Value of Reliability in Swiss Transport Systems

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Abstract

The reliability and variability of travel time significantly affect transport behavior, in particular transport mode and route choice. The goal of this research was to investigate empirically the influence of reliability on transport behavior and willingness to pay for a variety of trip lengths and purposes. A two-stage method was used to collect on line the necessary modelling data. First, a revealed preference (RP) survey and then a stated preference (SP) survey were conducted.

The data obtained from these surveys was used to develop trip purpose specific behavior models. It was also possible to estimate a common model with non-linear variables (interaction terms based on distance or income). The model results are plausible and robust, and it was possible to test the difference between planned and unplanned (stochastic) late/early arrivals. According willingness-to-pay values were obtained.

1. Introduction

For a well-functioning transport system, the reliability is a criterion, which is important for users, operators and political decision makers. For the users is a reliable functioning transport system a basic requirement.

Due to the high infrastructure loading and more frequently traffic jams as well as lower time table stability, the assessment of reliability in project cost benefit analysis and demand forecast gets more important. Recent studies in Switzerland and other parts of the world show, that the reliability mainly impacts the mode and route choice.

For the calculation of demand forecast and project cost benefit analysis it is important to consider that the impact of the evaluation of reliability depends on the kind of mode, trip purpose and length etc. Furthermore, there are also differences within systems for example when a delay on a PuT-feeder line leads to failed connection to a long haul (railway) line.

The goal of the research study (Fröhlich *et al.*, 2014) is the empirical valuation of the influence of reliability on the transport behavior and the willingness to pay for different trip length and purpose.

2. Methodology and Literature

The assessment of reliability or in other words the travel time variability is topic of many national and international studies. A good overview can be found in Li *et al.*, 2010. Mainly SP surveys are used to investigate the subject. In the studies different presentations of reliability in SP questioners are discussed and willingness to pay derivered.

The reliability of transport systems consists of a repeated observation of the supply condition e.g. measured in travel time. The users can only estimate the variation of travel time between a certain origin destination pair, if they have own or others experiences from repetition of the same trip. The reliability is an additional element of the general costs (others are travel time, cost…). The transport system user can react on the additional costs of reliability with change of the departure time, route or mode choice changes. The most common reaction is usually the departure time change.

The approach of the "mean-variance" model (Fig 1) is based on the disutility of travel time. The scheduling model is founded on the assumption that the disutility derivers from the difference in arrival time to the desired arrival time. This means, the users arrives delate early or late. (Fig 2). This approach can be formulated as a choice under certainty or uncertainty. By the later the expected utility consists of two parts: the planned scheduling and the unplanned stochastic delay.

$E(U) = \alpha\, E(T) + \beta\, SD(T) + \gamma\, C$

E	expected
U	Nutzen (utility)
α,β,γ	parameter for the relevant attribut
T	travel time
SD	standard deviation
C	cost

Fig. 1 Mean-variance model

Choice under certainty (Small, 1982)

$U = \alpha\, T + \beta\, SDE + \gamma\, SDL + \theta\, D_L$

U	utility
α, β, γ, θ	parameter for the relevant attribute
T	travel time
SDE	schedule delay early
SDL	schedule delay late
D_L	Dummy variable is 1 for delay, otherwise 0

Choice under uncertainty (simplified) following Bates, 2001; Noland und Small, 1995: $E(U) = \alpha E(T) + \beta E(DE) + \gamma E(DL) + \delta P_L$ E expected U utility α, β, γ, δ parameter for the relevant attribute T travel time DE delay early DL delay later P_L probability of late arrival

Fig. 2 Scheduling models

The most recent approach is the mean lateness model which was presented by Bates und Ibañez (2009). Here only delays late are considered this occurs in public transport with a set time table and the model is used mainly in this area in the UK.

In Switzerland the topic of reliability was investigated by König und Axhausen, 2002; and König, 2004. These two studies show the important of reliability in transport system for the travel choices and derivered willingness to pay for reliability.

In the current study, the assessment of reliability will follow the scheduling approach under uncertainty, which allows separated valuation of plannend and unplannend delays early or late. The design of the questioners and choice situations are tuned with the scheduling approach.

