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Influence of Parking on Location and Mode Choice: A Stated Choice Survey

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ABSTRACT

This paper assesses the effects of parking availability on behavioral responses by travelers, and which approaches are appropriate for modeling those responses. In addition to the well-known trade-offs between travel times and fuel or transit ticket costs, parking search times and costs have a significant impact on travelers' decisions. A stated choice study of parking, location, and mode choice was conducted to assess those choices.

The survey was conducted with a sample of more than 1'200 pre-recruited respondents in Switzerland. Several characteristics of the respondents' regular travel were recorded during a recruitment interview, which the stated choice experiments were based on. The overall response rate was over 80 percent, and more than 14'000 observations were used for the estimation of the choice models presented here. Two different modeling approaches were tested: one with a deterministic model of taste heterogeneity (using interaction terms for trip distance, duration and income, as has been the practice in earlier studies), and one applying a random parameters approach. Both models were estimated in willingness-to-pay space.

The model results indicate that parking characteristics have a significant effect on mode and location choice. The sample distributions for the relevant willingness-to-pay measures and the sample average demand elasticities inferred by the two models, as well as the overall model fit statistics, are slightly different. The deterministic assessment of taste heterogeneity is preferable for application in forecasting models, as it allows the direct computation of the expected effects of a policy on market shares.

INTRODUCTION AND MOTIVATION

Parking characteristics and policies pertaining to such characteristics have a significant influence on travel behavior. For trips in urban areas, parking search time constitutes up to a third of total travel times (*1*), thus representing a significant factor of dissatisfaction with daily travel. The availability of parking spaces and the relevant policies influencing it may be assumed to have a significant impact on travel behavior in the short and long term. The short-term behavior depends on the characteristics of a specific trip and manifests itself as the decision of an individual whether or not to carry out a trip (and the activity that is conducted at the trip destination), the choice of a travel mode, the choice of a location to carry out an activity, and the choice of a parking space at that location. In the long term, the relevant decisions are the choice of mobility tools (such as cars and transit passes), workplace and residential location.

Shoup (*1*) summarizes the results of the English speaking literature on parking and shows the negative side effects that free parking may have in locations with high traffic demand. He argues that parking search traffic in such areas considerably slows down the overall traffic flow, leading to congested urban areas becoming less attractive destinations for travelers.

Beaton et al. (*2*) examine the effects of parking charges on the propensity to ride share for commute trips, and find that parking charges of 3.- US dollars a day may help to increase vehicle occupancy levels by up to 70 percent when flanked by additional measures such as ride share coupons and guaranteed ride home programs.

Newmark and Shiftan (*3*) list several studies that assess quantitative relations and elasticities between parking characteristics and travel behavior. These studies have as a common element the application of *stated preference* (SP) methodology for data collection. Hensher and King (*4*) describe a study on mode and parking location choice as a reaction to pricing policies and the limitation of parking time in Sydney's central business district. Axhausen and Polak (*5*) conducted various studies in Germany and the United Kingdom and point to the necessity of separating the different generalized cost components of a parking activity when modeling parking choices. Calthrop et al. (*6*) examine the joint effects of parking policies and road pricing schemes on welfare, travel speeds, the shares of alternative modes and the aggregate demand for transport services in Brussels, while Tsamboulas (*7*) assesses the acceptance of pricing levels in Athens. Shiftan and his co-authors (*8*, *9*) apply a *stated adaptation* approach to model reactions to pricing policies in Haifa and Tel Aviv, respectively. They find that the most frequent reactions to such policies are changes in transport mode or departure times.

In the Swiss context, Widmer and Vrtic (*10*) analyzed the influence of parking characteristics on travel behavior with combined *revealed preference* (RP) and *stated preference* (SP) data. They were limited to three specific locations and a small sample, and the present study may be seen as an extension of their work.

The research project that is described here, and which is steered by the Swiss Association of Transportation Engineers (SVI), is focused on reactions to parking policies, and their repercussions on travel behavior and energy consumption. It aims to provide transport planning authorities with better models of those reactions. Investors, environmental lobbies and local authorities are often at odds as to how effective limitations or management of the available parking spaces at newly planned demand generating facilities may be. With the availability of robust data on these questions, the debates may be conducted in a more objective way.

The relevant questions are analyzed with a *stated choice* (SC) survey comprising four different experiments. State-of-the-art choice models are used to represent the respondents' decisions. The results provide the relevant information necessary for the appraisal of parking policies.

The paper is structured as follows. First, the research questions to be answered in this paper will be posed, and a brief outline of how they will be addressed is given. The following chapter provides a brief description of the survey work. The description of the modeling methodology and results follows. A brief summary of the main findings concludes the paper.

RESEARCH QUESTIONS

The research questions arising from the discussion above can be broadly formulated as follows:

- Which parking characteristics influence travel behavior, in addition to the well-known trade-offs (between, among others, travel time and costs)?
  Here, the focus is on finding appropriate model specifications which account for effects implied by variations in parking characteristics, while controlling for all other relevant trip and socio-economic variables.
- How are variations in parking search times and costs perceived in comparison to other attributes?
  Willingness-to-pay values for various attributes as well as demand elasticities were computed, which allow an assessment of the relative perception of the parking characteristics against other variables.
- Which modeling approaches are suitable for the assessment of the stated behavioral responses?
  Two different choice model structures are presented: one with a deterministic assessment of taste heterogeneity (using interaction terms for trip distance, duration and income, as has been the practice in earlier Swiss studies), and one applying a random parameters (*Mixed Logit*) approach.

