Productive use of travel time, values of time and reliability in The Netherlands

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1. Introduction: three national surveys so far

Values of travel time (VTTs) are used in The Netherlands primarily for converting travel time changes into monetary benefits as part of cost-benefit analysis (CBA) of investment projects and policies in transport.[1] For this purpose, official standard tables with VTTs by travel purpose and mode (at some stage also by income group) have been available since 1990. As VTTs may change over time, which may not be properly captured by annual growth factors in VTT based on income elasticities, the official VTT tables need to be regularly updated. In passenger transport, the first national VTT study in The Netherlands was carried out in the period 1988-1990 (Hague Consulting Group, 1990). Later studies to get new up-to-date were carried out in 1997-1998 (Hague Consulting Group, 1998) and 2009-2013 (Significance et al., 2013; KiM, 2013; Kouwenhoven et al., 2014a).[2]

Some important study characteristics have remained the same in all three national surveys:

- Reliance on willingness-to-pay for travel time by travellers, determined using within-mode stated preference experiments (including two-attribute experiments) and discrete choice models, that take account of observed heterogeneity through personal and household interaction terms, for all modes and travel purposes.
- Combination of stated preference results for travellers with productivity measurements from the same survey for the employer, combined in the framework of the Hensher equation, for the business VTT.
- Expansion of the survey results to national average values using the national travel surveys.

On the other hand, there were also changes in the methodology that was employed, to benefit from methodological developments that had taken place over time and to meet new objectives:

- Shift from paper-based interviews to internet interview in the third survey, but with the same method of recruiting the travellers en-route (at stations, but stops, petrol stations and parkings).
- Inclusion of the value of travel time reliability (VTTR) as a second study objective besides VTT (also in the third survey).
- Use of nonlinear transport time and cost functions (in the third survey) and dependence on the offered changes in time and cost (in the third survey).
- Use of discrete choice methods (notably panel latent class models) that take account of unobserved heterogeneity (and heteroskedasticity) in the VTT distribution (in the third survey).

A comparison between the outcomes of the second and first survey (Gunn, 2001) has been carried out, as well as a comparison of the outcomes of third and second survey (Kouwenhoven et al., 2014b, 2017) to see what might be learned about changes in the VTT over time. Finally, the impact of worthwhile use of travel time itself on the VTT has been analysed in Kouwenhoven and de Jong (2018) using data from the third national survey.

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[1] The transport model that is mostly used for national and regional analyses, the National Model System (LMS) and its regional equivalents (NRMs) contain sub-models for mode-destination-time of day choice in which both time and cost coefficients were estimated. The VTTs that were determined for use in CBA are not used here.

[2] Three similar national surveys have been carried out for freight transport. These are not further discussed in this paper.

This ITF Roundtable paper will discuss work carried out in The Netherlands on the VTT itself as well as on some related topics that have received more attention in recent years extending the scope of VTT research. In chapter 2 we will present the main methodological characteristics and the key outcomes for both VTT and VTTR of the latest national study. Here we will also present some new results on the relation between VTT and travel time and cost for all purposes. The third chapter will discuss the use of the Hensher equation for business travel. Chapter 4 will look specifically at the issue of spending travel time in a useful way, generating utility which reduces the travel time disutility used in CBA. In chapter 5 we will look at the comparisons between the three valuation studies to see how the VTT changes over time. Finally in chapter 6 we will summarise the results and discuss what can be expected to happen to the VTT and its use in project appraisal in the future.

2. Some results from the third national VTT study in The Netherlands

2.1 The methods used to determine the travellers' VTT for business, work and other trips

The first and second national VTT studies in the Netherlands did not include the value of travel time reliability. In the first years of the new millennium decision-makers on projects in the Netherlands become to realise that including benefits from travel time variability improvements in CBAs could be important, since otherwise the benefits from transport investment might be underestimated. This change in perspective also resulted from a shift in transport policy from reducing travel time to reducing the uncertainty in travel time. Projects with a focus on the latter could not be properly evaluated. As a result, the third national study was not only undertaken to update the official values of time in both passenger and freight transport in the Netherlands, but also to deliver values of reliability based on empirical foundation.

In the third national VTT study in The Netherlands, the method used for the employee part of the business VTT is the same as for the full VTT for work and other trips. The Hensher equation (see section 3) was used to get the full business VTT including an employer and an a employee component.

For determining a VTT and VTTR of travellers, SP experiments were designed where respondents are asked to choose between two hypothetical alternatives for a trip they actually made. In all these experiments, respondents should trade between improvements and deteriorations of travel time and travel cost, and in some experiments also between changes in reliability and arrival time.

The questionnaire used in the 2009 and 2011 surveys included three SP experiments:

- A simple travel time and costs trade-off experiment (experiment 1).
- Two experiments that add reliability of travel time, but also include departure and arrival time (experiments 2a and 2b).

