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Proposal for Harmonised Guidelines

Peter Bickel
Rainer Friedrich
Arnaud Burgess
Patrizia Fagiani
Alistair Hunt
Gerard De Jong
James Laird
Christoph Lieb
Gunnar Lindberg
Peter Mackie
Stale Navrud
Thomas Odgaard
Andrea Ricci
Jeremy Shires
Lori Tavasszy

With contribution from partners.

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Abbreviations

ATOC	Association of Train Operating Companies
BCR	Benefit-Cost Ratio
CBA	Cost Benefit Assessment
EIA	Environmental Impact Assessment
ESA	Equivalent standard axles
FYRR	First Year Rate of Return
GWP	Global Warming Potential
HGV	Heavy Goods Vehicle
IFI	International financing institution
IPA	Impact Pathway Approach
IRR	Internal Rate of Return
IVT	In Vehicle Time
LGV	Light Goods Vehicle
MS	Member States
NPV	Net Present Value
PDFH	Passenger Demand Forecasting Handbook (UK)
PPP	Purchasing Power Parity
PVB	Present Value of Benefits
PVC	Present Value of Costs
RNPSS	Ratio of NPV and Public Sector Support
VOC	Vehicle Operating Costs
VSL	Value of a Statistical Life
VTTS	Value of Travel Time Savings
WTP	Willingness to Pay
YOLL	Years of Life Lost

0 Summary

0.1 Introduction

The objective of this document is to propose harmonised guidelines for project assessment for trans-national projects in Europe. This includes the provision of a consistent framework for monetary valuation based on the principles of welfare economics, contributing in the long run to consistency with transport costing. These guidelines have been developed within the EC funded research project HEATCO, based on latest research results on the different aspects of transport project appraisal and on an analysis of existing practice in the EU countries and Switzerland.

The review of existing practice documented in Odgaard et al. (2005) and further analysed in Bickel et al. (2005a) has shown considerable variation. In the context of selecting and financially supporting TEN-T projects, the need for consistent appraisal methodology arises. Thus, a consistent methodological framework for project appraisal has been developed and is described here. Apart from being used for TEN-T projects, it might also be used for other trans-national projects to ensure consistency across borders and the application of the state of the art methods. It is not the intention of HEATCO's proposal for harmonised guidelines to stipulate methods and values for national projects, however in the long run these guidelines might help to achieve a more harmonised approach also for national appraisal methods.

This summary gives an overview of the recommendations for harmonised guidelines for infrastructure project appraisal covering the following elements:

- General issues (incl. non-market valuation techniques, benefit transfer, treatment of non-monetised impacts, discounting and intra-generational equity issues, decision criteria, the project appraisal evaluation period, treatment of future risk and uncertainty, the marginal costs of public funds, producer surplus of transport providers, the treatment of indirect socio-economic effects),
- Value of time and congestion (incl. business passenger traffic, non-work passenger traffic, commercial goods traffic time savings and treatment of congestion, unexpected delays and reliability),
- Value of changes in accident risks (incl. accident impacts considered, estimating accident risks, valuing accident costs),
- Environmental costs (incl. air pollution, noise, global warming),
- Costs and indirect impacts of infrastructure investments (incl. capital costs for project implementation, costs for maintenance, operation and administration, changes in infrastructure costs on existing networks, optimism bias, residual value).

Country-specific fall-back values are suggested for application in cases where no state-of-the-art national values are available for valuation of

- time and congestion,
- accident casualties,
- damage due to air pollution, noise and global warming.

0.2 General issues

When carrying out a Cost-Benefit Analysis (CBA), we recommend the following 15 general principles:

1. Appraisal as a comparative tool. To estimate the costs and benefits of a project, one has to compare costs and benefits between two scenarios: the 'Do-Something' scenario, where the project under assessment is realised, and a 'Do-Minimum' scenario, which needs to be a realistic base case describing the future development. If there are several project alternatives, one has to create a scenario for each alternative and compare them with the 'Do-minimum case'.
2. Decision criteria. We recommend the use of NPV (net present value) to determine, whether a project is beneficial or not. In addition, depending on the decision-making context respectively the question to be addressed, BCR (benefit cost ratio) and RNPSS (ratio of NPV and public sector support) decision rules could be used.
3. The project appraisal evaluation period. We recommend the use of a 40 year appraisal period, with residual effects being included, as a default evaluation period. Projects with a shorter lifetime should, however, use their actual length. For the comparison of potential future projects, a common final year should be determined by adding 40 years to the opening year of the last project.
4. Treatment of future risk and uncertainty. For the assessment of (non-probabilistic) uncertainty, we consider a sensitivity analysis or scenario technique as appropriate. If resources and data are available for probabilistic analysis, Monte Carlo simulation analysis can be undertaken.
5. Discounting. It is recommended to adopt the risk premium-free rate or weighted average of the rates currently used in national transport project appraisals in the countries in which the TEN-T project is to be located. The rates should be weighted with the proportion of total project finance contributed by the country concerned. In lower-bound sensitivity analyses, in order to reflect current estimates of the social time preference rate, a common discount rate of 3% should be utilised. For damage occurring beyond the 40 year appraisal period (intergenerational impacts), e.g. for climate change impacts, a declining discount rate system is recommended.
6. Intra-generational equity issues. We recommend, at minimum, that a "winners and losers" table should be developed, and presented alongside the results of the monetised CBA. Distributional matrices for alternative projects might be created and compared amongst each other. Additionally stakeholder analyses should be undertaken as well. It is recommended to use local values to assess unit benefit and cost measures.
7. Non-market valuation techniques. If impacts in transport project appraisals cannot be expressed in market prices, but are potentially significant in the overall appraisal, we recommend that – in the absence of robust transfer values – non-market techniques to estimate monetary values should be considered. We recommend that the choice of technique used to value individual impacts should be dictated by the type of impact and the nature of the project. However, Willingness to Pay (WTP) measures is preferable to cost-based measures. Values should be validated against existing European estimates.
8. Value Transfer. Value transfer means the use of economic impact estimates from previous studies to value similar impacts in the present appraisal context. Value transfers can be used when insufficient resources for new primary studies are available. The decision as to

whether to use unit transfers with income adjustments, value function transfer and/or meta-analyses will depend on the availability of existing values and experience to date with value transfers related to the impact in question.

9. Treatment of non-monetised impacts. We recommend, at a minimum, that if impacts cannot be expressed in monetary terms, they should be presented in qualitative or quantitative terms in addition to evidence on monetised impacts. If only a small number of non-monetised impacts can be assessed, sensitivity analysis may be used to indicate their potential importance. Alternatively, non-monetised impacts may also be included directly in the decision-making process by explicitly eliciting decision maker's weights for them vis-à-vis monetised impacts.
10. Treatment of indirect socio-economic effects. We recommend that if indirect effects are likely to be significant, an economic model, preferably a Spatially Computable General Equilibrium (SCGE) model, should be used. Qualitative assessment is recommended, if indirect effects cannot be modelled due to limited resources (high costs for the use of advanced modelling), insufficient availability of data, or lack of appropriate quantitative models or unreliable results.
11. Marginal Cost of Public Funds. Our recommendation is to assume a marginal cost of public funds of 1, i.e. not to use any additional cost (shadow price) for public funds. Instead, a cut-off value for the RNPSS of 1.5 should be used when relevant.
12. Producer Surplus of Transport Providers. We recommend to estimate (changes in) the producer surplus generated by changed traffic volumes or by the introduction and adjustment of transport pricing regimes.
13. Accounting procedures. a) Factor costs should be the adopted unit of account. This requires measures expressed in market prices - which include indirect taxes and subsidies – to be converted to factor costs. b) We recommend to convert all monetary values into € with a price level for a fixed year. In this report, monetary values are given as €₂₀₀₂, i.e. with 2002 as base year. However, the monetary values should be adjusted with the Purchasing Power Parity (PPP) as explained in Annex B, which also contains a table with PPP adjustment factors. However, these factors are only available for past years, whilst future PPP factors are likely to change as the economic growth rates differ amongst countries. As we assume, that income and prices grow faster in Member States with currently low income, PPP factors will tend to converge closer to 1 in the future. Therefore, we recommend that two calculations are made – one with and one without PPP adjustment – assuming that the true value will lie between the two results. c) Monetary values, i.e. preferences, for non-market goods like reduced risk of getting ill or reduced damage to the environment will increase with increasing income; thus we recommend increasing monetary values based on GDP growth – a table with possible country-specific GDP growth is given in Annex B.
14. Up-dating of values. The unit values supplied in this report represent the state-of-the-art for the individual impacts addressed. Nevertheless, all values will be subject to change as new empirical evidence becomes available and methodological developments take place. As a consequence, we recommend that values are reviewed and up-dated on a regular basis e.g. after three years at maximum.
15. Presentation of results. As far as possible, impacts should be expressed in both physical and monetary terms. The results of the sensitivity analysis and the non-monetised impacts should be reported together with the central monetised results.