IMPLEMENTATION OF THE SURVEY

The relevant questions are treated with a *stated choice* survey comprising experiments for the following decisions, each of which contain variables describing the parking supply:

- the choice of a parking space at a shopping or leisure location (SP 1 – 10 choice experiments);
- the choice of a destination for carrying out a shopping or leisure activity (SP 2 – 10 choice experiments);
- the choice of a mode for carrying out a commute, shopping or leisure trip (SP 3 – 10 choice experiments);
- the choice of a workplace (SP 4 – 6 choice experiments).

The sample of respondents was recruited via an existing online panel, which is representative for the Swiss population. Only employed respondents with at least occasional car availability were retained in the sample. Persons willing to participate were asked about their socio-economic characteristics, including additional questions about their workplace, frequent shopping and leisure locations and parking search strategies, which were used for the personalization of the choice tasks.

1'248 respondents were recruited for participation in the SP survey, with the recruitment period lasting from May 12 through June 23, 2011. They were made aware that participation in the survey would earn them an incentive worth 3.- Swiss Francs (at the time the survey was conducted, 1.- Swiss Franc was equivalent to about 1.15 US Dollars), accumulated via the internal bonus system of the online panel operator. 5 reported mailing addresses were found to be invalid, thus 1'243 questionnaires were dispatched by postal mail.

In an effort to reduce response burden, each respondent was faced with 2 out of the 4 choice experiments – one randomly drawn from SP 1 and SP 2, the other from SP 3 and SP 4. SP 3 and SP 4 were based on reported behavior. Automatic routing procedures based on geo-coded locations reported by the respondents during the recruitment interview were used for determining the attributes of the car and transit trips from the respondents' homes to the reported locations. The car trips were routed using the agent-based simulation software MATSim (*11*), while the transit attributes were obtained from an automatic query of the Swiss Federal Railway Company's online timetable. As not all activity locations could be geo-coded (some addresses were incompletely reported by the respondents), a part of the sample could not be assigned either SP 3 or SP 4. Those respondents were instead sent a questionnaire consisting of SP 1 and SP 2.

The present paper focuses on the short-term effects surveyed in SP 1, SP 2, and SP 3; SP 4 will be excluded from the following discussion.

The attributes used for the construction of the three remaining experiments are displayed in Table 1. In SP 1, the respondents chose between two parking locations for a given duration of stay at a shopping or leisure location, or the abortion of the search and the cancellation of the activity; in SP 2, between two locations for a given duration of carrying out a shopping or leisure activity, or the abortion of the trip; and in SP 3, between the available travel modes. In SP 1 and SP 2, the trip purpose was determined at random, and the attribute levels for the durations were assigned using the 25^{th}, 50^{th} and 85^{th} percentiles of the population distribution of activity durations for the specified type. The mode choice experiments were based on reported behavior, as has been the recent state of practice in *stated choice* surveys (*12*, *13*, *14*, *15*, *16*, *17*) and has been successfully done in former Swiss studies (*18, 19*, *20, 21*). Where the attributes are given in percent in the table, the values for the experiments were derived from the attributes of the trip to the respondents' work place, most frequent shopping or leisure location reported in the questionnaire. The service frequency levels that were used to compute the attributes presented to the respondents from the current state are intervals of 5, 8, 10, 15, 20, 30, 45, 60, 90 and 120 minutes between two courses. The attribute level combinations to be used in the choice experiments were obtained from efficient designs constructed using the software *Ngene* (*22*).

RESPONSE RATES

A total of 1'043 respondents returned the questionnaire, which corresponds to a response rate of 84 percent. This rate matches the experiences with comparable studies at the Institute for Transport Planning at Systems, ETH Zurich, as is shown in Figure 1. The ex-ante response burden for the various surveys included ion the graph was determined according to the scheme detailed in (*23*). The methodology assigns weighted scores to question types and aggregates them to calculate the response burden of a survey. The response rates that are considered here correspond to the *COOP4* cooperation rates as defined by the American Association for Public Opinion Research (*24*). Response rates decrease approximately linearly with response burden, and the present study fits in its context for surveys where respondents were pre-recruited and given an incentive to participate.

TABLE 1 Attribute Levels of the Variables Included in the Stated Choice Experiments

