Mode choice of commuters from 1970-2000

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Abstract

The paper's focus lies on modelling the mode choice of commuters from 1970 to 2000 in Switzerland. Substantial effort was made to produce data sets, which track the development of the private and public transport systems and the socioeconomic variables on municipality level. The mode choice models were estimated as multinomial logit. Major changes occur in the estimated parameters of travel cost, quantity adjusted car ownership cost and car ownership per licensed driver.

Resumo

O presente artigo trata da modelagem da escolha de modos de transportes por viajantes no período entre 1970 a 2000 na Suíça. Um esforço substancial foi realizado para produção do banco de dados, que retrata o desenvolvimento do sistema de transporte público e privado e das variáveis socioeconômicas em níveis locais. A escolha dos modos de transportes foram estimadas utilizando um modelo multinomial logit. As variáveis de grande representatividade no modelo foram: custo de viagem, custo ajustado para posse de automóvel e posse de automóvel por habilitação de motorista.

1 Introduction

Transport infrastructure projects are characterized by large investments and can change the travel behaviour and land use over time. Modelling the interaction between infrastructure, land use and travel behaviour is an especially interesting, challenging and current topic in transport planning research. Starting from the 1990s, few researchers have applied time series techniques to examine these interactions, see for example Cervero and Hansen (2002); Hansen and Huang (1997).

In almost all these time series studies the availability of accurate and valid data provides a serious problem; analyses are often carried out with highly aggregated datasets. For this study, mesoscopic commuter data sets from the Swiss census for the years 1970, 1980, 1990 and 2000 were linked to municipal-level socio-demographic and transport supply data to estimate sequential discrete choice models for mode, destination and trip generation models over the study time period. In this paper the mode choice aspect of the study is addressed. The project's main focus was to determine how the commuters' mode choice has changed over the last 30 years.

The paper is organised as follows: Chapter 2 reviews the methodology used and presents the utility function used for the mode choice model. Chapter 3 describes and analyses the data used in the study. In Chapter 4 the results are presented and the model results are interpreted. Finally, in Chapter 5 the study results are put into a broader context and present an outlook to future work.

2 Methodology

Discrete choice models and in particular multinomial Logit models (MNL), have been used frequently in transport planning for many years. The basic concepts for using MNL in transport planning are described in, among others, Louviere, Hensher and Swait (2000).

With the MNL, parameters (β) for alternative i are estimated with the levels of attributes x to maximise the utility (U) of a decision-maker and can be formulated as:

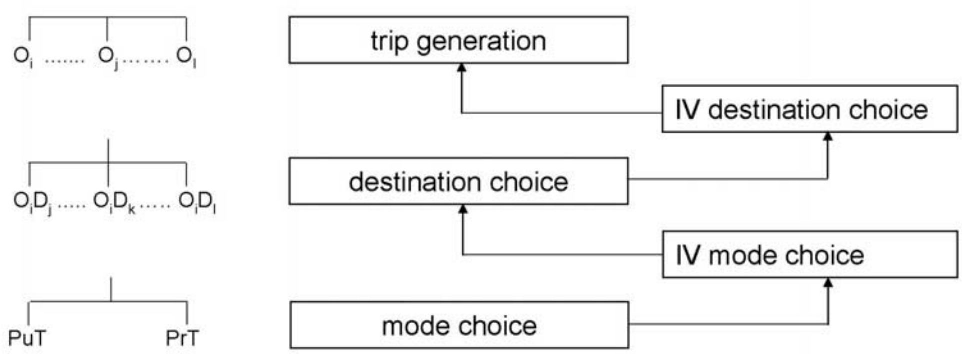
$$U_i = V_i + \varepsilon_i = \beta'_i x'_i + \varepsilon_i$$

Where V_i is the observed utility term and ε_i is the unobserved utility term.

Figure 1 presents an overview of the model structure of the entire research; the present paper focuses on the mode choice part of the study. The sequential hierarchic structure starts by calculating an Inclusive Value (IV) using MNL on the mode choice process. The IV for the MNL is formulated as:

$$IV = \log \sum_i \exp V_i$$

The inclusive value is then used in the utility function of the MNL model used to estimate destination choice. The same process is followed to estimate a Probit model for trip generation.