0.3 Value of time and congestion

0.3.1 Valuation Methodology

The underlying principle in the VTTS (value of travel time savings) guidelines is that local values should be used wherever possible, provided that they have been developed using an appropriate methodology. If no such local values exist then ‘default’ or ‘fallback’ values derived from international meta-analyses of value of time studies should be used. These fallback values are set out in Table 0.3, Table 0.4 and Table 0.5.

Economic theory suggests that different methods of valuation for VTTS should be used for passenger trips during work, that is to say on employer’s business, for passenger-non-work trips, that is for commuting, shopping and leisure purposes, and for commercial goods traffic. As set out in Table 0.1 for each of these purposes we recommend a minimum acceptable methodology for the valuation of time savings. The cost saving approach for employer’s business and commercial traffic is based on a theoretical argument regarding the marginal productivity of labour. Such an approach assumes no utility impact on the worker and that all travel time savings can be transferred to productive output. The more sophisticated Hensher approach (Hensher, 1977) allows for the fact that not all travel time is unproductive and not all savings are transferred to extra work. Willingness-to-pay surveys are based on either the revealed or stated preferences of individuals.

Table 0.1 Recommended valuation methodologies.

Trip Purpose	Minimum approach¹	More sophisticated approach
Passenger – work	Cost saving	Hensher approach
Passenger – non-work	Willingness-to-pay	
Commercial Goods traffic	Cost saving	Willingness-to-pay

¹ In the absence of sufficient resources to survey VTTS using the minimum approach the mathematical relationships derived from the HEATCO VTTS meta-analysis should be used.

0.3.2 VTTS values

Disaggregation

At a minimum, VTTS values should be disaggregated between passenger-work, passenger-non-work and commercial goods traffic. This is recommended because different valuation methods are used to calculate VTTS values for each of these purposes. Furthermore, due to the very different functions served by the various transport modes when transporting freight, commercial goods traffic should be disaggregated by mode at a minimum. For more sophisticated appraisals passenger VTTS could be disaggregated by mode and/or distance. A more data intensive and refined level of disaggregation would be to disaggregate by trip purpose, income, journey length and modal comfort. Disaggregation by income is strongly recommended for major infrastructure projects or projects that involve some form of user charging (tolled motorways, high speed rail, etc.). In such cases, consistency between values used in demand modelling and appraisal is required.

Walk, wait and interchange

In the absence of local data on travel time savings for walking, waiting and interchange, in-vehicle time should be weighted in order to reflect the additional willingness-to-pay for time savings. In-vehicle time should be weighted by 2 for walking time and 2.5 for waiting and interchange (or transfer) time.

Average waiting times for public transport services will vary systematically with the headway of the services. At high frequencies passengers arrive at random and the average idle time is half the headway. It is recommended that the modelling exercise explicitly models average waiting periods associated with the different service frequencies, and this time should be included in the appraisal weighted with a factor of 2.5. At lower frequencies arrival rates are not at random and average waiting times do not fully capture all the costs or benefits of a change in frequency. More complex appraisals may consider surveying values for these disbenefits which are often termed 'inconvenience' or 'scheduling' cost.

Sophisticated techniques exist for modelling and valuing the impact of travel times on many of the attributes associated with public transport (e.g. provision of information, seating whilst waiting, etc.). If the impact of such measures are to be modelled and valued the practitioner is referred to country appraisal manuals such as the Passenger Demand Forecasting Handbook (PDFH) in the UK (ATOC, 2002). It is outside the scope of these guidelines to provide such detailed advice.

Treatment of small time savings and sign of time saving

We recommend that a constant unit value for VTTS (i.e. per hour, per minute, per second) should be applied irrespective of the size or algebraic sign of the time saving. However, given the potential for errors in the measurement of small time savings within a transport model, we recommend that the proportion of the economic benefits derived from time savings attributable to small time savings (less than 3 minutes) is assessed.

Treatment of VTTS over time

For the estimation of future values of VTTS, we recommend to adjust the VTTS using an adjusted per capital growth rate of GDP. For the adjustment - in the absence of local data - a default inter-temporal elasticity to GDP per capita growth of 0.7 is recommended, with a sensitivity test at 1.0 (for all passenger travel purposes, work and non-work and also for commercial goods traffic).

0.3.3 Treatment of Congestion

Congestion can affect the performance and quality of the transport system in a number of ways: increased travel times; overcrowding in public transport; deterioration of the 'driving experience' with stop-start conditions; and reliability problems. The understanding is limited of people's preferences and the ability to model the effects brought about by a change in the transport system on many of these characteristics (except for increased average travel times). The technical challenge posed by modelling changes in reliability with existing methods and software cannot be overstated. At least a modelling system with a representation of space and time is required - congestion usually only affects certain parts of the transport network at

certain times of the day. The detailed representation of space and time within a modelling system can sometimes be at odds with the modelling simplifications necessary to analyse long distance (cross-European) trips that would be associated with the TEN-T.

Given the ready availability of data and tools to model the impacts of congestion it is felt that an appraisal should at least include changes in average travel times as a consequence of changing levels of congestion. More sophisticated appraisals, however, should consider the other impacts of congestion if data allow for.

Broadly speaking, there are two mutually exclusive approaches to modelling and appraising the reliability and quality impacts of congestion:

- Bottom-up approach- where each of the impacts is modelled separately. With this approach we recommend using:
 - Reliability: the standard deviation of the travel time can be used as the definition of reliability. Table 0.2 sets out the reliability ratios, which we recommend using in the absence of local data.
 - Quality: For public transport we recommend that a value of 1.5 times that of standard in-vehicle-time is used for passengers on public transport who have to stand in overcrowded conditions. There is insufficient evidence on the individual components that comprise quality of the driving experience in congested conditions to make a recommendation on such values.
- Top-down approach – where an aggregate transport indicator is used to reflect a variety of reliability and quality conditions. Within this approach we recommend using:
 - Road: if the volume to capacity ratio for a link is in excess of 1.0 then travel time could be valued at 1.5 times standard in-vehicle-time. Such a value represents a conflation of reliability and quality impacts.
 - Public transport: an alternative to explicitly modelling public transport reliability is to value average ‘delay’ or ‘lateness’ of services. In this situation we recommend using a VTTS value that is equivalent to that of waiting time (i.e. 2.5 times in-vehicle-time). Quality impacts associated with overcrowding are additional effects and therefore can also be included in the appraisal if this approach is adopted.

Table 0.2 Reliability ratios (Source: Hamer *et al.* (2005), Kouwenhoven *et al.* (2005a)).

Journey purpose	Mode	Reliability ratio*
Commuting (passenger)	Car	0.8
Business (passenger)	Car	0.8
Other (passenger)	Car	0.8
All (passenger)	Train	1.4
All (passenger)	Bus/tram/metro	1.4
Commercial Goods Traffic	Road	1.2

*The reliability ratio is the ratio of the value of one minute of standard deviation (i.e. value of reliability) to the value of one minute of average travel time.

There is little data on the value of congested conditions in airports, in train stations, on board airplanes and on board ships. If such conditions are considered important to the appraisal, it is recommended that local values are surveyed as part of the study.

0.3.4 Treatment of Uncertainty in VTTS values

Section 1.2 above identifies the recommendations for managing risk and uncertainty in an appraisal. As part of that analysis a number of sensitivity tests need to be undertaken. The following sensitivity tests for VTTS are recommended:

- VTTS values
 - *Local willingness-to-pay survey*: if VTTS values for the appraisal are derived from a local willingness-to-pay survey, then the appraisal results should be sensitivity tested to the upper and lower limits of the 95% confidence interval of the local VTTS values or +/- 10% whichever is larger.
 - *National VTTS values*: if the appraisal is conducted using values set out in the national appraisal guidance then the appraisal results should be sensitivity tested using values +/-20% of national VTTS values.
 - *Benefit transfer*: if the VTTS values have been derived from some form of benefit transfer procedure – such as the HEATCO meta-analysis – we recommend sensitivity testing the appraisal using values +/-40% of the benefit transfer values.
- Treatment of VTTS over time: uncertainty regarding the elasticity of GDP/capita growth implies that growth in VTTS over time should be sensitivity tested to elasticity to GDP/capita growth of 1.0.
- Small time savings: given the potential for errors in the measurement of small time savings within a transport model, the appraisal should be sensitivity tested by excluding time savings (positive and negative) below 3 minutes.

0.3.5 Implementation of VTTS Guidelines

The underlying principle regarding the implementation of the above guidelines is that values of travel time savings used in an appraisal should:

- (i) be developed according to the minimum standards set out above; and
- (ii) reflect the underlying willingness-to-pay (WTP) of the users of the transport network in the vicinity of the scheme and on the parts of the transport network(s) affected by the scheme.

The implication of this is that users of the transport system should be allocated a willingness-to-pay that reflects incomes, journey lengths and trip purposes. This may result in attributing national VTTS values. Obviously a trade-off exists between sophistication and the practicality of implementing a sophisticated approach in any particular country. Additionally, the effort which the analyst endures to obtain values that represent the underlying willingness-to-pay should also reflect the scale of the scheme: Obviously greater efforts should be made for large schemes with significant capital costs than for small schemes, where reasonable approximations to the underlying WTP maybe made. Some EU countries have well developed appraisal frameworks with large quantities of data available to the analyst whilst others do

not. In the latter situations it is unrealistic to expect scheme promoters to survey all the relevant data, therefore some values may have to be approximated and some may have to be imported from elsewhere. Appropriate assumptions will also have to be made in order to approximate the VTTS if the nationality or origins and destinations of traffic are unknown.

