APPENDIX D VALUATION OF TRAVEL TIME

D.1 Description of the Valuation of Travel Time (VOT) Tool

This section describes how to value travel time for passenger and freight transport. It identifies users, specifies the required inputs for using the tool; deals with the issue of uncertainty in applying the tool; provides recommendations on use of the tool within various evaluation techniques; identifies the advantages and disadvantages of the tool; and concludes by dealing with a range of other technical issues. An overview of current values as taken from the TRACE-project is also provided.

D.1.1 What is the tool, what does it do?

The VOT-tool is used to derive a monetary expression of the changes in travel time due to a change in the transport system.

D.1.2 Use of the VOT tool

Who will use the tool?

The users of the tool will be those interested in a socio-economic evaluation of a transport project and as such will mainly be public bodies. Sometimes private companies can be interested in performing a valuation of travel time, mainly when transport projects affect their logistics.

How to use it

The user firstly has to calculate / measure changes in travel time due to the implementation of a transport project. The changes for the various groups can be expressed in monetary values by multiplying the identified time changes by the corresponding VOTs. Usually very small changes will not be included in the valuation process.

It is important to note that the VOT is an individual value dependent on personal characteristics and trip characteristics. In evaluations individual values cannot be used. Instead use will be made of aggregated values (values for a group). Which aggregation should be used is dependent on the objectives of the project and the changes expected due to that particular pilot/demonstration project.

<u>Passengers</u>

When looking at passenger transport projects, VOT calculations may be carried out in relation to the following:

- the purpose of the trip
- the mode of travel
- the quality or level of service of the trip
- specific characteristics of the traveller
- phase of travel

The purpose of the travel

The value attached to time depends on the purpose of the trip. A leisure trip is usually characterised without hurry, whereas an ambulance or fire engine in case of emergency have priority over all other traffic in order to save scarce seconds or minutes.

Usually in VOT a distinction is made between business and non-business (commuting and other) purposes.

Economic theory in competitive markets states that a given firm operating in a competitive market will be in equilibrium when the marginal revenue product of a factor of production equals its price. In other words, the last good which is produced still earns money, but the next will not. If labour is taken to be an input to the firm, the firm will pay salaries up to the point that the worker adds profits to it, (i.e. his earning rate). Given those assumptions, the value of time for the business traveller is the wage rate, since he/she is travelling instead of working.

An extension of the theory of equilibrium to the consumer would value this category of time in the same way as the previous one (i.e. business travel). But most studies on this topic advise consideration of the value of the time spent in activities other than business as a percentage of the wage rate. The value of this percentage share is still the subject of debate, although the average is approximately 25-30%.

In addition to these ad hoc procedures, there are also some more sophisticated methods to estimate the VOT for different purposes of travel. These will be discussed in the next section.

The mode of travel

Empirical research shows that the value time differs for people travelling by different transport modes. In particular, VOTs for public transport seem on average lower than those for private cars. The values also differ for shorter and longer trips. Travelling a longer distance by train or air may make the travel time more productive by allowing time to do work, which in effect reduces the travel time.

The quality or level of service of the trip

The quality or level of service of a trip are important characteristics when the value of time is considered. When considering the mode of travel it has been shown that there are important differences in quality *between* modes which can influence the perception of the value of time by the user. But even *within* a mode the quality of service can differ substantially. In general when the quality or level of service of a mode improves the value of time will decrease.

Specific characteristics of the traveller

The most specific characteristic of the traveller which influences the perception of the value of time is income. An extra unit of money does not generate a big increase in the utility enjoyed by a person with a high income. As income rises therefore, the marginal utility of money decreases. On the other hand, the free time enjoyed by persons with high incomes is scarce and due to this scarcity, they will place a higher value on an additional unit of free time

than persons on lower incomes who may enjoy a lot of free time would. It seems then that as the income of a person increases, their perception of the value of travel time (VOT) will also increase.

Other characteristics of the traveller which can influence the VOT are for example the age of the traveller and family size.

Phase of travel

The valuation of time is also dependent on the phase of travel. This is why in the QUITS study [13] total travel time has been subdivided into pure travel time; disposition travel time; access/egress time; and wait/search time.

In practice different VOTs will very seldom be available for the different phases of a journey. Therefore this breakdown is not often used. The QUITS project [13] is one of the first projects which has tried to break down the valuation of travel time with respect to the different phases of travel.

