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Models of Mode Choice and Mobility Tool Ownership Beyond 2008 Fuel Prices

Claude Weis, Kay W. Axhausen, Robert Schlich, and René Zbinden

A recent project addressed how travelers would react to fuel prices rising above the high levels that were reached in mid 2008. Study participants were recruited during phone interviews, in the course of which trips made on a specified day were recorded. On the basis of one of those trips and the respondents' possession of mobility tools, stated preference (SP) experiments were constructed. The first part consisted of a mode choice situation under modified price (and travel time) settings (tactical decisions). The second part focused on long-term (strategic) choices between the current and an alternative fleet, including a redistribution of yearly mileage. From the SP data, multinomial logit models for mode and fleet choice were estimated. The mode choice models were estimated by using income- and distance-dependent nonlinear utility functions and separately for the various trip purposes (as was the practice in earlier Swiss studies on similar topics) and controlled for all relevant trip characteristics. The models for mobility tool ownership, which were formulated by using a new approach, aimed to yield trade-offs between the various attributes of the offered fleets and to forecast the distribution of annual transit passes under modified settings. The findings suggest that inertia is present in both mode choice and mobility tool ownership. Elasticities do not change much from previous studies, where more-conservative price increases were assumed. Transit pass ownership is expected to grow only when increasing fuel prices coincide with stable public transport fares.

This paper describes a study contracted by the Swiss Federal Railway Company's passenger traffic section that was recently conducted at the Institute for Transport Planning and Systems (IVT), ETH Zurich (*1*).

The first part of the study complements the results established in previous Swiss mode choice studies. Vrtic and Fröhlich presented demand elasticities derived from a comprehensive mode choice model (*2*). Axhausen et al. (*3, 4*) and Hess et al. (*5*) computed values of travel time savings for Switzerland. Their results were applied in the official Swiss cost–benefit guidelines for values of travel time savings (*6*). Literature on mobility tool—particularly transit pass—ownership is quite sparse. Most of the literature appears to focus on modeling car ownership and usage without considering other dimensions (*7–10*). This is surprising: considering transit passes as substitute goods for cars appears intuitive, at least in the context of regions with high-quality public transport service and widely available transit passes. Thus, modeling car and transit pass ownership jointly in such settings appears to be an obvious approach. Scott and Axhausen presented evidence of interactions between car and transit pass choices in a household context and show that commitment to one mode heavily influences the use of the other, confirming the substitution effect (*11*). However, their study lacks variation in the price levels, thus making it impossible to estimate their influence on mobility tool ownership. Vrtic et al. investigated the effects of potential mobility pricing schemes on travelers' tactical (mode choice) and strategic (long-term) decisions (*12, 13*). Their analyses were based on stated preference surveys with quite conservative price variations and yielded very low elasticities for transit pass ownership. Axhausen et al. used a structural equations model to test hypotheses on paths linking car ownership, transit pass ownership, and modal usage (*14*). However, they did not model the choice determinants for owning the various mobility tools.

The present study was sparked by increasing oil prices at the time it was initiated (mid 2008). Short-term mode choice and longer-term mobility tool ownership decisions were of equal interest. At the time, the price for a liter of regular nonleaded fuel was around CHF 2 (Swiss francs; as of February 2010, CHF 1 = $0.92), a circumstance that provided an opportunity for stated preference (SP) experiments implementing a much greater bandwidth in pricing schemes than in previous studies without losing realism in the experiments. Because customer reactions are assumed to vary with costs, a mere extrapolation of previous results to the new price levels could lead to biased forecasts. Specifically, demand elasticities are expected to increase nonlinearly with rising prices. Although the current worldwide economic crisis has counteracted increases in fuel prices, fuel at CHF 4 per liter and above remain quite imaginable in the mid- to long-term future, especially in the context of fossil energy shortage scenarios. [Several works offer qualitative analyses on the effects of supply disruptions in the United Kingdom in 2000 (*15–17*).]

In the short term, the interest focused on modeling individuals' mode choice under modified pricing schemes while accounting for other relevant decision variables. Here, the figures of interest were values willingness-to-pay (WTP) indicators and elasticities. These were estimated by means of discrete choice models based on SP mode choice experiments, where the situations were based on trips reported by the recruited respondents during previous phone interviews.