The calculation of the economic benefits associated with travel time savings is very straightforward. In essence it is the product of the five items of data:

- (i) **Demand** - the number of passengers/vehicles/goods traffic making a particular origin-destination trip in the Scenario “Do Minimum” (D_0) and in the Scenario “Do Something” (D_1);
- (ii) **Time saving** – the time saving experienced by the users making that particular origin-destination trip (T_0-T_1); and
- (iii) **VTTS** – the value of the travel time saving (for that segment of traffic)

The travel time saving element of the consumer surplus for that origin-destination trip is calculated using the rule of a half (see Chapter 4):

$$\frac{1}{2}(D_0+D_1)*(T_0-T_1)*VTTS$$

The total user benefit from travel time savings is the sum of all time saving related consumer surpluses for all origin-destination movements.

Some vehicle operating cost models for commercial goods vehicles and business traffic include the time elements of the journey (e.g. driver and crew wages). Care should be taken in such situations to avoid double counting this component in both time and vehicle operating cost benefits, both in modelling and appraisal.

It is our recommendation that modelling and appraisal values should reflect the same underlying willingness-to-pay of the transport users and should only differ in their unit of account. Basing values of time within an appraisal on underlying willingness-to-pay has implications for the equitable treatment of people with different incomes within the appraisal framework. It is therefore recommended that the analyst in addition to reporting the aggregate monetised travel time savings benefits also reports the absolute time savings and the income brackets of the users to whom they accrue.

Table 0.3 Estimated VTTS values – work (business) passenger trips (€₂₀₀₂ per passenger per hour, factor prices)

Country	Business		
	Air	Bus	Car, Train
Austria	39.11	22.79	28.40
Belgium	37.79	22.03	27.44
Cyprus	29.04	16.92	21.08
Czech Republic	19.65	11.45	14.27
Denmark	43.43	25.31	31.54
Estonia	17.66	10.30	12.82
Finland	38.77	22.59	28.15
France	38.14	22.23	27.70
Germany	38.37	22.35	27.86
Greece	26.74	15.59	19.42
Hungary	18.62	10.85	13.52
Ireland	41.14	23.97	29.87
Italy	35.29	20.57	25.63
Latvia	16.15	9.41	11.73
Lithuania	15.95	9.29	11.58
Luxembourg	52.36	30.51	38.02
Malta	25.67	14.96	18.64
Netherlands	38.56	22.47	28.00
Poland	17.72	10.33	12.87
Portugal	26.63	15.52	19.34
Slovakia	17.02	9.92	12.36
Slovenia	25.88	15.08	18.80
Spain	30.77	17.93	22.34
Sweden	41.72	24.32	30.30
United Kingdom	39.97	23.29	29.02
EU (25 Countries)	32.80	19.11	23.82
Switzerland	45.41	26.47	32.97

Table 0.4 Estimated VTTS values – non-work passenger trips (€₂₀₀₂ per passenger per hour, factor prices)

Country	Commute-Short Distance			Commute-Long Distance			Other-Short Distance			Other-Long Distance		
	Air	Bus	Car, train	Air	Bus	Car, train	Air	Bus	Car, train	Air	Bus	Car, train
Austria	11.98	5.78	8.03	15.40	7.42	10.32	10.05	4.84	6.73	12.91	6.22	8.65
Belgium	11.44	5.51	7.67	14.68	7.07	9.84	9.59	4.62	6.43	12.31	5.93	8.26
Cyprus	11.83	5.70	7.93	15.18	7.32	10.18	9.92	4.78	6.65	12.74	6.14	8.53
Czech Republic	8.57	4.13	5.75	11.00	5.31	7.38	7.19	3.46	4.82	9.23	4.45	6.18
Denmark	12.64	6.09	8.48	16.23	7.82	10.88	10.60	5.11	7.11	13.61	6.56	9.12
Estonia	7.44	3.58	4.99	9.55	4.60	6.40	6.24	3.01	4.18	8.01	3.86	5.36
Finland	11.31	5.45	7.58	14.52	7.00	9.73	9.48	4.57	6.36	12.17	5.87	8.16
France	16.34	7.87	10.95	20.97	10.11	14.06	13.70	6.60	9.18	17.58	8.47	11.79
Germany	11.99	5.78	8.04	15.40	7.42	10.32	10.05	4.85	6.74	12.91	6.22	8.65
Greece	10.34	4.98	6.93	13.28	6.40	8.90	8.67	4.18	5.82	11.14	5.37	7.46
Hungary	7.53	3.63	5.05	9.68	4.66	6.48	6.31	3.04	4.23	8.11	3.91	5.44
Ireland	12.51	6.03	8.39	16.07	7.74	10.77	10.49	5.06	7.04	13.48	6.49	9.03
Italy	15.16	7.31	10.16	19.47	9.38	13.04	12.71	6.12	8.52	16.32	7.86	10.94
Latvia	6.79	3.27	4.55	8.72	4.20	5.85	5.69	2.74	3.82	7.31	3.52	4.90
Lithuania	6.62	3.19	4.43	8.49	4.09	5.69	5.55	2.67	3.72	7.12	3.43	4.77
Luxembourg	17.77	8.60	11.91	22.82	11.00	15.30	14.90	7.18	9.99	19.13	9.22	12.83
Malta	9.73	4.69	6.53	12.50	6.02	8.37	8.17	3.93	5.47	10.48	5.05	7.02
Netherlands	11.59	5.59	7.77	14.88	7.17	9.97	9.72	4.68	6.52	12.48	6.01	8.37
Poland	7.36	3.55	4.94	9.46	4.56	6.34	6.17	2.97	4.14	7.93	3.82	5.32
Portugal	9.97	4.81	6.69	12.81	6.18	8.59	8.36	4.03	5.61	10.74	5.17	7.20
Slovakia	6.87	3.31	4.60	8.82	4.25	5.91	5.76	2.78	3.86	7.40	3.57	4.96
Slovenia	12.00	5.78	8.04	15.40	7.42	10.33	10.06	4.85	6.74	12.92	6.22	8.66
Spain	12.72	6.12	8.52	16.33	7.87	10.94	10.66	5.13	7.15	13.69	6.59	9.18
Sweden	12.24	5.90	8.20	15.71	7.57	10.53	10.26	4.94	6.88	13.17	6.35	8.83
United Kingdom	12.44	5.99	8.34	15.97	7.69	10.70	10.43	5.02	6.99	13.39	6.46	8.98
EU (25 Countries)	12.65	6.10	8.48	16.25	7.83	10.89	10.61	5.11	7.11	13.62	6.56	9.13
Switzerland	16.74	8.06	11.22	21.49	10.36	14.41	14.03	6.76	9.40	18.02	8.69	12.08

Table 0.5 Estimated VTTS values – freight trips (€₂₀₀₂ per freight tonne per hour, factor prices)

Country	Per tonne of freight carried ¹	
	Road	Rail
Austria	3.37	1.38
Belgium	3.29	1.35
Cyprus	2.73	1.12
Czech Republic	2.06	0.84
Denmark	3.63	1.49
Estonia	1.90	0.78
Finland	3.34	1.37
France	3.32	1.36
Germany	3.34	1.37
Greece	2.55	1.05
Hungary	1.99	0.82
Ireland	3.48	1.43
Italy	3.14	1.30
Latvia	1.78	0.73
Lithuania	1.76	0.72
Luxembourg	4.14	1.70
Malta	2.52	1.04
Netherlands	3.35	1.38
Poland	1.92	0.78
Portugal	2.58	1.06
Slovakia	1.86	0.77
Slovenia	2.51	1.03
Spain	2.84	1.17
Sweden	3.53	1.45
United Kingdom	3.42	1.40
EU (25 Countries)	2.98	1.22
Switzerland	3.75	1.54

¹ Value per tonne of freight carried and not for the maximum load of the vehicle or the weight of the vehicle.