Alternatives	Attribute	Values
SP 1: Parking choice		
Alternatives	Attribute	Values
Parking 1 / 2, abort	Activity type	Shopping, leisure
	Activity duration	15, 45, 120 (shop) / 45, 120, 180 (leisure) minutes
	Fixed parking cost	0.-, 2.-, 5.- Swiss Francs
	Variable parking cost	0.-, 2.-, 5.- Swiss Francs per hour
	Maximum parking cost	10.-, 20.-, 30.- Swiss Francs
	Total parking cost	Calculated from the previous three
	Type of parking	On-street, open lot, parking garage
	Car travel time	3, 7, 12 minutes
	Parking search time	0, 5, 15 minutes
	Access and egress time	5, 8, 12 minutes
	Total travel time	Sum of the previous three
SP 2: Destination choice		
Alternatives	Attribute	Values
Location 1 / 2, abort	Activity type	Shopping, leisure
	Activity duration	15, 45, 120 (shop) / 45,120, 180 (leisure) minutes
	Fixed parking cost	1.50, 3.-, 5.- Swiss Francs
	Variable parking cost	0.-, 1.-, 3.- Swiss Francs per hour
	Total parking cost	Calculated from the previous two
	Type of parking	On-street, open lot, parking garage
	Type of location	In a city center, in the outskirts
	Price level of location	low, medium, high
	Cost-performance-ratio of location	Adequate, good, very good
	Car travel time	5, 15, 30 minutes
	Parking search time	0, 3, 9 minutes
	Access and egress time	2, 4, 10 minutes
	Total travel time	Sum of the previous three
SP 3: Mode choice		
Alternatives	Attribute	Values
Walk / bike	Travel time	From reported trip, not varied
Car	Fuel cost	-15%, ±0%, +25% of current value
	Fixed parking cost	0.-, 1.50, 4.- Swiss Francs
	Variable parking cost	0.-, 1.-, 2.50 Swiss Francs per hour
	Total parking cost	Calculated from the previous two
	In-vehicle travel time	-10%, +10%, +30% of reported trip
	Parking search time	0, 3, 9 minutes
	Access and egress time	2, 4, 10 minutes
	Total travel time	Sum of the previous three
Transit	Ticket cost	-25%, -10%, +10% of current
	In-vehicle travel time	-15%, -5%, +5% of current
	Access and egress time	2, 4, 10 minutes
	Total travel time	Sum of the previous two
	Number of transfers	-1, ±0, +1 from current
	Headway	-2, -1, ±0 levels from current

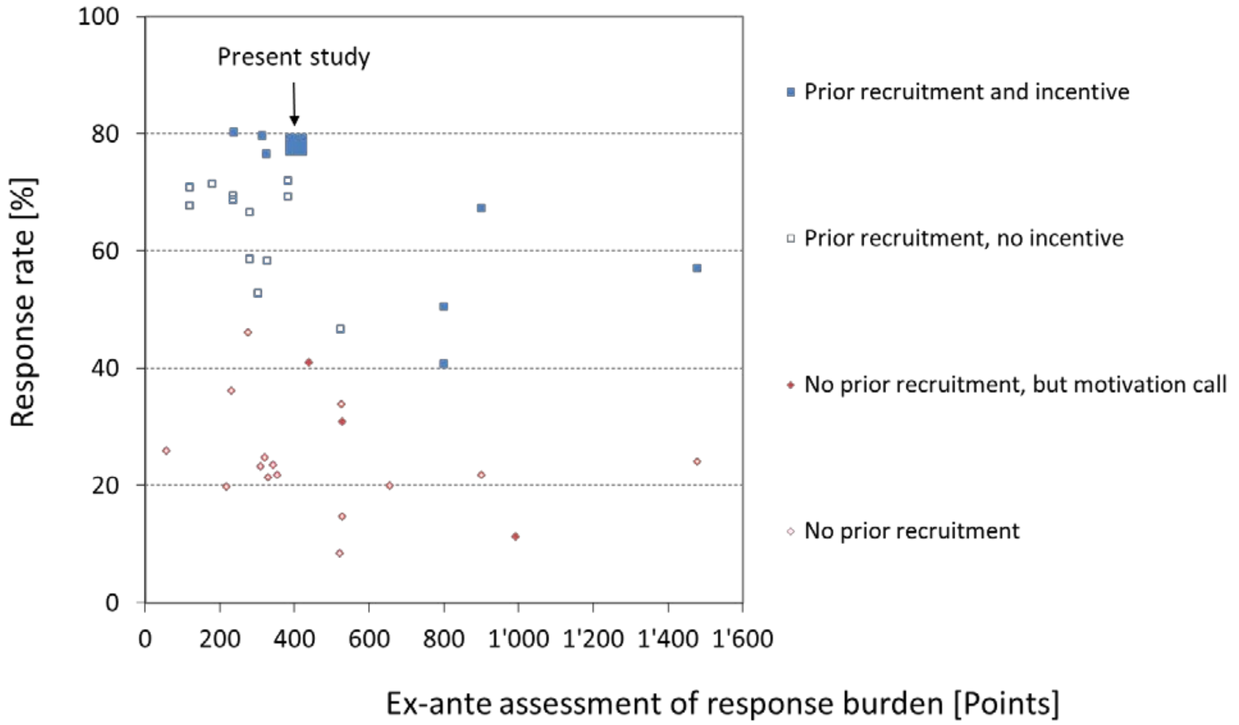

FIGURE 1 Response rates in the context of comparable studies (updated from (*24*)).

EXPLORATIVE ANALYSIS OF THE SAMPLE

Socio-economic characteristics

Table 2 presents key descriptive statistics for the respondent sample in comparison with (a) the base sample of recruited individuals and (b) the 2005 Swiss National Household Travel Survey (named "Mikrozensus Verkehrsverhalten 2005", abbreviated MZ '05), which is representative of the Swiss population (*25*). A bias towards well-educated respondents can be seen. Single person households are slightly underrepresented. A high share of respondents own public transport season tickets: the half-fare card, at a cost of 165.- Swiss Francs per year, provides a 50 percent discount on most transit lines, while the *Generalabonnement* is a flat-rate ticket which costs 3'300.- Swiss Francs and entitles the holder to free use of public transport on the complete Swiss transit network. The high ownership rates are common for surveys of the described type in Switzerland (*26*). Public transport users tend to be more interested in transport policy issues, leading to a higher propensity to participate in such surveys.