In the longer term, the main interest was in how customers would adapt their sets of mobility tools, and especially transit passes, to the aforementioned changes, and what the effects in the usage of these mobility tools would be (that is, if and how a redistribution of mileage from car to public transport would take place). Therefore, a second SP questionnaire was designed, focusing on the determinants of these choices. Because an iterative and interactive approach to the

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respondents' most-desirable setting was not feasible (pen-and-paper questionnaires were used as the survey instrument), an approach was used in which the interviewees were given choices between their current mobility tool setting (at new price levels) and alternative fleets, consisting of a new car, a redistribution of annual mileage, and the corresponding cheapest annual transit pass. The fleet choice models were formulated as mixed multinomial logit models incorporating the two offered fleets' attributes as linear terms in the utility functions. This approach, which is fairly straightforward and, to the authors' knowledge, new in its application, was chosen over a discrete-continuous formulation because of data considerations and to understand the trade-offs between transit pass prices and their ownership and use. Under the assumptions made in the study, the results should allow revenue managers to choose pricing strategies for transit passes as a function of fuel prices.

DATA COLLECTION

Respondent Recruitment

The data used for the study result from an SP survey. Respondents were recruited through an ongoing continuous computer-assisted telephone survey, in which approximately 400 persons per week were interviewed. The survey, called the kontinuierliche Erhebung Personenverkehr (KEP), was contracted by the Swiss Federal Railway Company and conducted by Link, and it comprised questions on respondents' sociodemographic characteristics and travel behavior (*18*). Trips of more than 3 km undertaken during a week are recorded along with relevant characteristics (origin, destination, travel and waiting times, distances). Following the interview, respondents who had a driving license were recruited for the SP survey. Limiting the recruitment process to licensed drivers ensured that the car alternative presented in the mode choice experiments was available to all respondents. For those fulfilling the requirements and who were willing to participate in the study, one reported trip was selected according to the following criteria:

- If at least one car trip was reported, the longest such trip was selected.
- Otherwise, the longest reported trip by railway was selected.

The personalized mode choice experiments for each respondent were constructed from the selected trip. This procedure made sure that every participant was presented with choice situations tailored to their actual behavior instead of hypothetical scenarios.

From September 8 to November 9, 2008 (calendar weeks 38 through 45), 1,200 respondents were recruited for the study. For various reasons, 200 of the recruited persons were excluded from the final survey; thus there was a total sample size of 993 participants, to which questionnaires were sent by post.

Design of SP Experiments

Mode Choice

In accordance with current practice (*19–23*), the SP experiments were designed on the basis of data reported by the respondents in the phone interviews. This procedure has been successfully applied in former Swiss studies (*12, 13, 24, 25*). The attribute levels used in the mode choice SP experiment were derived from the chosen trip. In construction of the experiments, the existing attributes of the trip and its mode alternative were increased or decreased by predetermined factors, which are shown in Table 1.

The attributes for the car alternative were derived from the Swiss network model (*26*). For the rail alternative, they were obtained from the Swiss Federal Railway Internet timetable by means of an automated script programmed for this purpose.

Four levels of fuel price ranging up to a 150% increase (resulting in CHF 5 per liter) were applied. The extreme scenario incorporated a 50% increase in public transport fares, because higher prices are unrealistic in the short term to midterm. More conservative value ranges were applied for travel times, because large infrastructure improvements are planned on neither the road nor the rail network, and thus travel times should not vary substantially in the short term. In the same vein, to avoid irrelevant planning situations and create unrealistic scenarios, only the status quo or improvements in the number of vehicle changes on the public transport side were considered (that is, connections are not assumed to worsen). The experimental designs for the SP experiments were determined by using the software Ngene (*27*). Every respondent was faced with six mode choice situations, which were displayed after a recapitulative overview of their reported trip.