Table D1 shows the combination of all the classifications in one scheme.

Table D1: Classification of VOT for passenger

characteristics of traveller ⇒		low income ⇔ high income			
		other			
purpose of travel ⇒		business ⇔ leisure ⇔ other			
phase of travel ⇒		pure travel time	Disposition time	access and aggress time	wait and search time
mode ⇓	quality ⇓				
car	high low				
train					
plane					
boat					
bus					
etc.					

In Deliverable 1 of the TRACE-project [14] other distinctions that may result in different values of time are presented in the appendix. However, not all of these distinctions will be relevant for a particular project as some of them are highly correlated.

Freight

There has not been a lot of research carried out concerning the VOT in freight transport. The VOT in freight transport is dependent on the nature and value of the freight, on the relative importance of transport and the internal and external logistical process within the total production process of the company.

In a report of the Hague Consulting Group [15] the following four categories of freight have been defined which result in different VOTs:

- low value raw materials/intermediate products
- high value raw materials/intermediate products
- final products without loss of value during transport
- final products with loss of value during transport

This division is especially important for road transport, because in road transport all categories of freight are transported.

D.1.3 When to use it?

The tool will be used as part of a socio-economic evaluation when a monetary expression of travel time changes is necessary. This is the case when it is desirable to express costs/benefit of projects in the same unit (e.g. money) in order to perform further calculations. As such, the VOT tool will be used in almost every cost-benefit analysis. The VOT actually serves as a (monetary) weight for the different user groups concerned in the analysis. In other methods, where non-monetary effects can be used as an input or when weighting for different groups is not important, one can use the travel time changes as a direct input.

The tool will only be relevant to use when travel time changes are considerable. Very small changes per individual cannot be expected to influence behaviour (mode choice, route choice etc.). Therefore it is only useful to use the VOT tool for projects with considerable travel time impact. A million trips shortened by only one second cannot be considered to have an equal monetary value to 278 trips shortened by one hour.

D.1.4 Required Inputs

Basics

The valuation of travel time can be expressed by the following formula:

$$Valuation\ of\ travel\ time\ = \sum_{i=1}^{n} VOT_i * \Delta T_i$$

So the user of the tool has to acquire the following inputs:

$$VOT_i = Value\ of\ time\ for\ group / segment\ i$$
$$\Delta T_i\ = Change\ in\ travel\ time\ for\ group / segment\ i$$

As such the valuation of travel time calculates the change in transport user benefit by weighting the travel time changes by the VOTs for the various groups.

The necessary inputs are thus the:

- Changes in travel time for each group considered in the analysis
- VOTs for these groups

Change in travel time

In order to be able to value the changes in travel time, these changes have to be obtained. The way in which these are obtained and the level of detail of the available data will depend upon the phase of the pilot/demonstration project.

D.2 Stagewise Application of VOT

The level of detail required from the VOT tool depends on the stage of the P/D project when it is used.

D.2.1 Initial evaluation

At this stage of the pilot/demonstration an initial change in the travel times will be expected. There may already be some insight into the overall travel times. A reduction can be expected in absolute values or in a percentage of the overall travel time.

In this case no measurements have been performed and any estimate will be fairly rough. As a result there will probably not be different expectations for different user groups. The travel time valuation in this case can be based on an overall average value.

D.2.2 Ex-ante evaluation

As part of the ex-ante evaluation measurements will be undertaken. These will include for example origin destination surveys and probably transport modelling exercises in order to estimate the overall transport effects. Before implementation travel time changes cannot be measured. Only current travel times can serve as input to transport models.

The estimated time changes within this phase will merely stem from these types of transport modelling. Usually the transport modelling will model the future situation with and without the pilot/demonstration project. The difference between the travel times in these situations is the effect. Valuation per group will be dependent on the classification distinguished within the modelling exercise.

D.2.3 Ex-post evaluation

In this stage the change in travel time can be measured by using the difference between the situation before the transport project has been carried out and the situation after implementation of the transport project. These measurements can be compared with the modelled outputs from the ex ante evaluation.

Differences in measured travel times can be valued using the VOT tool. In the analysis care should be taken of the causes of these differences. Effects other than the transport pilot/demonstration may have influenced the measurements (different origin-destination relations, other projects, unexpected traffic growth etc.).