3. Survey

The necessary data for the research was derivered in a two phase online survey. The work started with the revealed preference part in which the also participation of the respondent was checked and information to socio demographic attributes and travel behavior were asked. In a second stage, a Stated Preference survey was conducted.

The survey was performed in four waves, three of them in German and one in French. The first wave with 20% of the respondent was used as a pretest. Technical assistance for the online survey were provided by the market research institute Intervista AG (Bern) and sociotrend GmbH (Mannheim).

The basic population for the recruitment of respondent is the online panel of the company Intervista AG: Only adult person (over 18 years), who have conducted trips over 3km by car or PuT recently are considered. Trips on all weekdays are included, therefore the data are valid for daily traffic.

RP survey

Overall, 5756 members of the panel were invited to participate in the survey, of them 2061 filled in the RP questionnaire completely and correctly. That translates to a recruitment rate of approximate 36%.

Aside of the socio demographic attributes the respondent are asked to report trip conducted recently, thereby a rank system for the trip purpose was used to get for each trip purpose a sufficient sample. The possible trip alternatives are calculated using Google Maps. For a given address pair the car trips (travel time, distance) and the PuT attributes (ride time, distance, access and egress time, number of transfers and headway) were calculated. From the distance data the cost attributes are calculated. The obtained data from the RP-survey and the attributes calculated data are used to construct the SP experiments.

SP survey

In a SP survey, here formulated as stated choice experiment, the attributes of the alternatives vary in the different choice situation. The respondent has to pick the most likely choice. In the current study the respondent have 6 situations between two modes and two car route or public transport (PuT) connections.

The detailed search of the trip attributes in the RP part enables to construct personalized SP situation. This has the advantage that the respondent recognizes his situation better. Therefore, the respondent faces a realistic situation and not a hypothetic scenario or artificial decision situation.

The personalized experiments considers the attribute of the trips like travel time, cost and possible alternatives. For example, it doesn’t make sense to present car alternatives to respondent, who don’t have access to a car.

A special case are PuT trips, when there is a transfer from a minor PuT line (feeder line) to railway lines. This kind of transfers is handled separately and demands a further type of questionnaire (in the following this type is called “complex” or SP4). The advantage of an SP survey is to combine different levels of attributes of alternatives, which are not present in real world. In other words it is only possible to test reaction on such combination of attributes level in an experiment because they don’t exist under market condition. The reaction on tradeoffs between attributes is the desired observation. As an example, the decision between a slow cheap and a fast, but expensive alternative is of interest. Fig 3 shows the attributes which are used to describe the mode choice alternatives in SP1 with it variation of levels.

Fig. 3 Experimental design *SP 1(mode choice)*

Alt.	**Attribute**	**Level**
Car	Planned arrival time	in RP stated desired arrival time
	Travel time	-10%, +10%, +20%
	Departure time	Arrival time – travel time
	Traffic jam probability	10%, 20%, 30%
	Delay due to traffic jam	50%, 100%, 150% of stated tolerence
	Travel cost	-20%, -10%, +20%
PuT	Planned arrival time	desired arrival time +/-0%, +/-50%, +/-100% of headway
	Ride time	-20%, -10%, +20%
	Access and egress time	constant
	Departure time	Arrival time – travel time
	Delay late probability	10%, 20%, 30%
	Delay late period	50%, 100%, 150% of stated tolerence
	Travel cost	-20%, +10%, +20%
	Number of transfers	-1, +/-0, +1

The attributes are six times changes according to the experimental design and the respondent presented as choice situation as shown in Fig 4.

Auto			Öffentlicher Verkehr		
Startzeit	8:00	Uhr	Startzeit	8:00	Uhr
			Fusswege (zu / von Haltestellen) insgesamt	3	Minuten
Fahrtzeit ohne Stau	20	Minuten	Fahrtzeit	15	Minuten
Ankunftszeit	8:20	Uhr	Ankunftszeit	8:18	Uhr
Stauwahrscheinlichkeit	10	%	Verspätungswahrscheinlichkeit	20	%
Mittlere Zeit im Stau	10	Minuten	Mittlere Verspätungsdauer	5	Minuten
			Umsteigen	0	Mal
Fahrtkosten	3.00	CHF	Fahrtkosten	4.00	CHF

☐ **← Ihre Wahl →** ☐

Fig. 4 Example questonaire SP 1

The levels of the attributes, which are used in the car route choice (SP2) are shown in Fig 5. The presentations to the respondents are shown in Fig 6. The respondent must decide between two alternatives with, among others attributes, destingtive deviation to the desired arrival time. This kind of presentation provides a separate valuation of the planned early or late delay (deviation between actual and desired arrival time) and the unplanned early or late delay, which shows the reliability of the transport system.