Table 0.6 Estimated VTTS values – work (business) passenger trips (€₂₀₀₂ PPP per passenger per hour, factor prices)

Country	Business		
	Air	Bus	Car, train
Austria	37.50	21.85	27.23
Belgium	36.94	21.53	26.82
Cyprus	32.92	19.18	23.90
Czech Republic	36.59	21.31	26.57
Denmark	33.05	19.26	24.00
Estonia	31.76	18.52	23.07
Finland	34.61	20.17	25.13
France	36.57	21.31	26.56
Germany	34.53	20.12	25.07
Greece	34.07	19.86	24.74
Hungary	34.05	19.84	24.72
Ireland	35.43	20.65	25.73
Italy	36.91	21.51	26.81
Latvia	31.79	18.53	23.09
Lithuania	33.31	19.39	24.17
Luxembourg	46.14	26.88	33.50
Malta	36.99	21.56	26.85
Netherlands	36.13	21.06	26.24
Poland	32.34	18.85	23.48
Portugal	34.91	20.34	25.34
Slovakia	38.67	22.54	28.09
Slovenia	34.98	20.38	25.40
Spain	35.74	20.83	25.95
Sweden	35.24	20.54	25.59
United Kingdom	35.56	20.72	25.82
EU (25 Countries)	32.80	19.11	23.82
Switzerland	31.87	18.57	23.14

Table 0.7 Estimated VTTS values – non-work passenger trips (€₂₀₀₂ PPP per passenger per hour, factor prices)

Country	Commute-Short Distance			Commute-Long Distance			Other-Short Distance			Other-Long Distance		
	Air	Bus	Car, train	Air	Bus	Car, train	Air	Bus	Car, train	Air	Bus	Car, train
Austria	11.49	5.54	7.70	14.76	7.11	9.89	9.63	4.64	6.46	12.37	5.96	8.30
Belgium	11.18	5.38	7.50	14.35	6.91	9.62	9.37	4.51	6.28	12.03	5.80	8.07
Cyprus	13.41	6.46	8.99	17.22	8.29	11.54	11.25	5.42	7.54	14.44	6.96	9.68
Czech Republic	15.97	7.70	10.70	20.49	9.88	13.75	13.38	6.44	8.98	17.19	8.28	11.51
Denmark	9.62	4.64	6.45	12.35	5.95	8.28	8.07	3.89	5.41	10.36	4.99	6.94
Estonia	13.37	6.44	8.97	17.18	8.28	11.52	11.22	5.41	7.52	14.41	6.95	9.65
Finland	10.10	4.87	6.77	12.96	6.25	8.69	8.47	4.08	5.68	10.87	5.24	7.29
France	15.66	7.55	10.50	20.11	9.69	13.48	13.13	6.33	8.80	16.86	8.12	11.30
Germany	10.80	5.20	7.23	13.86	6.68	9.29	9.05	4.36	6.07	11.62	5.60	7.79
Greece	13.18	6.35	8.83	16.92	8.16	11.34	11.05	5.32	7.41	14.18	6.84	9.51
Hungary	13.77	6.64	9.24	17.69	8.52	11.86	11.54	5.56	7.74	14.83	7.15	9.94
Ireland	10.78	5.19	7.23	13.84	6.67	9.28	9.04	4.36	6.06	11.61	5.59	7.78
Italy	15.86	7.64	10.63	20.36	9.81	13.64	13.29	6.40	8.91	17.07	8.23	11.45
Latvia	13.37	6.44	8.96	17.17	8.27	11.51	11.21	5.40	7.52	14.39	6.93	9.65
Lithuania	13.81	6.66	9.25	17.73	8.54	11.88	11.58	5.58	7.76	14.87	7.17	9.96
Luxembourg	15.66	7.57	10.50	20.11	9.69	13.48	13.13	6.33	8.80	16.86	8.12	11.30
Malta	14.03	6.76	9.40	18.01	8.68	12.07	11.77	5.66	7.89	15.11	7.28	10.12
Netherlands	10.86	5.24	7.28	13.95	6.72	9.35	9.11	4.39	6.11	11.70	5.64	7.84
Poland	13.44	6.48	9.01	17.26	8.32	11.56	11.27	5.43	7.55	14.48	6.97	9.71
Portugal	13.07	6.30	8.77	16.79	8.10	11.26	10.96	5.29	7.35	14.08	6.78	9.43
Slovakia	15.61	7.52	10.46	20.04	9.66	13.44	13.09	6.32	8.78	16.81	8.11	11.26
Slovenia	16.21	7.82	10.87	20.82	10.03	13.96	13.59	6.55	9.11	17.45	8.41	11.70
Spain	14.77	7.11	9.90	18.96	9.14	12.71	12.38	5.96	8.30	15.90	7.66	10.66
Sweden	10.34	4.98	6.93	13.27	6.40	8.89	8.66	4.17	5.81	11.12	5.36	7.46
United Kingdom	11.07	5.33	7.42	14.21	6.84	9.52	9.28	4.47	6.22	11.91	5.74	7.99
EU (25 Countries)	12.65	6.10	8.48	16.25	7.83	10.89	10.61	5.11	7.11	13.62	6.56	9.13
Switzerland	11.75	5.66	7.88	15.08	7.27	10.11	9.85	4.74	6.60	12.65	6.10	8.48

Table 0.8 Estimated VTTS values – freight trips (€₂₀₀₂ PPP per freight tonne per hour, factor prices)

Country	Per tonne of freight carried ¹	
	Road	Rail
Austria	3.23	1.33
Belgium	3.22	1.32
Cyprus	3.10	1.27
Czech Republic	3.83	1.57
Denmark	2.76	1.14
Estonia	3.41	1.40
Finland	2.98	1.22
France	3.18	1.30
Germany	3.01	1.24
Greece	3.25	1.34
Hungary	3.64	1.49
Ireland	3.00	1.23
Italy	3.29	1.36
Latvia	3.50	1.43
Lithuania	3.67	1.50
Luxembourg	3.64	1.50
Malta	3.64	1.50
Netherlands	3.14	1.29
Poland	3.51	1.43
Portugal	3.39	1.39
Slovakia	4.24	1.74
Slovenia	3.39	1.39
Spain	3.30	1.36
Sweden	2.98	1.22
United Kingdom	3.04	1.25
EU (25 Countries)	2.98	1.22
Switzerland	2.63	1.08

¹ Value per tonne of freight carried and not for the maximum load of the vehicle or the weight of the vehicle.

0.4 Value of changes in accident risks

The recommendations given in the following, focus on a consistent set of monetary values for assessing accident risks and of factors for correcting underreporting for accident risks based on accident statistics. We assume that procedures for estimating accident risks for fatalities, severe and slight injuries have been established in the project planning process and are thus available for the appraisal.

We adopt a modified accident impact definition based on EUNET (Nellthorp et al. 1998)

- Fatality: death arising from the accident.
- Serious injury: casualties which require hospital treatment and have lasting injuries, but the victim does not die within the fatality recording period.
- Slight injury: casualties whose injuries do not require hospital treatment or, if they do, the effect of the injury quickly subsides.
- Damage-only accident: accident without casualties.

A 30 day period restriction for fatalities, as given in the original definition, is a pragmatic simplification for accident reporting, because it would be quite demanding to observe all severely injured persons for a longer time period, say e.g. 60 days. As there is evidence for considerable under-reporting due to the 30 day limit, we recommend correcting the available statistical data to include all fatalities due to accidents (see below).

It would be appropriate to distinguish at least between serious injuries entailing permanent invalidity and serious injuries where victims virtually recover entirely. However, often the necessary data are not available. Thus due to data limitations we recommend to use the EUNET definition as default.

Underreporting of road accidents is a well recognized problem in official (road) accident statistics. Therefore, the official figures underestimate the true number of accidents. Based on a literature review, we conclude that underreporting of accidents is only relevant for road transport. We recommend to apply the correction factors for unreported accidents (= ratio all accidents / reported accidents) as given in Table 0.9. The correction factor given for fatalities of 1.02 should be applied in all countries alike, since here the problem is not underreporting, but that some victims die after expiry of the recording period of 30 days.

Table 0.9 Recommendation for European average correction factors for unreported road accidents.

	Fatality	Serious injury	Slight injury	Average injury	Damage only
Average	1.02	1.50	3.00	2.25	6.00
Car	1.02	1.25	2.00	1.63	3.50
Motorbike/moped	1.02	1.55	3.20	2.38	6.50
Bicycle	1.02	2.75	8.00	5.38	18.50
Pedestrian	1.02	1.35	2.40	1.88	4.50

The valuation of an accident can be divided into direct economic costs, indirect economic costs and a value of safety per se. We recommend using values as follows:

- a) Value of safety per se: WTP for safeguarding human life based on stated preference studies carried out in the country concerned.
- b) Direct and indirect economic costs (mainly medical and rehabilitation cost, administrative cost of legal system, and production losses): cost values for the country under assessment.
- c) Material damage from accidents: cost values for the average damage caused by accidents in the country under assessment.

If such values are not available for a) and b) the values provided in Table 0.10 may be used. The split into value of safety per se and economic costs is given in the main text. The values expressed in PPPs, show a much smaller range.

Since the uncertainties in estimating the value of safety per se are comparably large, we recommend carrying out a sensitivity analysis for this value. Based on European Commission (2005) we recommend using $\sqrt{3}$ as lower boundary and $\sqrt{3}$ as high boundary of the sensitivity analysis (with v = value of safety per se).

Wherever possible, the values used in demand modelling and valuation of effects should be consistent. If the values used in demand modelling comply with the requirements above, these should be used for valuation. If this is not the case the values, given in Table 0.10 should be used for demand modelling.

Table 0.10 Estimated values for casualties avoided.