To clarify the underlying assumptions to the respondents, explanations on how the costs of car and rail trips were computed were displayed for each choice situation. Specifically, the fuel prices applied for the computation of the total car trip cost as well as the assumptions made for the rail fare were detailed. The latter was of utmost importance for owners of Generalabonnement (GA) transit passes. These flat-rate cards, bought once a year, entitle the holder to free use of public transport on the complete Swiss rail network and on local networks. To avoid confusion about why the fares in such cases

TABLE 1 Variable Values Used for Construction of Stated Preference Experiments

Alternative	Attribute	Values
Mode Choice Experiment		
Car	Total travel time	Sum of free-flow and congested travel time
	Free-flow travel time	−10%, ±0%, +10% of current level
	Congested travel time	0%, 10%, 20% of free-flow travel time
	Fuel price	−10%, +50%, +100%, +150% of current level
Rail	Total travel time	Sum of in-vehicle travel time and waiting time
	In-vehicle travel time	−10%, ±0%, +10% of current level
	Waiting time (at transfer)	0, 10, 15 min.
	Number of transfers	0, 1 times
	Fare	−10%, +20%, +50% of current level
Fleet Choice Experiment		
Car	Fixed costs	+20%, +60% of current level
	Fuel price	−10%, +60%, +140% of current level
	Fuel consumption	−25%, −10% of current level
Rail	Fares	−10%, +20%, +50% of current level
	Modal share	10%, 30%, 70% of total yearly mileage

were not set to zero, additional information about how the fare was calculated (cost of the transit pass, CHF 3,100, divided by the total yearly rail mileage) was displayed.

Long-Term Decisions

The long-term SP experiments consisted of six situations in which the characteristics of the respondents' mobility tool fleet were varied along with the distribution of yearly mileage. The attribute levels used for the construction of the experiments are displayed in Table 1. An example situation is displayed in Figure 1. Respondents choose either to keep their current set (under the new fuel and public transport pricing scheme) or switch to an alternative. Here, fuel price is assumed to increase to CHF 3.20 per liter and public transport fares to increase by 50%. The alternative set is constructed as follows. The mileage distribution determined by the experimental design is used to compute total public transport costs for three transit pass settings (no transit pass, half-fare card, and GA), the cheapest of which is chosen and displayed in the questionnaire. The other variables—fuel consumption of the alternate car and its fixed yearly costs (resulting from a distribution of purchase costs over the average lifespan of a car)—result from the experimental design.

Response Rates

The overall response rate was 58.3% (579 respondents), which can be considered as satisfactory considering the questionnaire's complexity and length. The rate matches the experience with comparable studies at IVT, as shown in Figure 2. The ex ante response burden for the different surveys was determined according to the scheme detailed in the work of Axhausen and Weis (*28*). The methodology assigns weighted scores to question types and sums them to calculate the response burden of the survey. The present study fits in the corresponding context for surveys with prior recruitment.

Nontrading Behavior

Nontraders are respondents in SP surveys who, regardless of the alternatives' attributes, always pick the same alternative. A rather high share of respondents (roughly 47%) in the mode choice experiments were nontraders. The share is slightly higher among public transport users than among those who had chosen the car in their reference trip. This may have several reasons, one of which is randomly picking the first or second alternative for every situation to reduce the mental effort of completing the questionnaire. Such behavior evidently biases the outcomes of the statistical analysis of the data, because these effects can lead to decisions that are not based on trade-offs between the alternatives' attributes (*29*). However, especially when respondents have a strong prior commitment to a specific transport mode, apparently illogical choices may well reflect true behavioral response. The most prominent examples of such effects are residential location (where the location type dictates the use of a certain means of transport, for example, the car in regions that are not or are barely accessible by public transport) or transit pass ownership (such as the afore-

Behavior	Current	Alternate
Transit pass	Half-fare card	GA
Price of transit pass	250.-CHF/year	4,500.-CHF/year
Public transport mileage	9,000 km/year (about 30%)	22,000 km/year (about 70%)
Total public transport costs	2,200.-CHF/year	4,500.-CHF/year
Car	Current	New
Fuel consumption	6.0 1/100 km	5.4 1/100 km
Fixed costs	600.-CHF/year	700.- CHF/year
Car mileage	22,000 km/year (about 70%)	9,000 km/year (about 30%)
Fuel costs*	4,200.-CHF/year	1,600.-CHF/year
Total car costs	4,800.-CHF/year	2,300.-CHF/year
Total mobility costs	7,100.-CHF/year	6,800.-CHF/year

☐ ← **Your choice** → ☐

* Result from an assumed fuel price of 3.20 CHF/l.