In earlier projects (RAND Europe, 2004; Hamer et al., 2005; HEATCO, 2006), it had already been decided that the variability of transport time should be measured by the standard deviation of the travel time distribution. The main reason behind this choice was the assessment that including travel time variability in transport forecasting models would be quite difficult, and that using the standard deviation would be the easiest option. Any formulation that would go beyond the standard deviation

of travel time (or its variance) would be asking too much from the national and regional models that are regularly used in CBA in The Netherlands.[3]

Even when one uses the standard deviation in the later modelling, it does not have to be used as such in the SP experiments. We realised that in a survey many respondents will not understand the concept of standard deviation. Therefore, in the SP experiments 2a and 2b reliability of travel time is presented by a series of five possible (equi-probable) travel times. Exploratory in-depth face-to-face interviews had been carried out earlier to determine the best concept and format for the presentation of the concept of reliability to respondents. The verbal presentation of five possible travel times turned out to work best in many respects (Significance et al., 2007; Tseng et al., 2009). Figure 1 gives a choice situation for the SP experiments that include reliability.

The difference between experiments 2a and 2b is that in experiment 2b the most likely arrival times (corresponding with the second and third travel times) for both alternatives are the same. In experiment 2a these are different, so that this experiment has more scope for re-scheduling.

Welke rit heeft uw voorkeur?

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Rit A			**Rit B**		
Vertrektijd:			*Vertrektijd:*		
08:10			**08:00**		
U heeft een even grote kans op elk van deze 5 reistijden en dus om op deze tijdstippen aan te komen:			*U heeft een even grote kans op elk van deze 5 reistijden en dus om op deze tijdstippen aan te komen:*		
Reistijd:		*Aankomsttijd:*	*Reistijd:*		*Aankomsttijd:*
25 min.	->	**08:35**	**35 min.**	->	**08:35**
35 min.	->	**08:45**	**45 min.**	->	**08:45**
35 min.	->	**08:45**	**45 min.**	->	**08:45**
55 min.	->	**09:05**	**55 min.**	->	**08:55**
75 min.	->	**09:25**	**65 min.**	->	**09:05**
Gebruikelijke reistijd:			*Gebruikelijke reistijd:*		
35 min.			**45 min.**		
Kosten:			*Kosten:*		
€ 1.80			**€ 2.80**		

○ Voorkeur voor Rit A   ○ Voorkeur voor Rit B

Figure 1: Example of an SP choice screen in experiments with reliability for car respondents

Translations:

Welke rit heeft u voorkeur?	Which trip do you prefer?
Rit A, B	Trip A, B
Vertrektijd	Departure time
U heeft een even grote kans op elk van deze 5 reistijden en dus om op deze tijdstippen aan te komen	You have an equal chance on each of the following 5 travel times and therefore to arrive at these points in time
Reistijd	Travel time
Aankomsttijd	Arrival time
Gebruikelijke reistijd	Usual travel time
Kosten	Cost
Voorkeur voor Rit A, B	Preference for Trip A, B

In the third national VTT study, the respondents were initially recruited from a commercial internet panel (the '2009 data'). This resulted in VTTs which were implausibly low, probably because the internet panel consists by its nature of people with a relatively low VTT (selectivity). A second round of data collection took place in 2011 with recruitment of travellers in railway stations at bus stops

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[3] Nevertheless, other specifications than the one where unreliability is measured as the standard deviation of transport time, such as the scheduling model, have been tried as well in the third national VTT study, to see which specification performs best on the data obtained. The scheduling model did not perform better in explaining the data than the models with the standard deviation of transport time.

and at petrol stations and parking garages, ports and airports, and with subsequent interviews using an internet link. The internet questionnaires contained both SP experiments as well as questions to obtain data to populate the Hensher equation (the latter is discussed in section 3).

Table 1: Number of completed surveys in 2011

	Commute	Business	Other	Total
Car	184	306	125	615
Public transport	256	69	194	519
Train	131	52	103	286
BTM	125	17	91	233
Air	9	29	163	201
Recr. navigation	0	0	95	95
Total	**449**	**404**	**577**	**1430**

The 2011 data on 1430 respondents have been treated as leading in the estimation of the final models. The internet panel responses (5760 respondents) are only used for the estimation of the interaction effects with person and households attributes.

For the travellers, we estimated advanced discrete choice models on the data from the three SP experiments. These models allow the values of time to depend on the actual travel time and travel cost, on the size of the time and cost changes offered in the SP experiments and on other attributes of the respondents (e.g. education, income, age, household composition). By using panel Latent Class models we also account for unobserved value of time differences in the population and for the fact that our estimation sample is a panel, i.e. that we have multiple observations from each respondent.

The recommended values of time were calculated by weighting the sampled respondents to represent the distribution of time travelled in the trips recorded in the national travel survey OViN 2010. The resulting values of time are displayed in Table 2.

Table 2: Values of time for passenger transport (Euro/hour, price level 2010)

	Car	Train	Bus, tram, metro	All surface modes	Air	Recr. navigation
Commute	9.25	11.50	7.75	9.75		
Business employee	*12.75*	*15.50*	*10.50*	*13.50*	*85.75*	
Business employer	*13.50*	*4.25*	*8.50*	*10.50*	*-*	
Business	26.25	19.75	19.00	24.00	85.75	
Other	7.50	7.00	6.00	7.00	47.00	8.25
All purposes	9.00	9.25	6.75	8.75	51.75	8.25

Notes:
- All values are rounded off to the nearest multiple of € 0.25
- These values include VAT.

