Value of Travel Time as a Function of Comfort

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Abstract

The value of travel time can theoretically be defined as the opportunity cost of travel minus the direct utility from spending the time during the trip. This paper searches for empirical evidence to support this formulation. We show that travellers who indicate that a shorter trip duration is useful or a longer trip duration is very inconvenient have a higher value of travel time. Furthermore, we show that people who can spend their travel time usefully have a lower value of travel time. Finally, the availability of a computer, laptop etc. during the trip increases the probability of travel time being useful. This study determines the sizes of these effects in a case study for The Netherlands. This is important since the value of travel time is likely to change over time. The outcomes of this paper can be used to estimate the size of the expected reduction in value of travel time as a result of future comfort improvements that increase the possibility to work, read a book, watch a movie and communicate during a trip.

Keywords

Value of travel time; comfort; discrete choice model; cost-benefit analysis

1. Introduction

There is abundant literature on the value of travel time (VTT), which is not surprising given that VTTs are used in many countries as an input for the appraisal of transport projects by means of cost-benefit analysis (CBA).[1] A particular strand of the empirical literature has studied the change of the VTT over time. Some authors (Gunn, 2001, Tapley et al. 2007, Börjesson et al., 2012, Kouwenhoven, 2014b), have already established that over time, the VTT does not increase as much as one would expect on the basis of the income changes alone. They mention that a possible explanation for this finding could be that because of innovations in information and communications technology, travel time can be used more productively and pleasantly than before.

This explanation is also supported by theoretical considerations. The formulation of the VTT as given by De Serpa (1971), Evans (1972), McFadden (1981) and Jara-Diaz (2008) implies that the VTT will decline when travel time can be spend more productively or more comfortably (see also section 2 of this paper).

[1] VTTs are also used as an input into traffic forecasting models, but in this paper we focus on appraisal values.

We define comfort here as the degree to which the travel time can be spent productively/pleasantly. It not only includes aspects of crowding and stability but also the possibility to carry out useful activities during the trip (such as working, reading, watching movies, communicating with other people). Technological innovations such as the introduction of laptops and smartphones have increased the level of comfort that is experienced during the trip. The empirical literature on the value (in money units) of comfort or the trade-off between comfort and travel time, is very limited (examples are: Wardman and Whelan, 2011; Kroes et al., 2014).

An overview on the relation between the digital revolution and the worthwhile use of travel time, for both business and non-business travellers, can be found in Wardman and Lyons (2016). For business travel some literature exists that tries to measure the components of the so-called 'Hensher equation', that includes the value of work done during the trip as a negative factor in the employer's component of the VTT. For non-business travel, the authors come to the conclusion that 'very little research has been conducted into the impact of worthwhile use of time on the value of time'. The current paper focusses on this research gap by looking at commuting, business and other travel.

Jain and Lyons (2008), partly following Redmond and Mokhtarian (2000), suggest treating travel time not as a burden, but as a gift, basing themselves on more qualitative methods, such as verbal descriptions of individual travellers about their journey experience. They allow for a negative value for travel time reductions, especially for pleasant trips (e.g. recreation).

Banerjee and Kanafani (2008) provide a theoretical model and a numerical example showing that transit riders that can work (at 80% of the efficiency they would attain at the workplace) during travel have a considerably lower VTT than travellers who cannot work on the train.

In a descriptive analysis of longitudinal data on rail passengers in Great Britain over the period 2004-2014, Lyons et al. (2016) found clear evidence of a shift from using paper-based to digital technologies when travelling on the train. Also there was an increase in the share of travellers that found their time use very worthwhile between 2004 and 2010, but not between 2010 and 2014 (maybe because of an increase in crowding in the latter period).

Mott McDonald (2009) carried out a study on the impact of useful travel time on business travellers. They found a 50% reduction in the value of travel time savings for business passengers, if they can spend the travel time in a useful way. Warffemius (2016), in an application for The Netherlands, used this result also for other trip purposes.

Malokin et al. (2017) compared millennials (people born between 1980 and 2000) to non-millennials and found that, after controlling for personal attitudes and the higher propensity of millennials to multitask, the millennials had a 10% to 15% lower value of time (both inside and outside a vehicle). This was partly explained by the millennials' wider usage of internet communication technologies during travel.

Lyons and Urry (2005) argue that the "boundaries between travel time and activity time are increasingly blurred." They specifically suggest that the information age is enabling people to use travel time itself to undertake activities. As a result, the value of travel time will deviate more and more from just the opportunity costs of not being able to participate in activities at the origin or destination end of the trip, since several non-travel activities can be performed very well during the trip itself. This is not restricted to productive work/business activities, but relates to any activity that provides utility to the traveller and that can be performed during travel (e.g. watching a movie or playing a video game in the train). Another way of putting this might be ‘multi-activity’: travellers are engaging in travel and other activities at the same time. Ben-Elia et al. (2014) also describe how, influenced by ICT, activities that used to be allocated to a specific time and location are becoming more freely allocated across time and space (‘activity fragmentation’).

An important implication of the above findings is that investments in comfort (such as installing Wi-Fi in trains) could lead to a reduction of the VTT. In practice, VTTs for project appraisal are updated (using new surveys) approximately once every ten years. Therefore the appraisal VTTs will not drop immediately after an increase in comfort. However when a new value of travel time survey is carried out, the resulting VTTs will be lower than they would have been without the investments in travel comfort.