Point of attention

Transport systems (especially passenger transport) suffer from high loads during peak hours. In this way measurements of travel time can differ according to the time of the day at which measurements take place. Depending on the objectives of the pilot/demonstration study measurements can be necessary in peak and off-peak situations. Due to the different composition of the traffic (modes used, purposes, income groups) the value of time can also be different for the peak and the off -peak. Very few studies exist which go into this level of detail.

D.3 Sources of Uncertainty

Uncertainty concerning the valuation of time can be classified as follows:

- Uncertainty in the segmentation of the VOT
- Uncertainty in the estimation of the VOT

Uncertainty in the segmentation of the VOT

As stated previously, VOTs are primarily individual values. In evaluation studies VOTs which are representative for groups are applied. Due to this an aggregation uncertainty occurs, because the determined value of time for this general group (e.g. car users) need not be the same as for the specific group related to the project (car users in contact with the new measure/facility).

Uncertainty in estimation of the VOT

- When using stated preference surveys there is a danger of strategic answers or non-serious answers;
- External factors cannot be excluded when using revealed preference surveys;
- When using model estimation, the model does not fully or partially reflect the reality
- VOT may not be invariant to the sign of the travel time change
- VOT may vary with the relative or absolute quantity of time lost or saved

(For the last two points mentioned see technical note 4.)

D.4 Further Use Of The Results

It is important to note that VOTs which have been estimated in the past can only be useful in recent estimations of the value of the change in travel time, if they are converted into current prices. Conversions are regularly made by using national consumer price indices. The valuation of travel time is a tool developed to monetise travel time savings, so it can be used as an input to a cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA). In the CBA the impacts of the project on society are expressed as costs and benefit. Other impacts like operating and investment costs and also external effects are all monetised, so a derivation of a monetary expression of the society's benefit of the investment is possible.

When other impacts cannot be monetised a CBA cannot be applied. In this circumstance other methods like multi-criteria analysis (MCA) or goals achievement methods (GAM) may be used. With respect to travel time as an input variable, there are two possible options for these two methods:

- Travel time savings/losses will not be monetised and will be used as a direct input in the evaluation
- Travel time savings/losses will be monetised by using a VOT and the monetised value will be used as an input in the evaluation

If VOTs are available it is recommended to use them. VOTs can be considered as neatly defined weighing factors to scale the overall travel time changes for the various groups under consideration. (Using only travel time changes does not reflect the transport user benefit of the impact for the various groups).

D.5 Advantages And Disadvantages Of The Tool

The following advantages and disadvantages of the tool can be mentioned (compared to non-monetisation of travel time changes).

Table D2: Advantages and disadvantages of the VOT tool.

Advantages	**Disadvantages**
Useful for a monetary evaluation	Several sources of estimation errors of the VOT[4]
Fair weighting of different user groups	Need for identifying different user groups in analysis
Possibility of an integrated evaluation of both passenger and freight transport	

D.5.1 Technical Note 1 - Rule Of Half

Travel time savings are beneficial for existing users of the transport system. Due to the travel time savings the demand for a particular transport service can expand, because the transport service will be more attractive for new users. The new users will also benefit from savings in travel time, although the benefit are not as high as for the existing users. This is shown in figure D1.

The benefit for existing users is:

$(T_0 - T_1) * Q_0$

The benefit for new users is:

$\frac{1}{2} * (T_0 - T_1)(Q_1 - Q_0)$

Adding up the benefit of the existing and the new users results in the total benefit.

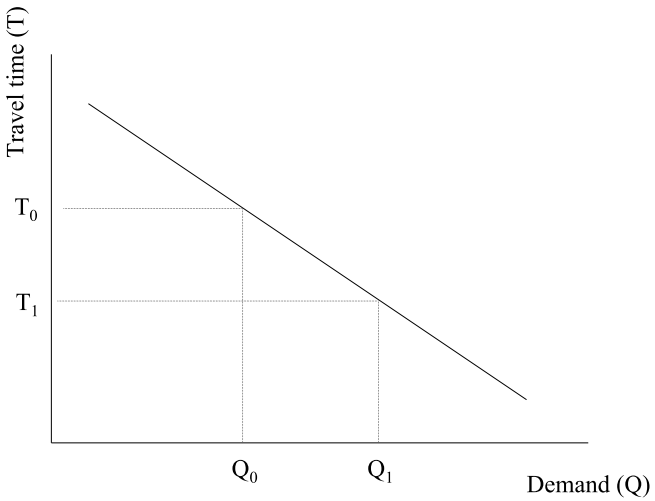

Figure D1. Savings in travel time for new and existing users

The total benefit is: $(T_0 - T_1) * Q_0 + \frac{1}{2} * (T_0 - T_1)(Q_1 - Q_0)$

This formula can be rewritten in: $\frac{1}{2} * (Q_0 + Q_1)(T_0 - T_1)$

This formula is the 'rule of half', which states that the benefit of a travel time saving is equal to the average use of a transport service (before and after the investment) multiplied by the travel time savings.