FIGURE 1 Example of fleet choice experiment (original is in German).

FIGURE 2 Response rate in context of comparable studies.

mentioned GA, which binds customers to the public transport alternative).

Thus, nontrading in itself does not necessarily imply inconsistent responses. Hence, rather than excluding nontraders from the analysis (which would drastically reduce the sample size), special care was taken to model the possible influences on individuals' choice behavior, such as variables describing the trip (distance and purpose), sociodemographic characteristics (especially the availability of mobility tools) of the respondents, and the mode choice in the reference case as an inertia indicator. Obviously, mode choice is determined jointly by all these attributes and not solely by travel times and costs.

In the long-term experiment, only 30% of the respondents were nontraders. This is somewhat surprising because of the slightly more complex nature of the second SP experiment, which as stated above would naturally tend to increase the share of random responses. However, the experiment clearly indicated the cost implications of choosing a specific alternative, thus simplifying the process for the respondents. Individuals appear to be more willing to adapt their behavior in the long than in the short run.

SAMPLE SUMMARY STATISTICS

Table 2 presents key statistics for the respondent sample in comparison with (*a*) the KEP base sample of recruited individuals and (*b*) the 2005 Swiss National Household Travel Survey (*Mikrozensus Verkehrsverhalten* 2005, or MZ '05), which is representative of the Swiss population (*30*).

A bias toward well-educated, rather wealthy respondents can be seen (although the income figures cannot be directly compared to those of the MZ '05, as different measures were used). Single-person households are slightly underrepresented. A high share of respondents own transit passes, as is common for surveys of the described type—users of public transport tend to be more interested in transport policy issues, leading to a higher propensity to participate in the survey. Because only holders of driving licenses were sampled for the study and respondents for which car availability is impossible were excluded, the share of those regularly having a car at their disposal is slightly higher in the KEP than in the population. The share of respondents without a car is higher in the final sample, again indicating an affinity toward public transport users.

The discrepancy of the sociodemographic attributes between the sample and the Swiss population raises the question of the necessity of sample reweighting. As has been stated in the literature (*31*), weighting should be applied in explorative analyses. For the estimation of

TABLE 2 Sample Descriptive Statistics

Variable	Value	Sample	KEP	MZ '05
Gender	Male	48.1	49.4	48.7
	Female	51.9	50.6	51.3
Age (in years)	18–35	17.7	12.3	28.4
	36–50	38.2	39.1	30.4
	51–65	30.5	39.2	23.2
	>65	13.7	9.4	18.1
Education level	Primary or secondary school	6.9	8.0	17.9
	Professional school	47.6	48.3	59.6
	College or university	45.5	43.8	22.5
Number of persons in household	1	15.2	14.3	18.9
	2	41.9	36.4	36.9
	3	13.1	17.1	16.5
	4	17.7	20.0	18.3
	>4	12.1	12.0	9.4
Income (in CHF/ month)	<2,000	16.3	19.0	
	2,000–4,000	17.4	19.3	
	4,000–6,000	28.7	29.2	
	6,000–8,000	19.1	17.0	
	8,000–10,000	10.8	8.7	
	>10,000	7.8	6.8	
Transit pass	None	42.7	51.2	67.2
	Half-fare card	44.8	39.3	26.5
	Generalabonnement	12.5	9.5	6.3
Car availability	Always	77.2	79.8	79.4
	Sometimes	15.5	15.0	15.7
	Never	7.3	5.8	4.9
Car fuel consumption (in l/100 km)	<5	6.5	6.0	
	5–8	69.6	70.2	
	8–12	21.6	21.7	
	12–15	1.9	1.7	
	>15	0.4	0.4	

the discrete choice models described here, weighting is not necessary under the condition that the selectivity variables are included in the models (*31*).