Note: IV means Inclusive Value

Figure 1 Overview of the model structure

The mode choice utility functions for private transport (PrT) and public transport (PuT) are formulated as:

$$
\begin{aligned}
V_{PrT} = {} & \beta_{PrT\,tt} * \text{PrT travel time} + \beta_{tc} * \text{PrT travel cost} \\
& + \beta_{car} * \text{car by licenceholder} + \beta_{inc} * \ln(\text{income}) \\
& + \beta_{qacoc} * \text{quality adjusted car ownership cost} \\
& + \beta_{11} * \text{OD-P 11} + \beta_{12} * \text{OD-P 12} + \beta_{13} * \text{OD-P 13} \\
& + \beta_{14} * \text{OD-P 14} + \beta_{21} * \text{OD-P 21} + \beta_{22} * \text{OD-P 22} \\
& + \beta_{23} * \text{OD-P 23} + \beta_{24} * \text{OD-P 24} + \beta_{31} * \text{OD-P 31} \\
& + \beta_{32} * \text{OD-P 32} + \beta_{33} * \text{OD-P 33} + \beta_{34} * \text{OD-P 34} \\
& + \beta_{41} * \text{OD-P 41} + \beta_{42} * \text{OD-P 42} + \beta_{43} * \text{OD-P 43} \\
& + \beta_{44} * \text{OD-P 44}
\end{aligned}
$$

$$
\begin{aligned}
V_{PuT} = {} & \beta_{PuT\,tt} * \text{PuT travel time} + \beta_{tc} * \text{PuT travel cost} \\
& + \beta_{T} * \text{number of transfers} + \beta_{HW} * \text{headway}
\end{aligned}
$$

The spatial type OD pairs (OD-P) are effect coded in the data set, which is an alternative method for the more common dummy coding of categorical variables. The main advantages of effect coding by discrete choice models are (Bech and Gyrd-Hansen (2005):

1) the estimated parameters are uncorrelated with the alternative specific constant, and
2) better to interpret.

Sixteen different spatial type OD pairs were defined and tested using four categories: major city (1), suburban (2), small city (3), and rural (4).The parameters capture the spatial dispersion and transport specific effects (e.g. transport system reliability, lack of parking space, parking charges, etc.), which were not represented in the other transport variables. Furthermore, the transport models used in this study for the different years contain the average daily workday traffic and therefore do not consider demand variations or possible overloading (congestion) during the day.

The MNL-models were estimated using the software package LIMDEP-NLOGIT (Greene, 2002) and the observed aggregated choice data (inter-zone work trips) by mode of the total (PrT and PuT) number of trips where used as frequencies.

Elasticity values show the impact of the change of one variable on another variable, for example, the relative change in market share based on a relative change in price. Direct elasticity measures the relative change (in percent) of mode choice probability for a given alternative (in this case public transport and private transport) in relation to the relative change in one attribute of the same alternative. The cross elasticity measures the relative change (in percent) of the mode choice probability for a given alternative in relation to the relative change in one attribute of the competing alternative.

The elasticity calculation was computed using the Probability Weighted Sample Enumeration (PWSE) (Louviere, Hensher and Swait, 2000). Using this method the aggregated elasticity (E) is calculated as follows:

$$E_{x_{ik}}^{\bar{P}(i)} = \left(\sum_{q=1}^{Q} \hat{P}_{iq} E_{x_{ikq}}^{P_{iq}} \right) \Bigg/ \sum_{q=1}^{Q} \hat{P}_{iq}$$

with $\bar{P}_i$ for the aggregated choice probability of alternative i and

$\hat{P}_{iq}$ for the estimated choice probability of alternative i by individual q.

The PWSE method is recommended for calculating elasticity values over the average and the naïve pooling methods, because the latter methods tend to overestimate the elasticity values.