TABLE 2 Sample Descriptive Statistics

Variable	Value	Recruited	Responded	MZ’05
Gender	Male	50.2 %	49.9 %	48.3 %
	Female	49.8 %	50.1 %	51.7 %
Age (in years)	18 – 35	17.7 %	15.5 %	28.6 %
	36 – 50	51.9 %	53.3 %	29.6 %
	> 50	30.4 %	31.2 %	41.8 %
Household size	1	16.1 %	13.7 %	32.9 %
	2	35.5 %	36.5 %	37.1 %
	3	16.6 %	17.0 %	12.1 %
	4+	31.8 %	32.8 %	17.9 %
Income (in Swiss Francs per month*)	< 2’000	6.9 %	6.2 %	3.2 %
	2’000 – 4’000	13.7 %	13.0 %	17.4 %
	4’000 – 6’000	23.1 %	21.5 %	26.5 %
	6’000 – 8’000	24.8 %	24.5 %	20.3 %
	8’000 – 10’000	14.0 %	15.7 %	13.3 %
	> 10’000	17.6 %	19.2 %	19.4 %
Education level	Primary or secondary school	7.3 %	6.1 %	11.2 %
	Vocational school	33.0 %	33.1 %	60.1 %
	Baccalaureate	11.8 %	12.4 %	7.2 %
	Higher education	47.9 %	48.4 %	19.2 %
Transit pass	None	14.8 %	14.2 %	50.9 %
	Half-fare card	60.4 %	59.2 %	39.7 %
	Generalabonnement	24.8 %	26.6 %	9.4 %

*At the time the survey was conducted, 1.- Swiss Franc was equivalent to about 1.15 US Dollars.

Non-Trading Behavior

Non-traders are respondents in a *stated preference* survey who, regardless of the available alternatives’ attributes, always make the same choice. 27 percent of respondents in the mode choice experiments never varied their choices. This may have several reasons, one of which is picking the same alternative for every situation in order to reduce the mental effort to complete the questionnaire. Such behavior, which may be caused by attrition due to the complexity of the questionnaire, evidently biases the outcomes of the statistical analysis of the data. Another reason could be misunderstanding of the questions.

These effects can lead to decisions that are not based on trade-offs between the alternatives’ attributes (*27*). However, especially when respondents with a strong prior commitment to a specific transport mode are at hand, seemingly illogical choices may well reflect true behavior. The most prominent examples of such self-selection effects are residential location (where the location type dictates the use of a certain means of transport, for example the car in regions which are not or hardly accessible by public transport) or the ownership of transit tickets. Thus, non-trading does not necessarily imply inconsistent responses.

Hence, rather than excluding *non-traders* from the analysis, the possible influences on individuals’ choice behavior were modeled via the inclusion of the relevant variables, such as trip distance and purpose and the availability of mobility tools.

MODELING FRAMEWORK

Two different approaches were used for modeling the respondents' choices: one applying the *Multinomial Logit* (MNL) framework, the other being a *Mixed Logit* (ML) model, which allows for the assessment of random taste heterogeneity via the inclusion of randomly distributed parameters (28, *29*, *30*). The models were estimated using the *BIOGEME* software package (*31*, *32*) on a *Quad-Core* computer under the *Unix* operating system. The three short-term *stated choice* experiments were pooled for the estimation of the choice models.

For the pooled model of short-term decisions that is presented here, it is important to allow for differences in scale between observations from the three *stated choice* experiments, as the relative weights of the observed and unobserved utility components may vary across the experiments. As stated by Hess et al. (*33*), these scale differences are most prominent when data from different sources are used for the estimation of one common model, but also apply to cases where data is collected through different sub-surveys, as is the case here. As detailed in (*33*), scale parameters are estimated relatively to an arbitrarily fixed reference sub-sample, for which the scale parameter is fixed to the value of one. If an estimated scale parameter is greater than one, then the variance of the unobserved utility in the corresponding sub-sample is smaller than that in the reference sub-sample, and vice-versa.

The models were estimated in *willingness-to-pay (WTP) space*. The utility functions were formulated in a way to directly yield the WTP measures for the attributes of interest (*34*). In the *Mixed Logit* case, this specification has the advantage of providing the distribution parameters for the WTP without needing to simulate values from the ratio of two randomly distributed parameters (the travel time and cost parameters). The WTP measures calculated are those for car and transit travel times (known as the *value of travel time savings*, or VTTS) and that for reductions in parking search time.

The utility functions for the MNL model include non-linear interaction terms, which follow the formulation that was introduced in the seminal study by Mackie et al. (*35*). It has been applied in several Swiss studies (*26*, *33*, *36*, *37*) and underlies the current Swiss value of travel time savings (VTTS) guideline (*38*). It extends the standard linear utility formulation by allowing continuous interactions between variables. As Hess et al. (*33*) state, the methodology has various advantages over the arbitrary segmentation into discrete groups, such as the deterministic computation of taste heterogeneity, and the considerably faster estimation compared to random coefficient approaches.

The general specification of the utility function is as follows:

$$f(y,x) = \beta_x \cdot \left(\frac{y}{\bar{y}} \right)^{\lambda_{y,x}} \cdot x \qquad (1)$$

where:

- x = (dis)utility generating variable, such as travel time or cost;
- β_x = utility parameter associated with x, to be estimated;
- y = variable assumed to interact with x, such as income or trip distance;
- $\bar{y}$ = reference value for variable y, such as the sample mean or median;
- $\lambda_{y,x}$ = elasticity of the influence of y on the (dis)utility generated by x, to be estimated.

