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**HEATCO**

Developing **H**armonised **E**uropean **A**pproaches for
**T**ransport **Co**sting and Project Assessment

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# Proposal for Harmonised Guidelines for the Integrated Assessment of Transport Projects in Europe

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# HEATCO
# Proposal for Harmonised Guidelines for the Integrated Assessment of Transport Projects in Europe

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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 approach[1] | 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 adjusts 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):

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

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 v/3 as lower boundary and v*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 $PM_{10}$ emissions and not the emissions of $PM_{10}$) 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 ($PM_{10}$ for emissions from power plants),
- $NO_x$ as precursor of nitrate aerosols and ozone,
- $SO_2$ 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 $SO_2$ 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 $SO_2$ 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** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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 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.

The recommended calculation procedure is as follows:

**Step 1**: quantification of change in pollutant emissions ($NO_x$, $SO_2$, NMVOC, $PM_{2.5}$/$PM_{10}$) 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 overestimate 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** | **Central values** | | | **New approach** | | | **High values** | | |
|---|---|---|---|---|---|---|---|---|---|
| **$L_{den}$ (dB(A))** | **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 $CO_2$ equivalents) basically consists of multiplying the amount of $CO_2$ 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 $CO_2$ 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 $CO_2$ it is 1.

In high altitudes other emissions than $CO_2$ 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 $CO_2$ 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 $CO_2$ emissions by a factor of 2 to consider the warming effect of other species than $CO_2$.

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 $CO_2$ 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% $CO_2$ 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 $CO_2$ equivalent emitted – no PPP adjustment necessary as values are not country specific.

| | Central guidance | For sensitivity analysis | |
|---|---|---|---|
| **Year of emission** | | **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 ($CO_2$, $CH_4$, $N_2O$; 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 $CO_2$ equivalents of ground level emissions; multiplication of high altitude aircraft $CO_2$ emissions with a factor of 2 (to consider warming effects of other species).

**Step 3**: multiplication of $CO_2$ 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 uplifts[1]. 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-

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[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 spilt 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 treatmens 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 maintanance** | | | |
| | Removal of pot-holes, spilling of joints | | No | Yes |
| | Minor repairs | Minor repairs | Partly | Partly |
| | Pavement renewal | Ballast cleaning, compression | No | Yes |
| Ongoing maintanance and operation | **Operation, servicing and ongoing maintanance** [1)] | | | |
| | Winter maintanance (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)

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[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 sectors 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.

# 1 Introduction

## 1.1 Transport appraisal

Transport appraisal is the assessment of value for money of transport projects and policies. This statement implies many questions – assessment by whom, for whom, from which perspective, at what stage. One of the features of transport decisions is that they typically impact on many parties – transport operators, individual transport users, shippers, local residents and businesses, land and property owners, national and local taxpayers. Each of these stakeholders will seek to assess the impact of a project from the perspective of his/her own interest. But the overarching perspective of transport appraisal needs to be a *social* one, that is, one which takes account of significant impacts of the project or policy *whoever is affected*. So the key question which appraisal seeks to address is:

> Is a project or a policy intervention worthwhile from an overall social point of view?

Most of this document is concerned with the technical aspects of trying to answer this question. We recommend the use of a framework approach containing at its core a cost-benefit analysis of those elements which can justifiably be valued in monetary terms, but with additional reporting of environmental impacts, wider economic impacts and other impacts on broader policy issues. The cost-benefit analysis and the broader environmental and policy indicators need to be brought together in a coherent, logical way in order to produce the overall assessment.

Before coming to the technical issues, it is worth making a few observations about the context within which the social appraisal of transport projects takes place.

First, technical appraisal by the professional community of engineers, planners, economists and modellers, is an input into a broader political decision-making process. It is not possible at the technical level to put a value on the psychic benefit of helping to create a united Europe. So, there are boundaries to technical appraisal which need to be recognised, and technical appraisal needs to speak to, aid and inform political decision-makers. It cannot replace them.

Secondly, appraisal is a process. The gestation period for transport infrastructure in Europe is typically long – say ten to twenty years from conception to delivery. Several stages in the project cycle may be identified:

- The initial definition of a project or policy for feasibility study
- Sifting/screening from a large number of possible projects or project options to a manageable set of alternatives for full appraisal
- Final project selection including accept/reject, choice between alternatives and prioritisation.

A well-known paradox is that whereas decisions are most open to influence at the early stages in the cycle, appraisal results are frequently not available until the very end. Appraisal needs to be integrated more securely into the project cycle. Clearly at the initial stage of project conception and also at the sifting/screening stage, it will not be cost-effective to develop the appraisal to the level needed for final project selection. But the indicators used at the earlier stages of the project cycle should relate to the criteria by which the final decision will be taken. Even if the signpost is a very simple one, it should be pointing in the right direction.

Thirdly, the technical appraisal itself is likely to be multi-dimensional. As well as the overall social value for money we are likely to be interested in questions such as the pattern of the gains and losses by stratum of society and/or location, the financial viability of the project and impact on relevant stakeholders (who pays, who gains), the practicability of the project and barriers to implementation (will it fly?).

Some characteristics of transport appraisal may be noted:

- Appraisal is a comparative tool. It considers the difference between alternative states of the world (scenarios, such as Do-Something against Do-Minimum) and the cost and benefits of a project or policy intervention. A Do-Something scenario is one in which the project/policy is included in the transport system. A separate Do-Something scenario is required for each alternative tested. The Do-Minimum scenario needs to be a realistic base case against which the project/policy options are assessed. Therefore, appropriate definition and selection of the alternatives for consideration is crucial.
- Appraisal relies on data, modelling and forecasting. Without the straw of basic data on demand and supply, an economic model (which may be very simple) and a way of rolling forward from the base year into the future, the bricks of the appraisal cannot be made. The phrase ‘garbage in, garbage out’ applies if the economic appraisal is based on weak data inputs, then the appraisal itself will be fragile.
- Appraisal should reflect human behaviour and be evidence-based as far as is reasonably possible. So knowledge of the factors which drive behaviour, and the way in which transport improvements are likely to impact is important. In practice there is a trade-off between the cost and time to acquire data and the need for local evidence to support the appraisal. In any case, local data on key parameters such as the values of time will need to be benchmarked against wider evidence reviewed here.
- Appraisal needs to be holistic in nature, that is to say, it needs to cover economic, social and environmental impacts of projects and policies in a coherent and consistent manner.
- Appraisal needs to respect capital budgeting rules, dealing with costs and benefits over the life time of the project/policy and representing risk and uncertainty.
- Appraisal needs to be in scale with the size of the project and the risks involved. The economic appraisal treatment of a new bridge or tunnel across an estuary needs to be more sophisticated than the appraisal of the re-design of a junction because more public resources are at stake, the risks are greater, and the effects are likely to be far-reaching. The estuary crossing probably requires a purpose-built transportation and economic model, while the junction re-design problems might rely on standardised data and forecasting procedures.

To summarise, appraisal needs to be fit for a purpose:

- Timely and cost-effective in relation to the resources at stake
- Provide evidence on project impacts on society as a whole and from the perspective of individual agents or social groups; and

- Support the decision against the key tests of social value for money, financial sustainability and practicability.

## 1.2 Transport appraisal within the policy process

The core aim of transport appraisal must be to get a good measure of the primary impacts of the project on travel patterns, journey times and costs, and hence on user benefits, revenues and costs. This needs to be complemented by an environmental assessment of transport infrastructure and operations. Consideration of wider impacts on the economy and society **may** be required in particular cases (e.g. project with significant 'opening-up' or generative effects).

## 1.3 The HEATCO guidelines and other supra-national guidelines at a EU level

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. However, it is not the intention of HEATCO's proposal for harmonised guidelines to stipulate methods and values; it might also be used as a support for achieving a consistent appraisal practice for other national and trans-national projects in the European context. National values are not to be replaced by uniform European values. Comparability of appraisal results, however, calls for a consistent methodological framework to derive (country-specific) values. This is the aim of the work presented in this document, which is open for discussion.

The HEATCO guidelines are the most recent of a series of guidelines/manuals/handbooks for project appraisal which have been promoted in the last years by the EC and/or other international financing institutions (IFIs).

Looking at the more recent ones (TINA, DG REGIO, RAILPAG), differences in e.g. sectoral coverage, level of detail of guidance to cost calculation, etc. are evident (see Table 1.1 for a detailed assessment). Despite differences in approaches and methodologies, promoting the performance of high quality project appraisals procedures for projects eligible for international co-funding (EC and other IFIs) seems to be the common rationale behind them. This could allow on one side to promote a virtuous cycle of penetration into national practices of robust appraisal techniques (especially valuable for those countries with a poorer appraisal experience) and on the other to rationalise decision making at a supra-national level, allowing funding institutions to allocate their (limited) budget over a number of projects assessed in a broadly comparable way.

In addition to this, the evolution of EU transport policy in relation with cohesion and development policy implies that an increasing number of infrastructure projects have a trans-national relevance, either in terms of their geographical location (e.g. cross-border projects), or in terms of the location of the costs/benefits they generate. This raises concerns as to how these questions can be correctly dealt with from a methodological point of view and on how problems of delays in decision making due to low coordination between two or more member states (MS) sharing the interest for an infrastructure can be avoided. Table 1.1 below provides a comparative overview of the approach of the guidelines mentioned above with the one suggested in HEATCO. It has to be mentioned that the guidelines issued by the EC-DG Regional Policy have a broader range of application than the others, covering all sectors eligible for Structural Funds, Cohesion Funds and the Instrument for Structural Pre-Accession Aid (ISPA). Guidelines on how to adapt the general approach to the transport sector are however provided. TINA, RAILPAG and HEATCO are instead focused on the transport sector.

RAILPAG and HEATCO move from the work done in TINA, innovating in different directions. RAILPAG focuses on the rail sector, proposing solutions on how to extend the CBA approach in such a way that the features of this rapidly changing sector can be properly taken into account. The critical issues of appraising rail infrastructure projects are highlighted (multiplicity of stakeholders, need for a multimodal approach to capture integrated effects, interoperability, etc.), and the approach suggested is an “extended” CBA (quali/quantitative) complemented by a distributional analysis. The identification of possible trade-offs in the allocation of costs and benefits between stakeholders through a disaggregated CBA is at the core of RAILPAG proposal. RAILPAG is planned to be regularly revisited in order to provide an updated guidance on specific appraisal procedures.

HEATCO is not mode-specific, and innovates in several aspects with respect to existing guidelines:

- It starts from a recognition of national appraisal practices, identifying best practices;
- It provides a comprehensive guidance to costs and benefits calculation, proposing both basic appraisal procedures and more sophisticated ones: this allows higher usability of the guidelines especially for those countries with less sophisticated appraisal traditions and poorer data availability.

**Table 1.1** DG Regional Policy Guidelines, TINA, RAILPAG, HEATCO: a comparative overview.

| | **DG Regional Policy 2003** | **TINA 1999** | **RAILPAG 2005** | **HEATCO 2006** |
|---|---|---|---|---|
| Target user | EC officers in charge of evaluating projects for funding; Project promoters (MS) applying for EC funds. | Project promoters: as a benchmark for quality of project definition and appraisal.<br>IFIs: to promote the adoption of a common approach based on TINA guidelines. | Practitioners, project promoters: as a benchmark for quality of project definition and appraisal. The purpose is facilitating project promoters to obtain funds from EC and other IFIs. | Practitioners, project promoters: as a benchmark for quality of project definition and appraisal. |
| Focus | Project appraisal in the framework of Structural funds, Cohesion funds, ISPA.<br>Applicable to all sectors eligible for the above funds. | Project appraisal in the framework of TEN-T investments. Especially directed to countries applying for ISPA funds. | Focus on large investments in the rail sector. Not specific for project screening, rather suitable for well identified projects with several alternatives. | Project appraisal in the framework of TEN-T and other transnational investments. The framework also applies to national investments. |
| Approach | "Framework approach": socio-economic CBA including all *monetisable* impacts, MCA for all *quantifiable but non monetisable* impacts. Political judgement as a final synthesis. | "Framework approach": socio-economic CBA (*monetisable* impacts), all other impacts (*quantifiable but non monetisable* and *non quantifiable*) must be taken into account. No methodologies suggested on how integrate these aspects, decision is a political deliberation over the two components. | "Extended CBA": comprehensive socio-economic CBA including all *monetisable* impacts, complemented by a distributional analysis (see below). *Non monetisable* impacts introduced in the disaggregated CBA as indicators ("markers"). MCA excluded. | The same as TINA. In addition, it is suggested that the final political deliberation should also be backed by *switching values* as a threshold for non-monetised impacts. |
| Treatment of monetised impacts | Socio-economic CBA (use of accounting/shadow prices).<br>Indications on how to calculate cost/benefit categories are provided.<br>The various options to calculate external costs are shortly described. | Socio-economic CBA includes economic efficiency and safety. Indications on how to calculate cost/benefit categories are provided.<br>External environmental costs are not included in CBA: mitigation measures considered within investment costs, for other impacts reference is made to EIA procedures. | Refers to TINA for the basic financial and socio-economic appraisal procedures. Describes in detail only complementary and/or railways specific aspects. Detailed description of procedures for cost/benefit calculation is currently under development. | Comprehensive and detailed guidance for the calculation of all cost/benefit categories. Suggested methodology for external costs is IPA. |

| | **DG Regional Policy 2003** | **TINA 1999** | **RAILPAG 2005** | **HEATCO 2006** |
|---|---|---|---|---|
| Treatment of non-monetised impacts | Included in MCA | Quantitative (non monetised) and/or qualitative assessment. | Quantitative (non monetised) and/or qualitative assessment. CBA extends “qualitatively” to highlight the presence of such effects into the SE matrix. Switching values can be calculated to give order of magnitude of these impacts. | Quantitative (non monetised) and/or qualitative assessment. In case non-monetised impacts are small, sensitivity analysis suggested. In case they are relevant, eliciting decision maker’s weight for them vs. monetised impacts. |
| Treatment of indirect socio-economic effects | Not included. | Not included. | General equilibrium models suggest estimating e.g. economic growth or job creation. | Qualitative assessment at a minimum. Use of Spatially Computable General Equilibrium Models if possible. |
| Equity (intra-generational) | Either included in CBA (through shadow prices) or in MCA (quantified e.g. through statistical measures such as Gini index). No disaggregation of impacts between stakeholder categories. | Disaggregated results of CBA (per type of user, public vs. private, etc.). | Disaggregated results of CBA through Stakeholders-Effects Matrix (SE Matrix). | Winners and losers tables at minimum, distributional matrices as a more sophisticated approach. |
| Treatment of future risk and uncertainty | Sensitivity analysis<br>Scenario analysis<br>Risk probability analysis | Sensitivity analysis<br>Scenario analysis | Not widely treated yet. Sensitivity analysis suggested | Sensitivity analysis at minimum, Monte Carlo simulations as a more sophisticated approach. |
| Decision criteria | Economic Rate of Return (ERR)<br>Economic Net Present Value (ENPV)<br>Benefit-Cost Ratio (BCR) | Internal Rate of Return (IRR)<br>Net Present Value (NPV)<br>Benefit-Cost Ratio (BCR) | Internal Rate of Return (IRR)<br>Net Present Value (NPV)<br>Benefit-Cost Ratio (BCR) | Various indicators are provided, according to the aims of the analysis:<br>Net Present Value (NPV)<br>Benefit-Cost Ratio (BCR)<br>Ratio of NPV and Public Sector Support (RNPSS)<br>First Year Rate of Return (FYRR) |

MS: Member States
IFIs: International Financing Institutions
EIA: Environmental Impact Assessment
IPA: Impact Pathway Approach

## 1.4 The structure of these guidelines

Chapters 2 and 3 set the context of the project appraisal framework and give recommendations for the treatment of general issues. In chapter 4 suggestions for valuing time and congestion are made. Chapter 5 deals with the valuation of changes in accident risks, whereas chapter 6 focuses on the valuation of environmental costs due to air pollution, noise and global warming. Chapter 7 gives recommendations for the broad area of the costs and indirect impacts of infrastructure investment. Finally chapter 8 explains how vehicle operating costs should be valued. Country-specific fall-back values are suggested for application in cases where no state-of-the-art national values are available for valuation:

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

# 2 Transport Cost Benefit Analysis[3]

## 2.1 Overview

A key aim of an economic appraisal of a transport project is to measure the magnitude of the economic impact resulting from the investment. Ideally, this would measure the total benefits from increased output across all final product sectors and would include measurement of the level of employment and the wage rate in the labour market, the prices of goods and services in the product market and the value of property in the land market. In practice, however, the analytical models required to undertake such an analysis require a level of sophistication and refinement that is typically beyond that available from both technical and resource standpoints. As such the cost benefit analysis process is based around a partial equilibrium approach[4] that concentrates on the "primary" impacts incurred by transport users, operators and governments. The basic calculation is summarised below:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Overall Economic Impact | = | Change in transport user benefits (Consumer Surplus) | + | Change in system operating costs and revenues (Producer Surplus and Government impacts) | - | Change in costs of externalities (Environmental costs, accidents, etc.) | - | Investment costs (including mitigation measures) |

This apparently simple calculation can in fact become a quite complex exercise as it becomes necessary to consider:

- The scope of the appraisal in terms of mode, study area and range of impacts;
- The definition of the alternatives – particularly the reference case or the Do Minimum scenario;
- The calculation of transport user benefits (consumer surplus);
- The calculation of impacts on transport providers and the government (includes producer surplus and investment costs);
- Monetary valuation of time and safety;
- The treatment of environmental impacts and other externalities.
- The mechanics of the process including inputs, project life, discounting, aggregation of benefits and costs, unit of account.

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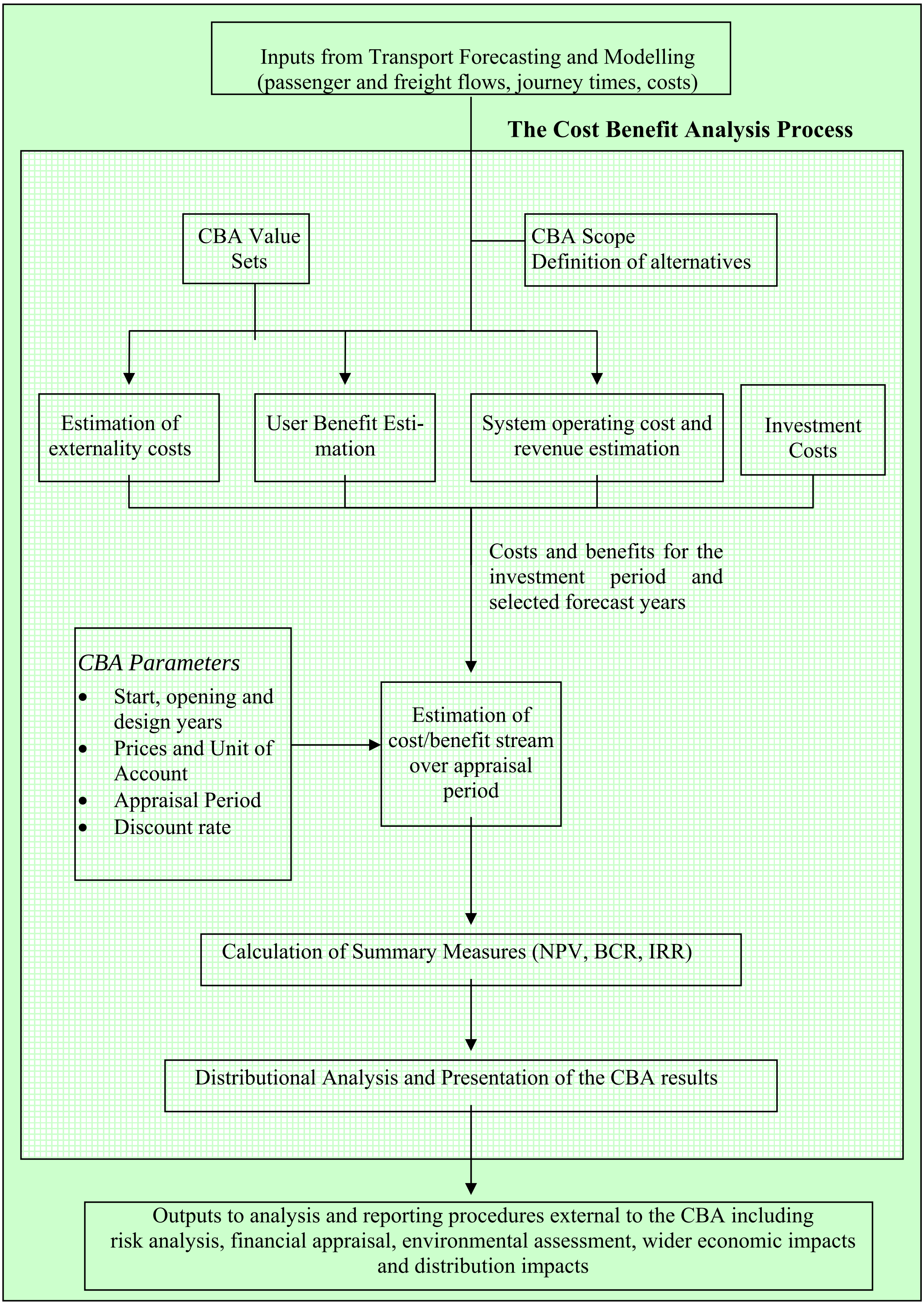
[3] This chapter has been drawn from the work undertaken by the Institute for Transport Studies, University of Leeds on behalf of the World Bank (see Mackie, Nellthorp, Laird and Ahmed, 2003)

[4] This assumes that all transport using sectors of the economy are in perfect competition and that there are no significant scale economies in production. This allows the social economic analysis to focus exclusively on the transport sector.

**Box 1: Transport Economic Appraisal**



Box 1 summarises the steps involved in carrying out the cost-benefit analysis for transport infrastructure projects and illustrates that it comprises of a number of distinct stages and that a range of internal inputs are required. The rest of this chapter is structured around the elements in Box 1, and many of the subsequent chapters are clearly linked to this structure.