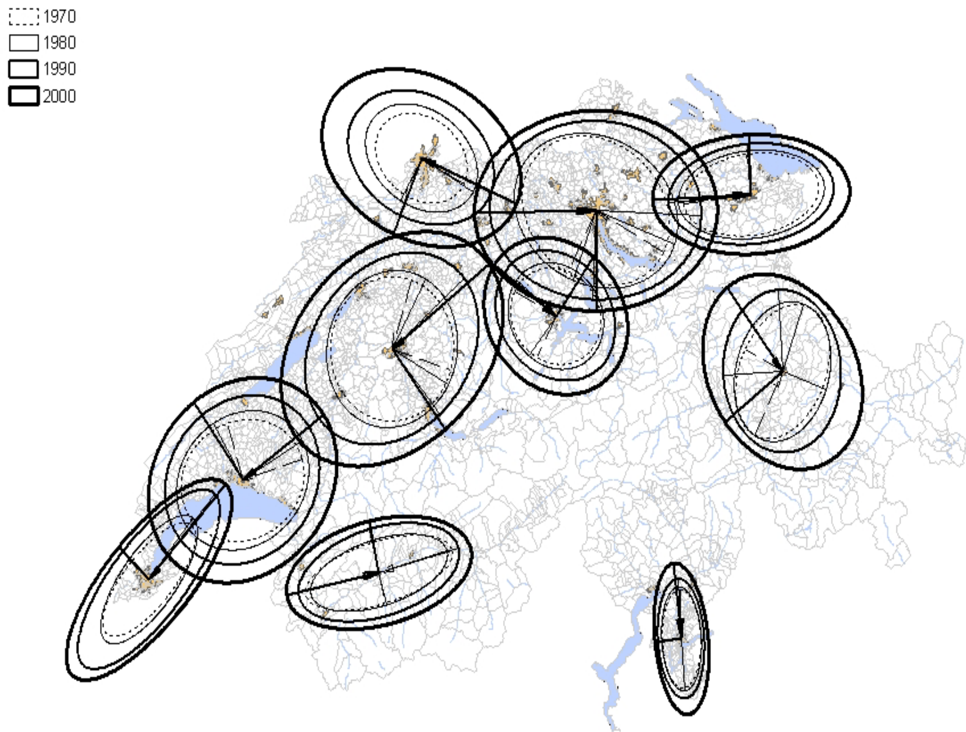
3 Data

Availability of accurate, consistent data is an essential and crucial ingredient of all statistical research and holds especially true for analyses considering a long time periods. In this research different transport networks were constructed for private transport (PrT) and public transport (PuT) for each time horizon (2000, 1990, 1980 and 1970). These models were used to obtain appropriate impedance values (e.g., PrT travel time, number of transfers, PrT travel cost,…) for PrT and PuT between all 2,900 municipalities in Switzerland. This work is described in Fröhlich and Axhausen (2004).

For this study, demand data obtained from the commuter survey conducted within the Swiss national census was used. This is a very valuable dataset as it includes all work trips made by the entire Swiss workforce (defined as working over 6 hours per week) by mode. Table 1 presents an overview of the inter-zone (between zones) work trips. As shown, the patterns of trips get more dispersed over time. Figure 2 displays the catchment areas of the major cities and shows theirs expansion overtime.

Number of trips	1970	1980	1990	2000
PrT and PuT	946‘229	1‘252‘184	1‘814’674	2‘023‘295
PrT	506‘894	788‘978	1‘121‘107	1‘339‘685
PuT	439‘335	463‘836	693‘567	683‘610
Non-zero OD relations	99‘980	141‘264	209‘983	265‘040

Table 1 Overview: Number of inter zone trips 1970-2000



Source: Botte (2003)

Figure 2 Catchment area of commuters for major cities 1970-2000

The distribution of the demand-weighted travel speed for public and private transport modes for the different years is shown in Figure 3. For private transport the median speed increases from 30 to 48 km/h. This clearly shows the impact of building major motorways in the 1970s. The travel speed in public transport increased less in absolute terms, from 15 km/h to 22 km/h. This reflects the fact that during the 1970s the public transport system was only slightly improved, however more significant improvements followed in the 1980s and 1990s.