FORMULATION AND ESTIMATION OF DISCRETE CHOICE MODELS

The models for the tactical and strategic decisions make use of discrete choice methodology (*31, 32*), specifically the multinomial logit model. All models were estimated by using the Biogeme software package (*33, 34*).

Mode Choice

Mode Choice Model Formulation

The formulation of the mode choice models follows the form that was introduced in the study by Mackie et al. (*35*) and has been used in several Swiss studies (*3–6*). It adds continuous interactions between variables to the linear utility formulation. As Hess et al. state, the methodology's advantages over an arbitrary segmentation into classes or random parameter models include the computation of deterministic taste heterogeneity and faster estimation times (*5*). The general specification of the utility function is as follows:

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

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; and
$\lambda_{y,x}$ = elasticity of the influence of y on the (dis)utility generated by x, to be estimated.

Traveler sensitivity to attribute x is assumed to vary with the value of attribute y. In the present case, income and trip distance are assumed to influence the disutility generated by travel time and cost. Normalizing y with its mean ensures that the linear parameter indicates the valuation of x at that point (as the interaction term then equals 1). Additionally, it was assumed that the valuation of travel time and costs would differ between trip purposes. The formulation of the final model therefore includes segmentation into the four categories commuting (work or education), shopping, business, and leisure.

Mode Choice Results

Parameter estimates for the final model are displayed in Table 3. A linear utility specification was estimated first, then the nonlinear interactions and the purpose segmentation were gradually added. The results for the purpose-specific nonlinear model (purpose-specific parameters could be found only for the travel time and cost variables) are shown. Parameter values are displayed along with their *t*-statistics

TABLE 3 Parameter Estimates and Model Fit for Mode Choice Model

		Commuting $n = 592$		Shopping $n = 438$		Business $n = 306$		Leisure $n = 1,975$	
Attribute	Parameter	Est.	*t*-Stat.	Est.	*t*-Stat.	Est.	*t*-Stat.	Est.	*t*-Stat.
Car Alternative									
Inertia	β_{car}	1.492	12.13	1.492	12.13	1.492	12.13	1.492	12.13
Congestion	β_{cong}	−1.456	−2.82	−1.456	−2.82	−1.456	−2.82	−1.456	−2.82
Car availability	β_{car_avail}	0.202	2.69	0.202	2.69	0.202	2.69	0.202	2.69
Travel time	$\beta_{tt_{car}}$	−0.029	−1.77	−0.042	−4.82	−0.005	−0.74	−0.031	−7.79
	$\lambda_{dist,tt_{car}}$	−1.909	−2.78	—	—	−2.020	−3.25	−0.551	−5.28
	$\lambda_{inc,tt_{car}}$	1.144	2.08	—	—	3.933	1.49	−0.210	−6.26
Fuel cost	$\beta_{cost_{car}}$	−0.085	3.29	−0.044	−2.61	−0.039	−2.60	−0.038	−7.66
	$\lambda_{dist,cost_{car}}$	—	—	—	—	—	—	−0.261	−2.63
	$\lambda_{inc,cost_{car}}$	−0.985	−3.38	−1.427	−3.50	—	—	−0.184	−1.28
Public Transport Alternative									
Transfers	$\beta_{transfers}$	−0.328	−2.42	−0.328	−2.42	−0.328	−2.42	−0.328	−2.42
Waiting time	$\beta_{waiting\_time}$	−0.020	−1.70	−0.020	−1.70	−0.020	−1.70	−0.020	−1.70
Half-fare card	β_{HTA}	1.301	12.57	1.301	12.57	1.301	12.57	1.301	12.57
GA	β_{GA}	1.891	12.10	1.891	12.10	1.891	12.10	1.891	12.10
Travel time	$\beta_{tt_{public}}$	−0.037	−3.34	−0.020	−3.49	−0.050	−3.25	−0.016	−8.27
	$\lambda_{dist,tt_{public}}$	−1.034	−2.15	—	—	−2.693	−3.61	−0.632	−5.51
	$\lambda_{inc,tt_{public}}$	0.617	1.19	1.210	1.90	—	—	—	—
Fare	$\beta_{cost_{public}}$	−0.046	−2.56	−0.040	−2.54	−0.039	−2.60	−0.047	−6.26
	$\lambda_{dist,cost_{public}}$	—	—	—	—	—	—	−0.261	−2.63
	$\lambda_{inc,cost_{public}}$	−0.985	−3.38	−1.427	−3.50	—	—	−0.184	−1.28
								Adjusted $\rho^2 = 0.305$	

NOTE: n = number of observations, est. = estimate, *t*-Stat. = *t*-statistic, dist = distance, inc = income.