Fig. 5 experimental design *SP 2 (Car route choice)*

Alternative	Attribute	Level
Route 1 / 2	Planned arrival time	Desired arrival time +/-0%, +/-50%, +/-100% of stated tolerence
	Travel time	-10%, +10%, +20%
	Departure time	Arrival time – travel time
	Deviation 1	-50%, -20% of stated tolerence
	Deviation 2	-20%, +/-0% of stated tolerence
	Deviation 3	+/-0%, +50% of stated tolerence
	Deviation 4	+50%, +100% of stated tolerence
	Deviation 5	+100%, +150% of stated tolerence
	Travel costs	20%, -10%, +20%

Every respondent gets six different choice situations where the attributes are varied according to the experimental design like shown in Fig.6.

	Route 1		Route 2	
Startzeit	08:00	Uhr	07:50	Uhr
Fahrtzeit	20	Minuten	25	Minuten
Ankunftszeit	08:20	Uhr	08:15	Uhr
Sie haben die gleiche Chance, zu einem der folgenden Zeitpunkte anzukommen:	10	Minuten früher	10	Minuten früher
	5	Minuten früher		pünktlich
		pünktlich	5	Minuten später
	5	Minuten später	5	Minuten später
	10	Minuten später	5	Minuten später
Fahrtkosten	3.00	CHF	3.00	CHF
Ihre Wahl:	☐		☐	

Fig. 6 Example questonaire SP 2

For the PuT similar experiment for the connection choice are performed. The attributes and levels are shown in Fig 7. Differently to the car route choice in the PuT connection choice no delay early option, because the PuT line are following a time table, the PuT can reach a stop at the earliest at the planned arrival time.

The SP 3 and 4 different with an attribute called “risk of missing connection”. Fig 8 gives an example for SP 4, the complex PuT connection choice with the additional attribute. In addition to the distribution of the arrival time of the main PuT line (railway) here the probability to miss the connection must be considered. The headway is used to calculate the start time for the second connection.

Fig. 7 Experimental design *SP 3 / 4 (PuT connection choice)*

Alternative	Attribute	Level
Verb. 1 / 2	Headway	+/-0%, -50%, +50%
	Planned arrival time	Desired arrival time +/-0%, +/-50%, +/-100% of stated tolerence
	Ride time	-10%, +10%, +20%
	Access and egress time	constant
	Departure time	Arrival time – travel time
	Deviation 1	+/-0% of stated tolerence
	Deviation 2	+/-0%, +50% of stated tolerence
	Deviation 3	+50%, +100% of stated tolerence
	Deviation 4	+100%, +125% of stated tolerence
	Deviation 5	+125%, +150% of stated tolerence
	Travel costs	-20%, -10%, +20%
	Number of transfers	-1, +/-0, +1
	Risk missing connection	10%, 20%, 30% (only SP 4)

	Verbindung 1		Verbindung 2	
Startzeit	08:00	Uhr	08:15	Uhr
Fusswege (zu und von der Haltestelle) insgesamt	5	Minuten	5	Minuten
Fahrtzeit	20	Minuten	25	Minuten
Ankunftszeit	08:25	Uhr	08:45	Uhr
Sie haben die gleiche Chance, zu einem der folgenden Zeitpunkte anzukommen:		pünktlich		pünktlich
	5	Minuten später		pünktlich
	5	Minuten später	5	Minuten später
	10	Minuten später	5	Minuten später
	10	Minuten später	10	Minuten später
Umsteigen	2	Mal	1	Mal
Risiko, den Zug zu verpassen (wegen Verspätung des Trams oder Busses)	20	%	5	%
Fahrtkosten	6.00	CHF	4.00	CHF
Ihre Wahl:	☐		☐	

Fig. 8 Example questonaire SP 4

Return rate

The current project is the first online based large SP survey in Switzerland. Of the 1'859 sent SP questionnaire 1'536 complete filled questioners are returned. This leads to a in this context quite high return rate of 82,6%.