The respondents' valuation of attribute *x* is assumed to vary with the value of attribute *y*. Normalizing *y* assures that the estimate of the linear parameter indicates the valuation of *x* at the point of normalization (as the interaction term then equals one).

In the present case, the following interactions are assumed:

- between trip (fuel or ticket) cost and VTTS, and trip distance and income;
- and between parking cost and the WTP for parking search time, and the duration of stay at the destination and income.

The interactions for the VTTS measures correspond to a re-formulation of those proposed in (*33*), whereas the specification for the parking search time WTP is novel and related to the subject of the present study.

For the *Mixed Logit* (ML) model, the interaction terms, which represent a deterministic explanation for taste heterogeneity, were replaced by random distributions for the cost and WTP parameters. 1'000 Halton draws were used in the *Maximum Simulated Likelihood* estimation for the final *Mixed Logit* model. Approaches with a normal, uniform, triangular, and log-normal distribution were tested, of which the normal distribution proved to be the best fit for the present situation. The *Mixed Logit* models were estimated with the recognition of the panel nature of the data, that is taste heterogeneity was assumed to be present across, but not within, individuals. Furthermore, the covariance between the WTP values and the cost parameters is accounted for, as discussed in (*34*).

MODEL RESULTS

This section presents the findings obtained from the estimation both modeling approaches described above. A total sample of 14'499 observations was used (5'475 observations from SP 1, 5'891 from SP 2, and 3'133 from SP 3). The parameter estimates are shown in Table 3, along with the corresponding *t-statistics* (where values above 1.96 indicate that the parameter is significant at the 95 percent level). Goodness-of-fit statistics are also shown. Both models perform very well in terms of model fit, with an *adjusted* ρ^2 of over 0.4. The interaction parameters from the MNL and the standard deviations estimated for the *Mixed Logit* model both indicate the existence of taste heterogeneity for the corresponding variables.

All linear parameters are of the expected sign, and most are significant at the 5 percent level. Various socio-economic characteristics were included in the utility functions for the mode choice component (results for car and transit are found in the first two parts of the table, respectively). Male respondents have a higher tendency to choose the car. The availability of mobility tools has the expected positive influence on the propensity to choose the corresponding mode: transit pass owners prefer to travel by transit, while respondents that always have a car at their disposal tend to favor travel by car. Increased headways between courses and transfers between vehicles reduce the utility for the transit alternative. For the MNL model, the interaction parameters indicate that the sensitivity for price increases is lower for persons with a high income, and for longer trips. Thus, the VTTS increases with these interaction variables. The functional form of the relation between trip distance and the VTTS is shown in Figure 2 (at the sample mean for income). The VTTS is considerably lower for transit passengers than for car drivers. A comparison to the values from the Swiss VTTS guideline (*38*) shows that car VTTS is higher in the sample than in the population. This may be due to the higher average income in the sample, as well as the framing of the choice experiments, which place an emphasis on parking characteristics, thus perhaps reducing the respondents' alertness to changes in fuel costs.

TABLE 3 Model Estimation Results

	MNL		Mixed Logit	
Attribute	Parameter	t statistic	Parameter	t statistic
Car VTTS (in Swiss Francs per minute)	0.717	1..4	*0.296*	*3.92*
interacted with trip distance (in kilometers)	0.233	1.28	-	-
interacted with income (in Swiss Francs per month)	*0.946*	*3.47*	-	-
standard deviation	-	-	*0.122*	*4.60*
Fuel cost (in Swiss Francs)	-0.066	-1.68	*-0.289*	*-4.10*
interacted with trip distance (in kilometers)	-0.062	-0.39	-	-
interacted with income (in Swiss Francs per month)	*-0.904*	*-3.38*	-	-
standard deviation	-	-	*0.161*	*4.12*
Parking search time WTP (in Swiss Francs per minute)	*0.604*	*12.96*	*0.508*	*20.89*
interacted with duration of stay (in minutes)	*-0.334*	*-10.17*	-	-
interacted with income (in Swiss Francs per month)	0.092	1.22	-	-
standard deviation	-	-	*0.175*	6.39
Parking cost (in Swiss Francs)	*-0.129*	*-18.4*	*-0.335*	*-15.97*
interacted with income (in Swiss Francs per month)	-0.067	-1.65	-	-
standard deviation	-	-	*0.199*	*14.10*
Trip purpose: shop (reference category: commute)	*0.928*	*7.46*	*0.957*	3.85
Trip purpose: leisure (reference category: commute)	0.120	1.00	*-0.692*	*-2.27*
Gender: male (reference category: female)	*0.435*	*4.41*	*0.754*	3.59
Car always available	*1.380*	*9.74*	*2.030*	*4.63*
Transit VTTS (in Swiss Francs per minute)	*0.431*	*3.50*	*0.336*	*5.09*
interacted with trip distance (in kilometers)	*0.455*	*3.14*	-	-
interacted with income (in Swiss Francs per month)	0.318	1.49	-	-
standard deviation	-	-	*0.306*	*4.47*
Ticket cost (in Swiss Francs)	*-0.114*	*-3.77*	*-0.109*	*-2.02*
interacted with trip distance (in kilometers)	*-0.401*	*-3.48*	-	-
interacted with income (in Swiss Francs per month)	-0.315	-1.75	-	-
standard deviation	-	-	*0.027*	*2.35*
Number of transfers	*-0.304*	*-6.01*	*-0.594*	*-6.89*
Headway (in minutes)	*-0.020*	*-9.19*	*-0.041*	*-8.48*
Transit card: Half-fare (reference category: none)	*0.493*	*2.89*	*0.819*	*2.29*
Transit card: Generalabonnement (reference category: none)	*1.040*	*4.20*	*1.570*	*3.59*
Walk travel time / acces and egress time (in minutes)	*-0.118*	*-20.16*	*-0.151*	*-16.15*
Bike travel time (in minutes)	*-0.151*	*-13.74*	*-0.233*	*-13.93*
Parking type: open lot (reference category: on-street)	0.075	1.60	*0.266*	*4.12*
Parking type: garage (reference category: on-street)	*0.192*	*3.96*	*0.519*	*7.27*
Location type: outskirts (reference category: city center)	*-0.245*	*-6.40*	*-0.317*	*-6.35*
Pricing level: medium (reference category: low)	-0.003	-0.06	-0.010	-0.17
Pricing level: high	*-0.341*	*-7.39*	*-0.531*	*-8.41*
Cost-performance-ratio: good (reference category: adequate)	0.055	1.22	0.079	1.44
Cost-performance-ratio: very good (reference category: adequate)	*0.284*	*5.85*	*0.444*	*6.97*
Constant: abort search	*-4.300*	*-21.14*	*-7.030*	*-16.53*
Constant: bicycle (reference category: walk)	*-0.536*	*-2.17*	-0.316	-1.00
Constant: car (reference category: walk)	*-3.150*	*-13.30*	*-3.160*	*-5.83*
Constant: transit (reference category: walk)	*-1.110*	*-3.81*	*-1.240*	*-2.84*
Scale parameter: parking choice (reference category: mode choice)	*1.270*	*4.11*	*1.040*	*2.24*
Scale parameter: location choice (reference category: mode choice)	1.010	0.24	0.982	0.82
Null Log-Likelihood		-19'817		-19'817
Final Log-Likelihood		-11'547		-9'906
Adjusted ρ^2		0.415		0.498
Number of observations		15'459		15'459
Run time for estimation		2 hours		27 hours