2.2 The impact of distance on the VTT

Distance was not explicitly included in the discrete choice models estimated on the 2011 (and 2009) survey data. However, the models do include the (non-linear) influence of travel time and travel cost on the on the VTT. This refers to the direct dependence of the VTT on the travel time and costs of the reference trip (base time and base cost). However, there are also indirect effects (i.e. through income). Up to now, the over-all influence of base time and cost on the VTT has not been quantified. Below we present some new evidence on this, based on a sample enumeration on the 2011 respondents, with expansion factors based on the OViN national travel survey 2010. The outcomes for the three trip purposes for the dependence on time are in Figure 2 below (In Annex 1 are the actual numbers).
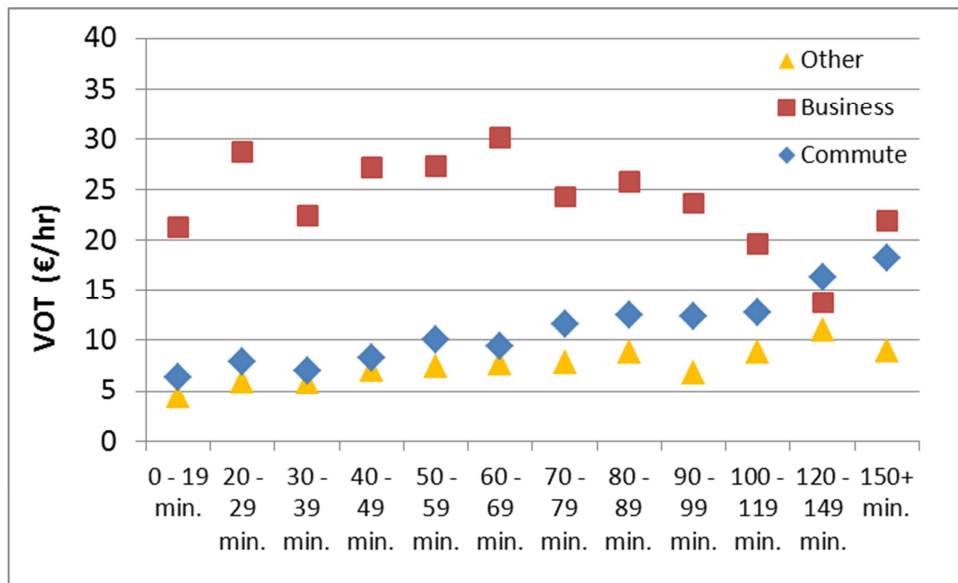

Figure 2: VTT by trip purpose as a function of travel time in the observed reference situation

In Figure 2 we see that for commuting there is a clear increase of the VTT (from 6 to 18 euro per hour) with increasing travel time. For other trips, there also is an increase with time, but not as strong (from 4 to 9 euro per hour). For business trips there is no clear trend.

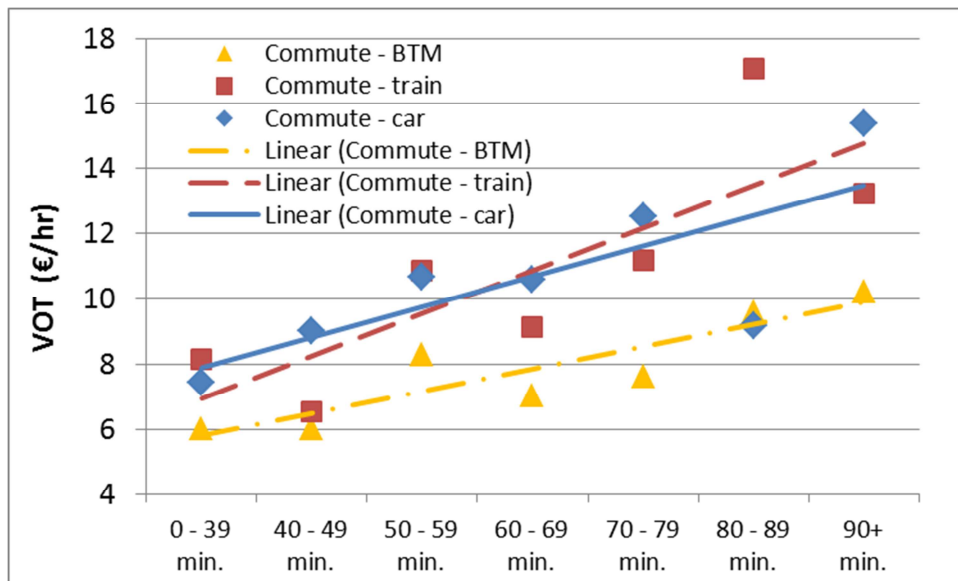For commuting, we have enough respondents to further segment by mode: see Figure 3.

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Figure 3: VTT for commuting by mode as a function of travel time in the observed reference situation

The increasing pattern for commuting holds for all three modes, but the VTT increases fastest with travel time for car, then for train and finally for bus. Note that the functions for car and train seem to overlap, suggesting that respondents travelling by car or train have similar values of travel time for a given reference travel time. Table 2 showed a clear VTT difference between car and train users. This suggests that the average distance of a car trip is shorter than of a train trip.