Country	Fatality	Severe injury	Slight injury	Fatality	Severe injury	Slight injury
	(€ ₂₀₀₂ , factor prices)			(€ ₂₀₀₂ PPP, factor prices)		
Austria	1,760,000	240,300	19,000	1,685,000	230,100	18,200
Belgium	1,639,000	249,000	16,000	1,603,000	243,200	15,700
Cyprus	704,000	92,900	6,800	798,000	105,500	7,700
Czech Republic	495,000	67,100	4,800	932,000	125,200	9,100
Denmark	2,200,000	272,300	21,300	1,672,000	206,900	16,200
Estonia	352,000	46,500	3,400	630,000	84,400	6,100
Finland	1,738,000	230,600	17,300	1,548,000	205,900	15,400
France	1,617,000	225,800	17,000	1,548,000	216,300	16,200
Germany	1,661,000	229,400	18,600	1,493,000	206,500	16,700
Greece	836,000	109,500	8,400	1,069,000	139,700	10,700
Hungary	440,000	59,000	4,300	808,000	108,400	7,900
Ireland	2,134,000	270,100	20,700	1,836,000	232,600	17,800
Italy	1,430,000	183,700	14,100	1,493,000	191,900	14,700
Latvia	275,000	36,700	2,700	534,000	72,300	5,200
Lithuania	275,000	38,000	2,700	575,000	78,500	5,700
Luxembourg	2,332,000	363,700	21,900	2,055,000	320,200	19,300
Malta	1,001,000	127,800	9,500	1,445,000	183,500	13,700
Netherlands	1,782,000	236,600	19,000	1,672,000	221,500	17,900
Norway	2,893,000	406,000	29,100	2,055,000	288,300	20,700
Poland	341,000	46,500	3,300	630,000	84,500	6,100
Portugal	803,000	107,400	7,400	1,055,000	141,000	9,700
Slovakia	308,000	42,100	3,000	699,000	96,400	6,900
Slovenia	759,000	99,000	7,300	1,028,000	133,500	9,800
Spain	1,122,000	138,900	10,500	1,302,000	161,800	12,200
Sweden	1,870,000	273,300	19,700	1,576,000	231,300	16,600
Switzerland	2,574,000	353,800	27,100	1,809,000	248,000	19,100
United Kingdom	1,815,000	235,100	18,600	1,617,000	208,900	16,600

Notes: Value of safety per se based on UNITE (see Nellthorp et al., 2001): fatality €1.50 million (market price 1998 – €1.25 million factor costs 2002); severe/slight injury 0.13/0.01 of fatality; Direct and indirect economic costs: fatality 0.10 of value of safety per se; severe and slight injury based on European Commission (1994).

We recommend increasing values for future years based on a default inter-temporal elasticity to GDP per capita growth of 1.0. If accident costs prove to contribute an important part of the benefits quantified in an assessment, we recommend sensitivity testing with an income elasticity of 0.7.

Please note that the assumption of linearly growing values clearly requires explicit and careful demand modelling over time. If this is not the case, the results are likely to overestimate benefits from a transport project.

The recommended calculation procedure is as follows:

- Step 1:** quantification of changes in the number of fatalities, serious injuries, slight injuries, and material damage due to a project using local or national risk functions.
- Step 2:** adjustment for underreporting of casualties with national (if available) or European factors.
- Step 3:** preparation of the cost factor table by increasing the cost factor according to the assumed country-specific GDP per capita growth for each year of the analysis.
- Step 4:** multiplication of casualties with cost factors.
- Step 5:** reporting of casualties and costs.

0.5 Environmental costs

Our general recommendation is – wherever possible – to value impacts, not environmental burden (for example value mortality risks caused by PM₁₀ emissions and not the emissions of PM₁₀) and to monetise impacts as far as possible using values based on the WTP concept. To increase transparency and allow for alternative valuations both costs and (key) impacts should be reported.

In the following sections we provide values that can be used if no country-specific state-of-the-art values are available for calculating environmental costs due to air pollution, noise and global warming.

0.5.1 Air pollution

We recommend using country-specific values taking into account local population density and regional climate. Cost factors measured in € per tonne of pollutant emitted in different environments (urban areas, outside built-up areas) are provided below. The list of pollutants should cover

- primary PM_{2.5} for transport emissions (PM₁₀ for emissions from power plants),
- NO_x as precursor of nitrate aerosols and ozone,
- SO₂ for direct effects and as precursor of sulphate aerosols, and
- NMVOC as precursor of ozone.

Project related emissions should be calculated using national emission factors; if such factors are not available, emission factors from international sources can be applied, taking into account national vehicle fleet compositions as far as possible.

Existing research identified damage to human health as the most important effect in terms of quantifiable costs. In particular the reduction of life expectancy in terms of Years of Life Lost (YOLL) contributes to health costs. Therefore, YOLL is a good indicator for physical impacts caused.

Table 0.11 presents the recommended cost factors in € per tonne of pollutant emitted by road and other ground level transport (e.g. diesel trains), Please note however, that the monetary values given do not only assess YOLLs, but include a number of other health impacts and in addition damage to crops and materials. Table 0.13 presents the impact factors. The corresponding values for high stack emissions from electricity production in power plants are given in the main text.

The cost factors are estimated average values based on the spatial distribution of emissions within a country. The impacts and costs may vary within one country, particularly in large ones. The variation in costs due to NO_x, NMVOC and SO₂ between countries is mainly caused by air chemistry (incl. ozone formation) and the population affected. For primary particulates no air chemistry is involved, therefore differences reflect the number of population affected, which is determined mainly by distance to the emission source and the prevailing wind direction.

The PPP adjusted values in Table 0.12 differ from the values in Table 0.11 only for costs due to primary particle emissions. NO_x, NMVOC and SO₂ have virtually no local effects as most of their impact is caused after chemical transformation to other substances (ammonium nitrates and sulphates, ozone); damages occur far from the emission source, mostly in other countries. For keeping modelling effort reasonable trans-boundary impacts are valued at European average values. Rounding masks differences between € and PPP results. In contrast, for primary particles local effects play an important role, therefore the PPP weighted cost factors differ from those expressed in real €.

Table 0.11 Cost factors for road transport emissions* per tonne of pollutant emitted in €₂₀₀₂ (factor prices).

Pollutant emitted	NO _x	NM VOC	SO ₂	PM _{2.5}	
Effective pollutant	O ₃ , Nitrates, Crops	O ₃	Sulphates, Acid deposition, Crops	primary PM _{2.5}	
Local environment				urban	outside built-up areas
Austria	4,300	600	3,900	450,000	73,000
Belgium	2,700	1,100	5,400	440,000	95,000
Cyprus**	500	1,100	500	230,000	20,000
Czech Republic	3,200	1,100	4,100	170,000	61,000
Denmark	1,800	800	1,900	520,000	54,000
Estonia	1,400	500	1,200	100,000	23,000
Finland	900	200	600	400,000	33,000
France	4,600	800	4,300	430,000	83,000
Germany	3,100	1,100	4,500	430,000	80,000
Greece	2,200	600	1,400	210,000	34,000
Hungary	5,000	800	4,100	150,000	54,000
Ireland	2,000	400	1,600	510,000	50,000
Italy	3,200	1,600	3,500	370,000	70,000
Latvia	1,800	500	1,400	80,000	22,000
Lithuania	2,600	500	1,800	90,000	28,000
Luxemburg	4,800	1,400	4,900	590,000	96,000
Malta (O ₃ estimated)	500	1,100	500	170,000	16,000
Netherlands	2,600	1,000	5,000	470,000	88,000
Poland	3,000	800	3,500	130,000	53,000
Portugal	2,800	1,000	1,900	210,000	37,000
Slovakia	4,600	1,100	3,800	110,000	49,000
Slovenia	4,400	700	4,000	220,000	55,000
Spain	2,700	500	2,100	280,000	41,000
Sweden	1,300	300	1,000	440,000	40,000
Switzerland	4,500	600	3,900	640,000	86,000
United Kingdom	1,600	700	2,900	450,000	67,000

Notes: Cost categories included are: human health, crop losses, material damages.

* Values are applicable to all emissions at ground level (e.g. diesel locomotives).

** Estimated values as Cyprus outside of modelling domain.

Table 0.12 Cost factors for road transport emissions* per tonne of pollutant emitted in €₂₀₀₂ PPP (factor prices).

Pollutant emitted	NO _x	NM VOC	SO ₂	PM _{2.5}	
Effective pollutant	O ₃ , Nitrates, Crops	O ₃	Sulphates, Acid deposition, Crops	primary PM _{2.5}	
Local environment				urban	outside built-up areas
Austria	4,300	600	3,900	430,000	72,000
Belgium	2,700	1,100	5,400	440,000	95,000
Cyprus**	500	1,100	500	260,000	22,000
Czech Republic	3,200	1,100	4,100	270,000	67,000
Denmark	1,800	800	1,900	400,000	47,000
Estonia	1,400	500	1,200	160,000	27,000
Finland	900	200	600	360,000	30,000
France	4,600	800	4,300	410,000	82,000
Germany	3,100	1,100	4,500	400,000	78,000
Greece	2,200	600	1,400	270,000	38,000
Hungary	5,000	800	4,100	230,000	59,000
Ireland	2,000	400	1,600	440,000	46,000
Italy	3,200	1,600	3,500	390,000	71,000
Latvia	1,800	500	1,400	140,000	26,000
Lithuania	2,600	500	1,800	160,000	32,000
Luxemburg	4,800	1,400	4,900	730,000	104,000
Malta (O ₃ estimated)	500	1,100	500	240,000	20,000
Netherlands	2,600	1,000	5,000	440,000	86,000
Poland	3,000	800	3,500	190,000	57,000
Portugal	2,800	1,000	1,900	270,000	40,000
Slovakia	4,600	1,100	3,800	200,000	54,000
Slovenia	4,400	700	4,000	280,000	58,000
Spain	2,700	500	2,100	320,000	44,000
Sweden	1,300	300	1,000	370,000	36,000
Switzerland	4,500	600	3,900	460,000	76,000
United Kingdom	1,600	700	2,900	410,000	64,000

Notes: Cost categories included are: human health, crop losses, material damages.