Values in *italic* are significant at the 95 percent level (|t| > 1.96).

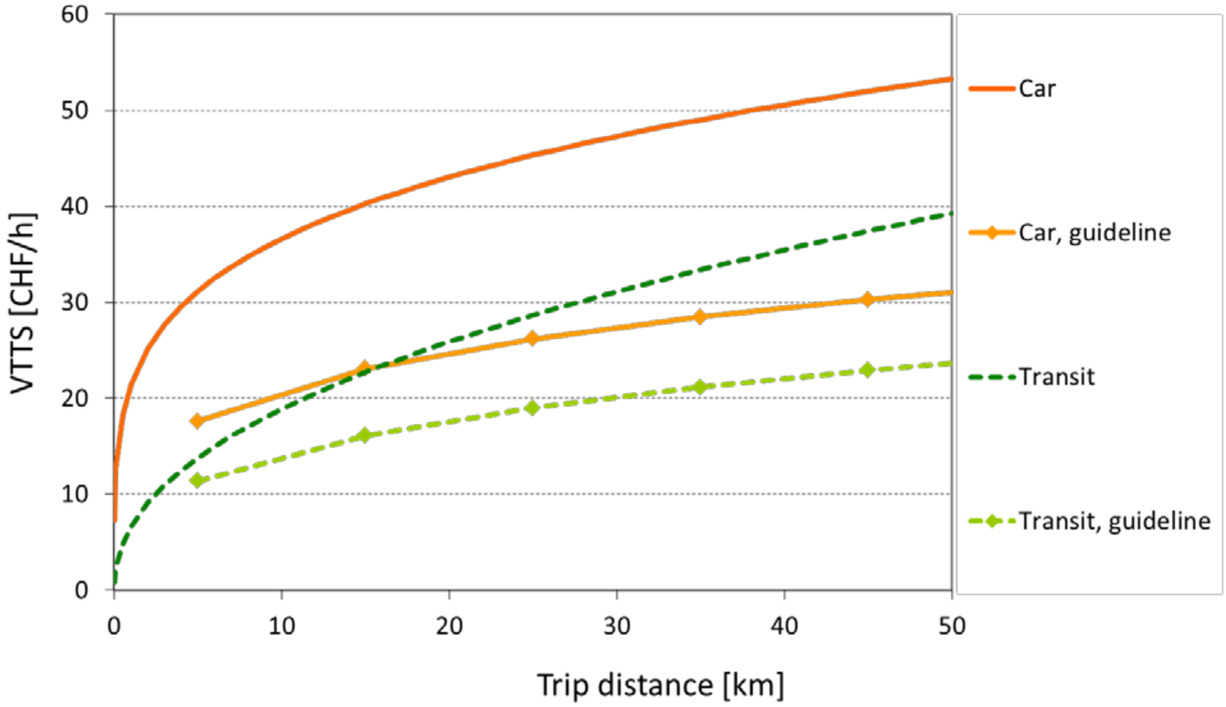

FIGURE 2 Car and transit values of travel time savings (VTTS) as a function of trip distance.