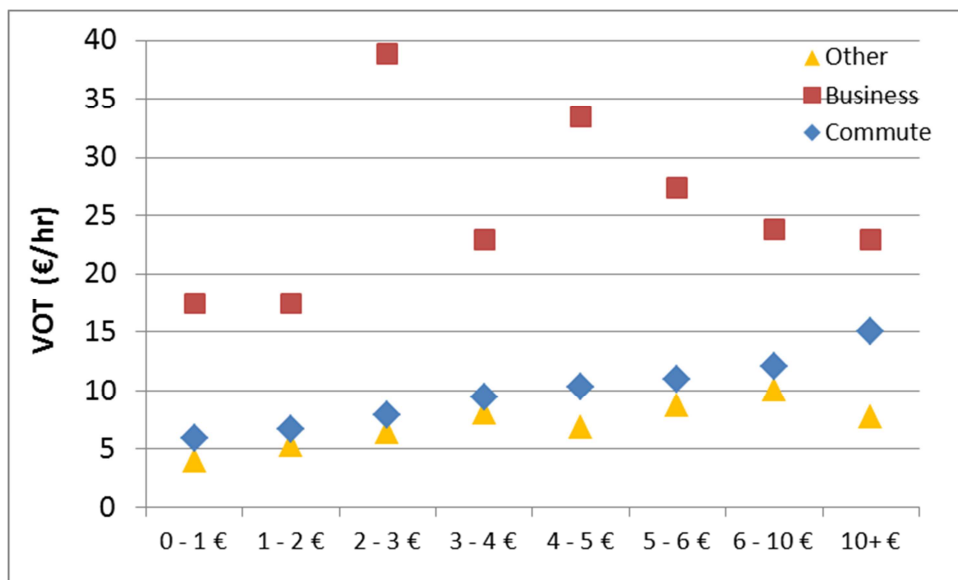The dependence of the VTT on travel cost is depicted in Figure 4.

Figure 4: VTT for by trip purpose as a function of travel cost in the observed reference situation

Figure 4 is quite similar to Figure 2: the patterns of time and cost dependence of the VTT by trip purpose are similar. For commuting, the increase with increasing cost is very clear (from 6 to 14 euro

per hour). For other trips there is a noticeable but less substantial increase (from 4 to 8 euro per hour). Finally for business, we do not see a clear pattern in the VTT with increasing travel cost.

For appraisal, The Netherlands did not adopt a distance-, time- or cost-based VTT. Instead a mean value is used based on a weighting using travel time from the national travel time survey (OViN). This is to a large degree due to a desire to use the same VTTs per hour irrespective of distance, time of cost levels of the base situation and of the size of the time and cost benefits (common appraisal value for all projects that are financed from the same budget). The official values based on the 1988 and 1997 surveys did not differentiate between distance classes either, but only between trip purpose and mode (and initially there was a distinction also by income class, but this was not used in practical appraisals due to lack of inputs on income classes).

2.3 Including the VTTR

One of the research questions for this study was whether in SP experiments without a reliability attribute the VTT might be higher because it might include some aspects of reliability. For the three surface mode segments for commute, business and other, we have estimated a VTT for each of the three experiments (1, 2a and 2b) separately using a simple MNL that also allowed for a reliability ratio. For each purpose, these VTTs were averaged (using the inverse variance of the estimated VTT as weight factor). Figure 5 shows the difference between the VTT of each experiment and the average VTT over the three experiments. Error bars indicate one standard deviation.

From this figure it is clear that there is no significant difference between the three experiments (within 2 standard errors). It has been hypothesized that the VTT of experiment 1 would be larger than of experiment 2a and 2b since in the latter two the value of reliability is estimated explicitly and in the former one it may be part of the VTT. However, as can be seen from Figure 5, there is no indication whatsoever that this hypothesis is true. There is no evidence that the VTT from experiment 1 (without a reliability attribute) contains any value of reliability.[4]

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[4] Of course, this analysis is based on relatively simple models. An analysis on the differences in the VTT between the three experiments using some of the more sophisticated models also used in the study is recommended as further work.
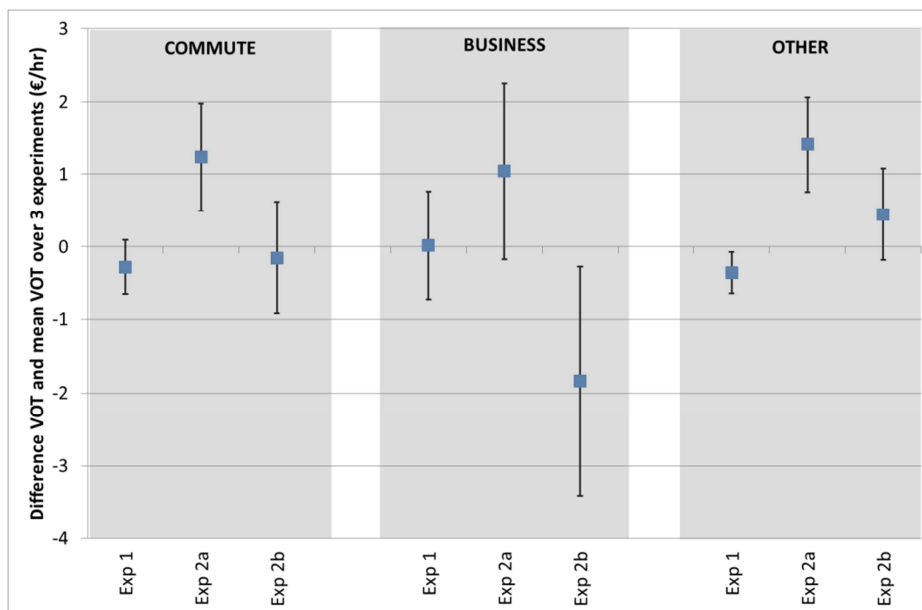
Figure 5: Differences in the VTT for car, train and bus, tram, metro between the SP experiments, by trip purpose