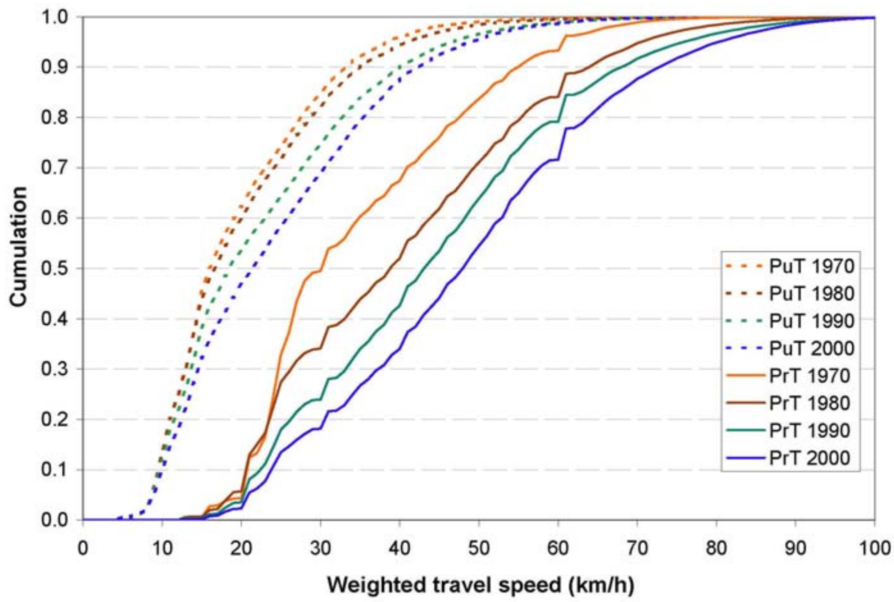


Figure 3 Demand-weighted travel speed for public transport (PuT) and private transport (PrT)

As part of the research, the income per municipality was calculated using data from tax statistics. Unfortunately, the income data is not consistent, because the minimum income needed to pay taxes did not increase significantly during the time period, and therefore the data has a downside bias in later years.

Another inconsistency occurred in the automobile registration data; during the 1970s the method of measuring registrations changed and therefore the 1970 data is not compatible with the data of the other years. Several validation procedures were applied and data from a few municipalities was omitted. Finally, the number of car per licence holder per municipality was obtained using information from cohort analysis of licence holders per gender and age group overtime (Beige, 2004) and the age distribution per gender in every municipality.

The cost functions for public transport and private transport were calculated using the price structure for 2000 and the transport cost index (Abay and Meier, 2000) over time. The structure of public transport pricing changed over time (more annual tickets and fewer single point to point tickets), and unfortunately there was no way to follow these changes precisely. The private transport cost function includes fuel cost and the cost for tyre abrasion. The quality adjusted automobile ownership cost was taken from Frei, 2005, where with the application of hedonic models a separation of quality and price changes were estimated. The reported price index from the work of Frei (2005) considers not only the price changes for passenger cars but also the increasing quality over time.

4 Results

The results of the mode choice models for 1970 to 2000 are shown in Table 2. All the estimated parameters are significant on the 95% level and carry the expected sign.