In most countries transport time benefits are included in the cost-benefit analysis of transport projects, but increases in comfort are not. The current appraisal methodology therefore does not contain incentives to invest in comfort (in public transport); on the contrary, investing in comfort may lower the benefits per passenger of travel time reduction. Of course this should be balanced against the increase in the number of (public transport) travellers (and the corresponding benefits) that results from the reduction of travel time (see Hultkrantz (2013) for an application in the case of high-speed rail). To incentivise projects that increase comfort for the travellers, the comfort benefits should be included in project appraisal and compared to the reduction in the time benefits. The study reported in this paper tries to contribute to this goal by investigating how VTT varies with different aspects and levels of comfort.

In this paper we present the outcomes of a new analysis carried out on the stated preference (SP) data for passenger transport collected as part of the most recent Dutch national study on value of travel time and travel time reliability (KiM, 2013, Significance et al., 2013, Kouwenhoven et al., 2014a). The questionnaires used at the time included questions about the use of travel time and the availability of mobile phones, laptops, iPods, etc. The answers to these questions were not used in the final models from which we derived the recommended VTTs and value of reliability (except for the use in the Hensher-equation for business trips). In this paper we include variables based on these answers to the choice models that explain the choices the respondents made, to see how they impact the VTT.

Section 2 of this paper discusses some theoretical considerations. It shows that a negative relation between the VTT and comfort is expected: the higher the level of comfort, the lower the VTT. Section 3 introduces the recent Dutch VTT-survey and discusses its most important characteristics. This survey includes four questions that are related to the level of comfort. In section 4, we analyse whether the answers to these questions have any explanatory power for the VTT and we discuss whether the signs of these effects are consistent with our theoretical considerations from section 2. In section 5 we develop a model that explains whether travellers are able to spend travel time in a useful way. Using this model we can simulate a situation where nobody or everybody has a computer available during their trip and calculate to what extent the VTT changes. Finally, conclusions are drawn in section 6.

2. Theoretical considerations

The VTT that is used in project evaluation can be interpreted as the difference between two monetary[2] factors (De Serpa, 1971, Evans, 1972, McFadden, 1981, Jara-Diaz, 2008):

$$VTT = \mu / \lambda - (\partial U / \partial T_{travel}) / \lambda \qquad [1]$$

where:

U = utility

T_{travel} = travel time

μ = Lagrangian multiplier of the time constraint

λ = Lagrangian multiplier of the money budget constraint (marginal utility of income).

In words: the VTT is the difference between:

- the opportunity value of time (the utility that could be attained if the travel time was used for some other activity at the origin or destination (e.g. for working), also called the "resource value" or "opportunity costs" of travel;
- the value of the utility that is created during the travel time (compared to some reference activity), e.g. by relaxing, reading and writing messages on a smartphone / laptop or watching a movie on a tablet.

The VTT may change over time or space if any of these factors change. The first component changes when activity time becomes more productive (it also depends on changes in the productivity of labour). The marginal utility of income is likely to decline with income. So, if income rises over time, the VTT goes up since the first component of equation [1] increases, and the second component decreases, whereby the first effect is likely to be larger. When the direct utility of travel time increases, through for instance increased presence of Wi-Fi connections or electric sockets in trains, the VTT goes down. An increase in the level of crowding on the other hand would raise the VTT.

3. The recent Dutch VTT-survey

In 2013, the Dutch Ministry of Infrastructure and the Environment published updates for the official CBA values of time for passenger transport (Kennisinstituut voor Mobiliteitsbeleid 2013, Significance et al. 2013, Kouwenhoven et al. 2014a). These values were derived from a stated preference (SP) survey completed in 2009 by 5760 members of an internet panel and additionally completed in 2011 by 1429 travellers recruited at petrol stations/service areas, parking garages, stations, bus stops, airports and ports. During the analysis it was concluded that the SP survey led to substantially lower VTTs when using members of this internet panel instead of en-route recruitment. This might be

[2] This implies that both factors are actually ratios of a numerator for changes in the number of minutes or hours travelled and a denominator which is the marginal utility of income (the latter for the translation into money units).

caused by self-selection bias of the internet panel. The final level of the VTT was determined using only the respondents of 2011.

The respondents completed an online questionnaire that contained questions regarding a recent trip they made and three stated preference experiments. During these experiments respondents were asked to choose between two alternative trips which were similar to their recent trip but had (somewhat) different travel times, travel costs, reliability and/or departure and arrival times. Typically, the attributes varied between -15% and +30% of their current base value. The experimental designs were either based on full designs (without dominant choice pairs) or on orthogonal designs with multiple folds in order to improve the coverage of the parameter space. Full details can be found in Kouwenhoven et al. (2014a).

