:[3]

- The frequency of service interruptions, expressed as 'number of times water is unavailable'. Four levels were utilized, varying from '12 times per year' to 'once every 10 years'.
- The average duration of an interruption, expressed as 'length of time that water is unavailable each time that it goes off'. Six levels were utilized, varying from '24 hours' to '1 hour'.
- The time of day that the water service is interrupted, expressed as 'time of day that water is unavailable each time that it goes out'. The times were described as one of the following: 'over the weekend', 'Mon-Fri sometime after 6 p.m.', 'Mon-Fri sometime after 8 a.m.', 'Mon-Fri sometime after midnight', and 'over a weekday'. The time periods were chosen to be consistent with the 'duration' attribute. For example, a duration of 24 hours could occur over the weekend or over a weekday, but not during the other three periods.
- Notification of the interruption, expressed as 'prior notification that water will be unavailable'. The levels were: 'no notification provided', '1 day', '2 days', '7 days', 'two weeks', and 'water unavailable due to emergency – no notification possible.' The distinction between 'no notification provided' and 'no notification possible' was included because participants in the focus groups indicated that they viewed these two situations differently: not receiving notice when an interruption was unexpected because of an emergency was considered less bothersome than not receiving notice of a planned or otherwise anticipated interruption.
- Information service provided during an interruption, expressed as 'response to phone inquiries in the event of water becoming unavailable'. The levels were: (i) 'your call is answered by an AUTOMATIC VOICE - the voice gives you the option of hearing a recorded message that gives you an up-to-date status report on any water supply issues by suburb, or to speak to someone but you may be put on hold before a person answers'; and (ii) 'you get straight through to a PERSON - you are not put on hold and there is no machine directing you to press buttons'.
- Price, expressed as 'total water and sewerage bill for the year'. The bill was calculated in the experiments as a randomly chosen percentage of the householder's estimate of their actual annual bill. For example, a household whose bill in the previous year had been $800 would see a price of $880 if the random number 1.1 was drawn.

Reliability of the wastewater service relates primarily to the frequency of incidents called sewer 'overflows' or 'surcharges'. These incidents occur due to pipe blockage or other capacity limitations, and involve raw sewage spilling out of drains, either in or at a customer's premise or out in the street. The scenarios for wastewater service included the following attributes:

- The frequency of disruptions to the wastewater service, expressed as 'number of times you experience an overflow of sewerage', with four levels varying from '2 times per year' to 'once every 10 years'.
- The coverage of the disruption, expressed as 'source of overflow'. The levels were 'inside your home', 'immediately outside your home' and 'at the nearest sewer manhole in the street'.
- The average duration of a disruption, expressed as 'length of time before overflow is contained'. Seven levels were utilized, varying from '2 days' to '1 hour'.
- Information service provided in the event of an overflow, expressed as 'response to phone inquiries in the event of a sewerage overflow'. The levels are the same as given above for the drinking water service.
- Price, expressed as 'total water and sewerage bill for the year' and calculated the same way as described above for the drinking water service

Each respondent was presented with a series of six experiments relating to the drinking water service followed by a series of six experiments regarding the wastewater service. The choice experiment exercise was pre-tested twice, in which respondents were queried about their understanding of the terms, whether they felt they could meaningfully evaluate the service options, and their attitudes about the number and presentation of the choice experiments. Some changes in wording were made after the first pre-test, and no changes were indicated in the second pre-test. In similar experiments on gas service (not reported here, but conducted as part of the same project), respondents in the pre-tests reported that they found 15 experiments to be too many and that they lost interest by the end. No such complaints were voiced in the pre-tests of the water service experiments.[4]

The attribute levels that were included in the experiments for each respondent were determined by random selection among the levels listed above for each attribute, with equal probability of each level. When a pair was constructed that consisted of identical options or a dominant option (i.e., at least as desirable on all attributes as the other option and strictly better on at least one attribute), the pair was discarded and another one constructed. A different set of experiments was presented to each respondent. Variation in attributes over respondents is therefore utilized in addition to the variation for each respondent. Given the large number of possible combinations relative to the number of choice situations faced by each respondent, this variation over respondents is useful in estimation, in the same way that variation over observations in revealed-preference data is useful.

Optimal design procedures have been developed that can potentially improve the efficiency of estimation and testing with stated-preference choice experiments relative to the random assignment methods that we used. Street et al. (2001) and Burgess and Street (2004a, b), for example, have developed optimal design strategies for forced-choice experiments. They identified optimal designs for a set of experiments administered to a respondent when the underlying model is logit with fixed coefficients and the goal is to test a particular null hypothesis, such as the hypothesis of no difference in response to differences in attribute levels. Their analysis does not examine the efficiency gains that can be attained by varying choice sets over respondents under a mixed logit with random coefficients, and does not identify designs that are optimal for estimation when responses to multiple levels are structurally related, as occurs when utility is a parametric function of the attributes or, more generally, monotonic in the attribute levels.[5] Nevertheless, their analysis indicates that large gains in efficiency can be obtained over random selection of attribute levels – a result than can be expected to carry-over to the mixed logit with variation over respondents and structurally related responses to attribute levels, once the optimal design in this situation is derived. Sándor and Wedel (2001) provide a Bayesian procedure for designing choice experiments that improves efficiency through the use of the researchers' or managers' prior beliefs about the parameters of the model. In our situation, we, the researchers, had few if any prior beliefs. Incorporating the prior beliefs of the ActewAGL managers also seemed inappropriate, since the results of the analysis might be used in regulatory proceedings where any imposition of the regulated entity's concepts could be perceived by the regulator as potentially self-serving. In any case, the level of efficiency of an experimental design is reflected in the standard errors of the estimates and more generally in the power of tests: more efficient designs provide smaller standard errors and more powerful tests. The standard errors for our estimated models, given in Tables I and III, are sufficiently small such that the hypothesis of no impact can be rejected for each attribute. However, as we discuss below, significant interaction effects were not found, which might have been identified (if they exist) under a more efficient experimental design.