## 2.2 Scope of CBA

At the start of the CBA process, a view will need to be taken on the scope of the analysis. This is often made simultaneously with the decision regarding the type and scale of the demand forecasting approach, as the two processes are inter-related. Ideally, the CBA process should include all impacts of the investment, no matter how small that impact is. However, setting such a broad scope for a CBA will result in extensive data collection and analysis that may well be expensive in terms of cost but also in terms of time required to complete, both will affect the ability to deliver the project. Given that the purpose of the CBA is to firstly ensure that a project is economically beneficial and secondly to aid the choice between alternatives, the scope of the CBA is in practice often narrowed by excluding minor or insignificant impacts as long as the exclusion of these impacts will not bias the appraisal. Key issues that require addressing in defining the scope of a CBA include:

Impacts: the measurement of changes in producer and consumer surplus requires the measurement of benefits, revenues and costs to transport operators and users. At a minimum these should include the investment cost and changes in infrastructure and system maintenance and operating costs, vehicle operating costs, journey times, safety, user charges and operator revenues.

Mode of transport: typically the modes of transport that are considered should include both those that will use the new infrastructure (e.g. a road) and those from which demand may be abstracted (e.g. rail).

Study area: should be the smallest area that allows for the development of robust results. It should therefore be large enough to capture network effects that include firstly the abstraction of demand from other routes and modes and secondly the impact of competing and complementary schemes that in combination with the project in question may comprise the country's development strategy. If cross-border impacts are expected (e.g. from transit traffic associated with land locked countries) then the study area should be defined so as to incorporate both domestic and international travel.

## 2.3 Definition of alternatives

A transport investment project is normally proposed as part of a planning process to solve a set of specific problems or to achieve certain objectives. As such there is usually a range of solutions or alternatives that require appraising. These alternatives are termed "Do-Something" scenarios. To ensure that the different scenarios can be compared against each other it is important to undertake the appraisal against a single reference case scenario which is termed the "Do-Minimum".

The Do-Minimum scenario is defined as the scenario which involves carrying out the investment and maintenance necessary to keep the system working without excessive deterioration. The implication is that the Do-Minimum includes a maintenance and renewal programme. The Do-Minimum is therefore very different from a do-nothing situation. This is because a do-nothing situation does not include a maintenance programme and therefore in the long term would not be able to even meet existing demand levels. The Do-Minimum scenario may result in very different traffic levels compared to those foreseen with the project implemented. This is expected. It is not there appropriate to take the Do-Minimum alternative to be the minimum level of investment required to provide for expected 'normal' traffic growth. Such an alternative (sometimes referred to as 'avoided investment') forms one of the Do-Something scenarios.

The Do-Something scenarios are easier to define as they represent the 'transport solutions' designed to solve existing transport related problems or to achieve a set of local, regional, national or supranational objectives. Some complexity can occur in their definition when several inter-linked projects are proposed. This is often of particular importance in rail appraisals (e.g. development of a high speed rail network). As set out in the RAILPAG guidelines one of the ways of handling such cases is to carry out appraisals of the bunched investment and of each of its individual components, to reach an optimal project selection and implementation programme. In practice this can be a challenging task as it is important to avoid double counting the 'network' benefits of the bunched appraisal in each of the individual appraisals. As such transport models with a wide geographic coverage are often required.

## 2.4 Transport User Benefits

The essential measure of benefits to users is consumer surplus, that is, the excess of consumer willingness to pay over the cost of a trip. Normally, we are interested in the change in consumer surplus resulting from some change in the cost of travel brought about by an improvement in transport conditions. Operationalising this in transport poses some practical problems. For most consumer goods the cost of the good (to the consumer) is its price. When it comes to transport, prices and money costs are only a proportion of the composite cost of travel, which in principle also incorporates the time spent by the individual, access times to public transport, discomfort, perceived safety risk and other elements. Therefore price alone is not an appropriate measure of either the cost of travel or the consumer's WTP, instead generalised cost is used. Generalised cost is an amount of money representing the overall cost and inconvenience to the transport user of travelling between a particular origin and destination by a particular mode. In practice, generalised cost is usually limited to a number of impacts which when summed comprise the components of user benefit:

(i) Time costs (Time in minutes * Value of Time in €/minute);

(ii) User charges (e.g. fares/tolls); and

(iii) Operating costs for private vehicles (VOCs).

It is important to note that the components of generalised cost tend to vary by mode. Public transport users (bus, coach, train, air and ferry) will pay a money fare and give up time in order to travel to their destination. Car users and own-account freight users give up time may be asked to pay an infrastructure access charge or toll, and pay for their own fuel and VOCs. Therefore there is a fundamental difference in the reported user benefits for users of different modes. Additionally, it is important to recognise that Values of Time vary between individuals and even for the same individual, depending on for example trip purpose. There is no unique willingness-to-pay for travel time savings. This has consequences for modelling and appraisal, especially for toll roads or urban mass transit, where suitable market segmentation is needed.

Box 2 describes the concept of consumer surplus measure of user benefits. The light shaded area in Figure 1 is known as the Rule of a Half measure of user benefits, for reasons discussed in Box 2. The Rule of a Half can also be applied separately to each of the user benefit impacts to provide a disaggregation by time, money costs and user operating cost savings. Such a disaggregation will most likely be required for presentation of the cost benefit analysis results.

Clearly the computation of generalised cost needs a calculation of the benefits of time savings and vehicle operating costs. This is discussed in detail in chapters 0 and 8.

## 2.5 Impacts on Transport Providers and Government

Although the user benefit analysis will often be the most testing part of the cost-benefit analysis, it needs to be undertaken alongside an analysis of revenues and costs which impact on both the transport providers and the government.

### 2.5.1 Producer surplus

Cost-benefit analysis is concerned not only with consumer surplus, but with total social surplus. This includes producer surplus (PS) as well as consumer surplus. The greatest scope for changes in producer surplus arises from public transport projects or toll road projects, which can affect operators' revenues without having an equal and offsetting effect on operating costs. Producer surplus is defined simply as total revenue (TR) minus total costs (TC):

$$PS = TR-TC \qquad \text{and therefore} \qquad \Delta PS = \Delta TR - \Delta TC$$

It should, however, be noted that there is an implicit assumption here that if the additional demand for this service is associated with reduced consumption of some other goods or services elsewhere in the economy, those goods and services are being priced at marginal cost, so that there is no offsetting or additional change in producer surplus elsewhere. This assumption is a facet of the partial equilibrium approach adopted, as discussed earlier, and whilst usually made is worth making explicit in the interests of transparency. Producer surplus is discussed further in section 3.9.

## Box 2: Consumer Surplus and the Rule of a Half

In Figure 1 an improvement in transport supply conditions, such as an investment in the road infrastructure between locations i and j is shown. The fall in transport costs have effects on two groups of users:

(i) Existing users – these gain the benefit of the cost change ($C^0 - C^1$) each, or area $C^0AEC^1$.

(ii) New users – these gain a benefit equal to the excess of their willingness to pay over their cost of travel, or area ABE.

User benefits are the sum of (i) and (ii) and can be written:

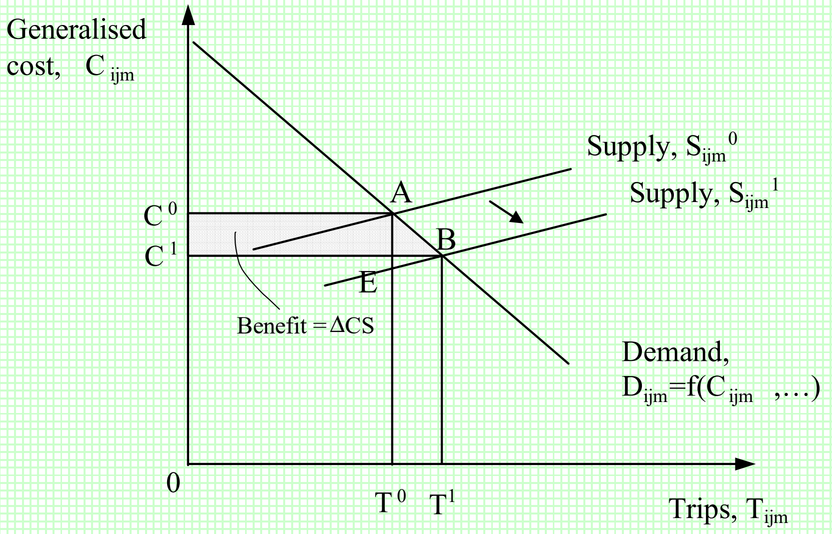
$$(C^0 - C^1)\, T^0 + ½(C^0 - C^1)(T^1 - T^0)$$

or

$$½\, C^0 - C^1)\, (T^0 + T^1)$$

This is rule of a half measure of user benefits. It can be extended to treatments of networks with simultaneous changes in costs on links and across modes.

**Figure 1: User benefit (=change in consumer surplus) in the do-something scenario compared with the do-minimum**



The rule of a half formula assumes the demand curve is linear between points A and B. Therefore, it is only an approximation to the true benefit – the more convex (or concave) the demand curve, and the larger the cost charge, the less accurate the approximation will be. Given the many sources of error in practical appraisal work, the rule of a half is considered acceptable except in cases such as estuary or mountain crossings, where cost changes may be considered “large” relative to base cost levels.

Revenue forecasts depend on traffic forecasts, and both depend on pricing policy. Therefore it is essential in appraisal that the price policy assumptions on which the traffic and benefit estimates are based are consistent with those used for revenue forecasting. The size of the revenue and user benefit effects, as well as their distribution, depends upon the pricing policy. Although this seems obvious, in many practical situations, the appraisal may be undertaken before the details of the toll or price regime have been finalised, so that provisional assumptions made for the appraisal can turn out to be wide of the mark.

Revenue forecasts will be needed both for the Cost Benefit Analysis and for the assessment of financial sustainability of projects. There may be a trade off in tariff-setting between the desire to maximise social benefits from the project and the imperative to satisfy budgetary constraints.

### 2.5.2 Investment costs

Typically the investment costs for transport infrastructure projects will be derived from engineering design studies and estimates. A number of adjustments, however, may have to be applied to these engineering cost estimates before they can be included in the appraisal. These adjustments are as follows:

- The cost of *mitigation measures* required by the environmental impact assessment;
- Conversion of the engineering costs to the correct price base and unit of account (discussed in section 3.11). This will include adjustments for:
    - Taxation (including import duties);
    - Inflation (between year of the engineering cost estimate and price base of the appraisal);

No adjustment is made for the manner in which the project is financed. That is the investment costs used in the appraisal are the same whether or not the project is financed directly by the government or financed through some form of private sector involvement (such as through public private partnerships (PPP or ‘lease-back’ arrangements). This is because the costs of financing under PPP or ‘lease back’ arrangements represent a transfer payment from the public to the private sector. As a transfer payment, the profit element of the costs of financing the project will not affect the project’s overall economic value (Net Present Value). However, the method of financing will have financial and distributive impacts. It is therefore important that a financial appraisal, comparing the costs and revenues of procuring the project by different methods, is undertaken.

Additionally, whilst not forming part of the investment costs, it is important that user benefits reflect any travel time and cost delays during construction. In the case of public transport projects, bitter experience suggests a need to allow for the effect on traffic and revenues of any disruptions to existing service quality while new schemes are constructed. The treatment of user delays during construction within the appraisal is similar to the treatment of user delays during routine maintenance.

The direct costs of the infrastructure investment are discussed in more detail in chapter 7.

### 2.5.3 Maintenance and system operating costs

Proper estimates are also needed of the costs of operating both the infrastructure and the services, which are mode and country-specific. The main items will typically be:

- The costs of infrastructure operation (e.g. signalling/traffic control);
- Maintenance costs (cleaning, minor repairs, winter servicing);
- Costs of renewals (road/rail reconstruction)[5]; and
- Changes in the vehicle operating costs of public transport services.

Maintenance costs from an important component of the definition of the Do Minimum scenario (the without project scenario) and should always be included in the definition of that scenario. Additionally, any disruption to transport users that occurs during periods of routine maintenance should be reflected in the appraisal as a user benefit impact. Chapter 7 discusses maintenance and system operating costs further.

### 2.5.4 Taxation and government revenue effects

A project can lead to change in government surplus by altering tax receipts, principally through changes in indirect taxation (fuel duty and VAT). It is important to include such a change in tax revenue in a cost-benefit analysis as the distortion effects of indirect taxation mean that an economic surplus is experienced by the government. When a project leads to a shift in demand between private and public transport, the implications for government tax revenue may be significant because private transport is often relatively heavily taxed and public transport is often relatively lightly taxed. These changes in indirect tax revenue to the government should be shown in the cost-benefit outputs. The two principal effects are:

(i) An increase in private and commercial goods vehicle kilometres on roads will increase the amount of fuel consumed, thereby increasing fuel duty receipts to government;
(ii) An increase in transport expenditure that is not subject to VAT (e.g. increased expenditure on public transport fares, road tolls, on-street parking fees) will decrease government tax receipts – as less money is spent in the general economy that is subject to indirect taxation.

Some large infrastructure projects in areas of high transport costs can be associated with employment gains at a national or supranational level. If such increases in employment are truly additional (i.e. do not occur as a consequence of job losses elsewhere) then the increase in tax revenue associated with the additional income tax receipts should also be included in the cost benefit analysis.

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[5] One aspect in the context of infrastructure maintenance and renewal is the burden on future budgets caused by a project: As transport infrastructures in Europe are ageing large scale investments will be necessary in future to keep up present levels of service. The increasing need for reinvestments will put severe constraints on future recurrent household budgets and hence limit the degree of freedom to use the funds adequately for needed investments. Therefore, present transport investments will have impacts on future recurrent household budgets and restrict future transport options.

## 2.6 Safety benefits

By convention, safety is treated differently from the other components of user benefit. Rather than being included as a component of generalised cost per trip, accidents and casualties are typically treated as random, occasional costs arising from the transport system, which can be evaluated by applying unit values per accident and per casualty, to forecast data on accident and casualty numbers by mode. The calculation is a simple multiplication of forecast accident numbers (by severity) with the costs of accidents (by severity). This treatment is akin to that of externalities (e.g. the environment (see below). Chapter 5 discusses safety benefits in more detail.

## 2.7 Impacts on the Environment

The environment of a transport project includes the surrounding objects and conditions (natural and man made) as well as the circumstances of human society in that area. This is a broad definition and includes amongst others:

- Health and safety impacts (i.e. the human costs of pollution and accidents, the latter of which has been discussed above);
- Involuntary re-settlement;
- Impacts on the natural environment; and
- Impacts on the man made environment (e.g. cultural heritage).

The directive 85/337/EEC as amended by 97/11/EC regulates the procedure to appraise the environmental consequences of a project (Environmental Impact Assessment, EIA). This procedure is designed in order to ensure that environmental impacts are adequately taken into account before the decision to go ahead with a project is taken: the directive identifies project categories subject to EIA, procedure (including public consultation) and content of the assessment.

It must be recognised, however, that the current state of the art regarding the valuation of environmental impacts is such that these impacts are handled via a mixture of qualitative, physical and monetary measures. Therefore within the economic appraisal it is considered that the key objectives with respect to environmental impacts are to:

- Firstly, ensure that all environmental impacts are considered within the Environmental Assessment; and
- Secondly, to assign an economic cost to quantified impacts if that cost represents a reasonable proxy for the *Total Economic Value*.

The treatment of environmental impacts that can be monetised are set out in chapter 6. The inclusion of non-monetised impacts in the decision making process is discussed in section 3.3.

## 2.8 Cost Benefit Analysis Parameters

So far the first six boxes of the CBA process detailed in Box 1 have been dealt with. These together give us the investment costs and the operating costs, revenues and user benefits for the base year. In developing a CBA it is important to move consistently from a single year to the valuation of the project over its whole life. This involves explicit treatment of forecasting growth over time, accounting issues such as the treatment of inflation and the unit of account, and capital budgeting issues such as discounting. Chapter 3 sets out guidelines on all these issues and also considers the summary indicators of value for money.

## 2.9 Risk and Uncertainty

One statement that can confidently be made about almost any transport project is that the costs and benefits are uncertain. This is because many of the elements of the NPV estimation are subject to error. It is therefore important to analyse the sensitivity of the calculated net benefit indicators to ranges in individual parameters (capital cost, traffic growth rate, etc.). The treatment of risk and uncertainty within the economic appraisal is discussed more extensively in section 3.7.

**Indirect socio-economic effects**

When transport investments are made, changes are expected to occur to distribution and production patterns, market areas served and labour market catchment areas. These impacts are often termed indirect socio-economic effects or wider economic impacts. However, as discussed at the outset of this chapter, the cost benefit analysis process does not start by attempting to estimate these wider impacts; instead the CBA measures the benefits in the transport market. This is appropriate provided that transport using sectors of the economy are competitive (so that surpluses are passed on to final users) and that there are no significant scale economies in production which a narrow transport sector analysis would fail to take into account.

From an appraisal point of view, the issue is not whether transport projects produce wider economic impacts, since that is one of their purposes. Instead, the issue is

(a) whether and in what circumstances the absolute final economic impacts may exceed the initial transport impacts – so-called *additionality*; and

(b) where the incidence of the final impacts is more (or less) socially beneficial than the incidence of the transport impacts. Even if there is zero additionality, are there *distributive effects*?

The presence of additionality depends on the presence of imperfect competition in the goods market, the land market or the labour market. The source of any additional benefits is to be found in divergences between prices and marginal social costs in relevant markets. In such cases, reductions in transport costs feed through to some extent into reductions in final goods prices and increases in output. Whereas under perfect competition, the price of this output reflects the marginal cost of production, in imperfect competition a correction is required to allow for the fact that price exceeds marginal cost. The size of this benefit depends on the size of the output effect, and the price: marginal cost margin. The measurement of the additional benefit due to imperfect markets is difficult due to the risk of double counting benefits. Section 3.10 discusses how to incorporate indirect socio-economic effects into an appraisal.

In addition to measures that indicate the overall economic impact of a project a key output from a social cost benefit analysis is the distribution of those impacts. That is which sectors of society are expected to gain and which sectors will experience a negative impact. Such distributive information is important for policy making, as investments are often targeted at improving socio-economic conditions within a particular area or for a particular group of people. It is therefore important from a policy perspective to know whether the targeted area or group is receiving the benefit.

It is possible to disaggregate the components of benefit by impact group; transport users (by mode), operators and providers (including the government), as discussed earlier. This disaggregation process is an important first step to understanding distributional impacts. Ideally, transport user benefits should also be segmented by socio-economic group if the data allows, however, impacts by mode will give some information regarding those members of society who are set to gain by the investment. Such information should be presented in a distributional matrix as illustrated in section 3.4 of these guidelines.

The impacts detailed in the cost benefit analysis table are transport impacts, and do not necessarily represent the distributive implications of the final economic impacts. To determine if the incidence of the final impacts is more (or less) socially beneficial than the incidence of the transport impacts two steps are required.

First, the impact on the distribution of economic activity needs to be forecast. It is essential to avoid jumping to conclusions. The fact that accessibility from a peripheral area to a regional centre is improved is no guarantee that economic activity will migrate to the periphery. Low transport costs are a centralising force, so if anything, improved transport facilities are more likely to cause migration to the regional centre. This is the ‘two way road’ effect. In pure production terms perhaps the most important requirement is that the region should hold natural or cost advantages for a reasonable range of economic activities in which transport is a significant input. Primary products are a relevant example of where improved transport may permit exploitation of assets fixed in location.

If market conditions are favourable for a displacement of economic activity, then the second question is whether there is a net social advantage from the redistribution of economic activity. Is the gaining region a target area for economic development? Is activity being displaced from more prosperous locations or from even more acute problem locations?

## 2.10 Reporting the Cost Benefit Analysis

As discussed in the introduction to these guidelines, the cost benefit analysis results have to be read alongside other components of the decision process including the environmental assessment and wider planning issues such as distributional and poverty impact analyses, financial sustainability, risk analyses and a consideration regarding whether or not there are social or technical barriers to implementation. The cost benefit analysis framework described within this document can be an important source of information regarding many of these wider issues.

To aid the decision process described above it is important to present the cost benefit analysis results in a clear and concise form. The key information that should be reported will be:

- Initial assumptions and scenario definitions;
- CBA parameters including:
- Start Year, Opening Year;
- Discount rate
- Price base/accounting units
- Shadow pricing assumptions
- Summary Measures of social value;
- Disaggregated CBA results, highlighting the following distributional issues within the overall costs and benefits:
    - Users' benefits versus net impact on operators;
    - Shares of user benefits by mode;
    - Composition of user benefit by item of benefit (Time, VOCs, etc);
    - Shares of time savings made up by personal travel (in non-working time) and business travel including freight and personal travel in working time;
    - Shares of international traffic versus domestic traffic in user benefits;
    - Shares of operator costs and revenue by mode;
    - Investment costs by group (that is, private operators, national government, financial institutions).

This disaggregated information could be presented in a range of different formats, some of which are more suitable than others for particular uses of the appraisal outputs.

# 3 General Issues

Cost-benefit analysis (CBA) has been identified (Odgaard et al. (2005)) as the most widely used appraisal methodology with regard to transport projects in the EU25. Guidance relating to CBA is therefore the focus of these guidelines. This section of the guidance outlines background detail – definitions, purpose in project appraisal, existing and best practice - and specific recommendations relating to the principal generic issues that modern transport cost-benefit analysis needs to consider. The usual starting point in CBA is an identification and monetisation of the components that are incorporated in the formula:

$$NPV = \sum_{n=0}^{N} \frac{(b_n - c_n)}{(1+r)^n}$$

where: b = project benefits; c = project costs; n = the year(s) in which the benefits and costs occur; r = discount rate; NPV = Net Present Value.