The recommended VTTR was calculated from the same models as the VTT. In the Table below we present the results for the VTTR (measured as the standard deviation of travel time) in the form of a reliability ratio RR (RR=VTTR/VTT). This (as RR) was also how reliability entered the choice models.

Table 3: Reliability ratios for passenger transport

	Car	Train	Bus, tram, metro	All surface modes	Air	Recr. navigation
Commute	0.4	0.4	0.4	0.4		
Business	1.1	1.1	1.1	1.1	0.7	
Other	0.6	0.6	0.6	0.6	0.7	0

Notes:
- All values are rounded off to the nearest multiple of 0.1

For business travel we have the situation that the RRs come from the individual travellers (the employees), but we have a VTT for business trips that consists of an employer and an employee component (though both were derived from interviewing the traveller). There is no information for calculating a separate employer component in the business VTTR. We think it is best to assume that the business RR applies to the sum of the employer and employee component, i.e. to the total business VTT.

3. Business travel VTT using the Hensher equation

3.1 The Hensher equation

Since the first national VTT study (Hague Consulting Group, 1990), The Netherlands has used the so-called so-called 'Hensher equation' (see Hensher, 1977; Fowkes et al., 1986 and Wardman et al., 2015), which decomposes the VTT into an employee and an employer component, for the VTT for

travelling on employer's business ('business travel'). The main reason for making this choice in the original study and for staying with it in later studies is that the most important competing approach internationally for business travel, the cost savings approach misses a number of potentially important aspects. The cost savings approach values business travel time at the marginal productivity of labour (in practice the wage cost for employers per unit of time).

The Hensher formula (see Gunn, 2008) tries to take account of several phenomena, that the cost savings approach ignores:

- The VTT for business travel is determined by the employer and the employee who both receive a benefit.
- Only the employer component depends on the marginal productivity of work time.
- The employee component also depends of the value of leisure time.
- Some share of the travel time is spent working (which in the formula is part of the employer benefit; useful travel time for the employee himself/herself is not specifically included in this framework), though the productivity of this time is not quite as high as that of working at the workplace.

$$VTT_{BUSI} = PVWT \cdot (W - TW \cdot PTW) + L \hspace{3cm} [1]$$

where:

VTT_{BUSI}:   the business VTT for use in appraisal

PVWT: productive value of a unit of work time to the employer

W: proportion of time savings returned to work in the work place; the remainder (1-W) is spent as leisure time

TW: proportion of travel time spent working

PTW: relative productivity of work undertaken while travelling

L: the value of business travel time savings to the employee

The first component on the right-hand side is that for the employer, the second component is that for the employee. The idea that the travel time might be spent working, thereby reducing the overall travel disutility, is perfectly in line with the underlying theory (see section 4 of this paper for a short exposition of the relevant theory). The formula above actually is a reduced Hensher equation. The original formulation also takes account of the impact of reduced travel fatigue when travel time decreases and the value of work time at the workplace versus leisure time to the employee. For a discussion of the full equation and results on this from various countries see Wardman et al. (2015).

3.2 Calculating the employer part on the business VTT

The employer's part of the business VOT is calculated on the basis of information from the 2011 VTT surveys in which travellers were interviewed, as was done for the first and second national VTT projects (where the data collection took place on 1988 and 1997 respectively).

For the calculation of the recommended VTTs, both for the employee and the employer components, we use sample enumeration with expansion to national totals from the national travel survey 2010 (OViN), so the means given below are indicative only. They are based on responses from the 404 business travellers interviewed, where we lose some further observations due to item non-response.

In Table 4, we compare new outcomes from the 2011 survey with those of the 1988 and 1997 surveys (Hague Consulting Group, 1990, 1998).

Table 4: Fraction of journey time spent working by mode (TW) for business trips

	1988			1997			2011		
	mean	stdev.	cases	mean	stdev.	cases	mean	stdev.	cases
Car	0.0168	0.0882	390	0.0351	0.1057	866	0.0359	0.1332	246
Train	0.1103	0.1518	59	0.1613	0.2243	226	0.1569	0.2338	41
BTM	0.0286	0.0947	20	0.0259	0.1035	69	0.0597	0.1121	11
Airplane							0.1356	0.2704	26
Total	**0.0291**	**0.1032**	**469**	**0.0591**	**0.1458**	**1161**	**0.0600**	**0.1703**	**324**

In 2011, almost the same part of journey time of business travellers using car or train is spent working as in 1997. For BTM this fraction has increased a lot, but it remains much smaller than for train. In planes it is higher than in cars and slightly lower than in trains.