* Values are applicable to all emissions at ground level (e.g. diesel locomotives).

** Estimated values as Cyprus outside of modelling domain.

Table 0.13 Impact factors for road transport emissions* (lost life expectancy in years of life lost per 1000 tonnes of pollutant emitted).

Pollutant emitted	NO_x	NMVOC	SO₂	PM_{2.5}	
Effective pollutant	O3, Nitrates	O3	Sulphates	primary PM_{2.5}	
Local environment				urban	outside built-up areas
Austria	61	0.6	58	5,800	1,080
Belgium	57	1.3	81	6,200	1,470
Cyprus**	8	0.5	8	5,100	400
Czech Republic	50	1.0	58	5,900	1,180
Denmark	29	0.9	28	5,400	680
Estonia	18	1.5	17	5,300	590
Finland	11	0.2	9	5,100	450
France	65	0.8	65	6,000	1,280
Germany	53	1.2	65	5,900	1,220
Greece	20	0.2	20	5,400	670
Hungary	63	0.6	58	5,800	1,080
Ireland	30	0.7	25	5,300	640
Italy	50	0.8	54	5,800	1,120
Latvia	22	0.9	21	5,300	590
Lithuania	29	0.9	26	5,400	690
Luxemburg	70	1.5	73	6,000	1,330
Malta (O ₃ estimated)	8	0.5	8	5,100	400
Netherlands	56	1.1	74	6,000	1,320
Poland	46	0.8	49	5,800	1,070
Portugal	31	0.5	30	5,400	720
Slovakia	57	1.0	55	5,700	1,020
Slovenia	63	0.5	59	5,700	1,020
Spain	34	0.4	33	5,400	720
Sweden	15	0.4	15	5,200	530
Switzerland	68	0.7	59	5,800	1,120
United Kingdom	35	1.0	44	5,700	980

Notes: * values are applicable to all emissions at ground level (e.g. diesel locomotives).

** Estimated values as Cyprus outside of modelling domain.

We recommend increasing values for future years based on a default inter-temporal elasticity to GDP per capita growth of 1.0. If air pollution costs prove to contribute an important part of the benefits quantified in an assessment we recommend sensitivity testing with an income elasticity of 0.7.

Please note that the assumption of linearly growing values over time clearly requires explicit and careful emission modelling over time. If this is not the case, the results are likely to over-estimate benefits from a transport project, as vehicle emissions can be assumed to decrease considerably in the future. Information on the future development of emission factors can be found for instance at <http://www.tremove.org/download/index.htm>.

The recommended calculation procedure is as follows:

- Step 1:** quantification of change in pollutant emissions (NO_x, SO₂, NMVOC, PM_{2.5}/PM₁₀) due to a project, measured in tonnes, using state-of-the-art national or European emission factors.
- Step 2:** classification of emissions according to height of emission sources (ground-level vs. high stack) and local environment (urban – outside built-up areas). Ground level emissions are released from internal combustion engines, high stack emissions are released during electricity production in power plants.
- Step 3:** preparation of the cost factor table by increasing the cost factor according to the assumed country-specific GDP per capita growth for each year of the analysis.
- Step 4:** calculation of impacts (multiplication of pollutant emissions by impact factor) and costs (multiplication of pollutant emissions by cost factor).
- Step 5:** reporting of impacts and costs.

0.5.2 Noise

For noise costs it is suggested to use country-specific values per person exposed to a certain noise level (see Table 0.14). The suggested impact indicator, which should be reported alongside with the monetary results, is the number of persons highly annoyed – see Table 0.15.

We recommend increasing monetary values for future years based on a default inter-temporal elasticity to GDP per capita growth of 1.0. If noise costs prove to contribute an important part of the benefits quantified in an assessment we recommend sensitivity testing with an income elasticity of 0.7.

Please note that the assumption of linearly growing values over time clearly requires explicit and careful emission modelling over time. If this is not the case, the results are likely to over-estimate benefits from a transport project, as vehicle emissions are likely to decrease in the future.

The recommended calculation procedure is as follows:

- Step 1:** quantification of the number of persons exposed to certain noise levels (should be available from noise calculations) for the Do-Minimum case and the Do-Something case.
- Step 2:** preparation of the cost factor table by increasing the cost factor according to the assumed country-specific GDP per capita growth for each year of the analysis.
- Step 3:** calculation of impacts (multiply percentage of highly annoyed persons by number of persons exposed) and costs (multiply cost per person by number of persons exposed) for both cases.
- Step 4:** subtraction of total costs for the Do-Something case from Do-Minimum case
- Step 5:** reporting of costs and impacts (change in number of people highly annoyed).

Table 0.14 Cost factors for noise exposure for Finland (€₂₀₀₂, factor costs, per year per person exposed; to derive €₂₀₀₂ PPP the values below are divided by the Finish PPP adjustment factor of 1.12). For values for all countries see main text.

Finland L _{den} (dB(A))	Central values			New approach			High values		
	Road	Rail	Aircraft	Road	Rail	Aircraft	Road	Rail	Aircraft
≥43	0	0	0	6	3	10	0	0	0
≥44	0	0	0	6	3	11	0	0	0
≥45	0	0	0	7	3	12	0	0	0
≥46	0	0	0	8	4	14	0	0	0
≥47	0	0	0	9	4	15	0	0	0
≥48	0	0	0	10	5	16	0	0	0
≥49	0	0	0	11	6	18	0	0	0
≥50	0	0	0	12	6	19	0	0	0
≥51	10	0	16	13	7	20	23	0	36
≥52	20	0	32	14	7	22	47	0	72
≥53	31	0	47	15	8	23	70	0	108
≥54	41	0	63	17	9	25	93	0	144
≥55	51	0	79	18	10	26	116	0	180
≥56	61	10	95	19	10	27	140	23	216
≥57	71	20	110	20	11	29	163	47	252
≥58	81	31	126	22	12	30	186	70	288
≥59	92	41	142	23	13	32	209	93	324
≥60	102	51	158	24	14	33	233	116	360
≥61	112	61	174	26	15	35	256	140	397
≥62	122	71	189	27	16	36	279	163	433
≥63	132	81	205	29	17	38	302	186	469
≥64	143	92	221	30	18	39	326	209	505
≥65	153	102	237	32	19	40	349	233	541
≥66	163	112	252	33	20	42	372	256	577
≥67	173	122	268	35	21	43	395	279	613
≥68	183	132	284	36	22	45	419	302	649
≥69	193	143	300	38	23	46	442	326	685
≥70	204	153	316	40	24	48	465	349	721
≥71	270	219	388	98	82	106	545	429	813
≥72	287	236	410	106	90	114	575	459	856
≥73	304	253	433	115	98	122	605	489	899
≥74	321	270	456	123	106	130	635	519	942
≥75	338	287	478	132	114	139	665	549	985
≥76	355	305	501	140	122	147	695	579	1028
≥77	372	322	524	149	131	155	725	609	1071
≥78	390	339	546	158	139	163	756	639	1114
≥79	407	356	569	166	147	172	786	669	1157
≥80	424	373	592	175	155	180	816	700	1200
≥81	441	390	614	183	164	188	846	730	1242

Notes: All values include health effects and annoyance. Central values comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003). For “New approach” annoyance was based on dose-response functions; monetary values were taken from the HEATCO surveys (see Navrud et al. 2006). High values include annoyance valuation based on hedonic pricing as applied in UNITE (see Bickel et al. 2003).

Table 0.15 Impact indicator for noise exposure: percentage of adult persons highly annoyed per person (all ages) exposed – based on functions given in European Commission (2002), assuming 80% of population are adults.