As far as the perception of the parking attributes – which are of main interest here – is concerned, most variables have the expected effects. Quite surprising is the fact that parking in a garage is preferred to on-street and open parking, as the corresponding positive parameter indicates. Respondents prefer to conduct shopping and leisure activities in a city center rather than in the outskirts. Low pricing levels and a good cost-performance-ratio both increase the utility of a location. Aborting the search for a parking space or an appropriate location and renouncing the corresponding activity is very negatively perceived and only an option in extreme cases. The mean WTP for the avoidance of such a scenario, which may be interpreted as the average opportunity cost of a forfeited activity, is computed by dividing the constant by the parking cost parameter, and amounts to roughly 30.- Swiss Francs.

Search times are perceived negatively, as is evidenced by the positive WTP for their reduction. With increasing duration of stay at a location however, the negative effect of having to search for a parking space is considerably reduced, as the corresponding negative interaction parameter shows. Thus, the WTP is high for very short activities, and steeply decreases as the activity duration rises. Figure 3 shows the functional form of the described relation, and it can be seen that reductions in search time are particularly valuable (up to 2.50 Swiss Francs per minute) at the lower end of the curve. Similarly to the VTTS mentioned above, the WTP for search time reductions slightly increases with the respondents' income, as is evidenced by the positive sign of the corresponding interaction parameter.

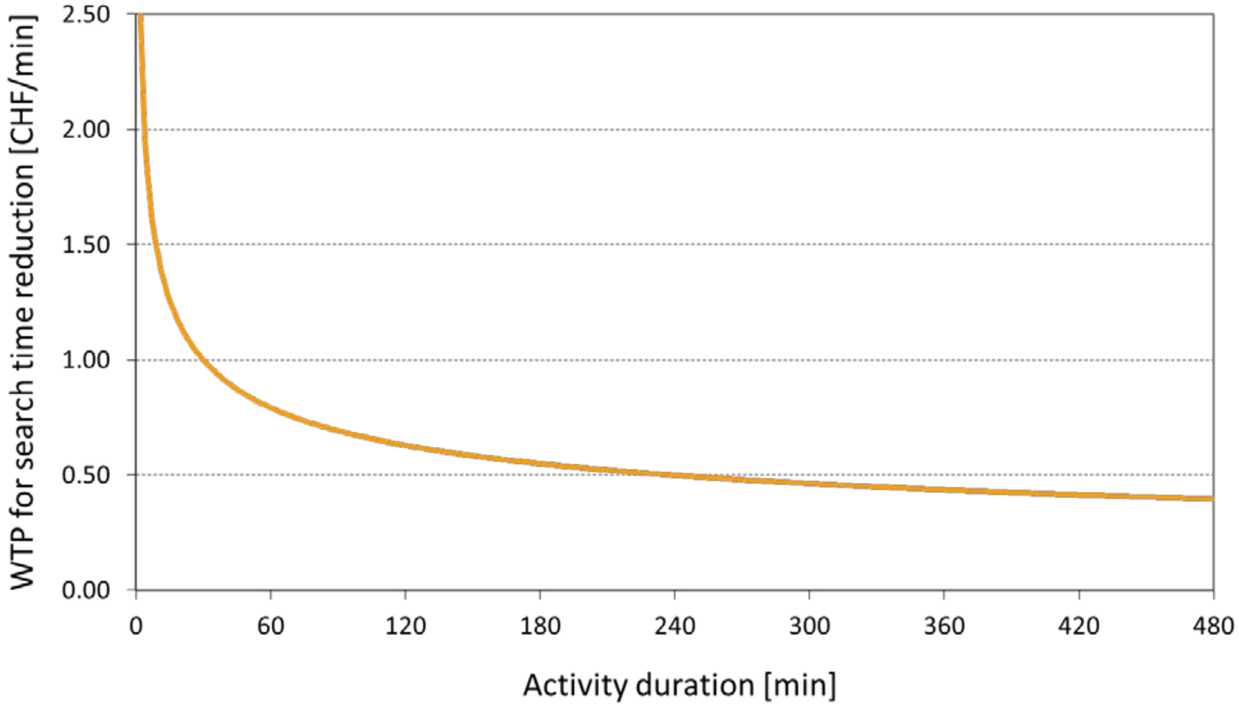

FIGURE 3 Willingness-to-pay (WTP) for search time reductions as a function of activity duration.

For both models, the WTP values for parking search time reductions were computed for the entire respondent sample. For the deterministic MNL, this was done using each respondent's combination of income and reported trip distance. For the *Mixed Logit* model, values for the WTP parameter were simulated for each respondent, based on the averages and standard deviations reported in Table 3. The sample distributions for the WTP values resulting from both models are displayed in Figure 4.

Differences can be made out in the WTP distributions resulting from both models. The distribution from the MNL model is driven by the activity duration distribution in the sample, and thus is very steep at a few distinctive values. The *Mixed Logit* model produces a smooth distribution, which is equally spread around the estimated sample mean for the WTP and overall seems to slightly under-estimate the WTP.

As the non-linear MNL allows a deterministic computation of willingness-to-pay values for each person or group of persons, is computationally less complex (as evidenced by the vast differences in computation times shown in Table 3), and allows a correct re-weighting for the computation of population level WTP values, it seems to be the more appropriate for applications in forecast models.

For the decision relevant attributes of the mode alternatives, sample mean WTP values were computed. Those means are shown in the first part of Table 4 for both modeling approaches, along with the reference values from the Swiss VTTS guideline (*38*), where those are available. The largest difference between the models is the car VTTS, which at the sample mean is more than double for the MNL than for the *Mixed Logit* model. In the *Mixed Logit* model, the WTP for reductions in parking search time is much higher than that for lower travel times; the opposite holds for the MNL.