Advanced multinomial logit models were estimated which were sensitive to differences between small and large time and cost changes and which were sensitive to differences between short and long base travel times and low and high base travel costs. Additionally, socio-economic interaction coefficients were included. The final utility function for respondent *i* and alternative *j* of choice task *k* is specified in equation [2]:

$$U_{i,j,k} = \beta_C \cdot \left(\left(\frac{C_{0,i}}{C_{ref}}\right)^{\lambda_C} \cdot \left(C_{0,i} + sgn(\Delta C_{i,j,k}) \cdot \Delta C_{ref} \cdot \left(\frac{|\Delta C_{i,j,k}|}{\Delta C_{ref}}\right)^{\gamma_C} \right) + \right.$$
$$VTT_{ref} \cdot (1 + coeff_{sociofac1} \cdot \delta_{sociofac1,i}) \cdot \dots \cdot (1 + coeff_{sociofacN} \cdot \delta_{sociofacN,i}) \cdot$$
$$\left. \left(\left(\frac{T_{0,i}}{T_{ref}}\right)^{\lambda_T} \cdot \left(T_{0,i} + sgn(\Delta T_{i,j,k}) \cdot \Delta T_{ref} \cdot \left(\frac{|\Delta T_{i,j,k}|}{\Delta T_{ref}}\right)^{\gamma_T} \right) + \left(\frac{\sigma_{0,i}}{\sigma_{ref}}\right)^{\lambda_R} \cdot RR \cdot \sigma_{i,j,k} \right) \right) \quad [2]$$

in which the following variables depend on the choice task:

$\Delta C_{i,j,k}$	=	the difference between the cost as offered in alternative *j* of SP choice task *k* and the base cost of respondent *i* (= $C_{0,i}$);
$\Delta T_{i,j,k}$	=	the difference between the time as offered in alternative *j* of SP choice task *k* and the base time of respondent *i* (= $T_{0,i}$);
$\sigma_{i,j,k}$	=	the standard deviation of the travel time distribution as offered in alternative *j* of SP choice task *k* of respondent *i* ;

the following variables are characteristics of the respondent and his/her journey:

$C_{0,i}$, $T_{0,i}$, $\sigma_{0,i}$	=	the base travel cost, base travel time and base standard deviation of the travel time distribution for respondent *i* ;
$\delta_{sociofac1 \dots N,i}$	=	dummy that indicates whether respondent *i* belongs to socio-economic class 1 … N. These dummies include dummies for gender, age groups, income groups, education level groups, household composition groups, etc;

the following coefficients are to be estimated:

β_C	=	the cost coefficient;

VTT_{ref}	=	the value of travel time. As is discussed in Kouwenhoven et al. (2014) the value of this coefficient depends on the (arbitrarily) chosen values of C_{ref} and T_{ref}, therefore the index *ref* was added;
RR	=	reliability ratio, i.e. the ratio of the value of travel time reliability and the value of travel time;
λ_C, λ_T, λ_R	=	exponent on the (relative) value of the base travel cost, base travel time and base standard deviation of the travel time distribution. These exponents allow for a diminishing sensitivity for higher base levels (Mackie et al., 2003; Stathopoulos and Hess, 2011);
γ_C, γ_T	=	exponent on the (relative) value of the cost difference and the time difference. These exponents allow for differences in the valuation of small and large cost and time changes (De Borger and Fosgerau (2008); Börjesson and Eliasson (2011));
$coeff_{sociofac1...N}$	=	interaction coefficient between socio-economic class 1 … N and the VTT_{ref}.

and finally, C_{ref}, ΔC_{ref}, T_{ref}, ΔT_{ref} and σ_{ref} are arbitrary reference values;

The way in which the socio-economic interaction factors are specified is relevant for this paper. The specification of these interaction variables is such that a coefficient value of 0.1 indicates that respondents of this socio-economic class have on average a 10% higher VTT compared to the reference class.

As part of the questionnaire, the respondents were asked the following questions:

1. Suppose that you would know in advance that your trip duration would be *DELTA* minutes shorter. Would such a shorter trip duration be useful?
    a. Yes
    b. No
2. Suppose that you would know in advance that your trip duration would be *DELTA* minutes longer. Would such a longer trip duration be very inconvenient?
    a. Yes
    b. No
3. Which devices were available to you during your trip? (multiple answers possible)
    a. None
    b. Mobile phone
    c. Computer, laptop, BlackBerry etc. [3]
    d. Music player (radio, CD, iPod, etc.)
    e. Other
4. Were you able to spend your travel time usefully?
    a. Yes

[3] The questionnaire for this survey was designed in 2008. At that moment, the BlackBerry was quite popular in the Netherlands. The iPhone had only just been introduced and the first Android phone was not yet on the market. Therefore, only the BlackBerry was mentioned in this list. It is possible that the effect of having a smartphone is comparable with having a BlackBerry in 2011, but we cannot conclude this from this research.

b. No

in which *DELTA* was replaced by the equivalent of 5% of the travel time (rounded to the nearest multiple of 5 minutes). The answers to these questions were not used in the final models that were reported (Kennisinstituut voor Mobiliteitsbeleid 2013, Significance et al. 2013, Kouwenhoven et al. 2014a), i.e. they were not used as socio-economic interaction factors in equation [2].

The first two questions ask respondents whether they could do a useful activity instead of travelling. This is related to the first term in equation [1]. It is expected that respondents who answer these questions positively, have on average a higher VTT than respondents who answer these questions negatively. The last two questions refer to the respondents' activities during the trip and their ability to use their travel time in a useful way. These questions are related to the second term in equation [1]. It is expected that respondents who have certain devices available or answer positively to the last question, have on average a lower VTT than otherwise.