L_{den}	Road	Rail	Aircraft
dB(A)	%	%	%
≥43	0.4	0.1	0.3
≥44	0.8	0.3	0.6
≥45	1.1	0.4	1.0
≥46	1.5	0.5	1.4
≥47	1.9	0.6	2.0
≥48	2.2	0.7	2.5
≥49	2.6	0.8	3.2
≥50	2.9	1.0	3.9
≥51	3.3	1.1	4.6
≥52	3.7	1.3	5.4
≥53	4.2	1.5	6.3
≥54	4.6	1.7	7.2
≥55	5.1	2.0	8.2
≥56	5.6	2.3	9.3
≥57	6.2	2.6	10.4
≥58	6.8	2.9	11.5
≥59	7.5	3.3	12.7
≥60	8.3	3.8	14.0
≥61	9.0	4.3	15.3
≥62	9.9	4.8	16.7
≥63	10.8	5.4	18.1
≥64	11.9	6.1	19.6
≥65	12.9	6.8	21.2
≥66	14.1	7.6	22.7
≥67	15.4	8.5	24.4
≥68	16.8	9.5	26.1
≥69	18.2	10.5	27.8
≥70	19.8	11.6	29.6
≥71	21.5	12.8	31.5
≥72	23.3	14.1	33.4
≥73	25.2	15.4	35.3
≥74	27.2	16.9	37.3
≥75	29.4	18.4	39.4
≥76	31.7	20.1	41.5
≥77	34.1	21.9	43.6
≥78	36.7	23.8	45.8
≥79	39.4	25.8	48.0
≥80	42.3	27.9	50.3
≥81	45.3	30.1	52.6

0.5.3 Global warming

The method of calculating costs due to the emission of greenhouse gases (usually expressed as CO₂ equivalents) basically consists of multiplying the amount of CO₂ equivalents emitted with a cost factor. Due to the global scale of the damage caused, there is no difference how and where in Europe the emissions of greenhouse gases take place. For this reason, we recommend to apply the same values in all countries. However the factor proposed is dependent on when (in which year) the emission takes place.

The CO₂ equivalent of a greenhouse gas is derived by multiplying the amount of the gas by the associated Global Warming Potential (GWP). The GWP for methane is 23, for nitrous oxide 296, and for CO₂ it is 1.

In high altitudes other emissions than CO₂ from aircrafts have a considerable climatic effect. The most important species are water vapour, sulphate and soot aerosols and nitrogen oxides. In 1999 the Intergovernmental Panel on Climate Change (IPCC) estimated that aviation's total impact is about 2 to 4 times higher than the effect of its past CO₂ emissions alone. Recent EU research results (see European Commission, 2005b, Annex 2) indicate that this ratio may be somewhat smaller (around a factor 2). Accordingly we recommend multiplying high altitude CO₂ emissions by a factor of 2 to consider the warming effect of other species than CO₂.

Recent work has confirmed the assumption that future emissions years will have stronger total impacts than present emissions (see e.g. Watkiss et al.; 2005a). Consequently for transport project appraisals, we need value estimates that include future increases. In a recent report for the Social Cost of Carbon Review on behalf of UK's Defra, Watkiss et al. (2005b) derive shadow price values, taking into account the expected future development of damage costs and abatement costs. This study is the most current and comprehensive exercise providing consistent values for CO₂ emissions for application in project appraisal. Whereas the damage cost estimates do not rely on specific assumptions for the UK, the abatement cost estimates are based on UK government's long-term goal of meeting a 60% CO₂ reduction by 2050 (which is broadly consistent with the EU's 2°C target). On one hand the costs for reaching a domestic reduction of 60% are higher than implementing a more flexible reduction scheme. On the other hand, the abatement costs only influence the cost curve for later years (starting around 2030) when uncertainties are higher. In addition, the damage cost estimates do not include some important risks. We recommend using the guidance value given in Table 0.16 as central estimate, with the lower and upper estimate for sensitivity analysis.

We recommend no additional increasing of the values in Table 0.16 with GDP growth, as we assume that the above mentioned aim (limitation of the temperature increase to 2 K) will not be changed with growing GDP.

Please note that the assumption of growing values over time clearly requires explicit and careful emission modelling over time. If this is not the case, the results are likely to overestimate benefits from a transport project, as vehicle emissions can be assumed to decrease considerably in the future. Information on the future development of emission factors can be found for instance at <http://www.tremove.org/download/index.htm>.

Table 0.16 Shadow prices based on Watkiss et al. (2005b), converted from £2000/t C to €₂₀₀₂ (factor prices) per tonne of CO₂ equivalent emitted – no PPP adjustment necessary as values are not country specific.

Year of emission	Central guidance	For sensitivity analysis	
		Lower central estimate	Upper central estimate
2000 – 2009	22	14	51
2010 – 2019	26	16	63
2020 – 2029	32	20	81
2030 – 2039	40	26	103
2040 – 2049	55	36	131
2050	83	51	166

Notes: Values are for year of emission and were derived combining damage cost and marginal abatement cost estimates. The damage cost estimates are based on declining discount rates and include equity weighting. Some major climatic system events as well as socially contingent effects are excluded. For details see Watkiss et al. (2005b)

The recommended calculation procedure is as follows:

- Step 1:** quantification of change in greenhouse gas emissions (CO₂, CH₄, N₂O; others if data available) due to a project measured in tonnes.
- Step 2:** classification of emissions according to height of emission sources (ground-level – high altitude aircraft). Calculation of CO₂ equivalents of ground level emissions; multiplication of high altitude aircraft CO₂ emissions with a factor of 2 (to consider warming effects of other species).
- Step 3:** multiplication of CO₂ equivalents with cost factor for year of emission.
- Step 4:** reporting of emissions and costs.

0.5.4 Other effects

Air pollution, global warming and noise represent the most important and relevant cost categories that can currently be assessed within a CBA. Environmental impacts such as vibration, severance, visual intrusion, loss of important sites, impairment of landscape, as well as soil and water pollution are difficult to include based on general values, because the impacts are very site specific (e.g. impairment of landscape). Usually such aspects are covered by the requirements for Environmental Impact Assessment and by obligations to meet certain target values. However, even if such standards are met, the remaining burdens lead to external costs, which should be considered. Where monetisation is not (yet) possible, these effects should be reported and considered beside the CBA. However, it is beyond the scope of HEATCO to suggest concrete values or detailed methodologies in these areas.

0.6 Costs and indirect costs of infrastructure investment

This section summarises the recommendations on how to treat the following five elements in a cost-benefit analysis framework;

- Capital costs of the infrastructure project
- Residual value
- Optimism-bias
- Costs of maintenance, operation and administration
- Changes in infrastructure costs on existing network

0.6.1 Capital costs of the infrastructure investment

It is recommended to use the following definition of *capital costs of the infrastructure investment*;

- *Construction costs*, including materials, labour, energy, preparation, professional fees and contingencies
- *Planning costs*, including design costs, planning authority resources and other planning costs
- *Land and property costs*, including the value of the land needed for the scheme (and any associated properties), compensation payment necessary under national laws and the related transactions and legal costs
- *Disruption costs*, e.g. the disruption to existing users to be estimated using the same values of time as are used for travel time savings arising from the scheme.

Furthermore the cost assessment should be based on the following two general principles;

- Costs should be attributed to the project year in which the resources become unavailable to alternative uses.
- It is necessary to distinguish between costs incurred before and after the decision whether to go ahead with the project or not; and retrievable and non-retrievable costs.

As the cost-benefit analysis only concerns costs that will be incurred due to the decision to go ahead with the project, non-retrievable costs incurred prior to the decision should not be included in the cost-benefit analysis.

The implications of these general principles are discussed in section 7.3 for each of the elements of capital costs together with element-specific issues.

0.6.2 Residual value

The residual value is an item in the appraisal which captures the net benefits beyond the formal evaluation period. In the cost-benefit analysis the capital costs of the infrastructure is reduced by the net present value of the residual value of the infrastructure.

We recommend a pragmatic approach for estimating the residual value, which includes:

- Determination of the fixed lifetime of the infrastructure - or its sub-components
- Determination of a depreciation profile

The minimum approach is to use a linear depreciation profile. More advanced approaches are however also possible.

A range of recommended lifetimes is provided in Table 0.17 for road and rail projects. For other modes the recommended lifetimes can be used as inspiration. If the appraiser uses lifetimes outside the ranges presented in Table 0.17, it must be explicitly stated why such an approach is chosen.

Table 0.17 Lifetimes by mode and group of components (road and rail).

Mode	Group of components	Min	Main	Max
Road	Base course	30	45	60
	Wearing course	10	20	30
	Environmental installations	10	20	30
	Drainage	50	75	100
	Retaining walls	50	75	100
	Bridges	50	75	100
	Tunnels	50	75	100
	Land	Infinite	Infinite	Infinite
Rail	Substructures	40	60	80
	Tracks	20	30	40
	Tech. Equip.,	10	20	30
	Power supply	20	30	40
	Environmental installations	10	30	50
	Bridges	50	75	100
	Tunnels	50	75	100
	Land	Infinite	Infinite	Infinite

0.6.3 Optimism-bias

Optimism-bias refers to the systematic tendency for project appraisers to underestimate construction costs. It is recommended that a side-analysis is conducted where optimism-uplifts are applied to the estimated construction costs (including contingencies). Table 0.18 shows the suggested optimism-bias uplifts¹. In case a project includes elements of different categories of project types, the relative size of each sub-project should be identified and the relevant uplift applied before aggregation to establish the total budget.

If the cost-benefit analysis still shows that the project is feasible, the project appraisal process can continue. If the project - which were considered feasible before the uplifts were applied - is 'not feasible' when the uplifts are applied, the group of planners must benchmark the cost estimates applied in the study to the realised costs of similar projects. If it can be documented that the original cost estimates are in line with the realised costs of similar projects, the pro-

¹ See Table 7.5 for more details.

ject appraisal process can continue. If not, the planners must either explicitly justify why the cost estimates are lower and/or revise the construction cost estimates.