The generic issues we address, together with an indication of how each relates to the CBA equation, are listed below. They include:

- Non-market valuation techniques. This relates to components b and c in the formula
- Value transfer. This relates to components b and c in the formula
- Non-monetised impacts. This relates to impacts that are not included in b or c.
- Discounting and intra-generational equity. This relates to the value of r and additional weightings that might be given to b and c.
- Project appraisal evaluation period. This relates to N.
- Decision criteria. This relates to the use of NPV which is only one of a number of decision rules.
- Risk & Uncertainty. This relates to the uncertainty involved in estimating b and c.
- Marginal cost of public funds. This relates to component c.
- Producer surplus. This relates to measurement of b.
- Indirect socio-economic effects. This relates to the definitions of b and c.
- Accounting procedures. This relates to components b and c.

## 3.1 Non-market valuation techniques

### 3.1.1 Definitions

Non-market valuation is a technical term used to describe the idea that a number of welfare components in transport (and other sectoral) project appraisal do not have the value of that welfare expressed in a market price. For example, environmental goods and services generally have characteristics6 that make it difficult or even impossible for markets for these services to

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[6] Non-excludability and non-rivalry in consumption are typical characteristics of environmental services, such as air quality and noise. These are also characteristics of public goods.

function. The public good feature of environmental services leads to market failure in the sense that individuals are not free to vary the level of the services they consume, independently of others (Freeman, 2003). They are therefore unwilling (and unable) to pay for their own consumption of the environmental services given that it may impact on others' consumption. A private market does not, therefore, operate.

As a result, non-market valuation techniques are necessary to estimate monetary values of welfare changes in consumption of environmental services. Two examples of non-market values include the welfare effects from i) changes in health status as a consequence of changes in pollution caused by the introduction of a transport project, and ii) of time-savings that the project allows. In neither case are the goods/services traded in a market but it is recognised that there is a welfare change. In order to represent these types of welfare changes in project CBA, project analysts therefore have to adopt non-market valuation techniques to measure them.

### 3.1.2 Purpose/role in project appraisal

In the TEN-T context, the primary purpose of estimating monetary values associated with goods or services not tradable in markets is their use in CBA where all costs and benefits associated with a given policy or project are required to be expressed in monetary terms. A number of externalities associated with transportation projects, such as air quality and noise impacts, or changes in traffic safety, as well as time savings, do not have market prices. Hence, non-market valuation techniques are needed to account for these impacts in monetary willingness-to-pay (WTP) terms.

### 3.1.3 Existing practice at EC and national levels

Odgaard et al. (2005) present the results of a survey of European transport ministries regarding the use of non-market valuation in transport-related project appraisal. The results show variable use of non-market valuation techniques in this context, perhaps reflecting the fact that such techniques are relatively resource intensive to administer and that there remains some uncertainty about the level of robustness that can be attached to the results of such studies. The description of best practice below outlines the principal individual valuation techniques currently used.

### 3.1.4 Best practice

**Production function approaches**

Production function approaches estimate the value of a given non-market good/service from the measurement of changes in marketed output as a consequence of changes in the provision of (usually environmental) inputs in the production of the output. In the **dose-response**, or exposure-response, method the physical output change as a result of a change in environmental quality is multiplied by the market price of the affected good to estimate an economic (use) value of the good. An example is the impact of low-level ozone caused by road transport on crop yields. Assuming that the loss of yield can be quantified using an exposure-response function, the quantity of crop lost can be multiplied by the market price of the crop. The great advantage of this method is that it relies on the use of market prices to derive values rather than having to infer values through indirect means.

The *replacement or restoration cost* method assumes that the economic cost of a non-market good can be estimated by the market price of a substitute market good that can replace or restore the original quantity or quality level of the non-market good. For example, a habitat may be disturbed in the construction of rail infrastructure, but its original condition may be restored by expenditure on the import of certain plant species. This expenditure may therefore be seen as a proxy for the value of this aspect of the habitat. If the expenditure is made it is, at best, a lower bound on true willingness to pay (WTP). If the expenditure is not made, it may be seen as an upper bound on true WTP.

**Indirect revealed preference techniques**
These techniques use models of relationships between marketed goods/services and the non-market good/service of interest, assuming that there is some kind of substitute or complementary relationship between the two goods. The advantage of this group of techniques is that they make use of information about people's actual behaviour and related personal preferences. Their principal disadvantage is that the statistical models used to isolate the value of interest from other influences are sensitive to the specification and functional form assumed. A number of econometric issues are generally involved in the estimation of the value of the desired attribute and it is a resource intensive exercise to make these estimates. Note that WTP values should be derived from individual's decisions and preferences rather than using those values derived from policy decisions since this would imply assuming that the policy decision is optimal (welfare optimising).

The *travel cost* method estimates recreational use values through the analysis of travel expenditures incurred by consumers to enjoy recreational activities.

*Avertive/abatement costs,* or defensive/preventive expenditures, assumes that individuals spend money on certain activities that reduce their risks (e.g. impact of pollution, risks of accidents) and that these activities are pursued to the point where their marginal cost, (i.e. the expenditure on the last unit purchased), equals their marginal value of reduced impact. Averting goods related to pollution include e.g. air filters, water purifiers, and noise insulation, while averting goods that reduce risks of death may include seat belts and fire detectors.

*Hedonic price* analysis refers to the estimation of non-market values by deriving prices for individual attributes of a market commodity that are implicit when environmental goods/services can be viewed as attributes of a market commodity, such as properties or wages. Thus, the hedonic price model provides the basis for deriving welfare change measures from observed differences in properties' prices or wages offered in the job market. For example, differences in ambient noise levels in two areas, and the values individuals place on these, may be reflected in relative house prices in the two areas.

**Stated preference techniques**
*Stated preference* is a generic name for a variety of techniques including the contingent valuation and choice experiments including contingent ranking, contingent choice and conjoint analysis. Using these techniques, researchers pose contingent or hypothetical questions to

respondents, inducing responses that trade off improvements in public goods and services for money. From the responses, preferences for the hypothetical good or the value of changes in provision of the hypothetical good can be inferred. Values are derived from preferences made in relation to (hypothetical) prices, or via trade-offs with other attributes. The major advantage of the technique is that the questions put to respondents can define exactly what needs to be valued. The main limitation is that the method provides hypothetical answers to hypothetical questions, which means no real payment is undertaken, so that no real commitment is made.

A belief that increased uncertainty is attendant to the values derived from techniques that move from production function approaches, through revealed preference approaches to stated preference in the UK has led the UK public sector appraisal guidance to recommend that, as data and resources allow, analysts should consider the use of the former approaches before considering the latter. In Switzerland, stated preference techniques are preferred to abatement ands replacement costs. Other existing guidelines e.g. those of DG Regional Policy are not as prescriptive (EC DG Regional Policy (2002)). These guidelines recommend that the most satisfactory valuation technique should be used, this being determined by the type of project, the types of impact being considered, and on the wider socio-economic and political context. Stakeholder validation of the resulting values is also suggested.

### 3.1.5 Recommendations

The best practice section above reflects the fact that there is no consensus in current guidance as to how non-market values should be derived and used. In UK, the guidance is prescriptive in recommending e.g. revealed preference techniques over stated preference techniques. EC DG Regional Policy is more flexible and responsive to the specific context, perhaps reflecting the fact that sectoral analytical expertise differs between countries. In the light of this our recommendations are similar to those of DG Regional Policy.

Recommendations for use of non-market valuation are:

- To undertake non-market valuation studies i) where the impact to be valued is likely to be significant in determining the outcome of the CBA, and ii) where the possibilities for robust value transfer (see next section) are limited.
- To select non-market valuation techniques on the basis of available expertise and previous experience in the EU relating to the specific impact.
- To use WTP measures in preference to cost-based measures such as abatement and replacement costs.
- To validate resulting non-market values through comparison with the values from other EU studies

## 3.2 Value Transfer

### 3.2.1 Definitions

Increased use of cost-benefit analysis (CBA) in the transport, environment, energy, health and cultural sectors has increased the demand for information on the economic value of environmental and other non-market goods by decision makers. Due to limited time and resources available to decision makers, new non-market valuation studies often cannot be performed. In this case decision makers must rely on transfer of valuation estimates of similar changes in non-market good quality from previous studies. This procedure is often termed benefit transfer, but since damage estimates can also be transferred a more appropriate term would be value transfer.

### 3.2.2 Purpose/role in project appraisal

Value transfer increases the uncertainty in the estimated value since the time and/or place of the original study (the study site) will be different from the new decision making context. Thus, a crucial question becomes: What level of (in) accuracy is acceptable in CBAs? Results from validity tests of value transfer procedures have shown that the uncertainty in spatial and temporal benefit transfer can be quite large. A consequence is that the analyst needs to take particular care when using value transfer in cost-benefit analysis in the instances where present value costs and benefits are very closely balanced.

There are two main approaches to benefit transfer: *Unit Value Transfer* with, and without, income adjustments; *Function Transfer* including Meta analysis.

**Unit value transfer**
*Simple unit transfer* is the easiest approach to transferring value estimates from one site to another. This approach assumes that the well-being experienced by an average individual at the study site is the same as will be experienced by the average individual at the policy site. Thus, we can directly transfer the value estimate, often expressed as mean WTP per household per year, from the study site to the policy site.

The simple unit value transfer approach may not be appropriate where transfer between countries with different income levels and costs of living is intended. Instead, *unit transfer with income adjustments* may be applied. Since most non-market valuation studies to date have been conducted in developed countries, this has become the general practice when conducting CBAs of infrastructure projects in developing countries, which rely on these studies. This is the case, for example, for the transfer of travel time unit values where cross-sectional evidence suggests the use of specific income elasticities in transfer between countries.

However, it should be noted that even if adjustment for differences in income and cost of living in different countries are made, these will not account for differences in individual preferences, initial environmental quality, and cultural and institutional conditions between countries (or even within different parts of a country). New evidence relating to noise valuation (Navrud et. al. forthcoming) suggests that for noise impacts, other factors additional to income may be significant or dominant.

**Function transfer**
With the value (or benefit) *function approach*, an empirical relationship (function) between WTP and characteristics of the affected population and the resource being assessed is specified. For a CV study, the benefit function can be written as:

$$WTP_{ij} = b_0 + b_1G_j + b_2 H_{ij} + e \qquad (1)$$

where $WTP_{ij}$ = the willingness-to-pay of household i at site j, $G_j$ = the set of characteristics of the environmental good at site j, and $H_{ij}$ = the set of characteristics of household i at site j, and $b_0$ , $b_1$ and $b_2$ are sets of parameters and e is the random error.

Transferring the entire *value function* is conceptually more appealing than just transferring unit values because more information is effectively taken into account in the transfer. Instead of transferring the benefit function from one selected valuation study, results from several valuation studies could be combined in a meta-analysis to estimate one common benefit function. *Meta-analysis* has been used to synthesize research findings and improve the quality of literature reviews of valuation studies in order to come up with adjusted unit values. In a meta-analysis, several original studies are analysed as a group, where the result from each study is treated as a single observation in a regression analysis. If multiple results from each study are used, various meta-regression specifications can be used to account for such panel effects.

### 3.2.3 Existing practice at EC and national levels

Value transfer is widespread in CBA of transportation projects at the EC and national levels due to the widespread use of “unit values” for non-market impacts such as e.g. time costs, noise, accident costs (mortality and morbidity), and in some instances also local air pollution impacts. This means that EC or national values are assumed to be constant for the whole EC or country (which implicitly means extensive use of “unit value transfer with no adjustments for differences in e.g. wealth, ecological conditions, health status etc. within the relevant geographical area). Between countries an income adjustment is often used to transfer values.

### 3.2.4 Best practice

Based on a review of value transfer studies and validity tests of transfer, Brouwer (2000) proposes a seven-step protocol, as a first attempt towards good practice for using value transfer techniques in CBA for environmental values.

Step 1 involves the identification of the relevant functions of the goods and services under consideration, and their importance for sustaining ecosystems and hence human systems. Step 2 focuses on identifying beneficiaries of the functions/services preserved or forgone, and is interdependent with Step 3, which identifies values held by different stakeholder groups in order to be able to sketch out the reasons why they value the good/service under consideration. Step 4 assesses the scope, acceptability and legitimacy of the valuation process(es): monetary and/or deliberative. In step 5 appropriate studies are selected, and study quality assessed by looking at their internal and external validity. Step 6 looks at the research design of the selected studies, and tries to assess comparability between them, and what kind of adjustment may be chosen to account for differences in design/approach for each chosen study. In step 7 values as obtained through the previous six steps are discussed with (representatives of) stakeholders, before they are extrapolated over the relevant population affected by the change under consideration. Finally, the economic aggregate is included in a CBA.

### 3.2.5 Recommendations

The steps outlined in the best practice section above emphasise the need for inclusiveness in the value derivation process, without being prescriptive about the precise transfer method to be adopted. Given the wide variation across Europe in the availability of impact specific study values for transfer this is likely to be a sensible principle to adopt in our recommendations for TEN-T project appraisal.

Recommendations for use of value transfer are:

- To use the following 7-step procedure:
    - Define the value(s) to be estimated at the policy site
    - Conduct a literature review to identify relevant valuation data
    - Assess the relevance of the study site values for transfer to the policy site
    - Assess the quality of the study site data
    - Select and summarise the data available from the study site(s)
    - Transfer value measures from the study site(s) to the policy site
    - Determine “market” over which value estimates are to be aggregated
- To select the transfer method most appropriate to the availability of study site values and findings of previous experience in value transfer related to the specific impact (see e.g. section 4.4.2 for unit value transfer recommendations relating to travel time).

## 3.3 Treatment of non-monetised impacts

### 3.3.1 Definitions

To the extent that the impacts of projects can be expressed in the same (monetary) terms the difference between the costs and benefits (i.e. the net cost or benefit of the project) provides a valid measure of the aggregate ‘worth’ of that project. However, there are instances where it is not possible to monetise impacts and this is most frequently the case in relation to impacts on ecosystems, species and biodiversity more generally. In these instances, appropriate quantitative data are either not available, thereby making economic valuation extremely difficult, if not impossible, or, given state of the art of economic valuation, it will not be possible to cost certain impacts even where quantitative data are available. These impacts are called non-monetised impacts.

### 3.3.2 Purpose/role in project appraisal

The lack of a monetary estimate for specific impacts does not mean that those impacts can be overlooked in any decision-making process. In order to ensure the inclusion of the non-monetised impacts, the analyst has to find a way of representing these non-monetised impacts in, or alongside, the cost benefit analysis.

### 3.3.3 Best practice

The principal method for representing non-monetised impacts within the decision-making into which CBA feeds is by presenting these non-monetised impacts alongside the monetised impacts in either qualitative or quantitative terms. Based on consideration of all the effects of the project – monetised and non-monetised ones – the decision maker then has to decide whether to approve the project. Hence, the decision is the outcome of a (political) deliberation of the (monetised and non-monetised) effects of the project.

To make the weighting of the different effects more transparent, the analyst can also undertake a sensitivity analysis. A sensitivity analysis simply shows what value the unvalued impacts must take in order to make:

- an ‘unfavourable’ NPV ‘favourable’; or
- a ‘favourable’ NPV ‘unfavourable’.

Once the magnitude of the unvalued impacts necessary to switch the estimated NPV from positive to negative, or vice versa, has been estimated it is possible for the decision-maker to make a judgement as to whether the unvalued impacts are likely or not to amount to this value. It therefore simply makes explicit the weighing up process that the decision-maker would undertake when considering the presentation of non-monetised impacts alongside the monetised impacts. The limitation of this method is that it becomes increasingly cumbersome when the number of non-monetised impacts increases.

### 3.3.4 Recommendations

Best practice as described above indicates that there are a number of increasingly involved variants for incorporating non-monetised impacts into project appraisal. Our recommendations for the treatment of non-monetised impacts are:

- At a minimum, to present evidence on non-monetised impacts in qualitative or quantitative terms alongside evidence on the monetised impacts. In any case, it is suggested that as far as possible, all impacts considered in an appraisal should be expressed in both physical and monetary terms.
- In the instance where a small number of non-monetised impacts are relevant, sensitivity analysis can be used to help make explicit the potential importance of non-monetised impacts in the CBA.
- Where a large numbers of non-monetised impacts are relevant, the non-monetised impacts can also be included directly in the decision-making process by explicitly eliciting decision maker’s weights for them vis-à-vis monetised impacts.

## 3.4 Discounting and intra-generational equity issues

### 3.4.1 Definitions

Discounting is the technique used to compare costs and benefits that occur at different points in time. The discount rate is the rate at which costs and benefits that occur in the future are discounted to the present. It is important to distinguish the discount rate used for purely financial project appraisal in contrast with the discount rate used in economic assessments. The former is usually referred as the financial discount rate while the latter is known as the social discount rate. The financial discount rate can be defined as the opportunity cost of capital, which represents the maximum rate of return of capital obtained from alternative investment projects. It is based on the market interest rate which is determined by the preferences expressed by lenders and borrowers in financial markets.

The social discount rate is the discount rate that is most appropriate to use in public policy. It is determined by time preference, therefore depending on the rate of pure time preference, on how fast consumption grows and, in turn, on how fast utility falls as consumption grows. The social rate of time preference is given by:

$$i = z + n \times g , \qquad (1)$$

where

$z$ is the rate of pure time preference (impatience – utility today is perceived as being better than utility tomorrow) plus catastrophe risk;

$g$ is the rate of growth of real consumption per capita;

$n$ is the percentage fall in the additional utility derived from each percentage increase in consumption ($n$ is referred to as the elasticity of the marginal utility of consumption).

With no growth in per capita consumption therefore, the social rate of time preference would be equal to the pure time preference rate, $z$. Market imperfections generally dictate that the discount rate derived from the opportunity cost of capital differs from that derived from the social time preference rate.

One might regard the determination of the discount rate for distant time periods one which has equity implications, in the sense that in the process of discounting, assumptions about the utility future generations will place on their consumption are being made. Thus, discussion of long term discount rates overlaps with consideration of inter-generational equity in cost benefit analysis. The other equity-related issue that is addressed in cost benefit analysis is that regarding the spread of impacts on the present generation, i.e., distributional impacts and intra-generational equity. We therefore discuss the role of discounting and distributional issues in the context of transport project appraisal alongside each other in this section.

### 3.4.2 Purpose/role in project appraisal

**Discounting**

The purpose of discounting is to express in present values the flow of costs and benefits involved in a project lifetime – or a determined appraisal period. Once the set of future values are expressed in present values they are comparable and therefore determine if the overall welfare gain arising from a project is worth its costs.

The present value of the future cost (or benefit) streams can be expressed as:

$$\mathrm{PV} = \sum_{t=0}^{T} C_t \times \frac{1}{(1+r)^t} \qquad \text{(a)}$$

where,

PV is the present value of the stream of costs from year *t* to year *T*,

$C_t$ is the cost incurred in year *t;*

*r* is the rate of discount.

**Distributional issues**

Consideration of intra-generational equity relates to how a project affects different social groups disproportionately in terms of income distribution e.g. lower income groups may be found to bear a disproportionately higher cost burden relative to higher income groups. Similarly, social groups defined on the basis of gender, race, age, health, skill or location may experience differential impacts as a result of a given project being implemented, and these distributional issues may or may not be correlated with income.

### 3.4.3 Existing practice at EC and national levels

**Discounting**

As reported in Odgaard et al. (2005), the variation in the discount rates used by national transport ministries within the EU can be explained partly on the basis of differential opportunity costs of capital in countries, and partly on the basis of the fact that some countries incorporating project risks in the discount rate. Nine of the 25 surveyed countries use a discount rate that includes a risk premium, whereas 13 countries (of which four also include a risk premium in the discount rate) use scenario analyses. It cannot be concluded that countries that include a risk premium in the discount rate on average use a higher discount rate. However, it can be concluded that the discount rates used in general exceed the recommendation of other pan-EU transport appraisal guidance. The EC Research project, UNITE, recommended a rate of 3% whilst EC DG Regional Policy (2002) suggests the use of a European social discount rate equal to 5%.

**Distributional issues**

Treatment of distributional issues is not addressed directly in Odgaard et al. (2005). However, it is recognised that those countries that use Multi-Criteria Analysis as an appraisal tool may include distributional effects of a proposed project as one of the criteria on which the decision-making is based. Additionally, a number of other sets of (not necessarily transport-specific) guidelines on CBA from national governments and DG TREN tend to recommend that a “winners and losers” table should be constructed, at a minimum alongside the results of the monetised CBA.

### 3.4.4 Best practice

**Discounting**

Discount rates are generally based on either the social opportunity cost of capital or the social time preference rate, though there remains disagreement as to which is most appropriate in the project appraisal context. The disagreement centres on whether the former measure based on observed behaviour should be used over the latter which is based on ethical consideration as to how future preferences should be valued. At present, it seems the case that the majority of EU countries adopt the social time preference rate measure.

Other controversial issues include the role of pure time preference, *z*, particularly in intergenerational assessments (e.g. the context for climate change impacts). In particular, arguments exist against permitting pure time preference to influence social discount rates, i.e., the rates used in connection with collective decisions. For example, it has been argued that public policy should reflect collective, not private, interests (Sen, 1982). The associated ethical argument is that to bring about intergenerational equity, impartiality implies that the well-being of one generation should not be counted differently from that of any other. There are therefore arguments for paternalism.

An alternative reason for re-examining the appropriateness of the standard discount rate is given by Weitzman (1998). He argues that for any period, the real rate of interest is determined by the marginal opportunity cost of capital and for the distant future it is the same. By applying constant discount rates, economists are implicitly assuming that the productivity of investment will be the same in the distant future as in the recent past. Weitzman does not see fundamental reasons why this should not be so. But, the distant future is totally uncertain. Uncertainty about future interest rates provides a strong generic rationale for using certainty-equivalent social interest rates that decline over time. This effect does not begin to operate until beyond the range of near-future, in which we can be fairly confident today's rates will prevail. The certainty-equivalent discount rate can be found by taking the average of the discount factor, rather than the discount rate itself. One such set of certainty-equivalent social interest rates has been adopted by the UK Government.