Table 5: Relative productivity of work during travel by mode (PTW) for business trips

	1988			1997			2011		
	mean	stdev.	cases	mean	stdev.	cases	mean	stdev.	cases
Car	0.8974	0.2453	26	0.9311	0.2128	145	0.9053	0.1930	22
Train	0.8867	0.1691	26	0.9025	0.1774	96	0.9405	0.1548	14
BTM	0.9333	0.1155	3	0.8889	0.1721	6	0.8333	0.2887	3
Airplane							1.0000	-	6
Total	**0.8943**	**0.2042**	**55**	**0.9189**	**0.1987**	**247**	**0.9149**	**0.1739**	**45**

For train the productivity of time spent working during travel has increased over time and now approaches the productivity of working at the workplace. For plane we have equivalence between the productivity at work and travelling, but here we have very few observations in 2011. This is after truncating the mean to be not higher than 1.

In 1988, 1997 and 2011, the share of time that would be used for all activities for the employer was used in the calculation of the employer VTT. This had dropped somewhat for all three modes between 1988 and 1997, and remained fairly constant between 1997 and 2011. For plane it is much lower than for the other modes.

Table 6: Fraction of saved time that would be spent working by mode (W) for business trips

	1988		1997		2011	
	factor	cases	factor	cases	factor	cases
Car	0.6654	390	0.5445	866	0.5589	246
Train	0.4661	59	0.3695	226	0.3780	41
BTM	0.5250	20	0.3406	69	0.5454	11
Airplane					0.2115	26
Total	**0.6343**	**469**	**0.4983**	**1161**	**0.5077**	**324**

The productive value of an hour worked (see Table 7), calculated on the basis of the income and number of workers per household information of 2011 is for car drivers slightly lower than the 1997 outcome (after conversion to euros using a factor 0.454 and inflation correction for 1997-2011 using a factor 1.375). For train and BTM, the 2011 values are clearly higher than in 1997 and more in line with those for car. The productive value for air travellers is the highest of all modes.

Table 7: Productive value of a unit of work time by mode (PVWT) for business trips

	1997 in 2010 euros			2011 in 2010 euros		
	mean	stdev.	cases	mean	stdev.	Cases
Car	34.84	23.22	866	31.17	15.49	22
Train	27.26	22.23	226	37.78	13.46	14
BTM	21.12	17.73	69	33.14	5.97	3
Airplane				39.12	16.66	6
Total	**32.55**	**22.70**	**1161**	**34.42**	**14.60**	**45**

This all leads to the following mean employer's VTT for 2011 (Table 8, last but one column).

Table 8: Mean employer's VTT for business trips in 2010 euros per hour*

	PVWT (in € 2010)	W	TW	PTW	Mean VTT 2011 (in € 2010)	Mean VTT 1997 (in € 2010)
Car	31.17	0.5589	0.0359	0.9053	16.41	18.31
Train	37.78	0.3780	0.1569	0.9405	8.71	5.14
BTM	33.14	0.5454	0.0597	0.8333	16.43	8.16
Airplane	39.12	0.2115	0.1356	1.0000	2.97	
Total	**34.42**	**0.5077**	**0.06**	**0.9149**	**15.59**	**15.14**

* in the recommended VTTs we do not use these means, but a mean employers' VTT based on sample enumeration and expansion to OViN

In the last column of Table 8 are the mean employer's values of time of 1997. We see a small decline in values for car travel. For train we see an increase, which is mainly due to a higher productive value per hour. The BTM value is much higher than in 1997, as a result of the higher share that would be spent working and the higher productive value of an hour. For plane the employer's VTT is quite low, mainly because only a fifth of the time savings would be allocated to work time.

4. The impact of spending travel time in a useful way

4.1 The theory

The VTT that is used in appraisal and that was determined in the previous sections can be written as the difference between two monetary[5] factors (De Serpa, 1971, Evans, 1972, McFadden, 1981, Jara-Diaz, 2008):

$$VTT = \mu / \lambda - (\partial U / \partial T_{travel}) / \lambda \qquad [2]$$

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); this value is sometimes called the 'resource value' or 'opportunity costs' of travel (see Tseng and Verhoef, 2008 on how this might change during the day).
- the value of the utility that is created during the travel time (compared to some reference activity), e.g. by relaxing, reading a book or a newspaper, writing messages on a smartphone / laptop or watching a movie on a tablet.

The VTT will change over time or space if any of these factors do. When activity time becomes more productive, the first component changes (this component also depends on changes in the productivity of labour). The marginal utility of income is likely to decline with income. Therefore, an increase in income over time, will raise the VTT, because the first component of equation [2] increases, and the second component decreases, whereby the former effect is likely to dominate. When the direct utility of travel time increases, for instance as a result of increased presence of Wi-Fi connections or electric sockets in trains, the VTT becomes lower. On the other hand, an increase in the level of crowding would increase the VTT.

4.2 Empirical results that corroborate the theory

The 2011 Dutch VTT survey has been re-analysed (Kouwenhoven and de Jong, 2018) to shed light on these issues. In this survey some specific questions were asked on the use of the travel time (could they do a useful activity during the trip; use of devices during the trip). We find that those respondents that indicate that a shorter travel time is useful to them, have on average a VTT that is

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[5] 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).