Carson et al. (2003, 2004) discuss incentive-compatibility in choice experiments and identify conditions under which respondents can be expected to answer honestly. We can examine our survey with respect to these conditions. Carson et al. first point out that the respondent needs to believe that its answers have a non-zero probability of affecting some outcome that matters to the respondent. Otherwise, there is no incentive for any particular kind of answer. This condition is known as consequentiality (i.e., questions that have associated with them real reasons for the individual to treat them as

Table I. Model of residential customers' choice among drinking water service options

Variables	Estimates	Std. Err.	T-stat.
Price as share of current bill	−5.6504	0.7753	−7.288
ln(1 + number of times water is not available): mean	−0.9279	0.1108	−8.377
standard deviation	0.7211	0.1369	5.269
ln(1 + length in hours): mean	−0.8153	0.0984	−8.281
standard deviation	0.2943	0.1973	1.491
M-F after 8am	0.3751	0.1853	2.025
M-F after 6pm	0.5394	0.1922	2.807
M-F after midnight	0.8156	0.1955	4.172
Weekdays	0.3689	0.2504	1.473
Any weekday time: standard deviation	0.9757	0.2739	3.562
1 day's notice	1.0730	0.2165	4.955
2 days' notice	1.0561	0.2174	4.858
7 days' notice	1.0327	0.2171	4.756
Two weeks' notice	0.8632	0.2212	3.903
Any notice: standard deviation	0.9431	0.2742	3.439
Emergency	0.6686	0.2033	3.290
Person answers: mean	0.2632	0.1197	2.198
standard deviation	0.6185	0.7753	2.301

of consequence). For our survey, each respondent was told in the initial interview and in a letter that accompanied the choice experiments that the analysis was being conducted to assist ACTEW Corporation and ActewAGL in determining future service levels and associated rates. Since each respondent is a customer of these utilities, each respondent would be affected by the decisions that are made. It seems reasonable to believe, therefore, that the respondents felt that their answers had at least a possibility of having an effect on the utilities' future decisions regarding service levels and rates and hence on their own welfare, satisfying Carson et al.'s first criterion. However, countering this argument is the fact that no information was provided to respondents (and in fact it was not possible to say) as to how exactly the respondents' answers would affect the rates and services that the utility provided. This lack of specificity might have operated against respondents' feeling that they have a personal stake in their answers. Carson et al. also point out that questions regarding public goods can be more readily incentive-compatible than those about private goods. A private good constitutes an option that a customer can exercise or not (i.e., buy or not buy), once it is produced. The respondent therefore has an incentive to exaggerate its interest and willingness to pay for a private good, in order to induce the manufacturer to produce the good, since having the option to buy is always better than not having that option. With public goods, each person is required to pay its allocated share of the costs, whether or not the benefits to that person exceed the costs. Therefore, unless the respondent thinks that a dishonest answer will help to induce some new option to emerge that differs from the one that is explicitly under consideration, answers to referenda regarding a public good with allocated, non-avoidable costs will be truthful. In our setting, the water service attributes are public goods whose costs each customer will unavoidably bear. Also, there does not seem to be any conceivable alternative to the setting of service levels that respondents might be trying to induce. In these regards, therefore, the survey seems to meet Carson et al.'s second criterion. Countering this argument, however, is the fact that each respondent is asked a series of questions, each with different pairs of service levels and costs, rather than one referendum for a given service level and cost. It is not clear what strategy the respondent might consider to be optimal in answering a series of such questions.

Other issues arise in stated-preference experiments that can affect their validity. Respondents might not be able to relate to the options that are presented, especially when the options differ greatly from anything they have experienced. This difficulty could potentially arise in our experiments, and we took steps to mitigate it.[6] The prices that each respondent saw were chosen to be close to the respondent's actual past bills, in order to assure a degree of realism in regard to payments. The service attributes, such as the frequency and duration of interruptions, were often quite different from the levels that customers have experienced historically, since the purpose of the analysis was to determine the response to these other levels. In this regard, there exists an innate tension in the use of stated-preference experiments: usually stated-preference experiments are utilized because historical data contain insufficient variation in attributes to allow estimation, and yet creating variation beyond that experienced historically can render the experimental results less reliable. In developing the descriptions of the attribute levels, we tried to ensure that respondents could understand and meaningfully relate to the options. As discussed above, the first pre-test identified problems that were corrected, and respondents did not evidence any further difficulties in the second pre-test. The question still remains, however, of whether respondents thought they could understand and relate to the options (and hence did not report any problems) while in actuality they perhaps could not.

Issues also relate to the status quo. There can be a tendency for respondents to prefer the status quo over changes in service levels in either direction, due to various factors including risk aversion, disutility of adjusting to change, and/or distrust of any suggested changes by a party such as the sponsor of the experiments who has a vested interest in the outcome. In our analysis, we attempted to reduce the impact of the status quo in several ways. None of the options in the choice experiments were identified as "your current service levels." The attributes of each option were stated in absolute terms, rather than relative to the respondent's current situation. (For example, frequency was stated in terms like "twice a year" rather than "twice as often as currently". Even the customer's bill under each option was stated in dollar terms, such as $880, rather than "10 percent more than you currently pay" even though it was calculated from the customer's historical bill.) Finally, since each option consists of numerous service attributes, the similarity of an option to the status quo is difficult to determine conceptually, even if the attributes were all compared against a known status quo. (E.g., if the frequency of interruptions is greater than historically but the duration of each is lower, how similar is the option to the status quo?) However, despite these mitigating factors, a bias for the status quo could nevertheless be evidenced if the respondent translated the absolute levels of the attributes into differences from the status quo and utilized a mechanism for aggregating (dis)similarities over attributes (such as only considering frequency of interruptions).