**Distributional issues**

Three approaches are typically used to incorporate distributional concerns within or alongside cost benefit analyses: (i) **income weighting**; (ii) the formulation of a **distributional matrix, and (iii) stakeholder analysis**. The first approach involves the use of income distribution weights to account for costs and benefits that affect individuals from different income classes. In this case changes in income are converted into changes in welfare, and it is assumed that an addition to the welfare of a lower income person is worth more than that of a richer person. This can be expressed in a formula:

$$\frac{\partial W}{\partial Y_i} = SMU_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\varepsilon}$$

where *W* is the social welfare function, $Y_i$ is the income of individual *i*; $\varepsilon$ is the elasticity of the social marginal utility of income (or inequality aversion parameter); $\bar{\mathrm{Y}}$ is the average per capita national income; $SMU_i$ is the social marginal utility of a small amount of income going to group *i* relative to income going to a person with the average *per capita income*. The values of $SMU_i$ are therefore the weights to be attached to costs and benefits to groups *i* relative to costs and benefits to a person with average income and those are determined by the analyst.

An issue closely related to that of income weighting is that of treatment of different unit values that exist in different countries where more than one country is impacted by the proposed transport project. In this case, the choice is likely to be between a) the adoption of country-specific values and b) values weighted to an average of county values. Whilst the use of country-specific values is in accordance with the efficiency-based foundations of cost benefit analysis in the theory of welfare economics, multi-country average values may be more acceptable from a political perspective.

The distributional matrix involves separating the costs and benefits of different alternative projects (columns) by income percentiles of the population affected by the projects (rows). The decision-maker is therefore able to consider the results of this matrix and decide, whether the inequalities of the burden sharing of each project are acceptable. For example, in a situation where all the projects that are being considered achieve the same benefits, but that whilst one alternative is the most cost-effective option, those costs are borne disproportionately by lower income groups it may be that an alternative, less cost-effective, project may be preferred in order to meet the equity criteria of the decision-maker. An example of a distributional matrix is presented in Table 3.1.

**Table 3.1** Example Distributional Matrix for a Transport Project Appraisal.

| | **Transport Project Option** | | | | | |
|---|---|---|---|---|---|---|
| | **Option 1** | | **Option 2** | | **Option 3** | |
| **Income Quintile** | (€'000) | (% of total) | (€'000) | (% of total) | (€'000) | (% of total) |
| > €50,000 | 12,000 | 19 | 6,000 | 10 | 10,000 | 9 |
| €28,000 - €49,999 | 14,000 | 22 | 8,000 | 14 | 18,000 | 16 |
| €16,000 - €27,999 | 15,000 | 23 | 12,000 | 21 | 25,000 | 22 |
| €8,000 - €15,999 | 13,000 | 20 | 14,000 | 24 | 28,000 | 25 |
| < €8,000 | 10,000 | 16 | 18,000 | 31 | 30,000 | 27 |
| **Total Net Cost** | **64,000** | **100** | **58,000** | **100** | **113,000** | **100** |

It should be noted, however, that this technique is demanding in terms of its data requirements. For this reason it is rarely used in practice. A simpler, more practical, means of presenting information on distributional impacts is to map out a matrix of winners and losers from the project. Various categories may be used, such as those based on geographical location, ownership (public or private) etc. A good example of such a matrix is provided by the UK transport appraisal guidelines (WEBTAG - http://www.webtag.org.uk/webdocuments/2_Project_Manager/7_Transport_Appraisal_Green_Book/). It is provided in three tables, given as exemplars, below. For TEN-T project appraisal each table should be disaggregated so that each box is completed for every individual country involved.

Distributional analysis also needs to incorporate the fact that the acceptability of a project may be dependent on the relative influence of the different stakeholder groups who are bearing the benefits and costs of such project i.e. the winners and losers. Thus, the judgement as to the acceptability of what the distributional matrix reveals about each project is made more explicitly with the views of stakeholder groups. A method of assessing this – stakeholder analysis – aims also to more systematically identify organisations or individuals whose interests are affected by the project, and to assess the potential influence they may have on the decision problem[7].

### 3.4.5 Recommendations

The issue of use of common or local values in multi-country transport project appraisal does not have an obvious solution, and it is clear that using either rule results in inconsistencies. These inconsistencies include those introduced in relation to decision-making protocols using in other economic sectors, as well as the differences in values used in transport demand/traffic models and those used in CBA. Our recommendations therefore reflect a pragmatic response to this issue. Recommendations for treatment of equity related issues are:

- In line with the recommendation to adopt local values, for TEN-T projects, to adopt the risk premium-free rate or weighted average of the rates currently used in national transport project appraisal in the countries in which the TEN-T project is to be located. The weighting will be determined by the proportion of total project finance contributed by the country concerned. A common discount rate regime across EU countries should be used in sensitivity analysis. For lower-bound sensitivity testing, a rate of 3% may be used and can be derived from using values for the components of the social time preference rate, substantiated by current empirical evidence of: $z = 1.5$; $n = 1$; $g = 1.5$. This rate is in line with the rate used by some EU national governments. It should, however, be recognised that use of this rate may result in not all projects with positive NPV being financed due to limited public resources. In this case, use of the decision criteria outlined in section 5.6 below becomes important.
- To adopt a declining discount rate profile for longer time periods in sensitivity analysis, where the countries concerned have such profiles existing in their appraisal guidance.
- To adopt local values for unit benefit and cost measures. Local values may be interpreted to mean national or sub-national level, as data allow.
- At minimum, to construct a winners and losers table, to be presented alongside the results of the monetised CBA. As data allows, distributional matrices for alternative projects should be evaluated by the decision-maker. Stakeholder consultation could also be used to inform this process. Where it is felt to be useful and worthwhile in terms of resource use sensitivity analysis may impose income weighting regimes.

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[7] It should be noted that the accounting procedure recommendation in section 3.11, to use purchasing power parity exchange rate as well as nominal exchange rate Euro, also has implications for the practical treatment of equity, in the sense that use of PPP better reflects real current purchasing power levels in a country and so gives a different weighting to values used for that country. Use of PPP however cannot be seen as a form of equity weighting since there is no a priori expectation of the way in which use of PPP values will differ from nominal values.

Example Distributional Matrix - Table 1 (Source: WEBTAG)

**Economic Efficiency of the Transport System (TEE)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Consumers** | **ALL MODES** | | **ROAD** | | **BUS & COACH** | **RAIL** | | **OTHER** |
| ***User benefits*** | **TOTAL** | | **Private Cars and LGVs** | | **Passengers** | **Passengers** | | |
| Travel time | | | | | | | | |
| Vehicle operating costs | | | | | ▨ | ▨ | ▨ | |
| User charges | | | | | | | | |
| During Construction & Maintenance | | | | | | | | |
| **NET CONSUMER BENEFITS** | | *(1)* | | | | | | |
| **Business** | | | | | | | | |
| ***User benefits*** | | | **Goods Vehicles** | **Business Cars & LGVs** | **Passengers** | **Freight** | **Passengers** | |
| Travel time | | | | | | | | |
| Vehicle operating costs | | | | | ▨ | ▨ | ▨ | |
| User charges | | | | | | | | |
| During Construction & Maintenance | | | | | | | | |
| **Subtotal** | | *(2)* | | | | | | |
| ***Private sector provider impacts*** | | | | | | **Freight** | **Passengers** | |
| Revenue | | | | | | | | |
| Operating costs | | | | | | | | |
| Investment costs | | | | | | | | |
| Grant/subsidy | | | | | | | | |
| **Subtotal** | | *(3)* | | | | | | |
| ***Other business impacts*** | | | | | | | | |
| Developer contributions | | *(4)* | | | | | | |
| **NET BUSINESS IMPACT** | | *(5) = (2) + (3) + (4)* | | | | | | |
| **TOTAL** | | | | | | | | |
| Present Value of Transport Economic Efficiency Benefits | | *(6) = (1) + (5)* | | | | | | |

Notes: Benefits appear as positive numbers, while costs appear as negative numbers.
All entries are discounted present values, in 2002 prices and values

Example Distributional Matrix - Table 2 (Source: WEBTAG)

## Public Accounts

| | **ALL MODES TOTAL** | | **ROAD INFRASTRUCTURE** | **BUS AND COACH** | **RAIL** | **OTHER** |
|---|---|---|---|---|---|---|
| **Local Government Funding** | | | | | | |
| Revenue | | | | | | |
| Operating Costs | | | | | | |
| Investment Costs | | | | | | |
| Developer and Other Contributions | | | | | | |
| Grant/Subsidy Payments | | | | | | |
| **NET IMPACT** | | *(7)* | | | | |
| **Central Government Funding** | | | | | | |
| Revenue | | | | | | |
| Operating costs | | | | | | |
| Investment Costs | | | | | | |
| Developer and Other Contributions | | | | | | |
| Grant/Subsidy Payments | | | | | | |
| Indirect Tax Revenues | | | | | | |
| **NET IMPACT** | | *(8)* | | | | |
| **TOTAL Present Value of Costs (PVC)** | | *(9) = (7) + (8)* | | | | |

Notes: Costs appear as positive numbers, while revenues and 'Developer and Other Contributions' appear as negative numbers.
All entries are discounted present values, in 2002 prices and values

Example Distributional Matrix - Table 3 (Source: WEBTAG)

**Analysis of Monetised Costs and Benefits**

| | | |
|---|---|---|
| Noise | | |
| Local Air Quality | | |
| Greenhouse Gases | | |
| Journey Ambience | | |
| Accidents | | |
| Consumer Users | | |
| Business Users and Providers | | |
| Reliability | | |
| Option Values | | |
| Present Value of Benefits (see notes) (PVB) | | |
| Public Accounts | | |
| Present Value of Costs (see notes) (PVC) | | |
| OVERALL IMPACTS | | |
| **Net Present Value (NPV)** | | *NPV=PVB-PVC* |
| **Benefit to Cost Ratio (BCR)** | | *BCR=PVB/PVC* |

Note: This table includes costs and benefits which are regularly or occasionally presented in monetised form in transport appraisals, together with some where monetisation is in prospect. There may also be other significant costs and benefits, some of which cannot be presented in monetised form. Where this is the case, the analysis presented above does NOT provide a good measure of value for money and should not be used as the sole basis for decisions.

## 3.5 The project appraisal evaluation period

### 3.5.1 Definitions

The evaluation period consists of the sum of two project phases: the planning and construction phase and the operational phase. The duration of the planning and construction phase is estimated in every project. To this the operational phase is added. Sometimes the operational phase is called the evaluation period (although the evaluation also contains the costs and benefits associated with the planning and construction phase). We will follow this convention below.

### 3.5.2 Purpose/role in project appraisal

The evaluation period determines the period of time considered in the project appraisal. Therefore it determines the time period in which costs and benefits are taken into account and thus also for which a forecast of benefits and costs is needed.

### 3.5.3 Existing practice at EC and nation al levels

In Odgaard et al. (2005) it is shown that the evaluation periods currently in use vary between 20 years and infinity.

### 3.5.4 Best practice

In theory, the time horizon of the project appraisal should equal the lifetime of the infrastructure to capture the full benefits of the project. However, the lifetime of a project can often not be easily determined. Moreover, the lifetime might be high – possibly 100 years. Furthermore, it is very hard to predict traffic demand for such a long time period. Therefore, the evaluation period is often limited to the period over which demand can be foreseen with reasonable accuracy. Experience suggests that changing parameter values with any confidence for periods over 40 years in to the future is very difficult to apply, though the use of longer time spans to cover all benefits might often be useful.

If the evaluation period is longer than the lifetime of a certain part of the infrastructure (e.g. road surface), reinvestments are necessary. If the evaluation period is shorter than the lifetime of another part, the residual value of this part has to be taken into account. In addition, the residual values of reinvestment should be included in the CBA. The treatment of residual value is discussed in more detail in Section below, though the general recommendation is a pragmatic one – that the value should be calculated according to the expected fixed lifetime of the infrastructure - or its sub-components. The default assumption is that a linear depreciation profile should be adopted, though alternative profiles may be used where more appropriate (e.g. convex functions in the case of rolling stock).

### 3.5.5 Recommendations

The recommendations that relate to the evaluation period are:

- To adopt an evaluation period of 40 years for TEN-T project appraisal (i.e. planning and construction phase plus 40 years of operational phase), as a default evaluation period. Projects with shorter lifetimes should, however, use their actual length. Consideration of periods longer than 40 years introduce too much uncertainty to give rise to meaningful values. Moreover, in general one would expect that whilst the precise NPV will change with longer evaluation periods, the sign will not, so that answers to questions as to whether to invest, and in which alternatives are likely to remain robust.
- If a project (or project variant) is compared to other projects (project variants) with different opening years, a common final year for all projects should be used. Thus, in all projects, costs and benefits are considered up to this common final year. The common final year is determined by adding 40 years to the opening year of the last project to be opened. Thus, projects which are started earlier are rewarded, because they start to generate benefits sooner.
- To estimate residual values according to the lifetimes of the assets involved and apply a linear depreciation profile. Alternative profiles may be used where more appropriate (e.g. convex functions in the case of rolling stock).

## 3.6 Decision criteria

### 3.6.1 Definitions

In a cost benefit analysis, when all costs and benefits have been valued, a decision has to be taken as to whether or not the project should be built, which project variant should be built, or which projects out of several independent projects should be built. Therefore a decision criterion has to be applied which helps inform the decision. A number of decision rules that can be applied within a cost-benefit framework have been developed:

- **Net present value (NPV)**: The NPV is the difference between the discounted benefits and the discounted costs. A project is recommended if the NPV is positive.
- **Annuity**: Converts the NPV into annual values, i.e. average net benefits per year during the evaluation period. A positive annuity means that the project can be recommended.
- **Benefit cost ratio (BCR)**: Ratio of the discounted benefits and the discounted costs. If the BCR of a project is greater than 1, the project can be recommended.
- **Internal rate of return (IRR)**: The IRR is the discount rate that equates the discounted benefits of a project to the discounted costs. The IRR can also be defined as the discount rate that makes a project’s NPV equal to zero. A project is recommended if its IRR is greater than the usual discount rate.
- **Pay back period:** The pay back period is the amount of time needed until the initial investment can be paid back. A project can be recommended if the pay back period is shorter than the evaluation period.

- **Ratio of NPV and public sector support (RNPSS):** The RNPSS is the ratio between the NPV of the whole project and the financial costs which have to be paid out of the state budget. This decision criterion is used when the state wants to select between different recommended projects but, operating with a constrained budget, cannot finance all of them.
- **First year rate of return (FYRR)**: The FYRR is the ratio of the benefits in the first year of operation of a project and the investment costs of the project. This decision criterion cannot be used to say whether the project should be recommended or not. Instead it is used to determine the optimal year to start construction.

The treatment of non-monetised impacts is as outlined in sub-section 3.3. Multi-Criteria Analysis, as outlined above, provides a further decision–making tool which can either be developed formally by the analyst, for use by the decision maker, or be used implicitly by the decision-maker when weighing up all the evidence relevant to the decision.

### 3.6.2 Purpose/role in project appraisal

The choice of a certain decision criterion may have a decisive role in project appraisal. The outcome of the application of a given decision criterion is guiding the final decision: Should the project be built? Which variant of a project should be built? Which projects out of several projects should be built? Should the project be built now or later on?

### 3.6.3 Existing practice at EC and national levels

Odgaard et al. (2005) reports on the current use of the different decision criteria in the EU 25 and Switzerland. The results show that all countries, except Finland and Sweden, use more than one decision rule for evaluating the costs and benefits of a project. The net present value and the benefit/cost ratio are the most widely used, followed by the internal rate of return. Other decision criteria currently in use include, for example, the pay back period (the Netherlands, Czech Republic and Slovak Republic) and the ratio of NPV and public sector support (UK, Switzerland).

### 3.6.4 Best practice

**Net present value (NPV)**
When evaluating a project the NPV should be determined first. All projects with a positive NPV are worthwhile, in principle. Projects with a negative NPV cannot be recommended and are therefore likely to be deleted in more detailed considerations (unless there are positive effects not included in the CBA which might make the implementation of the project worthwhile despite the negative NPV).

After deleting non- positive NPV projects, the remaining project variants have to be put in a ranking list. To build a ranking list the NPV is not suitable, because the NPV favours large projects. Instead the BCR should be used.8 This statement is illustrated with the example of the following table: Project 1 is only better when the BCR is considered. Several projects similar to project 1 with the same total costs as project 2 would have much higher benefits than project 2. The ranking list is based on the ratio of NPV and public sector support (RNPSS) and is currently used in the UK, the EC and Switzerland.

**Table 3.2 Net present value (NPV) versus benefit cost ratio (BCR)**

| | | |
|---|---|---|
| Project 1 | cost = 2<br>benefit = 5 | NPV = 3 (= 5 –2)<br>BCR = 2.5 (= 5 / 2) |
| Project 2 | cost = 40<br>benefit = 60 | NPV = 20 (= 60 – 40)<br>BCR = 1.5 (= 60 / 40) |

Furthermore, the NPV depends on the year for which the NPV is calculated (one year later the NPV is higher by a factor 1 + discount rate). The BCR, in contrast, is independent of this year (because the factor 1 + discount rate is both above and below the line and therefore cancels out).

**Benefit cost ratio (BCR)**
As shown above the BCR is well suited to the comparison of different project variants. The problem, however, is that the BCR can be manipulated if costs and benefits are not clearly defined. There is a certain danger that effects are labelled costs or benefits arbitrarily. This can lead to the fact that the ranking list looks different depending on the labelling of the effects. This is illustrated with the example in the following table. If the additional noise is taken to be part of costs, project 3 is preferable. In contrast, project 4 is preferable, if noise is looked at as a reduction of benefits.

**Table 3.3 The labelling of noise as costs or benefits determines the ranking list**

| | | |
|---|---|---|
| Project 3 | costs = 5<br>benefits = 12<br>noise = 1 | noise = costs BCR = 2.0 (= 12/(5+1))<br>noise = reduction of benefits BCR = 2.2 (= (12-1)/5) |
| Project 4 | costs = 7<br>benefits = 19<br>noise = 3 | noise = costs BCR = 1.9 (= 19/(7+3))<br>noise = reduction of benefits BCR = 2.3 (= (19-3)/7) |

Hence, a clear definition of costs and benefits is necessary. The following definition is recommended (where costs and benefits are always the NPV of costs and benefits):[9]

- Costs are the resource consumption of the operator (rare resource gains of the operator are included as negative costs, except for the revenues).

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[8] Department for Transport (2002), The Application of COBA, p 1/1, European Commission et al. (1999), Transport Infrastructure Needs Assessment, p. 23, EWS (1997), Kommentar zum Entwurf Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Strassen EWS, p. 12, European Commission (1996), Cost-benefit and multi-criteria analysis for new road construction, p. 72 and Abay (1984), Kosten-Nutzen-Analyse für Verkehrsinvestitionen, p. 112.

[9] This definition is taken from the Swiss Norm SN 671 810 (2005), Kosten-Nutzen-Analysen im Strassenverkehr and from Ecoplan (2005), Bewertungsmethode für die Priorisierung von Projekten im Schienenverkehr, p. 78.

- Benefits are the resource gains of users and third parties (resource consumptions of users and third parties are negative benefits) and the revenues by the public transport or road operator.

Thus costs are indicators such as investment costs, costs of maintenance, operation and administration (especially for public transport). Reductions in maintenance costs on old roads, where there is now less traffic, are negative costs.

The benefits include indicators such as time savings, vehicle operating costs (not for public transport projects), safety, all environmental indicators etc. and revenues by the (public transport or road) operator.

**Ratio of NPV and public sector support (RNPSS)**
The decision maker might be also confronted with the problem that he has to select a number of projects out of a bundle of projects, but has not enough financial resources to finance all profitable projects (with a positive NPV). In this case a further decision criterion is used which ensures that the constrained budget is allocated optimally. The ranking list is in this case based on the ratio of NPV and public sector support (RNPSS). The RNPSS is currently used in the UK, Scotland, the EU and Switzerland.[10]

To calculate the RNPSS the public sector support is defined as the NPV of the costs which are financed out of the constrained budget. This is often more or less equal to the investment costs (including taxes, which do not have to be considered in the CBA as they are only transfers). The RNPSS is a kind of a cost benefit ratio with a clear definition of the numerator ("cost") and the denominator ("benefits"). However, in the RNPSS the public sector support is contained in the numerator and in the denominator. Hence, the RNPSS for a profitable project is greater than 0 (not greater than 1 as the BCR).

With the RNPSS, projects can be put in a ranking list. Starting with the best project the projects can be financed until the budget is used up. Since the scarce resource – the constrained budget – is in the denominator of the RNPSS, this procedure ensures that the budget leads to the highest possible economic benefit.

If a project is partly privately financed, this eases the burden on the constrained state budget. In the RNPSS we nevertheless use only the public sector support in the denominator[11] because the aim is to reach a NPV as high as possible with the constrained budget. Hence, private money allows the government to use its own money for other profitable projects. Thus partly privately financed projects are favoured. But even partly privately financed projects should

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[10] ECMT (2001), Assessing the Benefits of Transport, p. 28, Odeck (2000), Valuing the Cost and Benefits of Road Transport, p. 29, European Commission (1996), Cost-benefit and multi-criteria analysis for new road construction, p. 73 and 385, Scottish Executive (2003), Scottish Transport Appraisal Guidance, p. 5-12 and Swiss Norm SN 671 810 (2005), Kosten-Nutzen-Analysen im Strassenverkehr. In Scotland public sector support is defined a bit broader. See also Bonnafous und Jensen (2004), Ranking Transport Projects by their Socioeconomic Value or Financial Interest rate of return?

[11] Odeck (2000), Valuing the Cost and Benefits of Road Transport, p. 29, Bonnafous und Jensen (2004), Ranking Transport Projects by their Socioeconomic Value or Financial Interest rate of return? and Ecoplan and Metron (2005), Comments on Kosten-Nutzen-Analysen im Strassenverkehr, p. 138.

only be constructed when the NPV is positive and when the ratio of the NPV and the remaining public sector contribution is high enough compared to other projects. If the project is completely privately financed, it should be implemented, if the NPV is positive.[12]

If several countries or one or several countries and the EU are contributing to the costs of a (large) project, there are probably several constrained budgets: that of the EU and that of the different countries. In this case the RNPSS has to be calculated for each country and the EU separately where only the costs and benefits to the individual country or to the EU are included, respectively. This might lead to the situation in which one country wants to build the project, but another country does not. In this case another allocation of the costs between the countries might solve the problem.