	1970	1980	1990	2000
Number of observations	54'374	74'998	117'292	162'848
Rho adj.	0.065476	0.134087	0.155832	0.203994
Log Likelihood function	-550'990.9	-629'135.7	-880'691.6	-960'201.4
Likelihood Ratio	77'258.4	194'897.8	325'202.8	492'203.2
PuT travel time (h)	-0.583	-0.485	-0.455	-0.628
Number of transfers (-)	-0.104	-0.265	-0.265	-0.140
Headway (h)	-0.103	-0.188	-0.194	-0.105
Travel cost (CHF)	-0.164	-0.080	-0.035	-0.040
PrT travel time (h)	-1.658	-1.838	-1.374	-1.593
Car per license holder	1.581	1.714	2.392	2.860
Income (CHF in real value of the year 2000)	0.207	0.073	-0.058	-0.192
Quality adj. car ownership cost (CHF in real value of the year 2000)	-0.063	-0.029	-0.023	-0.008
Spatial type OD pair 11	-1.135	-1.342	-1.403	-1.431
Spatial type OD pair 12	-0.089	-0.047	-0.051	-0.149
Spatial type OD pair 13	-0.181	-0.179	-0.118	-0.133
Spatial type OD pair 14	0.200	0.262	0.225	0.177
Spatial type OD pair 21	-0.230	-0.555	-0.801	-0.886
Spatial type OD pair 22	0.545	0.495	0.391	0.323
Spatial type OD pair 23	0.151	0.118	0.251	0.295
Spatial type OD pair 24	0.696	0.610	0.654	0.615
Spatial type OD pair 31	-0.739	-0.796	-0.951	-1.007
Spatial type OD pair 32	0.078	0.177	0.316	0.341
Spatial type OD pair 33	0.177	0.137	0.148	0.236
Spatial type OD pair 34	0.237	0.419	0.630	0.649
Spatial type OD pair 41	-0.428	-0.424	-0.734	-0.785
Spatial type OD pair 42	0.239	0.404	0.467	0.535
Spatial type OD pair 43	0.034	0.161	0.242	0.388
Spatial type OD pair 44	0.445	0.560	0.734	0.832

Table 2 Parameters mode choice of commuters 1970-2000

The same outline as in Part 2 will be followed: first the mode specific parameters will be discussed; second attention will be paid to the interpretation of the origin destination specific parameters. Finally, the obtained elasticities and values of travel time savings will be discussed.

All four mode-related parameters in the public transport utility function, i.e. travel time, travel cost, number of transfers and headway, carryall a negative sign, implying a negative influence on public transport utility. Parameters with a possible positive sign, such as the ownership of annual tickets, could not be used due to the lack of data.

As can be seen, the values of the public transport travel time parameter fluctuates around -0.5 over the study period; employees are not in a greater hurry to get to work today as they were 30 years ago. Another interpretation can be that the marginal utility of public transport travel time remains relatively constant over the observed time period. No trend can be deducted from the parameters for headway and number of transfers.

Both the private and public transport utility function contains the same travel cost parameter. This is based on the assumption that PuT and PrT users make decisions the same way about money. The cost parameter increased continuously from -0.17 in 1970 to -0.08 in 1980 and to -0.04 in 1990; after 1990 it stayed constant. The weight of travel cost in the utility function decreases significantly over time.

The parameter for private transport travel time falls from -1.64 (1970) to -1.80 (1980) before rising to -1.35 (1990) and then returning to the 1970 level of -1.58 in 2000. These results are consistent with those for public transport, namely that employees are in no greater hurry to get to work today than they were in the 1970s.

An increase can also be observed in the estimated parameters for car ownership per licensed driver: it doubles over the total observed time period: starting at 1.68 (1970), rising to 1.728 (1980), 2.411 (1990) and to 2.87 (2000), which shows that the marginal utility of car ownership in mode choice increased significantly over the last 30 years.

The estimated parameters for average income on private transport are slightly surprising. In 1970 and 1980 average income had a positive impact, while in the years 1990 and 2000 it had a negative impact. That this is surprising, is due to the fact that in many other studies income had a positive influence on the choice probability of private transport. However, most of these other studies were conducted with stated preference (SP) data and it was possible to use disaggregated income data.

As discussed in Part 3, the income data used in this study was the average income of tax paying inhabitants living in a municipality and is therefore aggregated. Furthermore, the minimum income for paying taxes only increased slightly over time (it did not increase with inflation). This means that today more people are reported in the tax record. Finally, the number of part time jobs increased over the study period. These factors combined lead to a downward bias over time of the income data.