The experiments are forced choices, in that the respondent was asked to choose the option that he/she prefers and was not given the option of saying "I don't want either". This forced choice is consistent with the nature of utility services, in that customers cannot do without the service, and the only question is what are the attributes of the service that all customers obtain. If the option of "I don't want either" was allowed, it would be necessary to understand exactly what the respondent considered to be the service attributes that would prevail when neither of the listed options was chosen. Doing so would entail implicitly allowing either (i) the status quo as an option in each choice situation, which would exacerbate the status quo bias, and would also essentially be a forced choice among the two listed options and the status quo, or (ii) some other option that the respondent envisions, which would violate the criterion for incentive compatibility that the respondent not be able to induce a new option by refusing the offered ones. Given these considerations, a forced choice between the listed options seemed more appropriate.

4. Model

This section describes the specification and estimation of the discrete choice models that are used to examine respondents' choices among service options. The description follows Revelt and Train (1998), to which the reader is referred for greater detail. In each choice situation, the respondent faces a choice between $J=2$ alternatives. Each respondent is presented a series of T such choices. The responses for drinking water service are modeled separately from those for wastewater service, such that $T=6$ for each.

The two options that the customer faces in a particular choice experiment are described in terms of their service attributes, such as the frequency, length, timing, etc., of interruptions under that scenario. The attributes of service option j in choice experiment t faced by respondent n are collectively labeled as vector X_{njt}. The utility that respondent n obtains from option j in choice experiment t is:

$$U_{njt} = \beta_n' X_{njt} + \varepsilon_{njt}, \quad (1)$$

where ε_{njt} is assumed to be distributed iid extreme value independent of β_n. The coefficient vector β_n is known to the respondent but not to the researcher. This coefficient vector is specified by the researcher to have density $g(\beta \mid \theta)$, where θ represents the parameters of this distribution. If β_n is specified to be the same for all respondents (i.e., a degenerate distribution), then θ is its value for all respondents; however, if β_n is specified to be normally distributed over respondents, θ represents the mean and covariance.

In each choice situation, the respondent chooses the scenario that provides the greater utility. Let y_{nt} denote the respondent's chosen scenario in situation t, and let $y_n = (y_{n1},\ldots,y_{nT})$ denote the respondent's sequence of choices in the T choice experiments. Since the ε_{njt}'s are distributed extreme value, the probability conditional on β_n that the respondent chooses scenario i in situation t is standard logit (McFadden, 1974):

$$L_n(i, t \mid \beta_n) = \frac{e^{\beta_n' X_{nit}}}{\sum_j e^{\beta_n' X_{njt}}}, \quad (2)$$

and since the ε_{njt}'s are independent over choice experiments, the probability of the respondent's sequence of choices, conditional on β_n, is the product of logits:

$$P(y_n \mid \beta_n) = L(y_{n1}, 1 \mid \beta_n) \cdot \ldots \cdot L(y_{nT}, T \mid \beta_n). \quad (3)$$

The researcher does not observe β_n, and so these conditional probabilities are integrated over all possible values of β_n, using the density of β_n,

$$P(y_n \mid \theta) = \int P(y_n|\beta) g(\beta|\theta) d\beta. \quad (4)$$

$P(y_n \mid \theta)$ is the probability of the respondent's sequences of choices conditional on the parameters of the distribution, $g(\beta \mid \theta)$. It is called a mixed logit probability, since it is a mixture of logit formulas. McFadden and Train (2000) show that any choice model can be approximated arbitrarily closely by a mixed logit with the appropriate specification of $g(\beta \mid \theta)$.

The integral in the mixed logit probability generally does not have a closed form, and so it is approximated numerically through simulation. In particular, R draws of β are taken from the density $g(\beta \mid \theta)$. For each draw, the product of logits in equation (3) is calculated, and the results are averaged over draws. The simulated probability, denoted $\tilde{P}(y_n \mid \theta)$, is this average:

$$\tilde{P}(y_n \mid \theta) = \frac{1}{R} \sum_r P(y_n \mid \beta^r). \quad (5)$$

The population parameters θ are estimated by inserting $\tilde{P}(y_n \mid \theta)$ for each customer into the log-likelihood function and maximizing the function over θ. The estimator is consistent if R is considered to rise with sample size, and is asymptotically normal and efficient, asymptotically equivalent to the maximum likelihood estimator on the (infeasible) exact probabilities, if R rises faster than the square root of sample size (Lee 1995; Hajivassiliou and Ruud, 1994). We use Halton intelligent draws for the simulation, which have been found to provide far greater accuracy than independent random draws in the estimation of mixed logits (Bhat 2001; Train 2000; and Hensher 2001). See Train (2003), for a general discussion of mixed logits and Halton draws.

5. Estimation Results

5.1. DRINKING WATER SERVICE

Table I gives the model that was estimated on respondents' choices among drinking water service options. Price enters as a share of the respondents' current annual bill. For example, if the price of the service option is \$900 and the respondents' current annual bill is \$1000, then 0.9 is entered as the price in the model. Various ways of entering price were tested, including price alone, non-linear transformations of price, and price as a share of current bill. The best fit was obtained with price as a share of current bill.