The problem with RNPSS might be that at the time of evaluation it is sometimes not yet known who will be paying how much. However, the RNPSS also allows an understanding of when the state should contribute or how the costs of the project can be fairly distributed.

**Internal rate of return (IRR)**

The normal conclusion that a high IRR is preferable holds only true when the costs are incurred initially and the benefits occur afterwards – as is normally the case with infrastructure investment projects. If in contrast the benefits arise before the costs, a low IRR is preferable, because with a high IRR the initial benefits increase with the high IRR over time and can eventually be used to pay for the final costs. If periods with net costs and net benefits follow each other, interchangeably (as is the case if reinvestments are necessary), the interpretation of the IRR can become somewhat difficult. Furthermore, there is a possibility of multiple solutions or no solution for the IRR. Moreover, the IRR gives the same ranking list as the benefit cost ratio (BCR), on principle.[13] The BCR may therefore be favoured over the IRR.[14] [15]

So far we have proceeded as if there was no uncertainty. In reality, however, we have to include the results of the sensitivity analyses in the decision. If the results of the sensitivity analyses are not the same as in the basic scenario, there is no simple decision rule.

So far we have only considered the optimal decision based on CBA-results. If non-monetized effects are also relevant, the decision becomes more complicated as this decision involves a value judgement which cannot be determined by science. Hence, a discussion of (monetized and non-monetized) costs and benefits is necessary. The ensuing decision is of course also a political one that takes account of, and weighs up, all evidence and interests.

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[12] Odeck (2000), Valuing the Cost and Benefits of Road Transport, p. 29 and Ecoplan and Metron (2005), Comments on Kosten-Nutzen-Analysen im Strassenverkehr, p. 138.

[13] ECMT (2001), Assessing the Benefits of Transport, p. 28. Nevertheless, it is possible that the BCR and the IRR do not lead to the same ranking list (Abay 1984, Kosten-Nutzen-Analyse für Verkehrsinvestitionen, p. 110-111).

[14] This conclusion is often found in the literature: See European Commission (1996), Cost-benefit and multi-criteria analysis for new road construction, p. 73, EWS (1997), Kommentar zum Entwurf Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Strassen EWS, p. 11, and Lee (2000), Methods for evaluation of transportation projects in the USA, p. 48.

[15] The advantage of the IRR is that no discount rate has to be set in advance.

To facilitate the political discussion the analyst summarizes the effects covered in the CBA, for example in the NPV. In addition, (s)he may describe the non-monetised effects alongside the CBA in quantitative or qualitative form. Based on these findings, the decision-maker then has to decide whether or not the proposed project is worthwhile.

Non-monetized effects are thus taken into account last. This is not because they are least important, but because they make value judgements necessary and because the ranking list based on the CBA-results can be derived without value judgements.

### 3.6.5 Recommendations

Ultimately the decision as to which projects will be put into action is a political one. The CBA can only guide this decision and give the decision makers information on which they can base their decision and perhaps help to prevent clearly wrong decisions. When taking the decision, the limits of the CBA must be kept in mind, i.e. that the CBA does not include non-monetised effects and that criteria other than economic efficiency may be important to the decision maker. Also, within the CBA framework, the decision criterion to be used depends on the decision to be taken. These points are reflected in the recommendations presented below.

Recommendations that relate to decision-making criteria are:

- Where the decision is whether or not to build a project with only one variant, the project can be recommended if the net present value (NPV) is positive.
- Where the decision relates to which variant of a project should be built, the variant with the highest benefit cost ratio (BCR) should be implemented (if its BCR is above 1). To calculate the BCR the benefits and costs are defined as follows: costs are the resource consumption of the operator, benefits are the resource gains of users and third parties and the revenues by the public transport or road operator.
- Where the decision relates to which projects or project variants should be included in a construction program, where a constrained public sector budget exists, the ratio of NPV and public sector support (RNPSS) should be used to determine the ranking list.
- Where the decision relates to determining the optimal opening year of a project the first year rate of return (FYRR) should be used.
- When interpreting the results of the CBA, the outcomes of sensitivity analyses of key variables should be included.
- Non-monetised impacts should be considered alongside the CBA. The weighting of non-monetized impacts should be left to the decision maker as this involves value judgements. If the decision maker asks for it, the implications of alternative weighting regimes applied to the project impacts can be presented to the decision-maker.

## 3.7 Treatment of future risk and uncertainty

### 3.7.1 Definitions

The future outcome of a project is not known with certainty. We define the situation where the analyst has poor knowledge of the probability of an event being realised and the magnitude of the likely consequences arising from this event, as *uncertainty*. Where the analyst is reasonably confident of the probability of an event, we define the problem as being one of *risk*. Techniques exist for dealing with these aspects in a project appraisal.

The main probabilistic (risk based) techniques are those such as Monte-Carlo simulation that result in expected values.

Where the decision-maker does not have an estimate of the probability distribution s/he will have to define alternative possible futures for the variable under consideration using non-probabilistic ways. In this case sensitivity analysis or scenario analysis may be appropriate techniques.

### 3.7.2 Purpose/role in project appraisal

The expected net present value is an important indicator when assessing and comparing projects, when the probability of occurrence of each possible outcome is known. When the probabilities are not known we may then generate a range of NPVs determined by the use of sensitivity analysis relating to key variables, and/or using scenario analysis. Since these estimates essentially determine the choice of the ‘best’ project, the decision-maker will want to know, in general, how sensitive the future estimates are to the input data and modelling approach used by the analyst, as well as the key assumptions adopted.

### 3.7.3 Existing practice at EC and national levels

Odgaard et al. (2005) indicate that the vast majority of European countries have explicitly formulated basic principles to undertake sensitivity analyses for project appraisal in the transport sector. Risks are either evaluated through their incorporation in the discount rate and scenario analysis. Additional methods for treatment of risk and uncertainty are used in a number of countries.

### 3.7.4 Best practice

A number of techniques exist for analysing the key factors that underpin the estimated outcomes in a decision problem. Chief amongst these are:

*Sensitivity analysis* (non-probabilistic approach). Sensitivity analysis (sometimes known as “side-analysis”) focuses on alternative assumptions that have a significant effect on the study’s results (for example NPV or benefit cost ratio). It can be applied in all cases in which anticipated costs and benefits are quantified. The purpose of sensitivity analysis is to show how large the risks of a project are and in particular to show whether a favourable project becomes unfavourable (or vice versa) if some assumption is changed. The importance of sensitivity analysis is borne out by the consideration of the optimism bias phenomenon relating to capital costs, and discussed in further detail in Section 7.5 below. Scenario analysis is a variation of sensitivity analysis involving the construction of alternative visions of how the future might look, and the implications of these on the key variables in the analysis.

While in sensitivity analysis only one assumption is changed at a time, in scenario analysis several assumptions are altered. An extension of this idea is interval analysis. Interval analysis simply involves taking the (absolute) lower value of the range of estimates for each model input, and combining them to define the *lower bound* of the final result; likewise, the (absolute) upper value of the range of estimates for each model input can be combined to define the *upper bound* of the final result. Lower bound and upper bound are also called worst and best case. In other words, interval analysis identifies the extreme lower and upper estimated outcomes for a given set of input variables, modelling assumptions *etc*. When undertaking interval analysis, we must be aware that the worst and best cases are both highly improbable since it is not likely that all assumptions take the worst or best values at the same time.

A further extension of the principle of sensitivity analysis is the use of switching values. A *switching value* may also be calculated in the following way. If, under base case assumptions, a positive Expected NVP (ENPV) is calculated, the switching value shows the percentage increase in a specific cost item (or equally, the percentage decline in a specific benefit item) required for the ENPV to become zero. The switching value is itself a percentage – basically, the percentage change in a variable required for the estimated ENPV to change sign. If the switching value is relatively high, a very substantial change in the variable is required before the ENPV changes sign. Conversely, if the switching value is relatively low, a small change in the variable is required to change the ENPV sign.

*Monte Carlo Simulation* (probabilistic). In Monte Carlo simulation typically computers are used to draw a large number of random samples assuming an underlying probability density function, calculate outcome descriptors, and record them. This is repeated a large number of times until an accurate picture of the distribution of possible outcomes has been built up. The resulting frequency distribution provides information about both the expected outcome (i.e. the mean value) and how far it is likely to deviate from the mean (i.e. the standard deviation). These two measures can be used to make statistical inferences, e.g. to identify the probability that the outcome will fall below some value.

The Monte Carlo analysis has two main drawbacks compared to the sensitivity analysis. First, it is more complex than sensitivity analysis and its findings cannot be explained to decision makers as easily. Second, Monte Carlo simulations are, themselves, based on probability distributions of several assumptions (for example, a probability distribution of the GDP growth rate). These distributions are not known, so that assumptions made by the analyst are still necessary. The result of the Monte Carlo simulation therefore heavily depends on these assumptions. In sensitivity analysis, however, only a lower and upper value of each input are required, and no data are needed on the probability density functions of each model input. Furthermore, in a Monte Carlo simulation we can easily change the assumptions of the valuation model, but we cannot easily incorporate the traffic model. Thus, different results from the traffic model can only be considered in a way which resembles the sensitivity analysis: we can calculate the traffic model for a set of different cases, but not for all the Monte Carlo simulations. Thus the advantage of the simulations is somewhat diminished – especially when we consider that the uncertainties may well be much larger in the traffic model than in the valuation model.

### 3.7.5 Recommendations

Treatment of risk and uncertainty is dictated by data availability, resources, and whether or not probabilistic distributions of variables are known. Experience in the context of transport project appraisal suggests that the issue of resources (modelling time, person-days etc.) is critical to what analysis is done, and that variables to be tested should therefore be prioritised. This constraint is recognised in the recommendations.

The recommendations that relate to the treatment of risk and uncertainty are:

- To undertake sensitivity analysis for the following assumptions: the discount rate; investment cost (optimism bias); valuation of safety; climate change impact costs; value of travel time saving; growth of real GDP and of real wage rates; and traffic growth. The latter four assumptions – value of travel time saving and the different growth rates – are also important inputs into the traffic model. Hence, for large projects the models should be rerun. Additional variables should also be explored as determined by the specific project context. The precise specifications of the sensitivity analysis will be determined by the analyst, according to context.
- To undertake Monte Carlo simulation analysis, if resources and data allow.

## 3.8 The Marginal Costs of Public Funds

### 3.8.1 Definitions

The financing of transport infrastructure projects through taxation may impose a cost on society greater than the pure cost of funds. The reasoning is the following: by causing agents to alter their behaviour as a result of the tax — consumers buy less, for example — the tax lowers welfare by more than it collects in revenue. The difference, often referred to as a “deadweight loss”, leads to the marginal cost to the economy of raising one € of public funds being more than one €. Conversely, if the tax acts to internalise an externality, efficiency may be improved and – other things being equal - the marginal cost will be less than one.

### 3.8.2 Existing practice at EC and national levels

Odgaard et al. (2005) shows that four of the 21 countries for which the information is available take distortion effects from tax financing into account. Some of these countries only include distortion effects for some transportation modes. In Denmark and Slovenia 20% is added to the net costs financed through public funds. Sweden uses a similar approach by adding 30% on the resources from the general budget. In Greece no specific value is given, though the issue is acknowledged in their project appraisal guidelines.

### 3.8.3 Best practice

To evaluate the true cost of public funds it is necessary to recognise that each source of finance – taken as it is from a different tax base - will have its own marginal cost. Thus, there is unlikely to be one value for the whole tax system. Current estimates of average national shadow costs of capital are: 1.56 for the USA and 1.28 for the European Commission (IPCC TAR WGIII p. 479). Further estimates based on empirical research give larger intervals spanning from 0.62 to 1.75. (see e.g. rates gathered for all OECD countries by Kleven and Kreiner (2003).

As recognised by a majority of EU national transport project appraisal guidelines, there are several reasons not to include the marginal costs of public funds:

- The large uncertainty about how large the marginal costs of public funds are (0.62 - 1.75) speaks against inclusion.
- The marginal costs of public funds are normally not considered when evaluating public projects outside the transport sector. Thus, inclusion in the transport sector would bias decisions against transport.
- In practice, the question of the inclusion might not be as important as it might seem. Because only the best projects get financed, these projects tend to have a high BCR or RNPSS. In Germany almost 70% of built road and inland waterways projects and 40% of the rail projects reached a BCR above 3. In the UK the accepted projects (37 out of 68 projects, i.e. 54%) reach a BCR of 3, at least.

Conversely, it may be that in the evaluation of public-private transport infrastructure initiatives a bias against private participation is introduced if the MCPF is not considered. However, it has been suggested that this problem may be in part surmounted by using a cut-off value for the Ratio of NPV and public sector support (RNPSS) of e.g. 1.5 since it effectively requires a higher return on the public funds used.

### 3.8.4 Recommendations

The high degree of uncertainty in the estimates of the marginal cost of public funds that are currently available, combined with the fact that use in transport appraisal would lead to a distortion effect on the allocation of public finance more generally, suggests that use of a marginal cost would not be justified.

The recommendation that relates to the treatment of the marginal cost of public funds is:

- To assume a marginal cost of public funds of 1, i.e. not to use any additional costs for public funds.
- To use a cut-off value for the RNPSS of 1.5 when applying decision criteria.

## 3.9 Producer Surplus of Transport Providers

### 3.9.1 Definitions

Producer surplus is the change in total producer revenue less the change in producer costs. The greatest scope for changes in producer surplus arises from public transport projects or toll road projects, which can affect operators' revenues without having an equal and offsetting effect on operating costs.

### 3.9.2 Existing and Best practice

Mackie et. al. (2003) reminds us that revenue forecasts depend on traffic forecasts, and both depend on pricing policy. Therefore it is essential in appraisal that the price policy assumptions on which the traffic and benefit estimates are based are consistent with those used for revenue forecasting. The size of the revenue and user benefit effects, as well as their distribution, depends upon the pricing policy. Since the appraisal may be undertaken before the details of the toll or price regime have been finalised, it should be noted that provisional assumptions made for the appraisal can turn out to be inaccurate. Sensitivity testing of the price regime at the appraisal stage is therefore often valuable.

Sometimes revenues of the operator are not included in the appraisal since it is argued that this is only a transfer from users to the operator which is not relevant for the economy as a whole. However, this reasoning is only valid for the existing traffic, but not for the newly generated traffic. For the newly generated traffic the additional revenues of the operator are a measure of the additional benefits of the additional traffic and must therefore be included in the evaluation.

### 3.9.3 Recommendations

Changes in producer surplus, along with changes in consumer surplus, comprise a measure of the welfare change that can be expected to result from a transport project. As highlighted above, the principal context in which changes in producer surplus are likely to be significant is when transport pricing regimes are changed, or introduced.

The recommendations relating to producer surplus are:

- To estimate (changes in) the producer surplus in the context of changed traffic volumes, (including situations of generated traffic) and possibly of the introduction and adjustment of transport pricing regimes.
- In the cases where producer surplus is estimated, sensitivity analysis of this variable should be undertaken.

## 3.10 Treatment of indirect socio-economic effects in European guidelines for transport appraisal

### 3.10.1 Definitions

In the presence of imperfect factor and/or goods markets total final economic impacts are likely to exceed those impacts measured directly in the transport sector i.e. there is additionality. (Note that sub-additionality is also possible). Since imperfect competition generally exists, it is important in transport project appraisal to distinguish direct and indirect economic effects in order to avoid the possibility of double-counting and generating an incorrect outcome of the CBA appraisal. Results from the FP5 IASON project provide a useful typology of this distinction (Tavasszy et al. 2004):

- **Direct effects**: effects on behavioural choice within the transport system, (route choice, mode choice, departure time choice and destination choice), by users of that part of the network to which the initiative applies (e.g., the number of users of a newly planned road).
- **Direct network effects**: effects on behavioural choice within the transport system transferred by network flows to other users of the network who are not themselves users of the part of the network to which the initiative applies (e.g. the change in train use in the area where the new road is planned).
- **Indirect effects**: effects outside the transport market as the result of a transport initiative, typically including changes in output, employment and residential population at particular locations (e.g. households moving to a city because it has better connections to their work due to a new road).
- **Indirect network effects**: effects on the transport network of choices made in other markets (land and property markets, the labour market, product markets and the capital market), as a result of changes in generalized cost brought about by a transport initiative (e.g. the changed traffic flow within a city due to more households locating in the city because of a new road).

The degree to which indirect effects are additional to direct effects differs widely in the literature; the general consensus, however, is that the additional effects are significant. Bröcker et al. (2003) find average indirect additional effects of +20% for the Trans-European Networks. This was established as a number for the whole European study area (outliers for individual regions were observed of up to 80%) and without considering the effects of reducing imperfections in the labour market. Other recent studies with models that do take into account labour market effects have found indirect impacts of up to 38% (see Elhorst et al. 2005). One of the conclusions of this latter paper is that "the use of a uniform 'additional economic benefits to direct transport benefits' ratio to approximate these additional benefits must be rejected".

### 3.10.2 Existing practice at EC and national levels

Odgaard et al. (2005) survey a total of 26 countries regarding their methods of assessment of indirect effects in transport appraisal. The effects covered, regardless of the method for assessment used (MCA, CBA or QM) include: land use, economic development, employment (short term and long term), cohesion (national and EU level), urbanisation, network effects,

effects on state finances, equity. The most frequently included indirect effects are the effects on employment and state finances. The inclusion of cohesion effects are mainly used in new EU countries such as Hungary, Czech Republic, Poland and Malta.

### 3.10.3 Best practice

To avoid double counting, the sources of genuine additionality to direct effects need to be distinguished (Mackie et al. 2001, p. 18). The starting point of the analysis may be to assume that a context exists comprising of markets with perfect competition (constant returns to scale, no externalities) without borders. In this situation no indirect effects exist. As in the real world markets are imperfect, additionalities exist. To handle this one can then introduce some realism in a model by incorporating market imperfections such as monopoly, monopsony, increasing returns to scale, externalities, information asymmetry, etc., as appropriate.

For the best assessment of indirect effects resulting from market imperfections, it is preferable to combine the advantages of different models rather than applying just one model since existing models do not feature standardised, complete inclusion of indirect effects. For example, a modelling approach used to assess urbanisation effects is different from the modelling approach used to assess labour market effects. It is therefore advisable to adapt the choice of model(s) to the type of effect likely to be most significant. If indirect effects can be expected to be large, we recommend the use of a Spatially Computable General Equilibrium Model (SCGE). Alternative models can be considered, although these do not follow CBA accounting principles as naturally as do SCGE models. The IASON project discusses some relevant alternative approaches (Land Use Transport Interaction models, Regional Production Function models, System Dynamics models and Macro-economic model). In order to gain an understanding of indirect effects across borders, models need to operate at the European level. At the moment the only available SCGE model at the European level is the CGEurope model (Bröcker et al, 2003). If indirect effects cannot be modelled due to high costs (of the use of advanced modelling), insufficient availability of data, lack of appropriate quantitative models or unreliable results, a qualitative description of expected impacts is recommended.

### 3.10.4 Recommendations

The gap between theory and practice is large. It can be bridged, in part, by harmonising and clarifying the concept of indirect effects and constructing models that more completely include indirect effects. However, in the meantime, these limitations inform our recommendations.

The recommendations relating to treatment of indirect effects are:

- At a minimum, qualitative assessment should be used to provide an indication to the decision-maker of the potential size of the additionalities. This assessment would be based on the findings of previous quantitative analyses undertaken in comparable contexts.
- To use an economic model, preferably a Spatially Computable General Equilibrium (SCGE) model, to estimate indirect effects, where indirect effects are likely to be significant.

## 3.11 Recommended Accounting procedures

It is important to illustrate how monetary data can be expressed in a way such that all monetary inputs into the TEN-T project appraisal process are expressed in consistent forms with each other. This consistency can be brought about by adopting

- a common unit of account (to account for taxes and subsidies)
- a common price base year for prices and values
- a common currency

The recommendations relating to accounting procedures are:

- Factor costs should be the unit of account. This requires measures expressed in market prices - which include indirect taxes and subsidies – to be converted to factor costs.
- All unit values should be expressed in a common price base year of 2002 but that this base year should be adjusted regularly, according to data availability in future years. This entails conversion from current prices to constant prices.
- In order to convert current price measures to constant price the price index for construction costs (PIC) should be used for construction costs whilst the consumer price index (in the EU measured by the HICP) should be used for user benefits and externalities.
- Changes in prices relative to changes in the general price level should be accounted for by adjusting specific prices on the basis of how the long run average trends in these prices differ from the long run trend in the general price level.
- Changes in the future value of a resource should be fully reflected in the unit value(s) related to that resource, on the basis of national GDP growth rates.
- Unit values should be expressed in base year nominal exchange rate € and in purchasing power equivalents. Where use of nominal € and PPP-equivalent € give different recommendations using the CBA decision-rule, the choice of which exchange rate to use will be dependent on the preference of the decision-maker.
- In order to retain consistency between project appraisals, the appropriate conversions should be made in the sequence order:
    1) to a common unit of account
    2) to a common base year
    3) to a common currency
    4) to projections of future unit values

A detailed presentation of the procedures including detailed examples and tables with data is given in Annex B.

## 3.12 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. Clearly, at any time when the guideline user is aware of new evidence becoming available this should be reviewed in terms of its quality and status in relation to the existing evidence on which the current unit values are based, and values should be adjusted accordingly.