Table 1 shows the answers to these questions from the 882 respondents recruited in 2011 and whose SP-answers were used in the estimation of the VTT.[4] The respondents were categorised into 9 segments based on the mode and purpose of their trip. In this analysis, we included the car, train and local public transport (i.e. bus, tram and metro) modes. Because of the possible self-selection bias in VTT in the 2009 internet panel survey we did not include these respondents in the analysis in this paper.

In Table 1 we see that public transport users, especially train users, have a higher share of finding a trip time reduction useful or of finding a trip time increase very inconvenient than car users. We also see in Table 1 that mobile phones are almost everywhere, but computers and the like are only available during the trip at the time for a minority, even among business travellers. On average just over a half of the travellers are able to spend their travel time in a useful way, with clearly higher shares for respondents travelling by train or making a business trip.

[4] About 20% of the respondents were not included in the final analysis because they reported implausible times, costs or speeds for their recent trip or because they selected the dominated alternative in a specific choice task.

Table 1: Answers to the comfort-related questions from the respondents in the 2011-survey.

Segm. numb.	Purpose	Mode	Number of respondents	Would a 5% shorter trip duration be useful ? Yes	Would a 5% longer trip duration be very inconvenient ? Yes	Which devices did you have available during the trip? mobile phone	computer, laptop, BlackBerry, etc.	music player (radio/CD/ iPod/ etc.)	Were you able to spend your travel time usefully? Yes
1	Commute	Car	150	48.7%	26.0%	89.3%	31.3%	68.0%	38.7%
2		Train	105	71.4%	60.0%	98.1%	24.8%	29.5%	74.3%
3		Local PT	97	61.9%	53.6%	84.5%	9.3%	27.8%	54.6%
4	Business	Car	236	56.4%	28.8%	92.4%	44.1%	63.1%	56.8%
5		Train	40	82.5%	77.5%	90.0%	45.0%	20.0%	87.5%
6		Local PT	12	58.3%	50.0%	100.0%	25.0%	25.0%	58.3%
7	Other	Car	93	33.3%	16.1%	86.0%	6.5%	53.8%	39.8%
8		Train	78	62.8%	61.5%	89.7%	15.4%	38.5%	67.9%
9		Local PT	71	35.2%	38.0%	94.4%	9.9%	33.8%	50.7%
1 - 9	Total		882	55.1%	39.6%	90.9%	26.3%	48.1%	55.7%

4. Analysis

In this section, we present the results of the re-estimation of the VTT with additional interaction variables based on the four survey questions that are related to the level of comfort. All estimations were unweighted and were carried out using BIOGEME (Bierlaire 2003). The empirical results of the various analyses are presented in sections 4.1 – 4.3. In section 4.4 we discuss the implications of these findings.

4.1 Effect of finding a shorter trip useful and a longer trip very inconvenient

First, we investigated to what extent the VTT depends on the answers to the first and second comfort question, i.e. the question whether a 5% shorter trip duration would have been useful and whether a 5% longer trip would have been very inconvenient. This was done by extending the utility function with an additional socio-economic interaction term, i.e. the VTT_{ref} in equation [2] is also multiplied with a factor

$$\left(1 + coeff_{ShorterIsUseful} \cdot \delta_{ShorterIsUseful}\right) \quad [3]$$

in which $coeff_{ShorterIsUseful}$ is the interaction coefficient to be estimated and $\delta_{ShorterIsUseful}$ is a dummy variable which equals 1 for respondents who answered that for them a shorter travel time would have been useful and which equals 0 for respondents who answered otherwise. In a similar way (and in a separate model estimation) an interaction coefficient was estimated for the question whether a longer travel time would have been very inconvenient.

These questions are related to the alternative activities at the origin and destination end of the trip, i.e. the same type of activities that the first term of equation [1] refers to. Therefore, we expect that if a shorter travel time is useful, this first term will be (relatively) larger and as a result, the VTT will be higher. Similarly, we expect that if a longer travel time is very inconvenient, the first term will be larger and the VTT higher. Therefore, we expect that the interaction coefficients $coeff_{ShorterIsUseful}$ and $coeff_{LongerIsInconvenient}$ are positive.

For each of the two questions, we estimated separate models for the 9 mode-purpose segments. We also estimated separate models for the three mode segments (i.e. combinations of segments of respondents using the same mode), and separate models for the three purpose segments (i.e. combinations of segments of respondents travelling for the same purpose). Finally, a model was estimated for the total sample. So, for each question, 16 models were estimated, each for a different (combination of) segment(s). Each model has estimates for 18 coefficients (Equation 2) of which we only present the estimates for the relevant interaction coefficient (Table 2). For the estimates of the other coefficients (which are not affected by the addition of the interaction coefficient of the comfort variables) we refer to Kouwenhoven et al. (2014).

Table 2: Estimates of the interaction coefficients for the answer to the questions whether a 5% shorter trip duration would have been useful and whether a longer trip duration would have been very inconvenient. t-ratios marked with an asterisk are significant at a 95% reliability level, i.e. t-ratio > 1.96 or t-ratio < -1.96.