D.5.2 Technical Note 2 - Estimation Of The VOT In Passenger Transport

Several methods for estimating the VOT are discussed in Daly [16]. In many countries VOTs have been derived using ad hoc procedures. A common procedure is that the wage rate is taken for the value of travel time to work and a percentage (often small) of the wage rate for non-travel time.

Most recent VOT studies have been trying to infer the value of time from models of consumer behaviour, acknowledging that the VOT is the outcome of a consumer decision process. In many situations consumers have to trade between time and money. These situations can be described by models. The models used most often are:

- mode choice models
- route choice models

The data used in model estimation can be determined by two kind of methods: revealed preference and stated preference.

Revealed preference

This method studies people who have to make a decision between time and money in reality. The VOT is estimated by looking at factors such as choice of route, modal split, location of residence or speed travelled. This will lead to an implicit valuation of travel time.

For example an estimation of time can be determined if people can choose between a fast toll road or a slower, free of charge alternative. When a speed study is carried out, the choice between the higher costs of driving faster (fuel and chance of a speeding penalty) and the time gain is studied.

When using revealed preference the assumption has to be made that people behave rational and have full information concerning all the costs and benefit of their behaviour. This assumption is far-reaching: in reality irrational considerations will play a major role. Most revealed preference methods concentrate on the modal split. In these studies people have to choose between a faster, but more expensive mode and a slower, but less costly mode An important complication is that the choice between modes will not only be determined by the price of the modes. Other characteristics like safety, reliability, privacy, comfort etc. can also be important in the decision process. In quantitative, empirical research it is often hard to make corrections for these factors, especially because in a lot of cases they are linked with speed. So the estimated VOT will be biased in a lot of cases because speed also reflects other non-measured characteristics of the mode.

Stated preference

This method tries to estimate the VOT by using surveys (choices of persons made in hypothetical situations defined by the researcher). Although there is a possibility that people do not give serious answers or answer the questions in a strategic way, this method has the advantage that all other non-observed, non-relevant factors will not disturb the valuation. So a clear distinction can be made between money and time.

Some stated preferences experiments used in VOT estimation are not for explicit mode or route choice, but the choice between alternatives with different travel time and cost, which all refer to the same mode and route. Transfer price data in which travellers are asked to say how much they would be willing to pay for an improvement or would need to be compensated for a deterioration can also be used.

The specific dangers of stated preferences mentioned above have been recognised and special survey techniques have been developed to minimise possible distortions. In the last years stated preference has become very popular.

It may be clear that both methods have their strengths and its weaknesses. This is why in most cases both methods are used. If both methods make more or less the same estimations of the VOT, than this will strengthen the confidence in the results of the research.

D.5.3 Technical Note 3 - Estimation Of The VOT In Freight Transport

In the report of HCG [15] two methods have been used to estimate the VOT in freight transport: the factor cost method and the contextual stated preference method.

The factor cost method

This method identifies the costs that change when the travel time increases or decreases. Because in the method both the constant and the variable costs are analysed, but the logistical structure of companies are assumed to be left unchanged, it is particularly a middle long term analysis. A long term analysis will result in higher VOTs, because in the long term companies will be able to alter their logistical process. On the other hand a short term analysis will result in lower VOTs, because only "marginal time" transport costs, like the wage costs of drivers and the variable costs per hour will be used as an input.

The contextual stated preference method

This method is very similar to the stated preference method used in passenger transport. Transport providers and companies are surveyed. They have to value some characteristics of the transport system (one of them being the value of time), thinking of their own context. In the research of HCG [15] the factor costs have been used as main starting point.

In table D3 the results of the Dutch study are presented.