# 4 Value of Time and Congestion

## 4.1 Purpose/role in project appraisal

There are countless examples in everyday life of people's willingness-to-pay to save travel time - think of a tolled bridge over an estuary, or the premium fare that a high speed train service attracts. Clearly therefore time savings have value. However, the apparently simple question as to what the value set is, has to be answered using many areas of economic thought including that of labour supply, home production and transport. The pioneering work of Becker (1965), Oort (1969), De Serpa (1971) and Evans (1972) considered these issues and has since led to some degree of consensus being developed. In essence changes in welfare occur when individuals transfer time from intermediate activities (such as travel) to leisure or work activities and vice versa. Along with changes in other elements of user benefit (e.g. out of pocket costs and vehicle operating costs), changes in travel time can manifest themselves in the wider economy as changes in land rents, wages, employment and output. The potential for double counting economic benefits through the inclusion of all these 'final' impacts means that travel related user benefits (of which the majority are travel time savings) are used in cost-benefit analysis as a proxy for these final impacts.

## 4.2 Definition

There is a high degree of consensus between the EU-25 countries plus Switzerland as to what constitutes a saving in travel time (Odgaard *et al.*, 2005). Whilst not all national appraisal guidelines include a definition of time savings the approach adopted across the EU typically takes any change in the door-to door journey time to constitute a change in travel time. The *change in door-to door journey time* is therefore the definition adopted in the HEATCO guidelines. This definition means that travel time is a composite of in vehicle and out of vehicle time.

## 4.3 Valuation Methodology

Economic theory suggests that the welfare impacts of savings in travel time for work and non-work trips occur through different mechanisms. The welfare benefits of travel time savings made during the course of work is related to the marginal product of labour, whilst that made in non-working time is not – instead it is a function of personal preferences. The very different nature of passenger and goods traffic also makes it reasonable to distinguish between these traffic types. It is therefore recommended that different valuation methodologies are used for the following three broad categories of trips: (i) passenger-work, (ii) passenger-non-work and (iii) commercial goods traffic. Commercial goods traffic is traffic whose primary function is the delivery of goods and products; business passenger traffic is traffic where the driver or occupants are travelling on behalf of their employer; and non-work related passenger traffic is the remainder. As set out in Table 4.1 for each of these traffic types we recommend a minimum acceptable methodology for the valuation of time savings. Clearly, more sophisticated techniques would also be appropriate for use in an economic appraisal – and such techniques have been identified.

**Table 4.1** Recommended valuation methodologies.

| **Trip category** | **Minimum approach**[1] | **More sophisticated approach**[2] |
|---|---|---|
| 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.
[2] The more sophisticated approaches are for illustration.

The cost saving approach is based on a theoretical argument regarding the marginal productivity of labour. Such an approach assumes that there is no utility impact on the worker and that all travel time savings can be transferred to productive output. For business travellers (passenger-work) 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. For commercial goods traffic a pure willingness-to-pay approach has also been used. Theoretically such an approach encapsulates all the cost savings that can be utilised by the firm from a reduction in the time associated with the transportation of goods – including vehicle operating costs and whether or not the time saved can be transferred to other productive output. Whilst this WTP approach may seem more appealing than the cost saving approach a key issue in underlying its reliability is a robust survey design. This is because it is absolutely critical that interviewees have a complete overview of the total impact of time savings, within the logistics chain, on the overall operations of the business. This is a challenging requirement and therefore the WTP approach is more sophisticated than the cost saving approach for deriving a value of travel time savings (VTTS) for commercial goods traffic. For an application see de Jong *et al*. (2004a).

There is no economic basis for saying that non-work passenger time savings vary directly proportionately with the wage rate. Consequently the minimum recommended approach to valuing non-work passenger time savings is some form of willingness-to-pay survey drawn from revealed and/or stated preference.

The valuation methodologies set out in Table 4.1 are those that should be adopted if a survey of the valuation of travel time savings is to be undertaken. Clearly such surveys are very resource intensive. In the absence of values derived using the methods recommended in Table 4.1 the relationships derived from the HEATCO meta-analysis should be used. This meta-analysis is based on 77 studies from 30 countries for passenger transport, and 33 studies from 18 countries for freight. These relationships are set out in Annex A in Tables A17, A18 and A19 for passenger work, passenger non-work and freight trips respectively.

## 4.4 VTTS values

### 4.4.1 Disaggregation

Since economic theory suggests that different methods of valuation for VTTS should be used for passenger-work, passenger-non-work and commercial goods traffic we recommend that at a minimum VTTS values are disaggregated in this manner.

**Passenger-work (business) VTTS**
Theory informs us that passenger-work (business) VTTS varies with the wage rate of the traveller (i.e. the income) - a proxy for the wage rate may be job/skill type. Appraisals that go beyond the minimum level of disaggregation can take this variation into account. For applications such as toll motorways or high speed rail at premium fares, segmentation by income group and journey purpose is essential. However, accounting for income is only possible if the traffic and transport modelling that underpins the appraisal is detailed. Even if the modelling is coarse, it may still represent travel by different modes of transport. Given that different modes of travel offer different levels of service (speed, journey length, comfort) for different prices we find that travellers with certain VTTS will typically choose to travel by a certain mode. As VTTS for work travellers is related to the wage rate, we find that the average incomes of travellers differ by mode. Thus disaggregating passenger-work VTTS by mode is a more sophisticated approach than having a single value for all passenger-work time savings, but is not as sophisticated as disaggregating by income.

**Passenger non-work VTTS**
Economic theory and evidence informs us that passenger-non-work VTTS may vary by:

- Journey purpose (commuting, shopping, leisure, other, etc.)
- Income of traveller;
- Socio-economic status (e.g. retired, child, etc.)
- Length of journey (e.g. long distance or short distance)
- Mode of transport (i.e. varies with comfort of travel)
- Congestion (i.e. varies with conditions under which travel is made)

Sophisticated appraisals should therefore disaggregate VTTS beyond the minimum standard to account for this variation. Similar arguments to that set out in the discussion on disaggregating business VTTS also apply to non-work VTTS. The ideal scenario is to disaggregate VTTS by journey purpose, income, distance and modal comfort. However, where the transport modelling does not support such a level of disaggregation average values by mode should be used. In such situations the modal VTTS values will reflect a conflation of the average income and journey length characteristics of the travellers (by mode) in conjunction with the comfort qualities associated with that mode.

Typically journeys, particularly public transport journeys, involve some elements of walking, waiting and interchange. For reasons of comfort and convenience the VTTS of these elements of a trip are viewed differently (and therefore valued differently) from the time spent in the vehicle (in-vehicle-time - IVT). Often public transport models distinguish between these different elements of a trip and therefore it is usually reasonably practical to disaggregate non-work VTTS in this manner as well.

Children and retired people typically exhibit lower non-work VTTS than do adults. This arises due to a mixture of lower incomes and lower resource values of time (arising through for example less onerous time constraints). Ideally VTTS should disaggregate between children, retired people and adults. However, the practicalities of obtaining travel demand data within a modelling system that disaggregates between these groups of travellers suggests that such a level of disaggregation is not practical within an appraisal. This does raise questions of deriving a suitable average from surveys which may be biased towards economically active sections of the population.

The above discussion relates to the VTTS value of passenger travel. Often road traffic models contain data only on the travel time saving per vehicle. In such instances it is necessary to use a VTTS value per vehicle in an appraisal. VTTS values per vehicle should reflect average vehicle occupancies. Additionally values may differ by vehicle occupant (car driver, car passenger, child, retired person). Average values for vehicles should reflect vehicle composition - if data reflecting the relative valuations of car drivers and passengers are available. In the absence of such data the same value for all occupants could be used.

**Commercial goods traffic VTTS**

The VTTS of commercial goods traffic relates to the anticipated cost saving that a reduction in journey time may give to the firm. Given the fact that the drivers and crews of different transport modes are paid different amounts, crewing ratios (e.g. per tonne of good transported) vary by mode and that time related vehicle costs can vary by mode and vehicle type, the minimum level of disaggregation for commercial goods traffic is mode. Cost savings due to journey time savings may also be a function of the type of good that is being transported – high value, just-in-time delivery, perishable food, etc. However, as only the most detailed of studies will have information on the type of goods being carried VTTS is not often disaggregated in this manner. Instead a suitable proxy for disaggregation for more sophisticated appraisals is whether or not the good is containerised.

**Table 4.2** Recommended level of disaggregation for travel time savings.

| Trip Category | Minimum level of disaggregation | More sophisticated level of disaggregation[1] | Further level of sophistication level of disaggregation[1] |
|---|---|---|---|
| **Passenger – work**<br>**(includes working drivers)**<br>Units: €/person-hr or €/vehicle-hr | None | Mode | Income or job/skill type |
| | | | IVT vs. walk, wait and interchange time *[only if used in conjunction with Hensher Model]* |
| **Passenger – non-work**<br>**(includes non-working drivers)**<br>Units: €/person-hr or €/vehicle-hr | None | Journey purpose (commuting and other) | Journey purpose (commuting and other) |
| | | Mode | Income<br>Socio-economic status (children, working age adults, retired people) |
| | | | Distance (long, short)<br>Modal quality/comfort |
| | | IVT vs. walk, wait and interchange time | IVT vs. walk, wait and interchange time |
| **Commercial Goods traffic**<br>Units: €/tonne-hr or €/vehicle-hr | Mode<br>(Road, Rail, Sea, Inland waterway, Air) | Road vehicle (LGV,HGV, HGV with trailer)<br>Rail category (containerised, bulk, wagonload)<br>Maritime category (containerised, other)<br>Inland waterway category (containerised, other)<br>Air | Road vehicle (LGV,HGV, HGV with trailer) by goods value (high/low) by goods perishability (high/low)<br>Rail category (containerised, bulk, wagonload)<br>Maritime category (containerised, other)<br>Inland waterway category (containerised, other)<br>Air |

[1] The more sophisticated approaches are for illustration only.

Table 4.2 summarises the minimum level of disaggregation and more sophisticated approaches. Clearly, the principal determinant in the level of disaggregation of VTTS is dictated by the transport modelling system. If the disaggregation of the modelling system is coarse then the VTTS disaggregation will be coarse. As it can be very resource intensive to develop a model with the most sophisticated level of disaggregation, such a level may only be achieved for the largest of TEN-T projects to be appraised.

### 4.4.2 Variation of Passenger VTTS with income

Undoubtedly passenger VTTS varies across the population with income and there is strong theoretical and empirical evidence of this. Theoretically we expect VTTS to vary with income as for time savings made during the course of work VTTS is related to the wage rate and, for time savings during non-work time VTTS is related to the marginal utility of income.

On the basis of empirical evidence two countries (Switzerland and the Netherlands) explicitly disaggregate non-work passenger VTTS by income. The recent UK value of time study found a cross-sectional elasticity to before tax household income of 0.36 (commuting trips) and 0.16 (other non-work trips) and recommended that for large transport infrastructure projects in the UK non-work VTTS should be disaggregated by income (Mackie et al., 2003). The Swedish and Norwegian national value of time study found similarly low cross-sectional elasticities of non-work time to income of 0.23 to 0.46 to before-tax individual income in Sweden and something similar for Norway (Algers et al., 1996; Ramjerdi et al., 1997). The HEATCO value of time meta-analysis also found that VTTS varies with income with an elasticity of 0.7. In contrast to these studies Fosgerau (2005) using the dataset from the Danish national value of time study has, however, found a cross-sectional (after-tax) income elasticity that is not significantly different from 1.0 for non-work travellers. Clearly the elasticity to income is sensitive to the units of income (before or after tax, individual or household). However, on balance it appears that there is considerable evidence suggesting that the non-work VTTS elasticity to income is less than unity.

The most common tradition for business passenger VTTS has been to assume that the income elasticity of VTTS is unity. This is based on the theory of the firm. Thus, for example, recommended business VTTS by mode used in the UK are directly proportional to the average incomes of the business travellers (by mode). However a number of studies and authors have cast doubt on the assumption of an elasticity to income of unity (e.g. Gunn et al., 1996; Hensher and Goodwin, 2004). The weight of evidence from the meta-analysis also supports a lower elasticity to income of between 0.4 and 0.5 for work (business) VTTS. These findings have important practical implications for the treatment of business VTTS in an appraisal where VTTS is allowed to vary with income. An elasticity to income of less than unity for business travellers may arise as the VTTS for work trips is also influenced by the valuation of the traveller as well as the firm (the Hensher model). Another possibility is that the true income elasticity is close to unity but that in-vehicle time becomes progressively more usable, valuable and comfortable with income (in-vehicle entertainment, mobile phones, lap-tops on trains etc). For example, those on higher incomes may have access to facilities that improve the journey experience. Higher paid ‘white-collar’ business travellers may reflect on a business meeting or a project whilst driving a car - which is a productive use of time - whilst lower paid manual workers may not be able to undertake any productive work whilst travelling.

On balance and weighing the available evidence we recommend a cross-sectional elasticity to before-tax income of 0.5 for passenger work trips and 0.7 for passenger non-work trips to be used in the absence of local data. We also recommend that the appraisal is sensitivity tested using a cross-sectional elasticity to income of 1.0 for work (business) trips.

The main objection to disaggregating VTTS by income is policy related and due to reasons of equity. Advocates for disaggregating non-work VTTS by income suggest that an incorrect measure of the economic benefit of a transport infrastructure project will result from the use of ‘standard’ values. This in turn could lead to a misallocation of resources. On the other hand those who argue for the use of a standard value in appraisal suggest that without a social weighting scheme that re-weights the costs and benefits of the project according to who they accrue to, the use of non-work VTTS values that vary by income will favour projects that serve those with higher incomes. The recent move to disaggregate VTTS by income (e.g. Switzerland and the recommendation by Mackie et al. for the UK) has been accompanied by improvements in the reporting of cost-benefit analysis through the use of a benefit incidence table (see section 3.4 on the treatment of distributional issues). Whilst a benefit incidence table is not a social weighting scheme it can make clear to the decision-maker who the beneficiaries of a scheme are and from which income groups they derive. This and the fact that the EC is not intending to compare projects between different parts of the EU (e.g. comparing a project in a low income part of the EU with a project in a high income part of the EU) means that we recommend that where possible VTTS should vary with income – particularly for major infrastructure projects or projects that involve some form of user charging.

### 4.4.3 Variation of Passenger VTTS with journey length

Economic theory informs us that VTTS could increase with journey length for one of three reasons. Firstly it could increase if the marginal disutility of travel increases, as long journeys become more tedious or fatiguing; secondly if the time constraints bind more tightly than budget constraints, as in cases where there is a desire to complete a round trip in a day; and finally if the mix of journey purposes varies with journey length. France, Sweden and Switzerland all use VTTS values that vary with journey length. However, the UK recently and controversially rejected varying VTTS with journey length. Whilst there appears to be significant empirical evidence indicating that a distance effect exists there is still some uncertainty regarding the scale of that effect – certainly in the context of the UK roads sector.

The HEATCO meta-analysis found for commuting and other non-work purposes that longer distances have a somewhat higher VTTS per time unit than shorter distances. This most likely reflects the different mix of purposes within non-work travel (e.g. more holiday trips and less shopping and commuting trips for longer distances) together with an increasing disutility of long trips (travellers getting tired and/or bored). For business travel and freight there was no significant difference between long and short distances in the unit value of time.

These guidelines are primarily intended to objectively appraise TEN-T projects that the EC will co-fund. As such long-distance trips are an important part of the market that will be served by the transport infrastructure projects that these guidelines will be applied to. It is therefore recommended that where the data allows non-work trips are disaggregated by distance and different VTTS values are applied to long-distance and short-distance trips. In the context of the HEATCO meta-analysis long distance trips were classified as inter-urban trips. In the absence of other data the HEATCO meta-analysis results for commuting and other travel (seeTable 4.6 and Table 4.7) can be used – long distance trips have a VTTS value 30% higher than short distance trips.

### 4.4.4 Variation of Passenger VTTS by journey purpose

As discussed above we expect VTTS to vary between work related and non-work related trips. Additionally, for non-work trips VTTS may also vary by journey purpose (e.g. commuting, shopping and leisure trips). We expect this because scheduling constraints – the need to undertake activities at certain times – in conjunctions with penalties for being late and the inconvenience of arriving early can affect the VTTS (Small, 1982).

Guidance values for non-work VTTS are disaggregated by journey purpose in nine EU countries. Typically they are disaggregated into 'commuting' and 'other non-work' trip purposes, though two countries (Switzerland and Latvia) further disaggregate into shopping and leisure. With the exception of Latvia, commuting VTTS are higher than other non-work trip purposes in all instances. There is however no fixed relationship between the VTTS of different trip purposes. Nevertheless, it does appear clear that the VTTS of other non-work trip purposes lies somewhere between 50% and 100% of the commuting value. The HEATCO meta-analysis identified that the VTTS for other non-work trip purposes is 84% of that for commuting trips (see Table 4.6 and Table 4.7).

### 4.4.5 Variation of Passenger VTTS by mode, walking, waiting, interchange and service frequency.

Given that different modes serve different market segments (e.g. long distance, short distance) we would expect the average VTTS of travellers using a particular mode to vary with the mode used. This is because average modal values will reflect a conflation of values associated with modal quality, the traveller's income, the trip length and the traveller's journey purpose. It is difficult to provide firm guidance on the relative values of such average modal values as the functions of the different modes varies across the EU. The recommendation is therefore to either use local average modal values or preferably to disaggregate by trip purpose, journey length and income. If the latter approach is taken there may be a need to allow explicitly for modal comfort differentials; it is not just time which explains modal choice for long-distance journeys, for example. Notwithstanding that the HEATCO meta-analysis has identified modal values, which could be used in the absence of local data (see Tables Table 4.6 and Table 4.7). It was found that the VTTS for air travellers is higher than that for other travellers (1.4 and 1.5 times the value of car VTTS for business and non-work respectively), whilst that for bus travellers was lower (0.8 and 0.7 times the value of car VTTS for business and non-work respectively). We expect that these differences are mainly caused by differences in the user groups of these modes (incomes, journey lengths, etc.), rather than the intrinsic time quality characteristics of the modes (modal comfort).

Focusing on the modal comfort aspect, we expect to find that the least comfortable modes are associated with the highest VTTS. Thus rail travel typically has the lowest 'modal comfort' VTTS with walking, waiting and interchange having the highest VTTS. The data used by the HEATCO meta-analysis do not provide information in the variation in VTTS by modal comfort. Thus no conclusions on modal comfort can be drawn from the meta-analysis and we need to look to other sources for evidence.

A number of countries, however, distinguish between time spent in a vehicle (in-vehicle-time, IVT) to time spent walking, waiting or interchanging. Denmark and Sweden[16] weight walk-time the same as in-vehicle-time, but weight wait-time and transfer-time at twice the value of in-vehicle-time. For air trips Sweden values transfer-time at 1.7 times the value of in-vehicle-time. Switzerland also values transfer-time at twice the value of in-vehicle-time but does not give specific guidance on the treatment of walk-time and wait-time components. The UK values time spent walking at twice the value of in-vehicle-time, whilst time spent waiting at 2.5 times the value. The apparent uniformity in the guideline values between countries, however, disguises substantial variation in the results from empirical research. Drawing from Wardman's (2001a, 2004) meta-analysis of 171 British studies Mackie *et al.* (2003) show that walk times can vary from 0.92 to 4.07 of the value of in-vehicle-time whilst wait time varies from 1.84 to 5.28 of the value of in-vehicle-time. Clearly therefore there is theoretical and empirical justification for valuing walk and wait times differently from in-vehicle-time. In the absence of local data we recommend using values from Wardman's meta-analysis. That is in-vehicle time is weighted by 2 for walk time and 2.5 for wait and interchange (or transfer) time.

Average wait times for public transport services will vary systematically with the headway of the services. At high frequencies passengers arrive at random and the average wait time is half the headway. It is recommended that the modelling exercise explicitly models average wait times associated with the different service frequencies, and this wait time is included in the appraisal weighted by a factor of 2.5. At lower levels of frequency arrival rates are not random and average wait times do not fully capture all the costs or benefits of a change in frequency. More complex appraisals may therefore consider surveying values for these additional benefits 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 passenger travel (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.

### 4.4.6 Variation of Commercial Goods Traffic VTTS

The theory of VTTS for commercial goods traffic usually starts from one of the following two aims:

(i) to measure willingness-to-pay (WTP) for freight time savings using Stated Preference and Revealed Preference techniques; or

(ii) to measure the change in freight operators' costs directly associated with freight journey time savings – in particular drivers' wages, associated overhead costs of employing drivers, and the fuel and non-fuel VOCs with respect to journey time.

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[16] Appraisal guidelines in Denmark and Sweden also provide values/weights associated with changes in service frequency or headway. However, as changes in such characteristics affect the amount of time spent waiting for a service they are used instead of (not as well as) wait-time values.

We would therefore expect VTTS to vary by mode because driver and crew staffing levels vary by mode, and the types of goods carried by the different modes also vary. Clearly there is also heterogeneity within each mode in terms of the nature of the goods that are carried – perishables, high value freight, etc. Where possible such heterogeneity should be accounted for within the modelling process and the VTTS values used, however, to do so will require quite sophisticated modelling techniques.

In the absence of local VTTS data associated with commercial goods traffic the relationships developed as part of the HEATCO meta-analysis, could be used (see Table 4.8). As the units of the HEATCO meta-analysis VTTS freight values are per tonne it is necessary to have local data on the average load per vehicle to be able to apply these values. An important finding from the meta-analysis is an elasticity of VTTS for commercial goods traffic to GDP per capita of between 0.3 and 0.4. This is much lower than unity. This is attributed to the fact that as transport markets are relatively open, international and competitive markets there is much less variation in freight transport costs or rates between countries than there is in GDP per capita. Therefore differences between countries in GDP per capita only partially translate into differences in VTTS.

### 4.4.7 Size and sign of time savings

Theory would lead us to expect that the value of time (i.e. the trade off between time and cost) will alter as either the money budget constraint or the time budget constraint bind tighter (i.e. the money or time budgets are close to exhaustion) (see Bates and Whelan, 2001 for a discussion). The implication of this is that VTTS may alter with both the size and the sign of the time saving. However, whilst theory leads us to expect non-linearity in VTTS it cannot inform as to whether the assumption of a constant unit value is a suitable approximation for changes in cost and time of the order of magnitude generated by a transport project (e.g. between +/- 0 and 20 minute time change). This is an empirical question.