	Seg-ment(s)	Purpose	Mode	$coeff_{ShorterIsUseful}$ estimate	robust t-ratio	$coeff_{LongerIsInconvenient}$ estimate	robust t-ratio
Purpose-mode segments	1	Commute	Car	0.100	1.2	0.245	2.7*
	2		Train	0.563	3.1*	0.075	0.7
	3		Local PT	0.329	2.2*	0.236	1.8
	4	Business	Car	0.129	1.9	0.137	1.8
	5		Train	-0.102	-0.5	0.475	1.6
	6		Local PT	-0.605	-1.6	-0.072	-0.1
	7	Other	Car	0.130	1.2	-0.025	-0.2
	8		Train	0.340	2.5*	0.367	2.6*
	9		Local PT	0.484	2.7*	0.369	2.9*
Combined segments	1,2,3	Commute	All	0.210	3.5*	0.148	2.6*
	4,5,6	Business	All	0.142	2.3*	0.190	2.9*
	7,8,9	Other	All	0.249	3.6*	0.163	2.4*
	1,4,7	All	Car	0.139	3.1*	0.173	3.4*
	2,5,8	All	Train	0.384	4.3*	0.284	3.6*
	3,6,9	All	Local PT	0.432	3.5*	0.280	2.7*
	1-9	All	All	0.221	6.0*	0.168	4.7*

The results for the purpose-mode segments (top-half of Table 2) show that 14 out of the 18 coefficients are positive. Seven of these coefficients are significantly positive. To further improve the significance level of the estimates we combined segments. Combining segments by mode gives a better result (i.e. higher t-ratios) than combining segments by purpose and the best results are obtained when all segments are combined.

This result confirms the hypothesis that respondents who have a good activity alternative for their travel time, have a higher VTT than other respondents. Respondents for whom a shorter trip duration is useful have a 22.1% ± 3.7% higher VTT than other respondents and respondents for whom a longer trip duration is very inconvenient have a 16.8% ± 3.5% higher VTT[5]. These percentages are higher for train and local public transport users than for car users.

4.2 Effect of having devices available during a trip

During the second step of the analysis, we investigated to what extent the VTT depends on the availability of devices (see section 3 for a list of possible devices that were presented to the respondents). The effect of having these devices available was estimated through a similar interaction coefficient as used in the previous section for finding a shorter trip duration useful. It is expected that a trip is more productive/pleasant and less of a nuisance when a traveller has (one of) these devices available. Therefore, it is expected that these respondents have a lower VTT . Therefore, we expect the interaction coefficients $coeff_{MobileAvail}$, $coeff_{ComputerAvail}$ and $coeff_{MusicAvail}$ to be negative. The results are displayed in Table 3.

From the results for the purpose-mode segments we conclude that 2 out of the 27 coefficients are significantly positive and 2 coefficients are significantly negative. The coefficient for the business / local public transport segment is strongly significant (t-ratio of -11.9). However this is based only on 12 respondents, so we believe this is a statistical coincidence rather than a strong result.

[5] Note that these two percentages may not be added for respondents for whom both a shorter trip is useful and a longer trip is very inconvenient.

Table 3: Estimates of the interaction coefficients for the answer to the questions whether a mobile phone, computer and a music player were available during the trip. t-ratios marked with an asterisk are significant at a 95% reliability level, i.e. t-ratio > 1.96 or t-ratio < -1.96.

	Seg-ment(s)	Purpose	Mode	$coeff_{MobileAvail}$ Estimate	robust t-ratio	$coeff_{ComputerAvail}$ estimate	robust t-ratio	$coeff_{MusicAvail}$ Estimate	robust t-ratio
Purpose-mode segments	1	Commute	Car	0.218	1.5	0.092	1.1	0.117	1.4
	2		Train	0.033	0.2	0.048	0.4	0.142	1.3
	3		Local PT	0.829	2.3*	-0.378	-2.6*	-0.104	-1.0
	4	Business	Car	0.168	1.1	-0.046	-0.8	0.125	1.7
	5		Train	0.998	1.9	-0.043	-0.3	0.113	0.6
	6		Local PT	-0.671	-11.9*	-0.320	-1.4	1.793	0.3
	7	Other	Car	-0.004	0.0	0.477	2.1*	0.017	0.2
	8		Train	0.244	1.2	0.261	1.9	-0.012	-0.1
	9		Local PT	-0.063	-0.2	0.503	1.5	-0.009	-0.1
Combined segments	1,2,3	Commute	All	0.198	1.9	0.086	1.4	0.088	1.7
	4,5,6	Business	All	0.368	2.1*	-0.055	-1.0	0.062	1.1
	7,8,9	Other	All	-0.014	-0.2	0.321	3.2*	0.031	0.5
	1,4,7	All	Car	0.163	2.0	0.063	1.4	0.120	2.6*
	2,5,8	All	Train	0.337	1.9	0.110	1.6	0.066	1.1
	3,6,9	All	Local PT	0.393	1.8	0.077	0.6	-0.102	-1.3
	1-9	All	All	0.203	3.0*	0.116	3.3*	0.091	2.9*

When combining segments, more coefficients become significant. However, t-ratios remain low. If all segments are combined, the availability of each device leads to a 10%-20% higher VTT . This is not what was expected based on the theory and this does not confirm our hypothesis (section 2). However, this hypothesis does not necessarily need to be rejected, since our research might suffer from selection effects such as:

- respondents who own these devices are usually travellers with higher incomes and therefore have a higher VTT. This implies that a correlation may exist between income and the availability of these devices that may show up in this analysis.
- respondents who own these devices are on average busier and rushed travellers, typically having a higher VTT.
- respondents who do not benefit from having such a device available, usually do not bring such a device. This implies that respondents who have or do not have such a device available belong to different population segments. Comparing these segments, as is done in the estimations shown above, tells us something about the differences between people in these segments, but does not tell us about the effect of having such a device available or not.