The parameters for quality adjusted car ownership cost are negative for all four study years, and increase over time starting at -0.06 (1970), -0.03 (1980), -0.02 (1990), and finally -0.01 (2000). This shows that the negative influence of car ownership cost decreases over time.

An important part of the research consisted of analyzing travel data based on origin-destination spatial types. In Figure 4 the trend of the parameters for the spatial type OD pairs (OD-P) are shown.

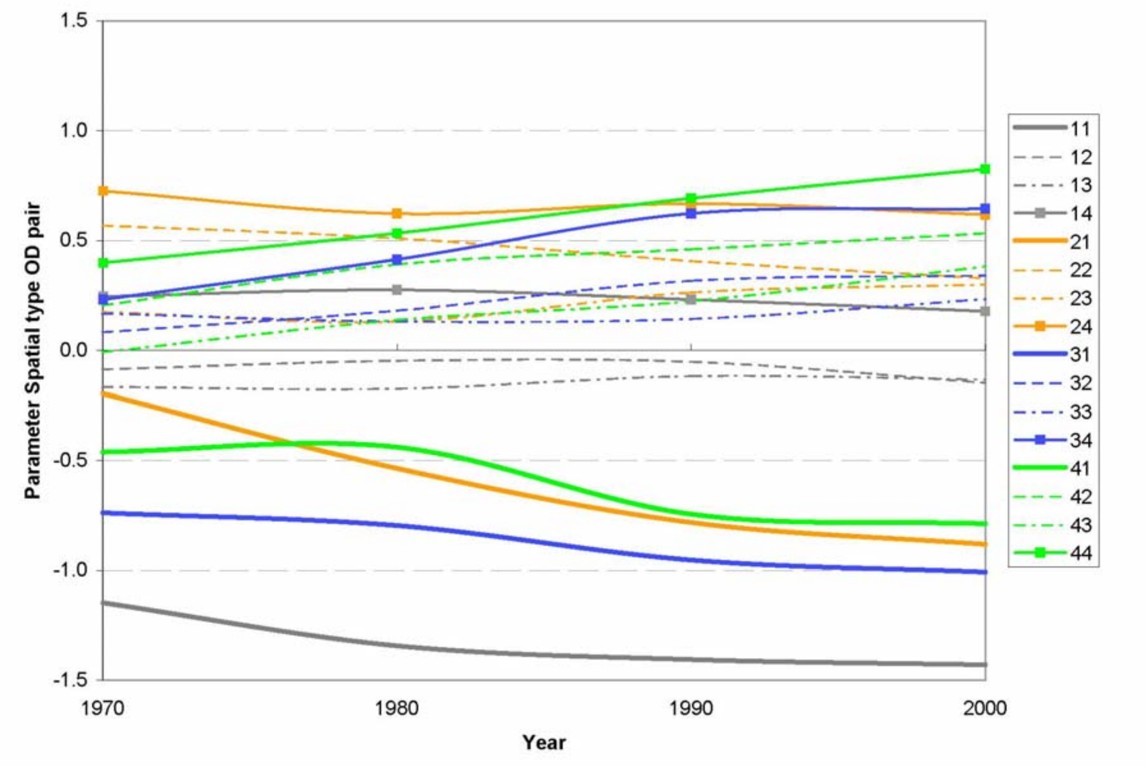


Figure 4 Development of the estimated parameters for spatial type OD pairs 1970-2000

All parameters estimated in the spatial pair analysis have the expected sign and are significant at the 95%-level. The model shows that utility of private transport is negatively influenced, because the spatial type OD pair variables are in the PrT utility function; if the trip starts-in (OD-P 1x), ends-in (OD-P x1), or both starts and ends within a major city (OD-P 11). On the other hand, for a trip starting and ending in a rural municipality the spatial pair's influence on mode choice for PrT is positive.

The parameter for the spatial type OD pair 11 (major city- major city) has the biggest negative value in 1970; over time this negative utility increases. This holds as well for other OD-pairs where the destination of the work trip is in a major city (OD-P 21, OD-P 31 and OD-P 41). The parameter OD-P 22 (suburban-suburban) is positive, but decreases during the study period. The parameter for OD-P 23, 24, 32 and 33 are positive and stay relatively constant. The parameters OD-P 42, 43, 34 and 44 are also positive and over time their values increase significantly.