Table D3: Value of time of freight transport in the Netherlands (in guilders by shipment and by hour)

	FCM	CSP	
Road: low value raw materials / intermediate products	65	67	70[1]
Road: high value raw materials / intermediate products	69	74	
Road: final products without loss of value	67	63	58[2]
Road: final products with loss of value	69	57	
Road: weighted average	67	63	
Rail: entire train	1590	1406	
Rail: coach	64	57	
Inland waterway ship	319	389	

Source: HCG (1992) [15]

[1] Weighted average of raw materials and intermediate products

[2] Weighted average of final products

The following comments have to be made:

- The average VOT of raw materials and intermediate products is higher than of final products. This probably reflects that raw materials and intermediate products have to be used in next stages of the production process, by which delay in transport will lead to hold-ups in the production process.
- The VOTs for train and ship are considerably higher than the VOTs for road due to differences in the average size of the shipments of these modes.

D.5.4 Technical Note 4 Sources Of Uncertainty

In section D.3 some sources of uncertainty in estimation of the VOT are described. The last two sources mentioned have to be elaborated:

The sign of the travel time change

The results of the 1994 UK and 1988 Dutch VOT studies on stated preference data indicate that time savings are valued less than time losses. Apparently, people are prepared to pay more for avoiding travel time increases than for achieving travel time decreases. However, between the various purposes there are some differences: the ratio of VOTs of travel time increase to decrease is about 3 for commuting, 2-2.5 for business travellers and 4-5 for other purposes. Thus, time savings are more important for business travellers than for other categories of traveller. A possible explanation of this phenomenon could be that time savings are more valuable if the time that is saved can be transferred into other more valuable activities, such as doing work.

The amount of travel time saved/lost

The VOT can be dependent on the amount of travel time saved or lost. For example the cumulative value of the benefit gained by sixty people incurred in a one minute time saving is not equal to that of a one hour saving to an individual.

The central question is if a small amount of travel time saving can be allocated in a useful way to other alternatives of spending time. Some people have limited possibilities to alter their daily pattern, especially when only a small amount of time can be reallocated. So for these people the possibilities to carry out additional activities are limited when a small amount of travel time has been saved. On the other hand, in the daily pattern of activities of other people some unutilised amount of time can be hidden. A small amount of extra time can give these people the possibility to “activate” this unutilised amount of time to an additional activity, which takes a lot more time than the small amount initially saved.

Alternatively, consecutive improvements to infrastructure can lead to accumulation of saved travel time. In this case, neglect of small savings in travel time will lead to an underestimation of the total amount of travel time saved.

In general a unit of a small and a big travel time saving are valued in the same way. However if the change in travel time is not perceptible than the travel time changes will not be valued at all.

D.6 Example Values for VOTs

In this section some VOTs will be presented. The references used are the result of the TRACE project [(14)] in which a review of 21 national VOT studies have been carried out. In most studies a distinction has been made in VOTs by mode and trip purpose. All VOTs were first converted into current prices using national consumer price indices and then converted to Euros using the January 1998 Euro to national currency rate published by the EC. One has to keep in mind that large differences exist in income per capita between countries, especially

between countries in Western, Southern and Eastern Europe. Generally speaking the VOT increases with increases in income (see section D.1.2, *characteristics of the traveller*).

Table D4: Values of time from several studies in Europe (in Euros per hour); value of total transport time (in *italics* if in-vehicle-time only).

Country	Source	Mode	Employer's business	Commuting	Other
Austria	Winkelbauer (1996) [17]	all modes	15.6/17.2	4.6	
	Graz (TRANSPRICE, 1997)	car user	2.6		
Belarus	Brown et al (1996) [18]	train passenger	1.0		
Belgium	Mouchart & Rutgeerts (1983) [19]	car or public transport user		4.0 to 4.7	
	EURET (1994) [10]	car	21.4		
Denmark	EURET (1994) [10]	car	18.6/19.4		
Finland	Pekkarinen (1993) [20]	all modes		15.3	
	EURET (1994) [10]	car	23.6/18.9		
	National Road Administration (in Pursula & Kurri, 1996) [21]	all modes	21.3	3.6	2.1
	Preliminary national VOT study (in Pursula & Kurri, 1996) [21]	urban bus passenger	1.7 to 3.4		
		car driver	4.3 to 8.6		
	Helsinki (TRANSPRICE, 1997)	car user	9.6		
France	EURET (1994) [10]	car	9.2/4.6		
	Lyon-Turin study (Jincheng, 1996) [22]	rail passenger	8.9 to 22.6		
Germany	PLANCO & Heusch-Boesefeldt (1991) [23]	car	18.9	3.6	
	EURET (1994) [10]	car	15.0/24.6		
	BMW (1994) [24]	car	53.0	26.5	10.6
	FGSV (1996) [25]	car	2.8/5.6		
		bus	63.1		
Greece	EURET (1994) [10]	car	5.3/6.4		
Ireland	EURET (1994) [10]	car	10.7/17.4		
	Gibbons et al (1998) [26]	car (vehicle)	4.2 to 5.1		
		public transport passenger	1.6 to 5.1		
		slow modes	3.3 to 10.2		
Italy	EURET (1994) [10]	car	21.0		
	Como (TRANSPRICE, 1997)	car user	17.0		
Luxembourg	EURET (1994)	car	19.9		
Moldova	Brown et al (1996) [17]	train passenger	0.3 to 2.4		