The coefficient of price is specified to be fixed, so as to facilitate the estimation of distributions of willingness to pay, as described below. This practice of fixing the price coefficient follows that of, e.g., Goett et al. (2002) and Revelt and Train (1998), and conforms to Ruud's (1996) observation that random coefficient models are nearly unidentified empirically unless one coefficient is fixed. Note that a fixed price coefficient does not imply that response to price is assumed to be the same for all customers. Since utility has no units, the only economically meaningful quantity is the relative valuation of attributes, i.e., ratios of marginal utilities rather than marginal utilities themselves. The marginal utility of price relative to that for any other attribute varies over customers even when the marginal utility of price is constant over customers due to variation in the latter. Instead, a fixed coefficient for price implies that the ratio of the marginal utility of price to the standard deviation of unobserved factors is the same for all customers. This constraint can be unrealistic, as Louviere (2003) points out, especially if different respondents evidence different degrees of pure randomness in their responses to the stated choice experiments. However, the alternative of allowing the price coefficient to be random is econometrically problematic, especially when the goal is to estimate the distribution of willingness to pay. If the price coefficient is random, willingness to pay for an attribute is the ratio of two random terms. In applications where the price coefficient is random as well as the attribute coefficient, the implied distributions of willingness to pay have often been unreasonable, implying extremely large willingness to pay by a large share of the population. See, for example, Sonnier et al. (2003), Hensher et al. (2004), and Train and Weeks (2004), all of whom identify the problem and discuss methods for addressing it. In particular, Sonnier et al. (2003) and Train and Weeks (2004) have investigated models that are parameterized directly in terms of the distribution of willingness to pay, rather than deriving this distribution from estimated distributions for the price and non-price coefficients. Both studies found that the re-parameterized model provided more reasonable willingness to pay distributions but fit the choice data considerably worse. These results suggest that alternative distributions are needed that either provide more reasonable distributions of willingness to pay when applied to coefficients or fit the data better when applied directly to willingness to pay. Since such distributions have not yet been identified, retaining a fixed price coefficient seems prudent.

The frequency and length of interruptions both enter in log form, which fit the data better than entering these variables linearly (i.e., without the log transformation). This result suggests that households adapt to both the length and number of water interruptions. The coefficients of the log of frequency and length are specified to be normally distributed in the population. Models with lognormal distributions were also estimated but obtained lower log-likelihood values. Also, interactions between frequency and duration of interruptions were tested and found to be insignificant. This result could indicate that the respondent was evaluating each attribute separably, or that the power of the tests are insufficient to identify the interactions.[7]

The estimated parameters can be used to calculate the amount that respondents evidenced, through their choices, that they are willing to pay to reduce the number and length of water service interruptions each year. The marginal willingness to pay (MWTP) for an attribute is the derivative of utility with respect to the attribute divided by the (negative of the) derivative of utility with respect to price. Since the coefficients of the non-price attributes vary over customers, the MTWP varies.

Table II gives statistics for the estimated distribution of MWTP to reduce the frequency of interruptions, as a share of bill and in Australian dollars.[8] To illustrate the procedure for calculating MWTP, consider the quantity A$41.51, which Table II gives as the average of residential customers' MWTP to reduce the frequency of interruptions assuming interruptions normally occur twice a year. From the model of Table I, the coefficient of the log of (1 + number of times not available) is normally distributed with mean −0.9279 and standard deviation 0.7211. The derivative of utility with respect to number of times water is not available is therefore normally distributed with mean −0.9279/(1 + number of times not available) and standard deviation 0.7211/(1 + number of times not available). The price coefficient is −5.6504, with price

Table II. Residential customers' MWTP for water service attributes

Frequency	Mean	Std. Dev.	25tile	Median	75tile
Panel A: To reduce the frequency of water service interruptions. Expressed as share of current water and sewerage bill:					
Once in 10 years	0.1478	0.1163	0.0698	0.1478	0.2255
Once a year	0.0813	0.0640	0.0384	0.0813	0.1240
Twice a year	0.0547	0.0427	0.0256	0.0542	0.0827
Monthly	0.0125	0.0098	0.0059	0.0125	0.0191
In Australian dollars:					
Once in 10 years	113.20	96.30	49.49	105.80	168.92
Once a year	62.26	52.97	27.22	58.19	92.91
Twice a year	41.51	35.31	18.15	38.79	61.94
Monthly	9.58	8.15	4.19	8.95	14.29
Length	Mean	Std Dev	25tile	Median	75tile
Panel B: To reduce length of water service interruptions. Expressed as share of current water and sewerage bill:					
1 hour	0.0723	0.0260	0.0549	0.0724	0.0897
2 hours	0.0482	0.0173	0.0366	0.0483	0.0598
5 hours	0.0241	0.0087	0.0183	0.0241	0.0299
8 hours	0.0161	0.0058	0.0122	0.0161	0.0199
12 hours	0.0111	0.0040	0.0084	0.0111	0.0138
24 hours	0.0058	0.0021	0.0044	0.0058	0.0072
In Australian dollars:					
1 hour	54.75	25.34	37.03	51.30	69.12
2 hours	36.50	16.89	24.69	34.20	46.08
5 hours	18.25	8.45	12.34	17.10	23.04
8 hours	12.17	5.63	8.23	11.40	15.36
12 hours	8.42	3.90	5.70	7.89	10.63
24 hours	4.38	2.03	2.96	4.10	5.53

expressed as a share of current bill. The MWTP is therefore normally distributed with a mean of (−0.9279/(1 + number of times not available))/ −5.6504, expressed as a share of bill. If interruptions occur twice a year, the mean MWTP to reduce the frequency of interruptions becomes: $-0.9279/(1+2)/-5.6504 = -0.9279/3/-5.6504 = 0.0547$, or 5.47 percent of current bill. The average water and sewerage bill for residential customers is A\$759, which gives an average MWTP of 0.0547*759 = A\$41.51, which is the figure given in Table II. Since this is a *marginal* WTP, it means that customers are willing to pay, on average, approximately A\$4.15 per year to reduce the frequency of interruptions by 0.1 - from 2 per year to 1.9 per year.