The most recent empirical evidence on whether VTTS varies with the sign of time savings is that set out in Bates and Whelan. Once they had corrected for an inertia effect in the stated preference data, they found no evidence for distinguishing between time gains and losses (within the range of +/- 20 minutes). This conclusion was based on the analysis of datasets from the two UK national value of time studies, and is they say, also consistent with findings from the dataset for Swedish national value of time study.

The value of small time savings is often a contentious issue. With the exception of Germany all the EU-25 countries plus Switzerland use a constant VTTS value irrespective of the size of the time saving. The German approach is to discount the value of small time savings on non-work trips by 30%. Previously, such practices had also been adopted in the Netherlands, France and the USA, though they have now been abandoned in favour of the use of a constant unit value (Welch and Williams, 1997). The arguments for and against a ‘constant unit value’ of VTTS are well rehearsed (see for example Mackie et al., 2001; Fowkes, 1999). The principal objections to the use of a constant unit value for VTTS is that small amounts of time cannot be usefully transferred to any other activity, they cannot be perceived and measurement error may be large in comparison to the size of a small time saving. However, with the exception of the measurement error problem there are strong counter-arguments to these points which lead us to favour the use of a constant unit value in appraisal for all modes. One pragmatic point is that within the context of incremental upgrades to a route or multiple design options, the aggregation issues associated with non-constant unit values are problematic.

We therefore recommend that a constant unit value for VTTS (i.e. per hour, per minute, per second) should be applied irrespective of the size or 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 identified.

### 4.4.8 Treatment of values of travel time savings over time

Theory gives some insight into the manner that VTTS values will grow over time. As the value of passenger business VTTS is related to the wage rate, this would suggest that the value of business VTTS should be related to the value of gross salary costs. 10 of the 12 countries that include growth in the real business VTTS in an appraisal use a function of either GDP/capita or gross salaries, and in all instances an elasticity of 1.0 is used. Unfortunately theory does not give a clear indication as to how the real value of passenger non-work VTTS will alter over time. This is because the rate of change in non-work VTTS will depend on the rate of change in the resource value of time and the rate of change in the marginal value of travelling. Furthermore the latter value is dependent both on the marginal utility of income and the marginal utility of travel.

We might also expect an inter-temporal elasticity of VTTS to growth in income to equal the cross-sectional elasticity to income (as set out in section 4.4.2) if there were no underlying changes in preferences and technology over time. In such a situation each individual simply moves up an income category and adopts the preferences of that higher income category. However, if individuals do not adopt the preferences of their new income category, or preferences alter over time or new technologies affect travel and time budgets then we may expect a growth (could be positive or negative) in the VTTS above and beyond that predicted by a cross-sectional elasticity to income.

The elasticities to income developed as part of the HEATCO meta-analysis principally reflect cross-sectional variations in income across the EU and therefore do not provide empirical evidence on inter-temporal elasticities. We therefore need to look to other sources for evidence. Wardman (2001b) in work undertaken as part of the UK national value of time study found an inter-temporal elasticity to GDP per capita of 0.72 for all journey purposes and modes. The elasticity to GDP/capita for passenger work trips did not vary significantly from this value. The Dutch value of time studies however found that values of travel time decreased over time, though this was offset with a real growth income. The net result being that values of travel time savings remained broadly constant. The possible explanations for lower than unit elasticities are:

- The relationship to gross household income might be close to unity consistently with the relationship to net personal disposable income being less than unity; and
- Lower paid workers may have more constrained time budgets than higher paid workers including less affordability of child care and other activities which must be fitted in.

However, another possibility is that the true income elasticity is unity but that in-vehicle time becomes progressively more usable and valuable with income (in-vehicle entertainment, mobile phones, lap-tops on trains etc) or as in the Dutch situation a reduction in the working week (to 36 hours). This is the same argument as that used for the explanation for a less than unity cross-sectional elasticity to income. However, in the context of inter-temporal growth in VTTS the implication of the evidence might be pointing in the direction of a once and for all shift in the VTTS rather than a lower income elasticity.

As regards the growth of commercial goods VTTS over time, theory would lead us to expect that the value will grow in relation to the main components of time-related costs. In the EU nine countries have explicit methods for updating their values from year to year, with the majority relating it to changes in GDP (with an elasticity of unity). The Netherlands has recently developed a more complex approach which is scenario-based and relates to different structures for international trade, but uses fixed growth rates per annum. Unfortunately, there is no comparable analysis to Wardman's meta-analysis for commercial goods traffic, and the HEATCO meta-analysis principally reflects cross-sectional elasticities of commercial goods traffic VTTS to GDP differences across the EU. As the principal time related cost for commercial goods traffic is driver and crew wages we would therefore recommend in the absence of other data the use of the same inter-temporal elasticity to income growth as used for passenger-work (business) travel.

In summary, weighing all the theoretical and empirical evidence we recommend, in the absence of local data, a default inter-temporal elasticity to GDP per capita growth of 0.7 with a sensitivity test at 1.0 (for all passenger travel purposes, work and non-work and also for commercial goods traffic).

#### 4.4.9 Uncertainty in the VTTS value

Surveyed VTTS values from a population sample are used as estimates of that population's VTTS. As such there is risk that the population's VTTS may differ from that of the surveyed sample. As set out in the section on risk and uncertainty the principal method recommended for assessing the impact of such uncertainty on the appraisal is sensitivity testing (see section 3.7). With respect to making a recommendation for a range of values for use in sensitivity tests it is useful to review the literature to understand the potential uncertainty in VTTS valuations.

Bates and Whelan (2001) report 95% confidence intervals from the UK value of time study dataset of between +/-5.4% and +/-9.3% (journey purpose specific). This uncertainty should however be viewed as a minimum as these intervals relate to a linear model, whilst the preferred model is non-linear and for which no confidence interval is reported. Such a confidence interval would need to be estimated by simulation. De Jong et al (1998) estimated 95% confidence intervals from the first Dutch national VTTS study using simulation. They found standard deviation in the VTTS value by travel purpose and mode between 6% and 24% (i.e. 95% confidence intervals between +/-12% and +/-47%). Lindqvist Dillen and Algers (1998) (cited in Beser Hugosson, 2004) report that the standard error in the Swedish national VTTS study is +/-16%. This implies a 95% confidence interval of +/-31%.

With respect to project specific data (in this case from the Swedish national passenger transport model SAMPERS), Beser Hugosson (2004) reports 95% confidence intervals in VTTS values for Swedish long-distance trips of between +/-16.6% and +/-23% (mode specific) estimated through simulation. Brundell-Freij (2000) also used simulation to estimate standard errors of between 3% and 20% of in-vehicle time - implying 95% confidence intervals between +/-6% to +/-39%.

Clearly the confidence interval associated with a surveyed VTTS value is dependent on the survey design, both in terms of sample size and quality of stated preference questionnaire design. Even with well designed surveys, such as those associated with national value of time studies, we find large confidence intervals and quite a large range in the size of confidence intervals by journey purpose and/or mode. On balance and from reviewing the available literature we therefore recommend:

- *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 the greater.
- *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 to VTTS values +/-20% of those national 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 to values +/-40% of the benefit transfer values.

As identified in the earlier sections we also recommend sensitivity testing:

- Treatment of VTTS over time: uncertainty in the elasticity to growth GDP/capita means that growth in VTTS over time should be sensitivity tested to an 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 proportion of total time saving benefits due to time savings below 3 minutes (positive and negative) should be identified**.**

## 4.5 Treatment of congestion

Congestion can affect the performance and quality of the transport system in a number of ways: increased travel times; overcrowding on public transport; deterioration in the ‘driving experience’ with stop-start conditions; and reliability problems. Theory informs us that a deterioration in travelling conditions, whether that be through increased overcrowding on public transport or stop-start driving conditions, by making travel more onerous will influence the willingness-to-pay for a travel time saving. However, this will in the main only affect non-work VTTS as conditions of travel may have only a little impact on business VTTS and commercial goods traffic (where the cost saving model of valuation dominates). Contrastingly the impact of another facet of congestion – that of reliability or lack of – is considered to impose a significant cost on business travellers and commercial goods traffic (see for example SACTRA, 1999; McQuaid et al., 2004). Travel time variability and large unexpected delays are two of the consequences of reliability problems.

The number of countries that monetise the impacts of congestion, beyond that of just increased travel time, is however limited. Partly this is due to a scarcity of evidence on the values of the impacts of congestion. Primarily, however, it is due to the difficulty in modelling changes reliability and overcrowding as a consequence of an infrastructure improvement. The technical challenge posed by modelling changes in reliability with existing methods and software cannot be overstated. At the minimum 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. We would therefore expect only the most sophisticated of TEN-T appraisals to take account of the impacts of congestion (aside from increases in expected travel time). Due to the technical difficulties, even where congestion impacts are accounted for within an appraisal, the approach may still be limited.

### 4.5.1 Reliability

The recommendations on reliability set in this section are made within the context of what is achievable using the existing knowledge base. Firstly, we need to define reliability or unreliability. There are three main definitions (de Jong *et al*., 2004b): the standard deviation of the travel time; the difference between percentiles of the travel time distribution; and the number of minutes one will depart or arrive earlier or later than preferred. One could describe the first definition as an analytical or mathematical definition, the second might be appropriate for policy objectives, whilst the third may have the most meaning to the people undertaking the trips. The third approach is also the definition that is most consistent with the behavioural theory (scheduling behaviour) that underlies the valuation of reliability, so ideally would be the preferred definition. However, the nature of traffic and transport models, particularly models of road networks, means that it is much easier (though still difficult) to get data and model predictions on the standard deviation of travel times than for the other definitions of reliability. Additionally, through assumptions on the distribution of travel times there is a theoretical link between the theory on scheduling behaviour and the standard deviation of travel times. With this justification but primarily for pragmatic reasons the standard deviation of the travel time is the definition of reliability that we recommend using.

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. The travel time variability literature suggests that there is quite a broad range in observed reliability ratios from 0.35 to 2.4. In a workshop of international experts convened by AVV, the transport research centre of the Dutch Ministry of Transport, some consensus regarding reasonable reliability ratios for passenger transport was reached (Hamer *et al*., 2005). No consensus on a reliability ratio for commercial goods traffic was reached. Kouwenhoven *et al*. (2005a) have since derived a reliability ratio for commercial goods achieved. This has been derived from the Dutch guidelines on the value of change in the percentage of goods that arrive on time. Table 4.3 sets out the resultant reliability ratios, which we recommend using in the absence of local data. These reliability ratios could be viewed as conservative, in that they are towards the lower end of the range of empirical results. Given the uncertainty associated with data such a stance seems an appropriate basis on which to recommend reliability ratios for TEN-T appraisal in the absence of local data. Of course if local data (e.g. at national level) were available such data would be used in place of the reliability ratios set out in Table 4.3.

**Table 4.3** Reliability ratios.

| 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 |

Source: Hamer *et al.* (2005), Kouwenhoven *et al.* (2005a)

As discussed above it is a far from trivial matter to apply the reliability ratios in practice due to the level of modelling that will be required. Without exception almost all the traffic and transport models that will underpin TEN-T appraisal will have a steady state form. That is they will provide predictions of average demand flows and average (or expected) travel times. They will not provide any predictions of the change in the standard deviation of travel time. Some form of ancillary modelling will therefore be required. It is recommended that this ancillary modelling focuses exclusively on the TEN-T route and excludes the surrounding road network. This will underestimate the total reliability benefits (as it will exclude any benefits associated with the surrounding network); however, it makes the problem more tractable and also focuses attention on the benefits attributable to the traffic using the TEN-T network.

To date three methods have been utilised, which can be grouped into two categories: bottom-up and top-down.

- **Bottom-up:**

(i) The reliability analysis can be focussed exclusively on the impact of incidents on travel time reliability. For situations where the transport network is operating under-capacity, incidents form the principal cause of travel time variability. An incident based analysis utilises data on the average number of incidents, the type of incident, the duration of incident, the times of day that the incidents occur at and the impact on capacity that such an incident has. Classic steady state queuing theory can then give predictions of the average additional delay associated with each incident type, from which a travel time distribution can be calculated. Such an approach is embodied in the UK's Department for Transport's model INCA (Ahuja *et al.,* 2002). Using the INCA software Ahuja *et al.* attribute substantial proportions of the economic benefit from incident reducing measures (e.g. provision of a hard shoulder on a multi-lane highway) to reductions in travel time variability - in excess of 50% of the normal journey time benefits.

(ii) For situations where incidents are not the principal cause of travel time variability or the network is over-capacity a detailed model of the TEN-T route corridor can be developed in a software package that explicitly models travel time variability (e.g. micro-simulation). European commercial road-based micro-simulation packages include DRACULA, Paramics, VISSIM and AIMSUN.

- **Top-down:**
  A relationship between travel time variability and traffic demand can be developed for roads of a standard similar to that being appraised. Such an aggregate model has been developed for the Dutch motorway network using data on traffic volumes and spot speeds in the peak period (Kouwenhoven *et al*., 2005b).

It should be noted that the above three approaches assume that a reduction in variability on the section of the TEN-T route, that is modelled, will lead to the same reduction in variability over the complete journey. That is a reduction in the standard deviation of travel time of say 5 minutes arising from an upgrade to a 100km section of the TEN-T network is assumed to give a 5 minute reduction in the standard deviation of travel time for a 500km international 'through' trip. For this to occur there has to be statistical independence in travel time variability between the sections of the transport network that are modelled and the sections that are not modelled. It is therefore recommended that the proportion of reliability benefits that are attributed to external traffic (i.e. traffic with an origin or destination outside the study area) is identified if one of the above approaches is adopted.

### 4.5.2 Public transport overcrowding

Clearly overcrowding on public transport makes a journey more onerous. Therefore we expect higher VTTS for travel in congested and overcrowded condition. French guidelines value travel in overcrowded conditions on public transport at 1.5 times the value of standard in-vehicle-time. The UK guidelines distinguish between passengers who sit in overcrowded conditions and those who stand, with the values for those standing far exceeding the values for sitting (ATOC, 2002). For non-work travel the values range from 1.1p/min to 30.8p/min which reflects a range of about 1.1 times in-vehicle-time to 4.5 times in-vehicle-time. The New Zealand value of time study found that values of travel time savings for standing passengers were 39% higher than for passengers with a seat (BCHF, 2002).

In the absence of local data on the VTTS of travelling in overcrowded public transport we recommend that a value of 1.5 times that of standard in-vehicle-time is used for passengers who have to stand. Such a weighting should only be applied to non-work time as business travel is normally valued using the cost saving approach. The weighting should also only be applied to those passengers who have to stand and not to all passengers on the overcrowded service. Clearly the modelling approach that would underpin such an appraisal would need to include data on individual service capacity and loadings, as we would expect only a subset of services to be overcrowded.

### 4.5.3 Quality of travel experience

Congestion can deteriorate the quality of the journey experience through overcrowding, poor driving conditions, poor public transport punctuality and poor reliability. Some studies have attempted to value the combined effect of all these characteristics and in some circumstances it may be possible to use such results in an appraisal. Clearly, if the individual characteristics of congestion are modelled and appraised separately (e.g. reliability and overcrowding impacts) then it would be in inappropriate to also include aggregate values for the combined effects of congestion.

**Road travel**
With respect to the aggregate effects of congestion on road travel Wardman (2001a, 2004) in his meta-analysis of 143 British studies found that travelling in congested conditions is valued 48% more highly on average than time spent driving in free flow traffic; Eliasson (2004) found similar values (about 1.5) for driving in queues, whilst Steer Davies Gleave (2004) found values ranging from 1.2 times in-vehicle-time (for busy conditions/light congestion) to almost twice in-vehicle-time for 'gridlock' conditions. The UK value of time study found that travel time in congested conditions was about 40% higher than in free-flow conditions for commuters though only just significant at the 95% level, whilst no significant effect was found for the 'other non-work' trip purposes (Mackie *et al.,* 2003). Outside the EU the recent New Zealand value of time study and guidelines suggest that high levels of congestion may lead to values of time savings between 1 and 1.5 times in-vehicle-time depending on the degree of congestion and whether the congestion occurs on urban or rural roads. A value of 1.5 times standard in-vehicle-time would therefore seem a reasonable value to ascribe to congested conditions.

As ever the difficulty comes in applying such a value in an appraisal. What does the term 'congested conditions' mean? And how can this be related to a traffic model with a basis in traffic engineering? In situations where route capacity is determined by the capacity of the road (rather than the capacity of the junctions) – as in many inter-urban routes – the ratio of volume to capacity of the link may be used as a measure of congestion. Volume to capacity ratios in excess of 1.00 are associated with congested conditions (level of service E as set out in the US Highway Capacity Manual (TRB, 1997), whilst volume to capacity ratios below 0.75 are associated with reasonable operating conditions (level of service C)[17]. We recommend that if the volume to capacity ratio for a link is in excess of 1.00 then travel time could be valued at 1.5 times standard in-vehicle-time. Clearly such a value includes the costs associated with reliability. Therefore if reliability is to be modelled explicitly some double counting of costs/benefits would occur. The VTTS value should therefore only be weighted if no explicit reliability modelling is undertaken. We also recommend, as with the reliability analysis, that such an approach is confined to the route of the upgraded TEN-T network, with the surrounding network excluded. Primarily this is because of the uncertainty as to what is considered to be congested conditions, particularly for parts of the network which will be influenced by the operation of junctions.

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[17] Multilane highways Table 7-1 Highway Capacity Manual (TRB, 1997)

Clearly, even this aggregate approach to all congestion effects is also non-trivial in operation, as the weighted VTTS value can only be applied to links which are congested and it is unlikely that all parts of trip will be undertaken in an over-capacity situation. For each trip the modelling process therefore needs to account for the amount of time that is spent in congested conditions and the amount of time that is spent in uncongested conditions. Only the time spent in congested conditions is weighted by 1.5 times in-vehicle-time.

**Public transport**
An alternative approach to modelling the reliability of public transport is to value the travel time in excess of that expected (i.e. delay). Denmark and the UK value delays at the same as that spent waiting for public transport (i.e. twice in-vehicle-time for Denmark and 2.5 times in-vehicle-time for the UK). Sweden on the other hand uses a range of values (from 1.6 to 3.71 times in-vehicle-time) depending on the journey purpose (work/non-work) and the mode. The single value mentioned in the UK's guidance disguises a range of values that have been found in UK studies. For example Bates *et al.* (2001) found that the value of a reduction in one minutes delay ranged from between 1 and 5 times the value of in-vehicle-time depending on journey length and purpose. Wardman (2001a, 2004) found values of 'late time' to be over 7 times the value of in-vehicle-time. However, it appears that some of the valuations on which the meta-analysis was based may in fact be capturing reliability costs and therefore this valuation is not wholly due to delays.

As an alternative to modelling and valuing public transport reliability, valuing average 'delay' or 'lateness' of services is an option. 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). Once again there is still a supply side modelling issue, as it is unclear how one would expect a change in capacity to affect average lateness of services.

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.

## 4.6 Implementation of VTTS Guidelines

### 4.6.1 Deriving VTTS for use in an appraisal

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 different users of the transport system should be allocated different willingness-to-pay that reflect incomes, journey lengths and trip purposes. This may result in attributing different VTTS values by nationality. Obviously a trade-off exists between sophistication and the practicality of implementing a sophisticated approach in any particular country. Additionally, the effort to which the analyst goes 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 a lot 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. Table 4.4 sets out methods that can be used to approximate VTTS where the nationality or true origins and destinations of traffic may not be known.

**Table 4.4** Approximating the underlying willingness-to-pay of traffic on the TEN-T.

| TEN-T Project | Passenger traffic | Goods traffic |
|---|---|---|
| **TEN-T schemes located wholly within a single nation state** | The majority of the passenger traffic will be related to trips within that nation state. In such a situation use of that nation's VTTS for all passenger trips may be reasonable. | On TEN-T projects a significant amount of goods traffic may be international:<br>• In the (probable) rare circumstances that the nationality of the haulier is known a VTTS value consistent with that nationality should be used.<br>• Where identification of the origins and destinations of the goods traffic can be made (e.g. Milan to Munich) but the nationality of the traffic is unknown (e.g. French or British) a pragmatic option is to use a VTTS consistent with the country of the trip origin.<br>• Where identification of the precise origins and destinations of the goods traffic is difficult and traffic is either classed as international or domestic - domestic goods traffic should be allocated the VTTS of the host nation, whilst international traffic should be given the EU-25 average VTTS. |
| **Cross-Border TEN-T schemes** | The majority of the passenger traffic will be related to trips between the nation states. In such a situation use of the respective nations' VTTS for trips that originate in that country maybe reasonable. | As for TEN-T schemes located wholly within a single nation state. |

The survey of national appraisal practice reported in Odgaard *et al.* (2005) allows a comparison to be made between the methodologies used to value travel times savings and the minimum recommended standards. Accordingly Table 4.5 identify whether, in the absence of reliable local data[18], the VTTS values set out in the national guidelines should be used or whether values derived from the HEATCO meta-analysis should be used instead. The meta-analysis models have been used to estimate VTTS values for each country (see Table 4.6,

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[18] and for the appraisal of TEN-T projects for EC co-funding

Table 4.7 and Table 4.8). The HEATCO meta-analysis for commercial goods traffic has been based on values for road and rail traffic only. Therefore, no values can be recommended by this research for other modes (inland waterway, maritime and air).