We conclude that this part of the analysis is not successful. We only find a weak result (low t-ratio) and the effect that is observed can also be explained by other selection effects. Therefore, we can neither confirm nor reject the hypothesis.

4.3 Effect of being able to spend travel time in a useful way

In the third step of the analysis, we investigated to what extent the VTT depended on the answer to the question whether a respondent was able to spend his travel time in a useful way. In a follow-up question, we asked in which activity/activities they participated during their travel. Roughly 16% of the respondents who answered positively to the former question selected working, 7% studying, 10% eating, 42% talking/making a call, 55% relaxing and 17% otherwise.

Again, we estimated the effect using an interaction coefficient. It is expected that people who can spend their travel time usefully have a lower VTT. Therefore, we expect the interaction coefficient $coeff_{SpendUsefully}$ for the different purpose-mode segments to be negative. The results are displayed in Table 4.

Table 4: Estimates of the interaction coefficient for the answer to the questions whether a respondent was able to spend his travel time usefully. t-ratios marked with an asterisk are significant at a 95% reliability level, i.e. t-ratio > 1.96 or t-ratio < -1.96.

	Seg-ment(s)	Purpose	Mode	$Coeff_{SpendUsefully}$ Estimate	robust t-ratio
Purpose-mode segments	1	Commute	Car	0.104	1.2
	2		Train	-0.348	-3.7*
	3		Local PT	-0.078	-0.9
	4	Business	Car	-0.027	-0.5
	5		Train	-0.107	-0.6
	6		Local PT	-0.435	-1.9
	7	Other	Car	0.005	0.0
	8		Train	0.017	0.2
	9		Local PT	-0.553	-4.1*
Combined segments	1,2,3	Commute	All	-0.098	-2.1*
	4,5,6	Business	All	-0.032	-0.6
	7,8,9	Other	All	-0.148	-3.1*
	1,4,7	All	Car	0.040	1.0
	2,5,8	All	Train	-0.200	-3.7*
	3,6,9	All	Local PT	-0.209	-3.8*
	1-9	All	All	-0.073	-2.7*

This table shows that most coefficients in the purpose-mode specific segments are negative and already two coefficients are clearly significant (commute-train and other-local public transport). A clearer pattern arises when segments are combined. Especially when purposes are combined, we see that respondents who can spend their travel time usefully in a train or in local public transport have about a 20% $\pm$ 6% lower VTT (t-ratio about 3.7). Car drivers do not have a negative $coeff_{SpendUsefully}$ as these respondents only have limited opportunities to spend their travel time on other things than driving and navigating. This immediately explains why mode-specific segments work better than purpose-specific segments or an estimation on the complete data set.

4.4 Discussion

In this section we come back to the results presented in sections 4.1 – 4.3 and discuss their implications.

We have tested whether or not the answers to four questions had a significant impact on the VTT. We saw that respondents who have a good activity alternative for their travel time have a higher VTT than other respondents, and we saw that respondents who were able to spend their (public transport) travel time in a useful way have a lower VTT. This all supports the theory on the concept of the VTT as presented in section 2.

The 20% $\pm$ 6% reduction in VTT for public transport (train or local public transport) users who can spend their time in a useful way is not very different from the 10% to 15% reduction found by Malokin et al. (2017), though they compared millennials to non-millennials whereas our findings apply to all age groups. Our result is clearly less than the 50% reduction found by Mott McDonald (2009) for business travellers. This difference may be caused by a different segmentation or a different definition of "spending time in a useful way". Here we note that this concept cannot be defined precisely. It appeals intuitively to a feeling of respondents, therefore, it is a question that they can answer. But it is also a concept that is difficult to model and compare across studies. In section 5, we combine the concept of being able to spend travel time usefully with better observable variables which are easier to include in transport models.

We also saw that having certain devices available during a trip has a small and positive effect on the VTT, where a negative effect was expected. This positive effect, however, is not consistent across purposes, modes and devices. Additionally, other selection effects may have had an effect on this as well. Therefore, this does not provide any evidence for confirming or rejecting our hypotheses on the VTT.

The data from the SP experiments were used to determine new and updated national values of travel time. For this, separate models were estimated by travel purpose (i.e. combined over all modes). More detailed models estimated by purpose and mode (such as the ones presented in the upper halves of Tables 2, 3 and 4) are based on a small number of respondents (as shown in Table 1) and should be treated with caution. The results for the combined segments (bottom halves of Tables 2, 3 and 4) are based on a larger number of respondents and are therefore more robust, as is evident from their t-ratios. None of the results for the purpose-mode segments can be considered an outlier compared to the results for the combined purpose or combined mode segments, with the exception of the business-local PT segment in Table 2 (column $coeff_{ShorterIsUseful}$) and Table 3 (column $coeff_{MobileAvail}$). This segment is small in reality (0.15% of all trip kilometres) and consists of only 12 respondents in our sample. Therefore, no conclusions can be drawn from this specific purpose-mode segment, but this is not a problem for the results of the much larger purpose segments and mode segments.