The MWTP to reduce the frequency of interruptions decreases as the number of interruptions per year rises. For example, the average MWTP to reduce the frequency of interruptions is \$41.51 when customers face two interruptions per year, while the average MWTP is only \$9.58 when customers face monthly interruptions. There are two reasons for this difference. First, if customers faced more interruptions, they are more likely to take actions to reduce their impact, such as storing water. Second, from a psychological perspective, a reduction from 12 to, say, 11 seems less important than a reduction from 2 to 1.

Panel B of Table II gives statistics for the MWTP that respondents evidenced to reduce the length of an interruption. Again, since length enters in log form, the willingness to pay depends on the length of interruptions that respondents face. For example, the average MWTP to reduce the length of interruptions is \$36.50 when customers face interruptions of 2 hours but is only \$4.38 when they face lengths of 24 hours. Essentially, reducing the interruption length from 2 hours to 1 hour is worth more to customers than reducing the length from 24 hours to 23 hours.

The other service attributes enter the model of Table I in intuitive ways. Respondents strongly prefer to have water service interruptions during the weekdays than on weekends, presumably because they are more likely to be away from home during weekdays and hence less affected by the interruption. For weekday interruptions, customers prefer interruptions later in the day, with after midnight - when the customer is usually asleep - being best.

Notice is valued very highly by respondents. In fact, the estimates imply that customers are willing to pay an average of A\$142 (19 percent of their annual bill) to receive advance notice of all interruptions. The coefficients for 1, 2, and 7 days' notice are nearly identical, indicating that customers are not concerned about the number of days of advance warning up to a week. However, two weeks' notice is considered worse than one week's notice. This difference mirrors results obtained in focus groups where customers stated that they were concerned that they might forget if notice were given two weeks in advance. Also as reflected in the focus group discussion, the estimates imply that respondents are forgiving of not receiving notice if the interruption was due to an emergency. Interactions between length of notice and the frequency and length of interruptions were tested and not found to be significant; as stated above, this lack of significance reflects either separability in respondents evaluation of the attributes or insufficient power of the tests.

Respondents prefer to have a person answer the phone when they call the water utility rather than have a voice system provide a message. The average willingness to pay for this service feature is estimated to be A\$35. The water utility can compare this average WTP with the cost of hiring employees year round to answer the phone, to determine whether the service feature is warranted.

Household characteristics were not entered into the model given above. The primary reasons to enter demographics are for the design of different levels of service for different demographic groups, to estimate equity impacts across demographic groups (such as income classes), and/or for forecasting the impact of changes in demographics. None of these tasks was a goal of the project. The water utility is not able to offer different service levels to different demographic groups, and the purpose of the study was to determine the current distribution of willingness to pay for service attributes for the population of customers as a whole. Nevertheless, we estimated some alternative models that included demographic variables, in order to obtain an indication of how response to service attributes differs over groups. Households with children were found to be more concerned about obtaining notification of an upcoming interruption than households without children. Households with children also evidenced a greater dislike for having service interruptions on weekdays than households without children, presumably because households with children are more likely to be home during weekdays. Higher income households were more concerned about obtaining notification, and were less concerned about having a person answer the phone when they call the utility (as opposed to a voice system with a message), than lower income households. Younger respondents (namely, those under forty years of age) were less concerned about the frequency of outages than older respondents, but both age groups were about the same in their assessment of the length of interruptions. Finally, and interestingly, male respondents evidenced significantly greater concern about the utility bill than female respondents. No significant differences were found between renters and owners, presumably because only renters who paid their utility bills (the same as owners) were included in the survey.

5.2. WASTEWATER SERVICE

Table III gives the model that was estimated on the respondents' choices among wastewater service options. Price enters as a share of current annual bill (as for the water service model); the number of overflows and time to fix the overflows enter in log form, since these specifications fit the data better than the alternatives. Table IV gives statistics for the estimated distribution of MWTP to reduce the frequency of overflows. The MWTP depends on the number of overflows that the customer experiences each year, reflecting, as for water service interruptions, a form of adaptation to overflows. For example, the average MWTP to reduce the number of overflows is A\$116.77 when customers face only one overflow per year but drops to A\$77.85 when customers face two overflows per year. If the customer currently experiences one overflow in ten years (which is close to the current situation), then the average MWTP to reduce the frequency by half, to one overflow in twenty years, is approximately A\$11 (one twentieth of \$212.32).