In general, the trend of the spatial pair parameters shows a decreasing utility contribution of the spatial type pairs in and around the major cities, in the rural parts of Switzerland however the commuters are very car oriented and this effect grows stronger over time.

Table 3 presents the direct and cross elasticity values. The elasticity values show the relative change in demand for a relative change in an attribute. For example, a direct elasticity of the public transport travel time of -0.31 and a cross elasticity of 0.21 means that a 10% increase in public transport travel time reduces the demand for public transport by 3.1% and increases the demand for private transport by 2.1%.

	1970		1980		1990		2000	
	PrT	PuT	PrT	PuT	PrT	PuT	PrT	PuT
PuT travel time	0.209	-0.313	0.129	-0.347	0.135	-0.362	0.171	-0.560
Number of transfers	0.020	-0.029	0.034	-0.091	0.045	-0.120	0.024	-0.077
Headway	0.061	-0.091	0.064	-0.172	0.045	-0.121	0.023	-0.076
PuT cost	0.123	-0.184	0.049	-0.131	0.028	-0.075	0.029	-0.095
PrT cost	-0.151	0.226	-0.063	0.169	-0.036	0.096	-0.045	0.146
PrT travel time	-0.239	0.358	-0.196	0.527	-0.178	0.480	-0.192	0.629
Car ownership rate	0.300	-0.450	0.319	-0.859	0.448	-1.206	0.452	-1.477
Income	0.433	-0.648	0.102	-0.274	-0.080	0.216	-0.222	0.726
Car cost	-0.657	0.983	-0.245	0.660	-0.225	0.605	-0.060	0.197

Table 3 Elasticity values for mode choice 1970-2000

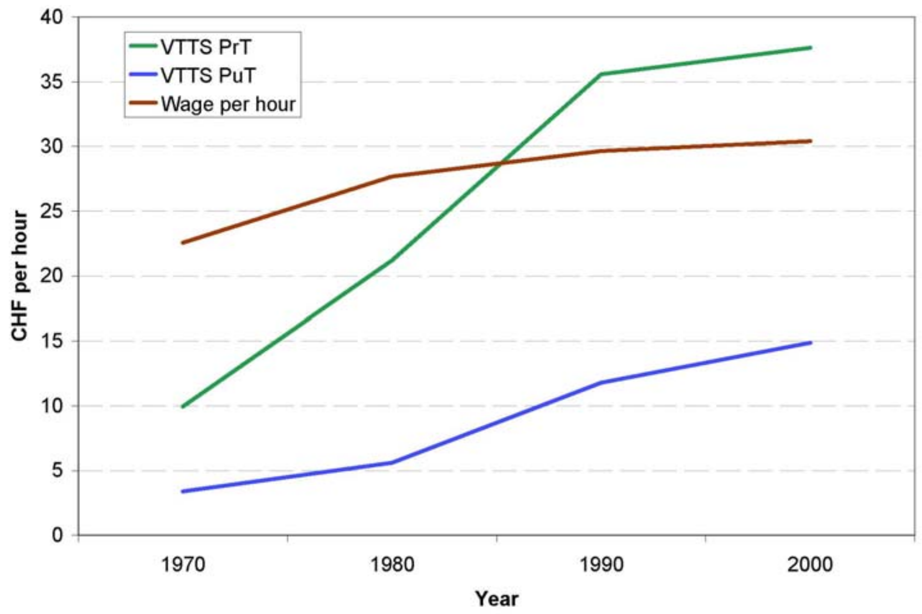
It can be seen that the direct elasticity of public transport travel time stays in the same range from 1970 to 1990 and increases in the year 2000. The cross elasticity decreases over time. The elasticity values of number of transfers and headway are small and stay in a narrow band over time.