The returned data are processed and a comprehensive data set of 1'859 RP and 17'148 SP choice observation (total 19'007 observation) derivered, which consist of all relevant data for the following model estimations.

A distortion of the socio demographic attributes against the national travel survey (ARE 2012) has to be accepted as PuT users and better educated people respond stronger to travel surveys. With the consideration of the relevant attribute (e.g. age, income, PuT seasonal ticket ownership…) in the utility function of the models the effect of the distortion is caught in the relevant parameters.

4. Modelling Transport Behavior

For the analysis of transport behavior and the respondents reaction on changes in the attributes of the alternatives discrete choice models and here in particular Multi Nominal Logit (MNL) models are used. For the model estimations the software Biogeme 2.2 is used.

At the beginning a basic model with linear utility components for all the attributes are estimated. Furthermore, models with nonlinear interaction terms and trip purpose specific models are estimated. The utilization of interaction terms was described by Mackie *et al.* (2003). Applications with Swiss data can be found in Axhausen *et al.* (2007, 2008), Hess *et al.* (2008), Weis *et al.* (2009, 2010), Weis *et al.* (2012, 2012a) and Widmer *et al.* (2013).

Differently to the arbitrage segregation in different group of sociodemographic properties continually interaction terms are used. The general form of the formulation with the interaction terms is:

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

x	Observed attribute, e.g. travel time, cost, …
β_x	Linear parameter for the observed attribute x
y	Observed value for other attribute
$\overline{y}$	Reference value for the attribute y (distance: 30 km; income: CHF 9‘000/Month)
$\lambda_{y,x}$	Elasticity

The choice of the reference value $\overline{y}$ is arbitrage and doesn’t have an influence on the estimated parameter or model quality (Hess *et al.*, 2008). The parameter β_x give directly, without considering $\lambda_{y,x}$, the value of one unit of the attribute x if $y = \overline{y}$, because the interaction term become 1 and is omitted from the equation. $\overline{y}$ is 30 km for distance and is CHF 9’000 per month for household income. These numbers are the rounded medians from the data collection.

The following interaction terms are used for attribute combinations: distance with costs, travel time, access and egress time, transfers, planned delay early, planned delay late, unplanned delay early, unplanned delay late as well as income with costs. The utility term for the attribute cost looks like this (the non linearity parameter λ is estimated simultaneously with the other parameters):

$$\beta_{cost} \cdot \left(\frac{income}{9'000}\right)^{\lambda_{\text{income,cost}}} \cdot \left(\frac{\text{distance}}{30}\right)^{\lambda_{\text{distance,cost}}} \cdot \text{cost}$$

To capture the influence of the socio demographic attributes on the choice behavior, they are included in the utility function. With this formulation the base value of one alternative is changed. Furthermore, an alternative specific constant for the car option is implemented, which captured influence of unobserved effect like comfort, personal preference, weather…

The model estimations are calculated with the entire data set of RP and SP observations (mode, car route and PuT connection choices). The joined estimation has against the separate one the advantage of a bigger sample and therefore leads to more robust parameter estimations. By joined SP/RP data estimations the use of scale parameters is important. Scale affects results from potential different dimension in the observed and unobserved terms of the utility function in the different data.

The model estimations are an iterative process which leads step by step to the final model formulation. First, linear models of the different SP data (SP 1-4) are estimated. These models are used to validate the data and the estimated parameters (plausible magnetite, significant, sign, model fit and parameter ratio). Second a linear model for the entire data set estimated to test for the stability of the results. Thirdly, the non-linear model is developed with progressively added in function of the different attribute with income and trip distance of the respondent. Finally, the entire model is segregated to a trip purpose specific model. Here again different model runs are performed to test which parameter should be estimated separately.

5. Model results

Fig 9 shows the results for the trip purpose specific and entire model. By the first one all parameters are estimated separately, when it is logical and proven relevant in the test runs.