Table III. Model of residential customers choice among wastewater service option

Variables	Estimates	Std. err.	T-stat.
Price as share of current bill	−4.0125	0.8161	−4.916
ln(1+ number of times there is an overflow): mean	−1.2343	0.2338	−5.280
standard deviation	1.5024	0.3619	4.151
Inside house: mean	−2.0734	0.2769	−7.488
standard deviation	2.0869	0.3436	6.074
Outside near house	−0.5177	0.1511	−3.426
Person: mean	0.6233	0.1618	3.853
standard deviation	1.2150	0.2490	4.880
ln(1 + hours to fix): mean	−0.9946	0.1189	−8.362
standard deviation	0.7291	0.1460	4.992

Table IV. Residential customers' MWTP for wastewater service attributes

Frequency	Mean	Std. Dev.	25tile	Median	75tile
Panel A: To reduce the frequency of overflows. Expressed as share of water and sewerage bill					
Once in 10 years	0.2794	0.3406	0.0504	0.2794	0.5076
Every other year	0.2049	0.2498	0.0370	0.2049	0.3722
Once a year	0.1537	0.1873	0.0277	0.1537	0.2792
Twice a year	0.1025	0.1249	0.0185	0.1025	0.1861
In Australian dollars					
Once in 10 years	212.32	273.90	35.59	197.96	373.73
Every other year	155.70	200.86	26.10	145.17	274.07
Once a year	116.77	150.64	19.58	108.88	205.55
Twice a year	77.85	100.43	13.05	72.59	137.03
Expressed as share of bill:					
Time until fixed	Mean	Std. Dev.	25tile	Median	75tile
Panel B: To reduce repair times					
1 hour	0.1232	0.0916	0.0625	0.1232	0.1857
2 hours	0.0821	0.0611	0.0416	0.0821	0.1238
4 hours	0.0493	0.0367	0.0250	0.0493	0.0743
8 hours	0.0274	0.0204	0.0139	0.0274	0.0413
12 hours	0.0190	0.0141	0.0096	0.0190	0.0286
24 hours	0.0099	0.0073	0.0050	0.0099	0.0149
In Australian dollars:					
1 hour	94.06	75.87	43.72	87.88	137.81
2 hours	62.71	50.58	29.15	58.59	91.87
4 hours	37.63	30.35	17.49	35.15	55.12
8 hours	20.90	16.86	9.72	19.53	30.62
12 hours	14.47	11.67	6.73	13.52	21.20
24 hours	7.53	6.07	3.50	7.03	11.02

For the location of overflows, the coefficient for overflows occurring on the street is normalized to zero, and the coefficients of the other locations are interpretable relative to this location. As expected, overflows inside the house are considered much more problematic than overflows on the street. Overflows that are outside but nearby the house are also considered worse than overflows on the street. On average, an overflow inside the house is four times worse than an overflow nearby outside, relative to on the street.

Respondents strongly prefer to have a person answer the phone when they call about an overflow. Understandably, respondents place far greater value on having a person answer the phone when they call about wastewater overflows than for drinking water interruptions.

Panel B of Table IV gives statistics for the distribution of MWTP to reduce repair times. The value of reducing repair time depends on the total amount of time lapsed until repair. For example, respondents evidenced a MWTP of \$62.71 on average to reduce repair time when the repair time is 2 hours but only \$7.53 when repair time is 24 hours.

6. Summary and Conclusions

The results indicate that reliability of the water and wastewater service is of value to residential customers. Both frequency and the length of disruptions are important, such that households are willing to pay to reduce the frequency and the duration of water service interruptions and wastewater overflows. This is consistent with the results of the focus groups, which indicated that customers' main concern with respect to wastewater overflows and water service interruptions was hygiene, which was perceived as a high priority.

Households' willingness to pay to avoid a water service interruption depends on the number of interruptions that the customer faces per year, with willingness to pay being smaller when the customer faces more interruptions. As noted, there are two reasons for this difference. First, if customers faced more frequent interruptions, they are more likely to adapt by taking actions to reduce their impact, such as storing water. Second, from a psychological perspective, a reduction from, say, 12 to 11 seems less important than a reduction from 2 to 1. Customers' willingness to pay to reduce the length of an interruption also depends on the length of the interruption, which again indicates that they are willing and able to adapt.

With respect to the timing of an interruption, residential customers expressed a strong preference to have water service interruptions during weekdays rather than on weekends, and the later in the day on weekdays, the better.

Customers greatly value having notice of an interruption when the interruption is planned. The amount of notice is not important; though there is evidence that customers prefer a week or less notice to two weeks' notice, presumably because, with two weeks' notice, they might forget the date of the interruption. Both the qualitative and quantitative results show that households are forgiving of not receiving notice if the interruption was due to an emergency.

Households' willingness to pay to avoid a wastewater overflow is dependent on the frequency of overflows, evidencing adaptation to frequent overflows. Households' willingness to pay to reduce the length of an overflow is similarly dependent on the expected length of the overflow. The longer the overflow is expected to last, the lesser amount a customer is willing to pay to reduce its length by an hour.

As expected, overflows inside the house are considered much more problematic than overflows on the street. Overflows that are outside but nearby the house are also considered worse than overflows on the street. On average, an overflow inside the house is four times worse than an overflow nearby outside, relative to on the street.

In the event of a service disruption, and particularly in the event of a wastewater overflow, householders expressed a strong preference for having a person answer the phone when they call to make an inquiry of the water utility.

Overall, the results confirm that water and wastewater service levels are important to customers. While the results indicate that householders' are able and willing to adapt to the frequency and duration of service interruptions to a degree, customers also revealed that they were willing to pay for incremental changes in service levels. There is therefore scope to optimize water and wastewater service levels with respect to price. This has been well recognized for some time in the context of electricity, but has been unclear in the water sector.

Interestingly, the results indicate that customers not only value minimal service interruptions, but also value other aspects of the service – those which perhaps traditionally receive less attention by water utilities. Attributes such as notification of an interruption, timing of planned service interruptions, and the method of handling customer calls are all very important to customers. These attributes affect customers' willingness to pay to avoid a service interruption, and are clearly worthy of attention. Hence, the study not only provides useful estimates of customers' willingness to pay for capital and maintenance planning, it also provides some guidance for water utilities' operational focus in the near to medium term.

Notes

1. Those who live in rented accommodation in Canberra are not necessarily obligated to pay for their water or wastewater service. ActewAGL bills the owner of the property, who may then pass the bill onto the tenant.