22.1% ± 3.7% higher than the other respondents – which is in line with the theory presented above (it is the first component of eq. [2]).

Also the data from our survey show that train or local public transport (bus, tram, metro) users that are able to spend their travel time usefully have on average respectively a 20.0% ± 5.5% and a 20.9% ± 5.6% lower VTT than others. This is the second component of eq. [2]. We did not find a significant effect on the VTT for the ability of car users to spend their travel time in a useful way.

Finally, we obtained the result 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 if nobody would have had a computer (laptop etc.) available during their trip. For local public transport users this is 0.9%. 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 (Kouwenhoven and de Jong, 2018).

An important implication of the above findings is that investments in the comfort of a trip that increase the possibility to work, read, watch movies and communicate with others during this trip may lead to a reduction of the VTT. These findings also underline the importance of including 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/her and which services (e.g. electricity sockets and Wi-Fi) were offered to him/her, and what the traveller would have done if these devices or services had been unavailable. This will allow further specification of the impact of comfort on the VTT (Kouwenhoven and de Jong, 2018).

5. Changes in the VTT over the years in The Netherlands

In this section we look at changes in the VTT in the same country over time. By time we mean the long run: over many years, possibly decades. CBA of transport investment projects needs to be done for a long time horizon (e.g. 30 years ahead), and part of the CBA analysis then is to predict how the VTT (in real terms: after correction for inflation) will change in the next decades until the end of the forecasting horizon. Usually simple escalation factors are used for this, that reflect the expected increase in GDP as well as an income elasticity of the VTT. This income elasticity or another way of predicting the future VTT in the long run can be based outcomes from a meta-analysis that cover VTT studies over many decades (e.g. Abrantes and Wardman, 2011 or Wardman et al., 2016). It can also be based on comparing VTT from several studies in the same country, whereby one carefully tries to avoid or control for any methodological differences in the survey and modelling techniques (repeat studies) to obtain a fair comparison. In this section we focus on such repeat studies. Only few such studies exist (e.g. Gunn, 2001; Tapley et al., 2007; Börjesson et al., 2012)

Accent and Hague Consulting Group (1999) found that in the UK, at the same income levels, the 1994/1995 values of travel time savings were even lower than in 1985, but this was believed to be largely due to the longer distances studied in 1985 (they also found that VTT increases with distance).

It has been suggested (Gunn, 2001) that another cause for this less than proportional growth of the VTT with income over time may be the change that has occurred in the disutility of travel time and the productivity of travel time, mainly through the introduction of new technology that can be used whilst travelling (mobile phones, laptop computers, audio and video equipment) and other comfort improvements.

Gunn (2001) also reports the outcomes from a repeat study carried out in the Netherlands. This comparison is based on the national VTT survey data collected in 1988 and 1997. These two surveys used essentially the same questionnaire and survey methods. Gunn (2001) found that between 1988 and 1997 the VTT grows with income over time, but clearly less than proportionally. As for the UK, he recommended distinguishing between the disutility of travel time and the productivity of travel time, where income growth leads to increases in the former and the introduction of new technology that can be used whilst travelling (mobile phones, laptop computers, audio and video equipment) and other comfort improvements increase the latter. This again is in line with the theory described in section 4.1. The net result can be a positive or a negative change. In this particular comparison, income growth itself might have led to a proportional increase in the VTT, but the difference from 1 is explained by the technological innovations that can be used while travelling.

Gunn suggested using an income elasticity of the VTT (all purposes, car & PT) of about 0.5. This has indeed been used in the Netherlands since then for the VTT escalation factor over time for CBA. A source of uncertainty however is that this relation not only depends on income effects but also on the introduction of new technology. Technological developments are by nature rather erratic, not a smooth line over the years; and have their own lifecycle. Therefore we cannot conclude from a single two-period comparison whether these findings constitute a once-and-for-all downward shift of the VTT or a structural trend that will continue in the future.

More recently a comparison of the second and third Dutch national VTT studies was carried out (data collection in 1997 and 2009/2011 respectively) and reported at conferences (Kouwenhoven et al., 2014b, 2017). It was found that in the period 1997-2009/2011 for most combinations of trip purpose and mode the average VTT went up by an amount that was smaller than the price change plus the full real income change (so the income elasticity would be less than 1). For some mode and purpose combination the VTT in real terms had even gone down over time (which would imply a negative income elasticity of the VTT). Differences between purposes (and modes) were also found that could be related to ICT developments and their use to make the trip more productive/pleasant.

6. Summary and discussion

In this paper we have presented the main methodology aspects and key outcomes of the third national VTT study in the Netherlands. We focussed on the use of the Hensher equation for business trips, which has been used since the first study that was reported in 1990. We also discussed some issues that have come to the fore in recent years, such as the dependence of the VVT on trip distance, the additional importance of travel time reliability (measured here as the standard deviation of travel time), the impact of the productive/pleasant use of travel time which reduces the VTT used for CBA and evidence from repeat studies on changes in the VTT over the years.