Demand elasticities computed from the parameter estimates are displayed in the second part of Table 4. It can be seen that car and transit travel times have the largest negative elasticities, thus relative increases in those attributes are expected lead to the greatest shifts in mode shares. Both parking characteristics (search time and costs) have negative demand elasticities, which indicates that policies aiming at varying those attributes (which in the short- to mid-term are more likely to be implemented than substantial changes in travel times) would have a significant effect on the propensity to choose alternative modes. Both models yield plausible elasticities, however the MNL again seems preferable for the computation of population-level values.

CONCLUSIONS

Results of a *stated choice* survey relating to parking behavior were presented. The main findings relating to the research questions posed in the introduction are:

- Parking characteristics, such as costs, search times and the parking type, have a significant influence on choices made by the respondents to the survey.
- The influence of the parking attributes is evidenced by the demand elasticities and willingness-to-pay (WTP) values relating to those attributes. Thus, measures aiming at changing those attributes may be a powerful policy tool for shifting modal shares and location choices, as large infrastructure extensions and the corresponding significant changes in travel times are not to be expected in the near future.

A model structure with a deterministic representation of taste heterogeneity was compared to one with a random parameter approach. While both models yield plausible results, the deterministic approach appears to be more suitable for applications in forecasting models in virtue of its ability to produce exact behavioral responses for individuals or groups of individuals via the specification of its utility form, its computational efficiency, and its convenience of use for the computation of population weighted values.

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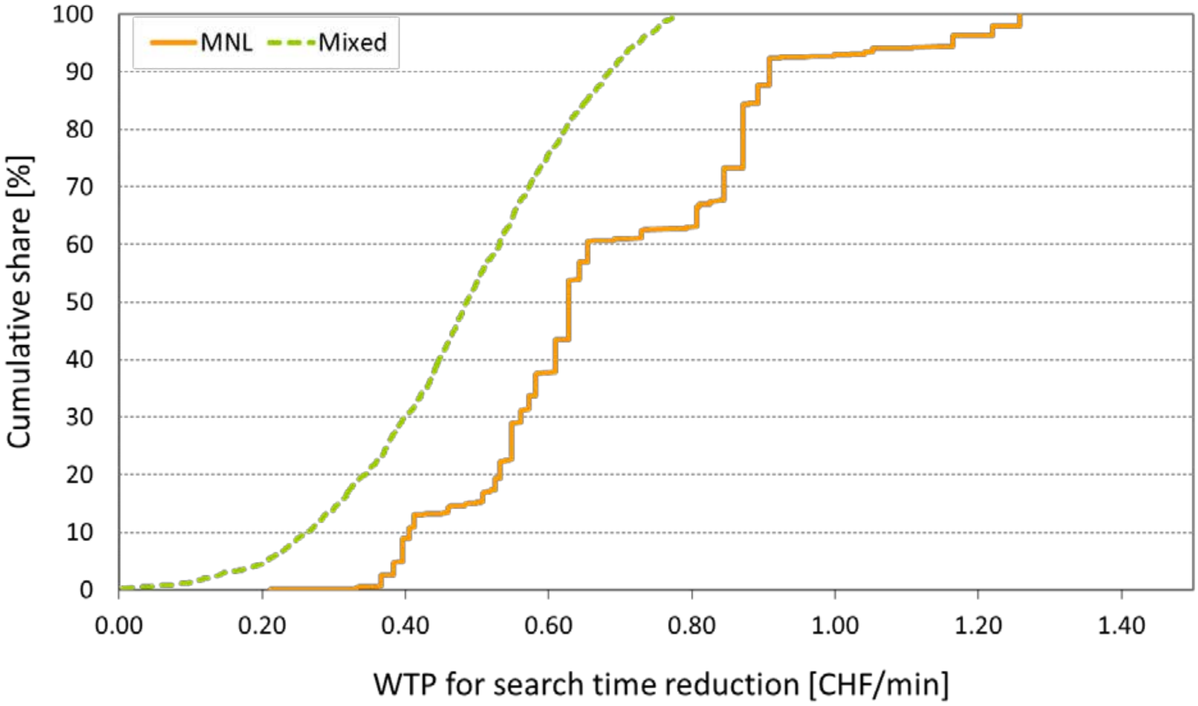

FIGURE 4 Willingness-to-pay (WTP) distributions: MNL vs. Mixed Logit.

TABLE 4 Sample Mean WTP Indicators and Demand Elasticities

WTP indicators	MNL	Mixed Logit	Swiss guideline
Car travel time (in Swiss Francs per hour)	59.3	13.1	19.4
Parking search time (in Swiss Francs per hour)	36.0	33.7	-
Transit travel time (in Swiss Francs per hour)	22.6	13.6	13.0
Headway (in Swiss Francs per hour)	9.8	8.6	-
Number of transfers (in Swiss Francs per transfer)	2.6	2.0	-
Demand elasticities	MNL	Mixed Logit	
Car travel time	-0.85	-1.25	
Parking search time	-0.20	-0.40	
Fuel cost	-0.12	-0.76	
Parking cost	-0.64	-1.34	
Transit travel time	-0.78	-0.87	
Ticket cost	-0.24	-0.44	
Headway	-0.31	-0.50	

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