2. 307 respondents agreed to be interviewed (486–179). 78 percent of these household ((307–67)/307) met the criteria for inclusion. Applying this share to all the households that were contacted (.78 * 486) gives an estimated 380 eligible households, of which 211 completed the choice experiments.
3. Attitudes to and preferences for other service attributes - such as clarity and taste, fluoridation and chlorination of drinking water - were also discussed with customers in the focus groups. However, as these attributes did not arise as particular willingness to pay issues, they were omitted from the choice experiments.
4. We could probably have included more choice experiments for each respondent. Louviere et al. (2003) argue that reliable data can be obtained with a fairly large number of choice experiments per respondent. Respondents' statements that the number of choice experiments is "about right" or "too many" (which we asked in the pre-tests) do not necessarily reflect the number of experiments from which useful data can be obtained. That is, a respondent might think and say that the survey is too long and yet still answer all the experiments accurately. In our situation, the ActewAGL managers did not want to risk irritating or alienating their customers, and so the number of choice experiments was guided by respondents' statements in the pre-tests. Hensher (2004) has argued with empirical evidence that relevancy is more important than complexity and that simple and limited experiments can often create more problems in terms of being able to gain a reliable response than designs with a lot of information. There is a great deal of heterogeneity in the information processing strategies of individuals and this should be accounted for in future design.
5. The analysis of Burgess and Street (2004b) provides a framework that can perhaps be used to derive the optimal designs for estimation of structural relations among levels, even though this task is not explicitly addressed. Street et al. (2001) and Burgess and Street (2004a) deal with attributes that take only two levels, such that structure among levels is not an issue.
6. Individuals have their own information processing strategy (IPS). Candidate strategies associated with relevance and complexity (Hensher 2004) include reference dependency (i.e., framing), attribute re-packaging, attribute preservation or elimination (including subtleties of inattention due to irrelevance or cognitive burden), and consequentiality (i.e., questions that have associated with them real reasons for the agent to treat them as of consequence – see Carson et al. 2003). Importantly these issues are as relevant in revealed preference data as they are in stated choice data.
7. The power of these tests is related to the design of the experiments. Designs that are more efficient with respect to two-way interactions than our random design would provide more powerful tests of these interactions.
8. At the time of the survey the Australian dollar was worth approximately 56 cents in US dollars.

Appendix: Interview Protocol and Example Experiments

Protocol for section of interview with respondent about the experiments, after the package of experiments were mailed to the respondent:

I also just want to double check that you have the right questionnaire in front of you. You should have ...:

IF RESIDENTIAL WATER: one (blue) questionnaire titled 'Water Reliability – Residential Questionnaire' < QUEST 1 > and one (white) questionnaire titled 'Waste-water

Service Reliability – Residential Questionnaire < QUEST 2 >'. Your name should be on the top of each page.

INSTRUCTIONS:

Now if you could please put the < QUEST X > in front of you.
Each page shows 2 PACKAGE descriptions, Package A and Package B, which have different CHARACTERISTICS.
The TYPES of characteristics are shown in bold print along the left hand side of each page. These characteristic types are identical on EVERY page. I will ask you to choose ONE of the two Packages shown on EACH page after you have read it.
I understand that many of the situations will not seem realistic, however I need you to IMAGINE that you are being offered ONLY the two Packages on the page in front of you and you **MUST** make a decision.
Before we begin, please take some time to have a read of JUST the very first page, and let me know if there is anything on it that you would like me to clarify. ALLOW READING TIME
For each page I will be asking you firstly to read me the REFERENCE NUMBER shown on the top right hand corner, and then I'll ask you to chose between Package A or Package B. We will repeat this exercise for every page – please ignore all other pages except the one you are looking at.
BEGIN WHEN YOU THINK RESPONDENT IS READY
IF RESPONDENT BEGINS REFERING TO CURRENT SERVICE LEVELS - SAY : 'Please put your current service levels aside for the moment. I would just like you to IMAGINE that you are being offered ONLY the two Packages on the page in front of you and you **MUST** make a decision'.
ASK – 'Why do you say that?' IMMEDIATELY AFTER THE ANSWER TO THE FIRST PAGE OF EACH QUESTIONNAIRE AND ONE OTHER PAGE IN EACH SET
NOTE: YOU NEED TO BE 'CONVINCED' THAT THE RESPONDENT UNDERSTANDS THE TASK AND IS CONSIDERING ALL THOSE CHARACTERISTICS IMPORTANT TO THEM. PLEASE ENSURE RESPONDENT TAKES NOTE OF **PRICE** ON EVERY PAGE

DATA COLLECTION – REPEAT FOR EACH PAGE:

Q1. ASK RESPONDENT TO CONFIRM REFERENCE NUMBER (TOP RIGHT HAND CORNER OF EACH PAGE)

Q2. If these were the only 2 options available to you, which option would you choose, Package A or Package B: **DO NOT READ OUT – SINGLE RESPONSE**

1. Package A
2. Package B
3. REFUSED

REPEAT INSTRUCTIONS AND DATA COLLECTION FOR <QUEST 2>

WATER RELIABILITY
Residential Questionnaire

	PACKAGE A	PACKAGE B
Number of times water is unavailable to your home:	1 time per year	2 times per year
Length of time that water is unavailable to your home each time that it goes off:	8 hours	5 hours
Time of day that water is unavailable to your home each time that it goes off:	Over the weekend	Mon-Fri sometime after 8am
Prior notification that water will be unavailable to your home:	1 day	2 days
Response to phone inquiries in the event of water becoming unavailable to your home:	You get straight through to a PERSON - you are not put on hold and there is no machine directing you to press buttons	You get straight through to a PERSON - you are not put on hold and there is no machine directing you to press buttons
Total Water & Sewerage bill for the year:	**$800**	**$850**

YOUR DECISION: If these were the only 2 options available to you, which option would you choose: Package A or Package B ?