Fig. 9 Model results

	Parameter	Trip purpose: Work	Education	Shopping	Commercial	Leisure	All purposes
Car	Cost [CHF]	**-0.104**	**-0.179**	**-0.216**	**-0.122**	**-0.160**	**-0.214**
	Interaction with distance	**-0.859**	**-0.666**	**-0.677**	**-0.921**	**-0.785**	**-0.820**
	Interaction with income	**-0.597**	-0.194	-0.061	-0.349	-0.213	**-0.248**
	Travel time [min]	**-0.050**	**-0.060**	**-0.049**	**-0.059**	**-0.045**	**-0.049**
	Interaction with distance	**-0.291**	**-0.435**	**-0.306**	**-0.369**	**-0.450**	**-0.390**
	Planned early arrival [min]	-0.012	-0.012	-0.012	-0.012	-0.012	-0.010
	Interaction with distance	-0.050	-0.050	-0.050	-0.050	-0.050	-0.081
	Unplanned early arrival [min]	-0.010	-0.010	-0.010	-0.010	-0.010	-0.009
	Interaction with distance	-0.058	-0.058	-0.058	-0.058	-0.058	-0.140
	Planned late arrival [min]	**-0.024**	**-0.021**	**-0.029**	**-0.037**	**-0.025**	**-0.026**
	Interaction with distance	**-0.431**	-	-0.115	**-0.206**	-	**-0.152**
	Unplanned late arrival [min]	**-0.055**	**-0.070**	**-0.101**	**-0.109**	**-0.083**	**-0.082**
	Interaction with distance	**-0.492**	**-0.292**	-0.119	**-0.170**	**-0.445**	**-0.303**
	Prob. of unplanned late arrival [%] / 100	**-0.398**	**-0.398**	**-0.398**	**-0.398**	**-0.398**	**-0.381**
	ASC Alternative specific constant	**3.900**	**3.610**	**4.590**	**4.230**	**3.660**	**2.920**
	Age (log)	**-1.140**	**-1.140**	**-1.140**	**-1.140**	**-1.140**	**-0.894**
	Gender: Male (vs. female)	0.086	0.086	0.086	0.086	0.086	0.025
	House hold size	**-0.058**	**-0.058**	**-0.058**	**-0.058**	**-0.058**	**-0.062**
	Car availability: always (vs. rare / never)	**1.430**	**1.430**	**1.430**	**1.430**	**1.430**	**1.410**
PuT	Cost [CHF]	**-0.104**	**-0.179**	**-0.216**	**-0.122**	**-0.160**	**-0.214**
	Interaction with distance	**-0.859**	**-0.666**	**-0.677**	**-0.921**	**-0.785**	**-0.820**
	Interaction with income	**-0.597**	-0.194	-0.061	-0.349	-0.213	**-0.248**
	Ride time [min]	**-0.031**	**-0.035**	**-0.032**	**-0.032**	**-0.032**	**-0.031**
	Interaction with distance	**-0.291**	**-0.435**	**-0.306**	**-0.369**	**-0.450**	**-0.390**
	Access and egress time [min]	**-0.039**	**-0.047**	**-0.029**	**-0.029**	**-0.041**	**-0.035**
	Interaction with distance	**-0.261**	**-0.217**	**-0.319**	**-0.454**	**-0.321**	**-0.334**
	Number of transfers [-]	**-0.302**	**-0.150**	**-0.388**	**-0.290**	**-0.379**	**-0.284**
	Interaction with distance	0.157	-0.351	**-0.066**	**-0.179**	**-0.369**	**-0.214**
	Planned early arrival [min]	**-0.015**	**-0.015**	**-0.015**	**-0.015**	**-0.015**	**-0.015**
	Interaction with distance	**-0.050**	**-0.050**	**-0.050**	**-0.050**	**-0.050**	-0.081
	Planned late arrival [min]	**-0.011**	**-0.022**	**-0.013**	**-0.023**	**-0.015**	**-0.017**
	Interaction with distance	**-0.431**	-	-0.115	**-0.206**	-	**-0.152**
	Unplanned late arrival [min]	**-0.050**	**-0.075**	**-0.040**	**-0.112**	**-0.060**	**-0.066**
	Interaction with distance	**-0.492**	-0.292	-0.119	**-0.170**	**-0.445**	**-0.303**
	Prob. of unplanned late arrival [%] / 100	**-0.476**	**-0.476**	**-0.476**	**-0.476**	**-0.476**	**-0.488**
	Risk missing connection [%] / 100	**-2.476**	**-1.505**	-2.369	**-3.597**	**-3.929**	**-2.940**
	PuT ticket: GA (vs. none)	**1.300**	**1.300**	**1.300**	**1.300**	**1.300**	**1.050**
	PuT ticket: Verbundabo (vs. none)	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	PuT ticket: Halbtax (vs. none)	**0.241**	**0.241**	**0.241**	**0.241**	**0.241**	0.102
	PuT ticket: Others (vs. none)	**0.537**	**0.537**	**0.537**	**0.537**	**0.537**	**0.526**
	Scale parameter RP			0.945			0.918
	SP 1 (fix)			1.000			1.000
	SP 2			**1.860**			**1.900**
	SP 3			**1.390**			**1.350**
	SP 4			**1.270**			**1.280**
	Number of observations			19‘007			19‘007
	Adjusted ρ^2			0.225			0.219