The direct elasticity of the public transport cost almost halves between 1970 and 2000 increasing from -0.18 to -0.10. This indicates that public transport demand reacts less strongly to price increases in 1990 and 2000, than it did in 1970 and 1980. The cross elasticity decreased even more. The direct elasticity for private transport cost decreased during the study period from -0.15 (1970) to -0.05 (2000).

For the direct elasticity of PrT travel time the same holds as the direct elasticity of PuT: it has a fairly constant value (-0.20) over time. The cross elasticity increases from 0.36 in 1970 over 0.53 in 1980 and 0.48 in 1990 to 0.63 in the year 2000. The impact of car ownership on the PrT demand increases by 50%. Much more elastic is the impact of car ownership on the public transport demand. Here the values start at -0.45 in 1970 decreases to -0.86 (1980), -1.21 (1990) and to -1.48 in 2000. The income elasticity is positive in 1970 and 1980 and becomes negative in the latter years. As outlined above, these results are probably biased.

The adjusted car ownership cost has a strongly negative elasticity on private transport demand, starting at a rate of -0.65 (1970) and increasing over the study period to -0.06 (2000). The cross elasticity falls significantly, i.e. it decreases from 0.98 in 1970 over 0.66 in 1980 and 0.61 in 1990 to 0.20 in 2000.

Figure 5 plots the value of travel time savings (VTTS) and the average hourly wage of Swiss industrial workers based on real (constant year 2000) values. The VTTS is calculated by dividing the travel time parameters with the travel cost parameter and measures the relative sensibility to time and cost changes. The VTTS also helps to evaluate the willingness to accept increases in cost in return for decreases in travel time. The industrial worker wage is probably upward biased in the early years because in the early 1970s Swiss industry was booming with an average unemployment rate of 0.3% causing significant upward pressure on wage rates.



Note: in real value for the year 2000

Figure 5 VTTS for PrT and PuT as well as wage per hour 1970-2000

The VTTS data show that employees travelling to work by automobile have a higher VTTS than those travelling by public transport. The ratio between VTTS for private transport and public transport has decreased over time. The biggest changes in the VTTS per decade occur for private transport during the 1970s, when the core motorway network was completed. For public transport the biggest change occurred a decade later, when the so called "Taktfahrplan" (headway based time table) was introduced.

The model specifications don't consider the change in working time from 1970 to 2000. For example, the average working time fell in the mechanical industry from 44.7 hours per week in the year 1970 to 41.3 hours per week in the year 2000. The major decrease in the working time took place at the beginning of the 90s. That may explain to some extent the huge increase of the VTTS, especially for the PrT, during the 70s and 80s. In the 90s with relative constant amount of working time and low increase of the real wage, the estimated VTTS for PrT and PuT show a low increase. Also Mackie, Jara-Diaz and Fowkes (2001) reported that VTTS for working trips rise faster than the real wage because of the fewer hours of working time.

The results for the year 2000 are, when the different travel length is considered, higher than the VTTS values from a SP-Study on mode choice in Switzerland (Vrtic, Axhausen, Maggi and Rossera, 2003).

5 Conclusions and Outlook

The research study's mode choice model results for commuter trips from 1970 to 2000 provide several interesting insights into the long term changes of the transport system in Switzerland. Major changes occur in the attributes travel cost, quantity adjusted car ownership cost and car ownership per licensed driver. The study also shows that cost is a less significant factor in mode choice today than it was 20 or 30 years ago.

The influence of car ownership on the utility function has become stronger over time, and is the attribute for which the demand reacts most elastically. If an employee owns a car, he will probably make a trip by private transport to the workplace.

Trips within or to major cities and to a lesser extent in their suburbs favour public transport; over time these effects become stronger. In rural areas, the use of private transport is positively influenced in the choice probability by the spatial type pairs. This trend is also continuous over time.

As mentioned in the introduction, the mode choice results presented in this paper only are part of a larger study and are used to calculate the inclusive value, which is then used together with data on the number of employees in the industrial (2nd sector) and service (3rd sector) in the destination choice model and afterwards in trip generation models to show the effects on the transport system of these changes over time.

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