WASTE-WATER SERVICE RELIABILITY
Residential Questionnaire

	PACKAGE A	PACKAGE B
Number of times you experience an overflow of sewerage:	2 times per year	1 time per year
Source of overflow:	At the nearest sewer manhole in the street	Inside your home
Response to phone inquiries in the event of a sewer overflow:	You get straight through to a PERSON - you are not put on hold and there is no machine directing you to press buttons	You get straight through to a PERSON - you are not put on hold and there is no machine directing you to press buttons
Length of time before overflow is contained:	2 days	1 hour
Total Water & Sewerage bill for the year:	**$800**	**$760**

YOUR DECISION: If these were the only 2 options available to you, which option would you choose: Package A or Package B ?

References

Bhat, C. (2001), 'Quasi-random Maximum Simulated Likelihood Estimation of the Mixed Multinomial Logit Model', *Transportation Research B*. **35**, 677–693.

Burgess, L. and D. Street (2004a) 'Optimal Designs for 2^k Choice Experiments,' Communications in Statistics – Theory and Methods, forthcoming.

Burgess, L. and D. Street (2004b) 'Optimal Designs for Choice Experiments with Asymmetric Attributes,' working paper, Department of Mathematical Sciences, University of Technology Sydney.

Cai, Y., I. Deilami and K. Train (1998), 'Customer Retention in a Competitive Power Market: Analysis of a ''Double-Bounded Plus Follow-ups' Questionnaire'', *The Energy Journal* **19**(2), 191–215.

Carson, R., T. Groves and M. Machina (2003), *Incentive and Informational Properties of Preference Questions, working paper*, San Diego: Department of Economics. University of California.

Carson, R., T. Groves, J. List and M. Machina (2004), *''Probabilistic Influence and Supplemental Benefits: A Field Test of the Two Key Assumptions Underlying Stated Preferences,'' working paper*, San Diego: Department of Economics. University of California.

Eto, J., J. Koomey, B. Lehman, N. Martin, E. Mills, C. Webber and E. Worrell (2001), *Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy, technical report*, Lawrence Berkeley Laboratory, Berkeley California: Energy Analysis Department.

Goett, A., K. Hudson and K. Train (2000), 'Customers' Choice Among Retail Energy Suppliers: The Willingness-to-Pay for Service Attributes', *The Energy Journal* **21**(4), 1–28.

Hajivassiliou, V. and P. Ruud (1994), 'Classical Estimation Methods for LDV Models using Simulation', in R. Engle and D. McFadden, eds., *Handbook of Econometrics*. Amsterdam: North-Holland.

Hensher, D. (2001), 'Evaluation of Commuter Travel Time Savings for Car Drivers in New Zealand: Evaluating Alternative Model Specifications', *Transportation* **28**, 110–118.

Hensher D. A. (2004) How do Respondents Handle Stated Choice Experiments? - Information processing strategies under varying information load, DoD Paper #5, Institute of Transport Studies, The University of Sydney, March.

Hensher, D., W. Greene and J. Rose (2004), *Deriving Willingness to Pay Estimates from Observation Specific Parameters using Classical Methods, working paper*, University of Sydney: Institute of Transport Studies.

Lee, L. (1995), 'Asymptotic Bias in Simulated Maximum Likelihood Estimation of Discrete Choice Models', *Econometric Theory* **11**, 437–483.

Louviere, J. (2003), *Random Utility Theory-Based Stated Preference Elicitation Methods: Applications in Health Economics with Special Reference to Combining Sources of Preference Data, keynote address*, Canberra: Australian Health Economics Society Conference.

Louviere, J., D. Hensher and J. Swait (2000), *Stated Choice Methods: Analysis and Applications*, New York: Cambridge University Press.

Louviere J., H. Oppewal, H. Timmermans and T. Thomas (2003) 'Handling Large Numbers of Attributes in Conjoint Applications,' working paper.

McFadden, D. (1974), 'Conditional Logit Analysis of Qualitative Choice Behavior', in P. Zarembka, eds., *Frontiers in Econometrics*'. New York: Academic Press.

McFadden, D. and K. Train (2000), 'Mixed MNL Models for Discrete Response', *Journal of Applied Econometrics* **15**(5), 447–470.

Revelt, D. and K. Train (1998), 'Mixed Logit with Repeated Choices: Households' Choices of Appliance Efficiency Level', *Review of Economics and Statistics* **LXXX**(4), 647–657.

Sándor, Z. and M. Wedel (2001), 'Designing Conjoint Choice Experiments Using Managers' Prior Beliefs', *Journal of Marketing Research* **36**, 430–444.

Sonnier, G., A. Ainslie and T. Otter (2003), *The Influence of Brand Image and Product Style on Consumer Brand Valuations, working paper, Anderson Graduate School of Management*, Los Angeles: University of California.

Street, D., D. Bunch and B. Moore (2001), 'Optimal Designs for 2^k Paired Comparison Experiments', *Communications in Statistics – Theory and Method* **30**, 2149–2171.

Train, K. (2000), *Halton Sequences for Mixed Logit, Working Paper, Department of Economics*, Berkeley: University of California.

Train, K. (2003), *Discrete Choice Methods with Simulation*, New York: Cambridge University Press.

Train, K. and M. Weeks (2004), *Discrete Choice Models in Preference Space and Willingness-to-Pay Space, working paper, Department of Economics*, Berkeley: University of California.