Bold value means statistical significant of the estimated parameter on t-stat 95% level (|t| > 1.96).

All estimated parameters have the expected sign, where a negative sign means a decrease of the expected utility of the alternative as the value of the attribute increase. Most of the parameters are statistical significant with a t-test value > 95% level.

Not significant are for the car option the planned and unplanned arrival early and their interaction terms. Differently to delay late an early arrival seams not to influence the choice behavior. In PuT the parameter for access and egress time is only slightly more negative than the ride time. This can be caused by the fact that in the SP the attribute for access and egress time was not variated. The negative perception of transfers is as expected. By unplanned delays late not only the time span but also the probability is important.

All distance interaction term parameters are negative. That means, that the sensitivity regarding an increase of a particular attribute (e.g. cost) with increase distance decline. The cost sensitivity decrease faster than for other attributes (like travel time). Also the interaction term between travel time and income is negative. This means that higher income persons are less sensitive to cost increase and therefore have a higher WTP.

The parameters for the socio demographic attributes are leading to the conclusion that the car option has a higher base value for older people and a slightly higher base value for male respondent. The alternative specific constant of the car option is positive, that means that there is a unexplained positive bias. Car or seasonal ticket ownership increase the utility of the regarding mode.

6. Willingness to pay

For the different willingness to pay, the following common definitions are used:

- Willingness to pay for travel time: VTTS (value of travel time savings);
- Willingness to pay for reliability: VOR (value of reliability);
- Willingness to pay for other attributes: WTP (willingness to pay).

The following Figures 10 and 11 show the distance depending WTP for the trip purpose specific model for reduction of unplanned delays. For the trip purpose shopping the VOR curve is cut at 50km, because only a few shopping trips are longer. It is obvious, that the segregation for the different trip purpose is important. The willingness to pay is quite different for the various trip purposes. The highest VTTS are for commercial and commuting trips.

Eye-catching is the strong increase of the reliability valuation for long commercial (business) trips. They are frequently day trips, where long delay lead to time problems in the day frame.