In Significance et al. (2013) and Kouwenhoven et al. (2014a) a weighting procedure was used for the calculation of the recommended VTT to correct for any (small) differences between (amongst others) the gender, age, household composition and income distributions of the sample and the national distributions. In the analysis presented in this paper, the impact of the comfort questions was always calculated as a relative factor (e.g. respondents who can spend their public transport travel time usefully have a 20% lower VTT). Therefore, in this paper weighting by gender, age, household composition and income was not necessary for the results to be representative.

Also note that due to the use of a relative factor for the impact of the comfort questions, respondents with a higher absolute VTT also have a larger absolute impact of comfort. We tested several additional interaction factors on the comfort interaction coefficient, but none of these were significant.

5 Case study: the impact of computers on the VTT in the Netherlands

5.1 Explanatory model for being able to spend travel time in a useful way

The models presented so far, cannot be used directly to calculate the impact of changes in the level of comfort. For instance, when investments in Wi-Fi connections are made in trains, it is likely that more travellers could spend their travel time in a useful way, but Table 4 does not provide a direct way to calculate the impact of this on the VTT.

In a next step we developed a logit model to determine which explanatory factors influence the ability to spend travel time in a useful way. In other words, we have tried to explain the answer to this question from the characteristics of the respondent and of the trip. Given the previous results, this model was based only on the answers from the respondents travelling by train or local public transport (segments 2, 3, 5, 6, 8 and 9) to this question. Combining these (similar) segments results in more significant and more robust results.

The model was developed in a step-wise approach.

- We first tried a model with an alternative specific constant for the answer “yes” and additional dummies for each purpose-mode segment (final loglikelihood (LL) = -247.3 for a model with six degrees of freedom (d.o.f.)). The dummy for the commute-train segment was constrained to zero as this was used as the reference segment. We found that several dummies were not significantly different from zero or from each other. The dummy for business-train trips was significant, as was the combined dummy for all local PT-trips. The dummy for other-train trips was combined with the dummy for commute-train trips and was constrained to zero. The LL for this model was -247.9 for a model with 3 degrees of freedom, which makes this model preferable over the first model.
- In the next step we added dummies for the socio-economic parameters, i.e. for gender, age group and income class (LL = -244.1 with 17 d.o.f.). Estimations showed that none of these parameters have a significant impact on the probability that a respondent can spend his travel time usefully. We also tried a linear or a part-wise linear income coefficient, but this was not successful either.

– Finally, we added dummies for those respondent who had certain devices available during their trip (LL = -242.6 with 6 d.o.f.). The dummies for the availability of mobile phones and of music players were not significant, however, the dummy for the availability of a computer was. Nevertheless, the inclusion of this computer-availability dummy reduced the t-ratio of the dummy for the business-train segment and this coefficient was no longer significant. Therefore, a final estimation was done without this dummy. This final model had a LL of -244.9 with 3 degrees of freedom, which makes this the best model.

Table 5 shows the estimated coefficients of the final model and some characteristics of the best model.

Table 5: Estimated coefficients of the multinomial logit model for the ability to spend travel time in a useful way. t-ratios marked with an asterisk are significant at a 95% reliability level, i.e. t-ratio > 1.96 or t-ratio < -1.96.

		Final model	
Model characteristics	Number of observations	403	
	Final loglikelihood	-244.9	
	Degrees of freedom	3	
	Rho^2(0)	0.061	
Coefficient estimates		Estimate	*robust t-ratio*
	ASC_Yes	0.8707	*5.3**
	Dummy_localPT	-0.8613	*-3.9**
	Dummy_ComputerAvail	1.055	*3.1**

5.2 Simulation of the effect of computer availability on the VTT

In section 4.2 it was concluded that we could not directly estimate the effect of the availability of a certain device on the VTT. In section 5.1 we were able to estimate the impact of the availability of a computer on the probability that a respondent was able to spend his travel time usefully. In section 4.3 we have seen that respondents who were able to spend their travel time usefully have about a 20% lower VTT. Therefore, it seems that the availability of a computer reduces the VTT. However, we only have established a correlation and not a causal relationship. It is well possible that travellers who have a computer available and are able to spend their travel time usefully, also would have been able to spend their travel time usefully without a computer. In retrospect, the survey should have included questions on what respondents would have been doing without such a device.

However, we still want to estimate the possible size of the effect of computer availability on the VTT. In order to do so, we have to assume that the relation is causal. In other words: we assume that travellers who have a computer available and are able to spend their travel time usefully, will not be able to spend their travel time usefully without a computer.

We have tried to determine the size of this effect in a joint model estimation in which several of the previously presented models were combined. However, this did not lead to a plausible result. This is likely to be caused by the same selection effects that are discussed in section 4.2. The size of this effect can also be demonstrated with a simulation, using the coefficients from Table 4 and Table 5.

In this simulation, we first calculated for each segment (3 purposes × 2 travel modes, i.e. train and local public transport) a forecast for the percentage of travellers with a computer, laptop, BlackBerry etc. that could spend their travel time in a useful way (note again that this is defined in a broad sense, it includes talking, calling and relaxing). The same was done for travellers who did not have access to a computer etc. From the survey, we know which percentage of respondents have a computer available, which enables us to calculate the percentage of travellers that is able to spend their travel time usefully. These percentages are presented in column (3) of Table 6 and they are in agreement with the observed percentage as presented in Table 1 (taking the fact into account that the percentages in Table 6 are from a simulation using an estimated model).