TABLE 4 Population-Weighted WTP Indicators and Demand Elasticities

	Commuting	Shopping	Business	Leisure
WTP Indicator				
Car travel time [CHF/h]	24.4 ± 7.3	55.9 ± 5.9	81.6 ± 61.6	94.4 ± 99.9
Rail travel time [CHF/h]	31.7 ± 5.6	29.1 ± 3.4	185.2 ± 204.2	43.3 ± 5.9
Transfer waiting time [CHF/h]	27.5	27.5	27.5	27.5
Number of transfers [CHF/transfer]	6.4	6.4	6.4	6.4
Travel Time Elasticities				
Car	–0.26	–0.49	–0.13	–0.71
Public transport	–1.29	–1.34	–1.39	–2.37
Price Elasticities				
Car	–0.23	–0.19	–0.46	–0.37
Public transport	–0.30	–0.30	–0.40	–0.56

(absolute values above 1.96 indicate significance of the parameters at the 5% level), as well as general model fit information. Only parameters with *t*-values above 1 were retained in the final model.

The adjusted ρ^2 value of 0.3 indicates a good model fit, and all the included variables are of the expected sign and statistically significant. The nonlinear interaction terms (that is, the λ's from the table) imply that

- With increasing trip distance, travel time and cost sensitivity decrease (negative signs for the parameters), and
- With increasing income, sensitivity to travel time increases (positive sign), whereas sensitivity to cost decreases (negative sign).

Table 4 shows the relevant WTP indicators and demand elasticities for the mode choice model. The WTP indicators are obtained by dividing an attribute's parameter by the cost parameter of the according alternative. As the valuation of the travel time and cost parameters vary with trip distance and income, so do the WTP indicators: WTP decreases with trip distance and increases with income (*1*). The values indicated in the table are weighted to represent distance and income averages for the respective trip purposes. Reweighting was done according to the procedure detailed by Hess et al. (*5*). The 95% confidence interval is indicated along with the mean values. The variation should be considered when the results are used to carry out cost–benefit analyses. For the WTP indicators relating to waiting time and number of transfers, the weighting procedure was not applied, because these attributes were included as linear terms in the utility function.

The value of travel time saving for business purposes has a very large confidence interval. The sample size for its computation being quite small (as few business trips were present in the sample), the values should be regarded with caution. In general, the willingness to pay for saving car travel time tends to be larger than that for public transport. This is in line with expectations, as car travelers are more sensitive to travel time than are users of public transport.

Fleet Choice

Fleet Choice Model Formulation

The utility functions for the fleet choice model were formulated as a linear combination of the attributes of the current and alternate fleets. Additionally, fuel price (in Swiss francs per liter) and the age of the current car were incorporated in the utility function for the alternate fleet, because both variables were expected to directly influence a respondent's decision to purchase a new car. Two inertia variables were included in the model: a constant term for the current alternative (modeling the base utility of that alternative as compared to the other) and a dummy variable indicating whether the transit pass present in the alternative considered was the same as the current one. The model was estimated as a panel mixed logit model; a normally distributed error term was included to model taste heterogeneity between respondents.

Fleet Choice Results

All parameters (Table 5) are of the expected sign and statistically significant. Although inertia is again obviously present (as highlighted by the large constant term), the random parameter associated with the inertia variables is quite large, signaling that there is a subset of travelers who are less inert and are willing to reconsider their choices when prices change. Car costs are perceived more negatively than public transport costs, and fixed costs more negatively than variable costs. The presence of a transit pass, especially the GA, has a positive effect on an alternatives' utility. Reallocating mileage from the car to public transport is valued negatively. The assumption that both fuel price and the age of the current car have a positive effect on the probability of choosing a new fleet is confirmed by the corresponding parameter estimates.