Many of these issues are relevant when it comes to forecasting the future VTT. ICT has already made it possible to work during the trip, to some degree in the car (hands-free mobile phone kit), but more so in the bus and especially in the train, adding to possibilities that already existed a long time ago (such as reading from paper). New technological development such as automated vehicle would increase the possibilities of working during a trip at a productivity level that is the same as in now in the train, or even higher (because it may be quieter in the car). The Hensher equation for business takes working during the trip into account. In the 2011 survey in The Netherlands shows that working on the train nowadays is almost as productive as in the workplace (factor of 0.94). If (at the margin) as much of the travel time would be spent working as at the workplace, and at the same productivity, the business VTT for appraisal would be reduced to zero. However, the fraction of the travel time that was spent working within business trips in the 2011 survey was only 16% for train users (and 4% for car users). It is likely that these fractions will increase in the future when new technology will make working during the trip easier, but to reduce the VTT for appraisal to zero, very large changes in the choice of activity during travel will be needed. It is unrealistic to think that this fraction can become 1 or even close to 1 for all business travellers. Some types of travellers can never do any work during business trips (e.g. blue collar workers such as plumbers and painters travelling to the next client). Furthermore, some travel time cannot be used for work anyway (such as time to find a seat in the train, or time in crowded conditions). Finally, even business travellers that currently are working effectively during their travel time still value shorter travel times, since they lack flexibility during the trip: they do not have everything at hand as they have in their office and not all types of working activities can be done during travelling, so they need to schedule their activities in order to be able to be fully productive during the trip.

Nevertheless, we have seen that in The Netherlands between 1988 and 1997 and again between 1997 and 2010, the VTT did not increase as much as could be expected from income change alone. We expect that this less than proportional relation with income is due to improvements in ICT technology which make the time travelled more productive and pleasant. This explanation is fully consistent with the underlying theory and has been corroborated by empirical research in The Netherlands on additional data collected in the third national VTT survey. Users of train and bus, tram and metro that could spend their travel time usefully were found to have a 20-21% lower VTT than other travellers. The possibilities to spend travel time in a useful way depend on many factors, for instance having a computer (laptop) available during the trip has an impact of not more than 5% on the VTT.

Furthermore, it is difficult to predict technological developments, and especially the speed of their large-scale adoption. There might be further innovations that make time in public transport more productive/pleasant than it is now. Automated vehicle technology could result in private (or shared) cars where the driver need not pay any attention to driving, so could result for many car users in a sort of 'mobile office'. However, a zero or very low VTT will only result if considerably more travellers than today would decide to spend the travel time performing an activity that has the same utility as at the origin and destination.

Taking all the above into account, we believe that in the future the VTT will not decrease all the way to zero. We also believe that it is likely that the VTT will not increase as much as income and that it may even decline in real terms. A practical implication is that time escalation factors of (close to) 1,

which are now used in several countries to determine the VTT for future years, should be reconsidered.

As a more methodological recommendation, we suggest that future studies on the value of travel time should focus more on how precisely travel time was spent and why. They should also ask explicitly whether the type of job of the respondent is such that work can be done during a business or commute trip (or even during a trip for another purpose).

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Annex 1. New results from the third national VTT study in The Netherlands on the impact of base time and distance on the VTT

Table A1: VTT by trip purpose as a function of travel time in the observed reference situation

TRIPLENGTH Class		Commute all modes	Business all modes	Commute all modes
0 - 19 minutes	1	6.41	21.22	4.41
20 - 29 minutes	2	7.84	28.81	5.98
30 - 39 minutes	3	6.94	22.41	5.88
40 - 49 minutes	4	8.20	27.17	7.07
50 - 59 minutes	5	9.98	27.33	7.48
60 - 69 minutes	6	9.40	30.09	7.73
70 - 79 minutes	7	11.54	24.32	7.84
80 - 89 minutes	8	12.44	25.80	8.91
90 - 99 minutes	9	12.35	23.71	6.89
100 - 119 minutes	10	12.73	19.62	8.84
120 - 149 minutes	11	16.25	13.73	11.08
150+ minutes	12	18.25	21.92	9.01

Table A2: VTT for commuting by mode as a function of travel time in the observed reference situation

TRIPLENGTH Class		Commute Car	Commute Train	Commute BTM
0 - 39 minutes	1	7.44	8.17	6.04
40 - 49 minutes	2	9.03	6.53	6.02
50 - 59 minutes	3	10.67	10.85	8.32
60 - 69 minutes	4	10.60	9.14	7.04
70 - 79 minutes	5	12.53	11.18	7.66
80 - 89 minutes	6	9.16	17.07	9.60
90+ minutes	7	15.38	13.21	10.25

Table A3: VTT for by trip purpose as a function of travel cost in the observed reference situation

TRIP COST Class		Commute All modes	Business All modes	Other All modes
0 - 1 €	1	5.92	17.49	4.00
1 - 2 €	2	6.65	17.45	5.32
2 - 3 €	3	7.92	38.84	6.51
3 - 4 €	4	9.45	22.97	8.06
4 - 5 €	5	10.32	33.53	6.89
5 - 6 €	6	11.02	27.40	8.79
6 - 10 €	7	12.03	23.81	10.06
10+ €	8	14.99	22.97	7.74