Country	Source	Mode	Employer's business	Commuting	Other
Netherlands	EURET (1994) [10]	car	19.3/20.6		
	1988 national VOT study (in HCG, 1998) [27]	car driver	20.9	6.3	5.1
		car passenger	16.7	5.0	4.0
		train passenger	18.4	6.5	4.4
		bus/tram passenger	18.3	5.3	3.1
		total	20.9	6.3	4.8
Norway	*national VOT study (Ramjerdi et al, 1997)* [28]	*car, inter-urban*	22.6	10.8	
		ferry, inter-urban	16.3	9.4	
		rail, inter-urban	14.5	6.8	
		bus, inter-urban	9.4	6.0	
		air, inter-urban	33.4	20.4	
		car, urban	17.1	4.9	
		rail, urban	13.3	6.0	
		bus/light rail, urban	13.3	3.6	
Portugal	EURET (1994) [10]	car	6.4/10.9		
Russia	Brown et al (1996) [18]	train passenger	1.0 to 1.5		
Spain	EURET (1994) [10]	car	6.4/12.9		
Sweden	EURET (1994) [10]	car	23.7/21.3		
	Jansson (1994) [29]	public transport passenger	1.0 to 1.3		
		car user	5.8 to 6.6		
	national VOT study (ALGERS et al, 1996) [30]	*car driver <50 km*	19.5	4.0	3.2
		car driver >50 km	19.5	9.5	
		air >50km	16.5	10.3	
		IC-train >50km	15.1	8.7	
		X2000 train >50 km	15.7	11.9	
		regional train <50km		6.3	
		regional train >50km		8.2	
		long distance bus <50km		5.5	3.3
		long distance bus >50km		7.6	

Country	Source	Mode	Employer's business	Commuting	Other
		regional bus <50km		5.0	3.3
		regional bus >50km		5.9	
	Göteburg (TRANSPRICE, 1997)	car user	21.0		
Ukraine	Brown et al (1996) [18]	train passenger	0.7		
UK	1985 national VOT study (MVA et al, 1987) [31]	car driver	5.8 to 11.5[3]	5.3 to 7.7	5.4 to 6.6
	Polak et al (1993) [32]	car driver		4.2 to 7.3	3.3 to 4.2
	COBA9 (in EURET, 1994) [10]; Gunn et al, 1996)[33]	car driver	18.5	5.4	
		car passenger	15.4	5.4	
		car (vehicle)	21.6	7.3	
		bus passenger	15.4		
		bus (vehicle)	81.6		
	EURET (1994) [10]	car	16.2/16.4		
	Cambridgeshire (Atkins, 1994) [34]	car	3.0 to 4.8	5.3 to 10.1	3.0 to 6.1
	1994 national VOT study (Gunn et al, 1996) [33]	car driver	20.8 (6.5[3])	5.2	4.4
		car passenger	20.8 (6.5[3])	5.8	3.0
		scheduled coach	48.5 to 58.0		
		motorway charter bus	22.5 to 32.0		
		scheduled bus	16.5		
		trunk road charter bus	0 to 24.0		
	York (TRANSPRICE, 1997)	car user	6.1		
	Leeds (TRANSPRICE, 1997)	car user	4.0		
	Wardman & Mackie (1997) [35]	all modes	20.8	5.8	
		car user		4.9	5.2

Source: TRACE, D1 (1998) [14]

[3] These values only refer to the valuation by the employee

Further details on this subject are available in Deliverable 1 of the DGVII TRACE project [14].