Trade-offs and price elasticities for the fleet choice model are displayed in Table 6. The trade-offs for the respective cost components indicate their relative valuation. That fixed car costs are valued more negatively than fuel costs indicates a lack of willingness to invest in a new, less consumption intense but more expensive vehicle, even with fuel prices rising significantly. On the other hand, the willingness to pay for lower fuel consumption, which is given by the ratio of the parameters for the fixed costs and consumption, amounts to CHF 320 per liter saved on a 100-km distance. Aggregated over the assumed 10-year life of a vehicle, this results in a total of CHF 3,200.

The ratio of the transit pass price and variable public transport cost parameters is even higher. Thus, respondents are willing to pay the costs for a transit pass only under the condition that a sufficient amount in variable costs can be saved. This is indicated by the ratio

TABLE 5 Parameter Estimates and Model Fit for Fleet Choice Model

Attribute	Parameter	Est.	*t*-Stat.
Constant current fleet	c	2.293	6.17
Standard deviation of the error term	σ	1.997	16.18
Current transit pass	$\beta_{current}$	0.643	4.98
No transit pass (reference category)	β_{none}	—	—
Half-fare card	β_{HTA}	0.110	0.70
GA	β_{GA}	1.192	2.02
Price of transit pass	$\beta_{season\_ticket\_price}$	–0.313	–2.03
Variable public transport costs	$\beta_{pt\_var\_costs}$	–0.038	–0.51
Fixed car costs	$\beta_{car\_fixed\_costs}$	–0.912	–9.70
Variable car costs (fuel)	$\beta_{car\_var\_costs}$	–0.242	–6.40
Yearly public transport mileage	$\beta_{pt\_mileage}$	–0.049	–2.95
Fuel consumption	$\beta_{fuel\_consumption}$	–0.292	–3.00
Fuel price (effect on alternate fleet)	β_{fuel_price}	0.351	6.76
Age of current car (effect on alternate fleet)	$\beta_{age_{car}}$	0.033	1.51
		Adj. $\rho^2 = 0.266$	

NOTE: Est. = estimate, *t*-stat. = *t*-statistic.

TABLE 6 Trade-Offs and Elasticities for Fleet Choice Model

Trade-Off	Unit	Value
$\frac{\beta_{car\_fixed\_costs}}{\beta_{season\_ticket\_price}}$	[—]	2.9
$\frac{\beta_{car\_var\_costs}}{\beta_{pt\_var\_costs}}$	[—]	6.4
$\frac{\beta_{car\_fixed\_costs}}{\beta_{car\_var\_costs}}$	[—]	3.8
$\frac{\beta_{season\_ticket\_price}}{\beta_{pt\_var\_costs}}$	[—]	8.2
$\frac{\beta_{season\_ticket\_price}}{\beta_{car\_var\_costs}}$	[—]	1.3
$\frac{\beta_{HTA}}{\beta_{season\_ticket\_price}}$	[CHF/Halbtax]	–350.1
$\frac{\beta_{GA}}{\beta_{season\_ticket\_price}}$	[CHF/GA]	–3,803.4
$\frac{\beta_{GA}}{\beta_{pt\_mileage}}$	[km/GA]	–21,929.1
$\frac{\beta_{car\_var\_costs}}{\beta_{pt\_mileage}}$	[km/CHF]	4.9
$\frac{\beta_{fuel\_consumption}}{\beta_{car\_fixed\_costs}}$	[CHF/(l/100 km)]	319.9

NOTE: GA: Direct price elasticity, –1.18; cross (fuel) price elasticity, 0.05. Half-fare card: direct price elasticity, –0.04; cross (fuel) price elasticity, 0.25.

of the GA parameter and the costs. Compared to a fleet that does not include a transit pass, the utility of one that has a GA is equal at about CHF 3,800 additional costs. This amount constitutes the willingness to pay for a GA, when the corresponding savings in variable costs are provided. The analogous willingness to pay for a half-fare card is CHF 320.