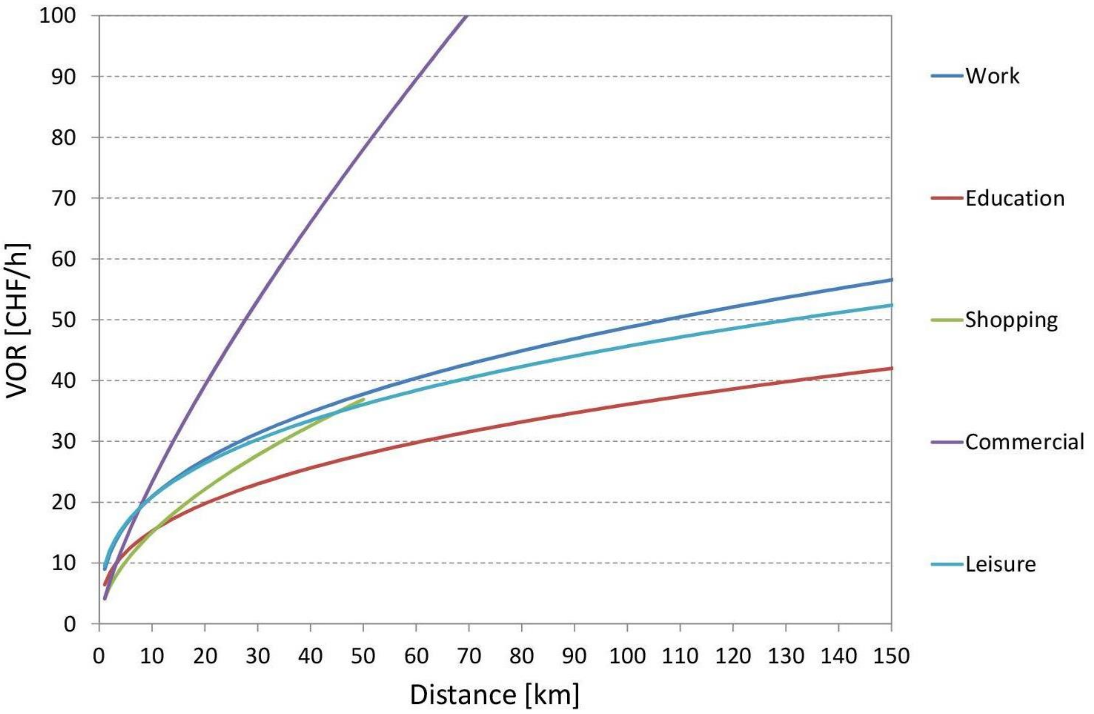

Fig. 10 Willingness to pay: Value of reliability VOR Car mode

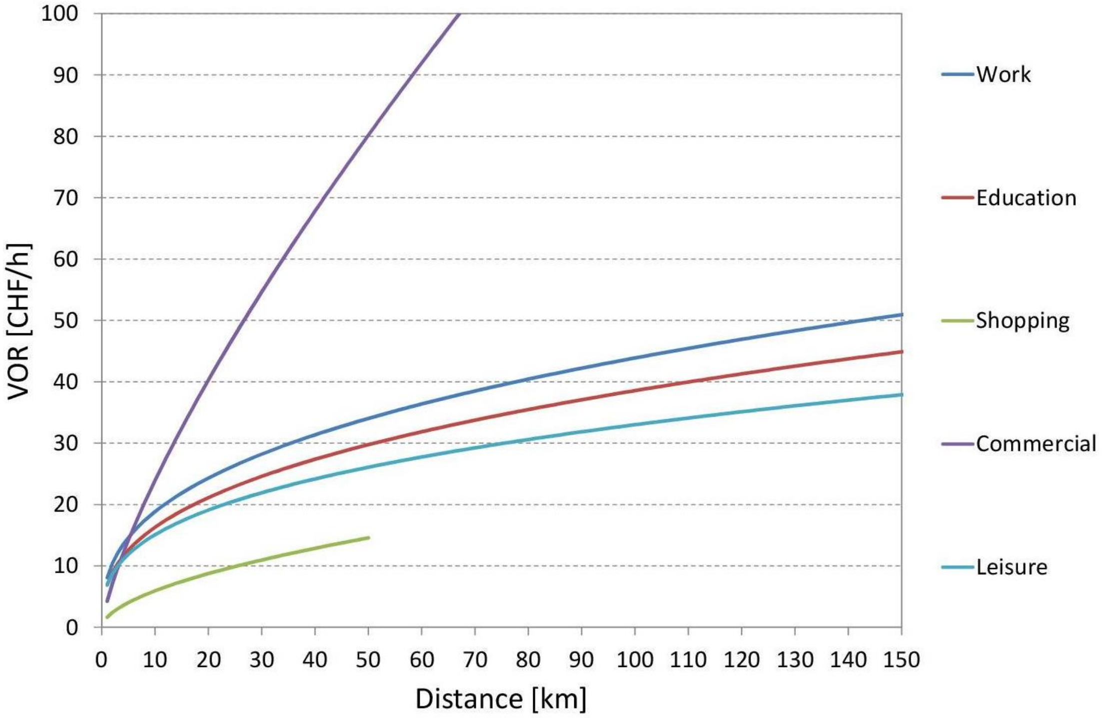

Fig. 11 Willingness to pay: Value of reliability VOR PuT mode

The different WTP for purpose, mode, trip length and income are calculated for the data of the national travel survey and with the associated person weights the weighted mean willingness-to-pay (WTP) values are projected.