Table 0.18 Applicable capital expenditure uplift (average cost escalation)

Category	Uplift
Road	22%
Rail	34%
Fixed links	43%
Building projects	25%
IT projects	100%

Source: based on British Department for Transport (2004b), Mott MacDonald (2002), Flyvbjerg et al (2002)

0.6.4 "Costs of maintenance, operation and administration" and "Changes in infrastructure costs on existing network"

Costs of maintenance, operation and administration are costs accrued during the operating life of the transport infrastructure by the infrastructure owner for the parts of the network which are changed by the project. In line with this, the *existing network* is defined as these parts of the network that are not changed by the project.

It is very complex task to give recommendations on how to include *costs of maintenance, operation and administration* and *changes in infrastructure costs on existing network*, as the countries have different standards of infrastructure, composition of traffic, maintenance practice etc. This means not only that it is impossible to generalise/transfer cost estimates, but also that the possible approach to estimating costs differs between countries. This means that the recommended approach, which is presented below, should only be perceived as a "way of thinking" rather than a recipe for estimating costs. In practice, the approach taken must be modified to accommodate for example data availability.

The **first best option** is to use national default values if they are available. It has to be carefully considered if the national standard figures are applicable to the infrastructure under consideration.

The **second best option** is to use a pragmatic approach based on aggregate cost data which is available in most countries. The approach is outlined here for road and rail, but is also applicable to other modes.

The calculation procedure follows:

Step 1: Distinction between fixed and variable costs

Step 2: Allocation of variable costs to cost drivers

The distinction between (short run) fixed costs and the variable costs (costs that vary with traffic use) are determined on the basis of national accounts/statistics and a general classification of cost categories. Table 0.19 shows the recommended split into fixed and variable costs for road and rail.

Table 0.19 Classification of cost categories into short run fixed costs and short run variable costs - Road and rail.

	Road - cost category	Rail - cost category	Short run Fixed costs	Short run Variable costs
Construction	Land purchase	Land purchase	Yes	No
	Construction of new roads	Construction of new lines	Yes	No
	Enlargement of roads/ adjustment to higher axle loads	Upgrading/enlargement of existing lines	Yes	No
	Replacement investments			
	(1) Major repairs			
	Dressing of thin layers and surfacing	Periodical treatments of route structure	Partly	Partly
	Repairs of bridges, supporting walls and other facilities	Major repairs of bridges, tunnels, switch boxes and platform which are only performed in larger time intervals	Partly	Partly
	(2) Renewal			
	Replacement of layers in underground engineering		Partly	Partly
	Replacement of bridges and other facilities which restores the full utility value	Replacement of bridges, tunnels, switch boxes and platforms (or parts of these) as well as replacement of tracks and other facilities which restores the full utility value.	Partly	Partly
	Construction maintenance			
	Removal of pot-holes, spilling of joints		No	Yes
	Minor repairs	Minor repairs	Partly	Partly
	Pavement renewal	Ballast cleaning, compression	No	Yes
Ongoing maintenance and operation	Operation, servicing and ongoing maintenance ¹⁾			
	Winter maintenance (snow sweeping)	Winter maintenance (thawing of switches, snow sweeping)	Yes	Partly
	Street marking		Yes	Partly
	Cleaning, cutting	Cleaning, cutting	Yes	No
	Check of facility Condition	Check of facility condition (route servicing, swithes)	Yes	Partly
	Servicing of bridge beddings, traffic lights for general safety reasons	Servicing of bridge beddings, signalling, telecommunication facilities for general safety reasons	Yes	No
		Operation of signalling/telecommunication facilities, switch towers (staff, electric power)	Mainly not	Yes
		Traction current	No	Yes
Administration	Over head	Overhead	Yes	No
	Police/ traffic control	Police	No	Yes
		Time tabling, train planning	No	Yes

Source: Link et al (1999)

The fixed costs of maintenance, operation and administration for the parts of the networks which are changed by the project can be determined on the basis of this classification. Remaining tasks include to estimate:

- The variable costs of maintenance, operation and administration for the parts of the networks, which are changed by the project
- The changes in infrastructure costs of the parts of the networks, which are not changed by the project (i.e. the existing network).

In order to estimate these costs it is recommended - for pragmatic reasons - to assume that:

- The marginal costs per vehicle can be approximated by the average variable costs
- Average variable costs/marginal costs are constant (and not for instance increasing with traffic).

Given these assumptions, the unit costs per vehicle type can be estimated on the basis of:

- Total variable costs
- Traffic data (number of vehicles per year by vehicle type for the infrastructure, which the cost data refers to)
- Information on which costs each vehicle type incurs.

A possible allocation procedure is outlined in Table 0.20 for the cost categories which were categorised as 'variable' or 'partly variable' in Table 0.19.

Table 0.20 Possible allocation factors for the allocation of variable costs to cost drivers.

	Variable cost category	Possible allocation
Weight dependent	Major repairs	Axle weight
	Renewal	Axle weight
	Construction maintenance	Axle weight
Non-weight dependent	Operation, servicing and ongoing maintenance	Vehicle kilometres
	Police	Vehicle kilometres

Source: Simplification of table in Link et al (1999)

A possible approach to allocation according to axle weight is to use equivalent standard axles (ESAs)². The ESA factors by vehicle type differ across countries due to for example different compositions of the fleet and different load factors.

As a minimum the classification for vehicle types should include:

- Passenger cars
- Heavy goods vehicles (>3.5 t max gross weight)

Ideally, the classification for vehicle types should include:

- Motorcycles
- Passenger cars
- Buses
- Light goods vehicles (<3,5 t max. gross weight)
- Heavy goods vehicles (>3.5 t max gross weight)

Trains should be classified according to wagon weight and speed, as these are the cost drivers. As a minimum the classification for trains should include:

- Freight trains (wagon load, combined transport, rolling road)
- Passenger trains (High speed trains. Euro-/Intercity and other long distance trains, regional trains, urban rail)

² See for example Transport and Road Research Laboratory, 1998.

Ideally, these categories could be sub-divided according to the following criteria:

- Operating requirements (number of stops, required distance to other trains)
- Construction standards (speed)
- Weight (axle weight)
- Number and type of wagons

0.7 Vehicle operating costs

Operating costs are clearly dependent on the prices of goods within a region (e.g. price of fuel, vehicle spare parts, etc.). However, operating costs can also be influenced by the regulatory and institutional characteristics of the environment in which the transport industry operates. This is particularly the case for the rail, shipping and air sectors. Operating cost relationships for road vehicles are far more generic and transferable between countries. Off the shelf models and computer software exists for the calculation of such road vehicle operating costs, however, these models require to be populated with some local data (e.g. fuel costs). It is therefore recommended that local country specific data on prices and relationships for modal operating costs should be utilised in project appraisal.

Whilst we recommend that local relationships and prices are used in the calculation of vehicle operating costs, we recommend that the following cost components are included in that model (see also Nellthorp *et al.*, 1998):

Standing cost components

- Depreciation (time dependent share)
- Interest on capital
- Repair and maintenance costs
- Materials costs
- Insurance
- Overheads
- Administration

Operating cost components:

- Personnel costs (if not included in travel time savings – see Chapter 4 of these guidelines);
- Depreciation (distance related share)
- Fuel and lubricants

In the absence of local relationships for road vehicle operating costs the generic relationships in the Highway Design Model (HDM) model can be used (HDMGlobal, 2005). This model is also recommended for World Bank funded road projects. The HDM model needs to be populated with some local data reflecting road and vehicle characteristics (including the price of replacement parts). There is no equivalent model to HDM for the rail, air and maritime sec-

tors and as such the operating costs for trains, aircraft and ships should be developed in collaboration with the specialists working in these sectors.

The calculation of the economic benefits (costs) associated with vehicle operating costs varies by mode due to variation in vehicle operating cost relationships between modes. In essence three types of data area required:

- Demand - the number of vehicles making a particular origin-destination trip for the Do-Minimum and the Do-Something cases;
- Vehicle kilometres – the change in vehicle kilometres induced to the traffic on that particular origin-destination trip for the Do-Minimum and the Do-Something cases; and
- The unit cost of a vehicle kilometre – this in turn will require data on:
 - the transport network characteristics (e.g. gradient)
 - vehicle characteristics (e.g. vehicle type, speed, cost of replacement parts and maintenance, load, etc.)
 - vehicle utilisation

Each of these characteristics may vary between the Do-Minimum and Do-Something.

As with travel time savings the user benefit associated with vehicle operating cost savings is calculated at an origin-destination pair level using the rule-of-half (see Chapter 2) and then summed over all origin-destination pairs. Care should be taken to avoid double counting time related cost elements that are included in the values of time (e.g. driver and crew wages).

Ideally, all data for the appraisal should be local. However, it is possible to transfer relationships and prices from other countries, though this is most appropriate for road vehicles rather than rail, air or water modes.