The ratio for the transit pass price and fuel costs parameters is 1.3. This can be interpreted as follows. When replacing the half-fare card by a GA, equal utility is reached when variable car costs are reduced by CHF 3,700 (the difference in transit pass prices multiplied by the aforementioned factor). At the mean fuel consumption (8 liters per 100 km) and a fuel price of CHF 2 per liter, this corresponds to a reallocation of yearly mileage of about 23,000 km. Thus, acquiring a GA is seen as a commitment to public transport that is amortized by traveling more by that mode.

With increasing fuel prices, the propensity of acquiring a GA and reassigning mileage to public transport increases. Assuming fuel price will double and reach CHF 4 per liter, acquiring a GA at the current costs of CHF 3,100 will be profitable when 11,000 km are shifted from car to rail (as the CHF 3,700 savings in variable car costs is then reached).

From the estimated parameters, probabilities for possessing no annual transit pass, a half-fare card, or a GA, were computed under various pricing scenarios. The results are shown in Figure 3. The fuel price of CHF 2 per liter and zero increase in transit pass costs form the base scenario. At the time of writing, about 28.5% of Swiss residents owned a half-fare card, and approximately 4.9% were GA holders. At the current fare setting, fuel price increases would lead to transit pass holder shares of up to 40% in the scenario of CHF 5 per liter. At the same time, when fuel prices do not increase or do so only moderately (as can be realistically assumed after the recent developments), transit pass sales can be increased only if fares are held constant. As shown in Table 6, the direct price elasticity for the GA is at about –1.2, and the cross elasticity is quite low (*1*).

CONCLUSION AND OUTLOOK

The findings in this paper suggest that even if fuel prices again increase dramatically, inertia is present in both mode choice and mobility tool ownership and mileage distribution. Price elasticities computed from the discrete choice models suggest that respondents are more sensitive to public transport price increases than to rising fuel prices. Thus, if the demand for rail services and transit pass sales is to be maintained, no wide margin exists for increasing public transport fares. Travel times appear to be of greater importance in determining mode choice. These findings are interesting in view of the improvements to the Swiss rail infrastructure that are to be made in the midterm future, such as the opening of the Gotthard Base tunnel. Effects of such improvements on the share of annual transit pass holders cannot be ignored and should be thoroughly investigated in the future, as they hold a significant potential for modal shifts if the fares are held at the current level.

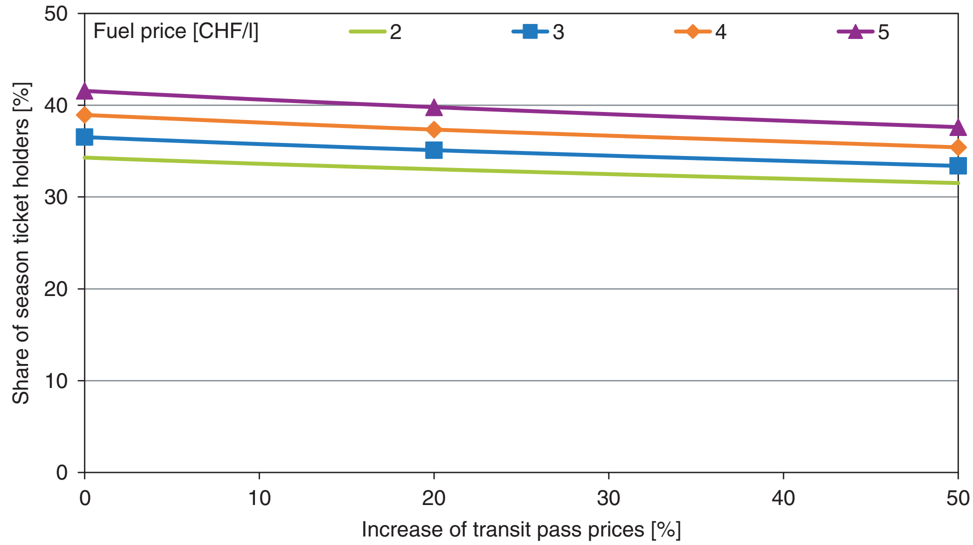

FIGURE 3 Forecast of share of transit pass owners under various price settings.

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