The following table provides an overview of the weighted mean willingness-to-pay (WTP) values for the relevant attributes. These values represent the monetary valuations of reducing the corresponding attribute. For example, the willingness-to-pay for a one hour reduction in car travel time amounts to 14.6 CHF.

Mean willingness-to-pay values [CHF per unit]

Attribute		Work	Education	Shopping	Commercial	Leisure	All purposes
Car	Travel time [h]	18.8	17.0	9.1	22.9	12.9	14.6
	Planned late arrival [h]	9.8	4.9	4.6	14.8	6.2	7.5
	Planned early arrival [h]	4.1	2.9	1.8	4.7	2.9	3.1
	Unplanned late arrival [h]	23.3	18.5	16.0	42.4	23.5	22.9
	Unplanned early arrival [h]	4.5	3.1	2.5	4.0	3.1	3.5
	Probability of unplanned late arrival [%]	1.3	1.0	0.6	1.6	1.0	1.0
PuT	Ride time [h]	13.3	10.2	5.9	18.1	9.1	10.7
	Access and egress time [h]	16.3	13.0	5.5	15.5	11.4	12.8
	Number of transfers [-]	2.1	0.7	1.0	3.0	1.8	1.7
	Planned late arrival [h]	5.1	6.1	2.1	16.6	4.1	4.7
	Planned early arrival [h]	6.1	4.0	2.3	10.0	3.9	4.8
	Unplanned late arrival [h]	22.8	21.0	6.6	70.7	17.3	19.7
	Probability of unplanned late arrival [%]	2.0	1.3	0.7	3.4	1.3	1.6
	Risk missing connection [%]	10.6	12.2	7.7	19.2	10.7	10.5

The willingness to pay for reduction of unplanned delays late is much higher than the VTTS. Delays early are valued lower. The WTP for a reduction of the access and egress time is higher than the VTTS.

The WTP for reduction of the probability of unplanned late arrival is higher for PuT than for cars. For the PuT there is a very high value for avoiding the risk too miss a (major) connection. As no comparison figures are available, it is hard to classify the “Risk of missing connection”-values.

7. Conclusions

The scheduling model under uncertainty is used to address the main question of this research: The value of reliability. The analysis of the reply and the estimated model results show that the respondents were capable to understand the situation and make reasonable choices (rational or intuitive).

The two step survey, starting with the RP part followed by a personalized SP with a medium number of attribute supported the meaningful results. Furthermore, the applied display was format proved and tested.

With the derivered data from the survey robust and meaningful trip purpose specific and all purpose models with nonlinear attributes (interaction terms with distance and income) could be estimated. In short, the researchers successfully achieved their research objective, testing the difference between planned and unplanned (stochastic) late/early arrivals.

The main findings, derived from the research, are:

- The value of travel time savings increases with travel distance; this is most true for work and commercial trips;
- The value of travel time savings for car users is higher than for public transport users.
- The willingness to pay for reliability and for arriving on schedule is slightly higher for automobile travel than for public transport.
- The willingness to pay for avoiding delays is significantly higher than for preventing early arrivals (the estimated model parameters for preventing early arrivals were much less significant).
- The willingness to pay for avoiding unplanned delays compared reducing travel time varied depending on trip purpose. The factor ranged from 1.1 to 2.0 (and was 3.5 for commercial trips on public transport).
- The willingness to pay for travel time reductions and reliability differs based on trip purpose. The highest values were found for commercial and commuter trips.
- In public transport, there is a very high willingness to pay to reduce the risk of missing a connection.

The values found in this research are approximately one-third lower than values presented in previous studies including those reported in the VSS-norm (SN 641 822a – Cost benefits analysis in road transport, Value of Time in Passenger Transport). These differences may be due to different modelling approaches and/or to differences in the survey data.

In order to arrive at reliable estimates for the characteristics considered in this research and to reduce the possible differences that could be caused by the survey wording, we recommend that the models developed in this research be jointly estimated using results of all the sample SP surveys made in Switzerland in recent years.

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