Table 6: Simulation results for the impact of computer availability on the value of travel time.

			Suppose that **nobody** has a computer available during their trip		**Current level** of computer availability		Suppose that **everybody** has a computer available during their trip	
	Purpose	Mode	Percentage respondents that is able to spend their travel time usefully	VTT (index)	Percentage respondents that is able to spend their travel time usefully	VTT (index)	Percentage respondents that is able to spend their travel time usefully	VTT (index)
			(1)	(2)	(3)	(4)	(5)	(6)
Purpose-mode segments	Commute	Train	70.5%	101.0	74.7%	100.0	87.3%	97.0
		Local PT	50.2%	100.6	52.7%	100.0	74.3%	94.9
	Business	Train	70.5%	101.8	77.9%	100.0	87.3%	97.8
		Local PT	50.2%	102.0	58.7%	100.0	74.3%	96.3
	Other	Train	70.5%	100.5	72.4%	100.0	87.3%	96.5
		Local PT	50.2%	100.7	53.4%	100.0	74.3%	95.1
Comb.	All	Train		100.9		100.0		97.0
	All	Local PT		100.8		100.0		95.1

We repeated this simulation for a situation in which no respondent had a computer available and a situation in which all respondents had a computer available. This respectively led to a lower and higher percentage of respondents that is able to spend their travel time usefully (see column (1) and (5) of Table 6). In section 4.3 we concluded that train users who can spend their travel time usefully have a 20.0% lower VTT, and local public transport users have a 20.9% lower VTT. We can now calculate what the VTT will be for these two extreme situations. The resulting change in the VTT can be found in columns (2) and (6) of Table 6, in which we have set the index for the current VTT at 100. The bottom rows of Table 6 show an average over all purposes, for which we used the number of respondents as a weighting factor. These rows show that when nobody has a computer available, the VTT will be 0.9% (train) and 0.8% (local public transport) higher. If all travellers have a computer available, the VTT will decrease by 3.0% (train) and 4.9% (local public transport).

Conclusions

This is one of the first papers that empirically establishes the relation between the VTT and the ability to spend travel time usefully. In this paper, this relation is also quantified and applied in a simulation.

From theoretical considerations, we expect that the VTT increases when more valuable activities, e.g. at the origin or at the destination of the trip, can be done in the time that is normally required for travelling. Data from the 2011 Dutch VTT survey is in agreement with this hypothesis. Respondents who indicated that a shorter travel time is useful to them, have on average a 22.1% $\pm$ 3.7% higher VTT compared to other respondents.

Based on the same theoretical considerations, we expect that the VTT decreases when the travel time itself could be spent in a more useful way. Again, data from our survey corroborates this hypothesis: respondents who travel by train or by local public transport (bus, tram, metro) and who are able to spend their travel time usefully have on average respectively a 20.0% $\pm$ 5.5% and a 20.9% $\pm$ 5.6% lower VTT than other respondents. For car users, we did not find a significant effect for the ability to spend their travel time in a useful way on the VTT.

We were not able to determine a direct effect of the availability of devices such as computers, mobile phones and music players on the VTT. Several selection effects may have caused correlations in the data which prevented such a direct measurement. However, we were able to determine that train and local public transport users who had a computer, laptop, BlackBerry etc. available during their trip, had an above average ability to spend their travel time usefully. Assuming that this correlation is actually a causal relation, we determined that VTT for train passengers would have been 0.8% higher (0.9% for local public transport users) if nobody would have had a computer (laptop etc.) available during their trip. The current VTT would decrease by 3.0% (train users) and 4.9% (local public transport users) if everybody would have access to a computer (etc.) during their trip.

An important implication of the above findings is that investments in comfort that increase the possibility to do work, read a newspaper, watch movies and communicate with people during a trip may lead to a reduction of the VTT. For this to be valid, it is crucial that a causal relation is established between the investment and the increased possibility to spend travel time usefully. For instance, investments in electricity sockets and WiFi in public transport do not always lead to increased possibility to work, since the travellers may already be relying on their own laptop batteries and on mobile internet connections. However, if such a causal relation is established, a typical value for the VTT reduction will be 20% for an individual traveller for whom this comfort improvement leads to the ability to spend travel time usefully. When calculating the overall impact, it should be taken into account that the 20% reduction of VTT does not apply to each individual traveller. Decisions by public transport operators on how much to invest in comfort can benefit from these results.

These findings underline the importance of having questions concerning the way travel time is used in VTT-surveys. These surveys should not only include questions on whether travellers were able to spend their travel time in a useful way, but also on different aspects of comfort during the journey, such as the level of crowding, whether the traveller was sitting or standing, which devices were available to him and which services (e.g. electricity sockets and Wi-Fi) were offered to him, and what the traveller would have done if these devices or services were unavailable. This will allow further specification of the impact of comfort on the VTT.

Besides asking background questions about useful travel time and activities during the trip (multi-activity), new VTT surveys could also specifically include the useful travel time in the SP experiments that are the key element of these surveys. Apart from presenting travel cost, travel time (and travel time reliability) as attributes, the SP experiment could offer various other combinations of ICT services and activities that could be carried out during the trip. This would make it possible to develop more elaborate choice models that include travel choices as well as choices on activities during the trip that affect the VTT.

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