**Table 4.5** Recommended source for deriving passenger VTTS (based on 2004 survey of EU member states appraisal methodology).

| | **Passenger VTTS** | | **Commercial Goods Traffic** | |
|---|---|---|---|---|
| | **Work** | **Non-work** | **Road** | **Rail** |
| **North/West** | | | | |
| Austria | HEATCO | HEATCO | National guidelines | National guidelines |
| Belgium | HEATCO | HEATCO | HEATCO | HEATCO |
| Denmark | National guidelines | HEATCO | National guidelines | HEATCO |
| Finland | National guidelines | HEATCO | National guidelines | HEATCO |
| France | National guidelines | HEATCO | National guidelines | National guidelines |
| Germany | National guidelines | National guidelines | National guidelines | HEATCO |
| Ireland | National guidelines | HEATCO | National guidelines | HEATCO |
| Luxemburg | HEATCO | HEATCO | HEATCO | HEATCO |
| Netherlands | National guidelines | National guidelines | National guidelines | National guidelines |
| Sweden | National guidelines | National guidelines | National guidelines | National guidelines |
| Switzerland | HEATCO | National guidelines | National guidelines | HEATCO |
| UK | National guidelines | National guidelines | National guidelines | HEATCO |
| **East** | | | | |
| Czech Republic | HEATCO | HEATCO | National guidelines | HEATCO |
| Estonia | HEATCO | HEATCO | HEATCO | HEATCO |
| Hungary | HEATCO | HEATCO | National guidelines | HEATCO |
| Latvia | National guidelines | HEATCO | National guidelines | HEATCO |
| Lithuania | HEATCO | HEATCO | National guidelines | HEATCO |
| Poland | HEATCO | HEATCO | HEATCO | HEATCO |
| Slovak Republic | HEATCO | HEATCO | National guidelines | HEATCO |
| Slovenia | National guidelines | HEATCO | National guidelines | HEATCO |
| **South** | | | | |
| Cyprus | HEATCO | HEATCO | HEATCO | HEATCO |
| Greece | National guidelines | National guidelines | National guidelines | HEATCO |
| Italy | HEATCO | HEATCO | HEATCO | HEATCO |
| Malta | National guidelines | HEATCO | National guidelines | HEATCO |
| Portugal | HEATCO | HEATCO | HEATCO | HEATCO |
| Spain | HEATCO | HEATCO | National guidelines | HEATCO |

**Table 4.6** 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 4.7** 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 4.8** Estimated VTTS values – freight trips (€2002 per freight tonne per hour, factor prices)

| **Country** | **Freight** | |
|---|---|---|
| | **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 |

**Table 4.9** 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 4.10** 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 4.11** 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.

### 4.6.2 VTTS data requirements

The calculation of the economic benefit 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 Do Minimum ($D_0$) and in the Do Something ($D_1$);

(ii) **Time saving** – the time saving experienced by the traffic 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 2):

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

The total user benefit from travel time savings is then 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.

**Table 4.12** Use of local data or benefit transfer procedures.

| | **Local data in all instances** | **Can be calculated from benefit transfer** |
|---|---|---|
| Passenger work VTTS | Proportion of passenger journeys that are work trips | Value of work VTTS (from GDP/capita) |
| | Average vehicle occupancy | Value of work VTTS over time |
| Passenger non-work VTTS | Proportion of non-work trips that are for commuting and proportion that are for ‘other’ purposes | Value of non-work VTTS |
| | Average vehicle occupancy | Relationship between VTTS for commuting and VTTS for ‘other’ non-work trip purposes |
| | --- | Value of non-work VTTS over time |
| Disaggregation of passenger VTTS values | Origins and destinations (regions/nationality) of traffic | Elasticity of work VTTS to income |
| | Income distribution by mode | Elasticity of non-work VTTS to income |
| | Journey length distribution by mode | VTTS for long distance trips relative to short distance trips (non-work only) |
| | --- | VTTS for walk, wait and interchange relative to in-vehicle time |
| Commercial goods traffic | Proportions of commercial goods traffic by vehicle type, mode and type of goods | Value of VTTS for commercial goods traffic |
| | --- | Value of commercial goods traffic VTTS over time |
| Treatment of congestion | Standard deviation of travel times | Reliability ratio |
| | Number of passengers who have to stand in overcrowded public transport conditions | VTTS of time spent in overcrowded conditions relative to the value of in-vehicle-time |
| | Percentage of travel time (per trip) spent in over-capacity conditions (road only) | VTTS of time spent in congested conditions relative to uncongested conditions |
| | Delay or lateness of public transport service (public transport only) | VTTS of time delayed relative to the value of in-vehicle-time |

Ideally all data should be local to the appraisal, however, it is possible to use local demand and time saving data and use benefit transfer procedures to derive the VTTS. Table 4.12 sets out in more detail the data needed within an appraisal and whether it should be data local to the project or whether it can be transferred, from for example the HEATCO meta-analysis. We would wish to caveat this table as each scheme should be treated on a case by case basis, and not all the data set out in Table 4.12 will be used in every circumstance.

### 4.6.3 VTTS in modelling and appraisal

We also need to distinguish between values used for forecasting travel demand and values used in the economic appraisal. Ideally the same basic values should be used in both processes, bearing in mind that the appraisal and modelling will be undertaken using different units of account. An appraisal will be undertaken in either market prices or factor prices, whilst demand forecasts maybe undertaken using behavioural values. The behavioural value for non-working time is market prices whilst that for working time is factor prices. Therefore some conversion of the unit of account between modelling and appraisal values of travel time savings will always be required.

The advantage of using the same underlying values in the modelling and the appraisal (except for unit of account) is that of achieving consistency between the demand forecasts and the economic appraisal. There are of course a number of situations in which the modelling and appraisal values may differ:

- The calibrated modelling values of time may differ from the social value of time (willingness-to-pay value) as a consequence of the functional form of the demand model;
- Where transport projects from regions with very different income distributions are compared within say a national roads programme using only monetised benefits (as the deciding factor between the projects). In such a situation the modelling values should reflect the underlying willingness-to-pay of the users of the local transport system, but the appraisal values may reflect say national averages.

It is our understanding that the HEATCO guidelines will not be used in the manner suggested by the second point (i.e. a transport project in the Czech Republic will not be compared to a transport project in Sweden). It is therefore 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.

### 4.6.4 Reporting and equity

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 categories of the users to whom they accrue.

# 5 Value of Changes in Accident Risks

Traffic accidents belong to the most visible and important negative impacts of transport. The reduction of the number of accidents and the associated damages and costs is one of the most important criteria when assessing infrastructure projects.

The recommendations given in the following focus on a consistent set of monetary values and factors for correcting underreporting for accident risks based on accident statistics. We assume that procedures for estimating accident risks for different casualties (e.g. fatalities etc.) are established.

## 5.1 Purpose/role in project appraisal

Investment projects which improve the transport infrastructure typically lead to reductions in the number of accidents and casualties due to safer design standards relative to the situation without the project. On the other hand, however, projects may induce an increase in traffic and thus more accidents. As a consequence the overall effect is not clear a priori. The value of changes in accident risks represents a part of the user benefit in transport CBA and is an important element when trading off costs and benefits of a transport infrastructure project.

## 5.2 General Approach

The costs due to accidents can be expressed as

$$\Sigma_i (r_i * c_i * m) \tag{5.1}$$

with

$i$ = accident impact (fatality, serious injury, slight injury, material damage)
$r_i$ = risk of accident impact type i per vehicle-km
$c_i$ = cost per accident impact type i
$m$ = mileage in vehicle-kilometres

Additional costs may arise from indirect effects such as time losses and increased fuel use due to congestion caused by accidents. These costs are not included here, because general values cannot be given; however indirect effects should be considered as far as possible when assessing a specific project.

From the equation (5.1) above it can be seen that besides the kilometres driven the accident costs are determined by:

- the change in accident risks due to the project, and
- the valuation of the accident risks.

The former includes the model used to predict changes in accident risks due to the project, and the question whether accident risks derived from observed accident data should be adjusted due to underreporting.

For reasons of transparency and accuracy it is preferable to estimate and value clearly defined casualties and the associated risks. In the case of accidents these are

- fatalities,
- different injury severities, and
- material damages.

The quantification and reporting of physical casualties for a certain project alternative (e.g. number of fatalities) gives additional information and offers the opportunity for alternative valuation (e.g. in sensitivity analysis). Furthermore it allows a more precise valuation of the accident costs than the use of average values for predefined accident types.

### 5.2.1 Accident impacts considered

A central element in assessing accident costs is the definition of accident impacts. Starting point is the accident impact definition adopted by EUNET (Nellthorp et al. 1998), which we modify by removing the 30 day period for fatalities:

- 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 section 5.2.2).

The classification given above is broadly accepted and statistical data are available for many countries. However, this differentiation appears too rough in particular for severe injuries, for which a further differentiation would be desirable. It is estimated “that solely 1 per cent of injuries are actually very serious, and in this regard it would be helpful to draw up a breakdown of injuries in which the term ‘serious’ is not applied to injuries that simply mean that the person involved has to receive hospital treatment.” (ECMT 2000, p. 3).

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

### 5.2.2 Estimating accident risks

In the ideal case specific risk functions depending on infrastructure characteristics, traffic composition and volumes etc. would be used. In practice, however it is expected that such elaborate risk functions are not available in many cases. Therefore, future accident risks should be estimated using national or local data on accident rates and trends. Changes in infrastructure types and transport mode shares should be taken into account as far as possible when estimating the quantitative change in number and severity of accidents and casualties. There are different international databases providing statistical information on accidents for different countries which can be used e.g. CARE - **C**ommunity database on **A**ccidents on the **R**oads in **E**urope (EU)[19] or IRTAD - **I**nternational **R**oad **T**raffic and **A**ccident **D**atabase (OECD)[20].

Underreporting of road accidents is a well known problem in official (road) accident statistics. Therefore the official figures for road accidents underestimate the true number of accidents. We believe that unreported accidents should be included in careful evaluations because the true number of injury accidents may easily be the double of what official statistics show. While there is considerable literature on unreported road accidents, to our knowledge there is no – or almost no – literature on unreported accidents for other transport modes. For rail accidents it is sometimes stated that there are no unreported accidents or that only petty accidents – which are negligible – are not reported[21]: Rail traffic accidents are hard to hide because they are often accompanied by (severe) delays of the concerned train and of other trains and because even single accidents are not only observed by only one (car or train) driver but by several people (passengers or rail company workers). Thus it is believed that unreported accidents in rail traffic can be neglected (Ecoplan 2002, p. 32).

For air transport and navigation we could not find any literature at all. It can be expected that for air traffic there are also no unreported accidents (unless perhaps petty accidents) because of the mostly fatal consequences of an accident (even near-accidents are reported). For navigation accidents the lack of literature seems to indicate that unreported accidents are not relevant. Therefore we conclude that underreporting of accidents is a road specific problem.

**Table 5.1** 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 |

In road traffic we recommend to apply a correction factor for unreported accidents (= ratio all accidents / reported accidents). The number of reported accidents has to be increased by this factor. Correction factors for road transport are likely to be different in different countries. Whenever national estimates for correction factors are available these should be used. However, such factors are only available for 6 countries (Sweden, Denmark, Norway, Switzerland,

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[19] http://europa.eu.int/comm/transport/care/index_en.htm

[20] http://www.bast.de/htdocs/fachthemen/irtad/

[21] Suter et al. (2001), The Pilot Accounts of Switzerland – Appendix Report UNITE, p. 24.

Germany and UK – for details see Annex C, Table 1). For all other countries we have to transfer values – e.g. the average value derived from the results from these 6 countries. Cautious estimates of the average correction factors for unreported accidents are given in Table 5.1. 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 accidents victims die only after the first 30 days after the accident. For details on underreported accidents and the derivation of the correction factors see Annex C.

### 5.2.3 Valuing accident costs

The valuation of an accident can be divided into direct economic costs, indirect economic costs and a value of safety per se. The direct cost is observable as expenditure today or in the future. This includes medical and rehabilitation cost, legal cost, emergency services and property damage cost. The indirect cost is the lost production capacity to the economy that results from premature death or reduced working capability due to the accident.

However, direct and indirect economic costs alone do not reflect the well-being of people. People are willing to pay large amounts to reduce the probability of premature death irrespectively of their production capacity. This willingness-to-pay indicates a preference to reduce the risk of being injured or even die in an accident. In the following this aspect is called the value of safety per se, which has been measured empirically as value of a statistical life (VSL).

Different ways of presenting the components relevant for valuing accident risks can be found in the literature. For instance European Commission (1994) distinguishes the cost categories
1. medical costs
2. costs of lost productive capacity (lost output)
3. valuation of lost quality of life (loss of welfare due to crashes)
4. costs of property damage
5. administrative costs

These however comprise the same effects as considered here (see below), but in a different categorisation. The categories 1, 4, and 5 are part of the direct economic costs, category 2 belongs to the indirect economic costs and category 3 represents what we called the value of safety per se.

**Direct and indirect economic costs**
In the following we describe the method to estimate the direct and indirect economic accident cost by cost component:

- Medical and rehabilitation cost: The major direct cost of accidents is medical and rehabilitation costs. The cost consists both of the cost the year of the accident and future cost over the remaining lifetime for some injury types. The future cost is expressed as the present value over the expected lifetime of the patient, taken the annual development in hospital efficiency into account.
- Legal court and emergency service cost: The administrative cost of an accident consists of the cost for police, the court, private crash investigations, the emergency service and administrative costs of insurances.

- Material damages: compared to the values for casualties, material damages are of minor importance. We assume that data on costs is available in different countries and that consistency in valuation is less of a problem for material damages and recommend using national values.
- Production losses: The indirect economic cost of accidents consists of the value to society of goods and services that could have been produced by the person, if the accident had not occurred. The (marginal) value of a person's production is assumed to be equal to the gross labour cost, wage and additional labour cost, paid by employer. The losses of one year's accident will continue over time up to the retirement age of the youngest victim. The value of the lost production will grow with a growing economy over time.

Three types of production losses can be found:
i. due to premature death,
ii. due to reduced working capacity and
iii. due to days of illness.

When adding the value of a statistical life (VSL) to the estimate of accident cost, double counting may occur in relation to gross production losses. It is often assumed that the VSL includes the value of lost consumption of the deceased person. This is also included in the gross lost production. Two possibilities exist to avoid double counting: a) to subtract the deceased person's consumption from the gross lost production and express it as net lost production or b) to reduce the VSL by the amount of lost consumption which results in a so called human value. We recommend the former, using the net lost production.

**Value of safety per se**

When discussing the value of safety, it is important to note that not the (monetary) value of a life per se is assessed, but the value of a very small change in the risk of dying or getting injured in an accident.

Two basic methods can be used to estimate willingness-to-pay (WTP), *revealed preference* or *stated preference*. The former is based on actual market transactions by the individuals. The most frequent technique used to elicit the value of safety per se is wage-risk studies which estimate the wage premium associated with the fatality risk at work (see Viscusi et.al., 2003). The main disadvantage with revealed preference studies is the difficulty to find a distinctive traffic safety product on the market. However, some studies have derived VSL based on data from the car market (e.g. Andersson 2005).

In its place, stated preference methods have been the preferred method to elicit a value of traffic safety per se. A hypothetical market situation is created in which people are asked to value. A typical study would describe the safety situation on roads and then ask for the WTP of a private product or a public programme that increases the safety by, say, 10%[22].

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[22] This method is referred to as the contingent valuation (CV) method.

**Factors that affect the valuation of safety**

However, we expect the VSL to vary with a number of characteristics which would imply that it is not possible to define one single European VSL today. The value should vary with population (or sample) characteristics - age and health status, sex, education and income but also possibly culture differences and religion - or type of safety projects considered - initial risk level, risk reduction, public or private measures, dread effect, level of control etc.

The most important factor to consider when transferring values between countries is probably the income. In UNITE it was argued that income elasticity within studies can be around 0.3 (e.g. Persson et.al., 2000), but that income elasticities between countries tend to be higher reflecting culture and social differences. Miller (2000) estimated an 'income elasticity' between studies and countries of around 0.8 and UNITE recommended adjusting the value linearly with GDP/Capita, which implies an elasticity of 1.0. Viscusi et.al (2003) made surveys of mainly wage-risk studies and suggested income elasticity between 0.5 and 0.6.

We follow the UNITE recommendation of using an income elasticity of 1.0 when transferring values between countries.

Reductions in different types of risks could be valued differently. It has been suggested that considerations such as control, voluntariness, responsibility and dread will vary the VSL between different contexts and thus some type of risk may have a premium compared to other types. It has been reported that the WTP for a given reduction in number of deaths can vary by a factor of more than three for different contexts (Mendeloff and Kaplan (1989), Cropper and Subramanian (1995)). Even accidents in different transport modes could have different values for the individuals; reduction in underground accidents has been found to be valued one and a half times the value placed on road accidents (Jones-Lee and Loomes (1995)). They also conclude that this factor is applicable for rail accidents. However, more recent studies suggest that people do not have these strong context dependent preferences Chilton et.al. (2002) found a relation very close to 1:1 between rail and road safety. Viscusi et.al. (2003) recommended against any inclusion of a dread effect.

We recommend waiting with such more advanced differentiations until more evidence on the VSL is available. In other words: we recommend applying the same risk value for all modes.

So far we have discussed safety as a purely selfish problem. The affected individual may have relatives outside the household, and friends who care about his exposure to risk, and consequently have a willingness to pay for his risk reduction. Although only very few studies are aimed at estimating relatives' and friends' valuation a value of around 40% of the selfish value seems to be justified[23]. However, based on the argument put forward by Hochman and Rogers (1969) and Bergstrom (1982) no value reflecting relatives and friends valuation should be included for public investments under the assumption of *pure altruism.* The intuition is that a pure altruist would care both for other people's safety, and the lost well-being related to the cost they have to pay to have more safety.

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[23] Needleman (1976), Jones-Lee (1992), Schwab Christe and Soguel (1995).

As a consequence, we do not recommend modifying the VSL value to consider WTP for others.

**Country-specific or uniform values?**

We recommend using country-specific values for assessing risks, although some might argue that it is inequitable to use different values for assessing the same risk in different countries. However, the consequence of using the same (average) value in countries with different per capita incomes would imply a misallocation of resources: the country with low per capita income would invest too much money in safety and this money would be taken from other, more beneficial investments. In the country with high per capita income not enough would be invested in safety. In other words: in a richer country the willingness to pay for a defined risk reduction is higher than in a poorer country as the marginal utility gained by spending this amount for something else is lower. Therefore, both countries would reduce their welfare if they used the same marginal amount for risk reduction.

It should be noted that equity is ensured by applying the same safety standards (e.g. regulations about the features of vehicles, roads etc.) all over Europe.

**Non-fatal accidents**

ECMT (1998) suggests that the value for severe injuries is 13% and for slight injuries 1% of the VSL of fatalities. The analysis of existing practice in the EU countries as reported in Bickel et al. (2005a) suggests that on average this recommendation seems to be reasonable in absence of more accurate national information.

### 5.2.4 Recommended values

We recommend using values as follows:

a) Value of safety per se: WTP values based on stated preferences studies carried out in the country for which they are applied.
b) Direct and indirect economic costs: cost values for the country under assessment.
c) Material damages from accidents with material damage only: cost values for the country under assessment.

If such values are not available for a) and b) the values provided in Table 5.2 may be used. The values of safety per se as well as the direct and indirect costs of fatalities are based on UNITE values and assumptions. Direct and indirect costs of severe and slight injuries were estimated using data from European Commission (1994). Table 5.3 presents the values expressed in PPPs, which show a much smaller range.

Uncertainties in estimating the value of safety per se are large, therefore we recommend carrying out a sensitivity analysis for this value. Based on European Commission (2005) we recommend using v/3 as low and v*3 as high sensitivity (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 5.2 should be used for demand modelling as far as possible.

**Table 5.2** Estimated values for casualties avoided (€2002, factor prices).

| | Value of safety per se | | | Direct and indirect economic costs | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | Fatality** | Severe injury | Slight injury | Fatality | Severe injury | Slight injury | Fatality | Severe injury | Slight injury |
| Austria | 1,600,000 | 208,000 | 16,000 | 160,000 | 32,300 | 3,000 | 1,760,000 | 240,300 | 19,000 |
| Belgium | 1,490,000 | 194,000 | 14,900 | 149,000 | 55,000 | 1,100 | 1,639,000 | 249,000 | 16,000 |
| Cyprus | 640,000 | 83,000 | 6,400 | 64,000 | 9,900 | 400 | 704,000 | 92,900 | 6,800 |
| Czech Republic | 450,000 | 59,000 | 4,500 | 45,000 | 8,100 | 300 | 495,000 | 67,100 | 4,800 |
| Denmark | 2,000,000 | 260,000 | 20,000 | 200,000 | 12,300 | 1,300 | 2,200,000 | 272,300 | 21,300 |
| Estonia | 320,000 | 41,000 | 3,200 | 32,000 | 5,500 | 200 | 352,000 | 46,500 | 3,400 |
| Finland | 1,580,000 | 205,000 | 15,800 | 158,000 | 25,600 | 1,500 | 1,738,000 | 230,600 | 17,300 |
| France | 1,470,000 | 191,000 | 14,700 | 147,000 | 34,800 | 2,300 | 1,617,000 | 225,800 | 17,000 |
| Germany | 1,510,000 | 196,000 | 15,100 | 151,000 | 33,400 | 3,500 | 1,661,000 | 229,400 | 18,600 |
| Greece | 760,000 | 99,000 | 7,600 | 76,000 | 10,500 | 800 | 836,000 | 109,500 | 8,400 |
| Hungary | 400,000 | 52,000 | 4,000 | 40,000 | 7,000 | 300 | 440,000 | 59,000 | 4,300 |
| Ireland | 1,940,000 | 252,000 | 19,400 | 194,000 | 18,100 | 1,300 | 2,134,000 | 270,100 | 20,700 |
| Italy | 1,300,000 | 169,000 | 13,000 | 130,000 | 14,700 | 1,100 | 1,430,000 | 183,700 | 14,100 |
| Latvia | 250,000 | 32,000 | 2,500 | 25,000 | 4,700 | 200 | 275,000 | 36,700 | 2,700 |
| Lithuania | 250,000 | 33,000 | 2,500 | 25,000 | 5,000 | 200 | 275,000 | 38,000 | 2,700 |
| Luxembourg | 2,120,000 | 276,000 | 21,200 | 212,000 | 87,700 | 700 | 2,332,000 | 363,700 | 21,900 |
| Malta | 910,000 | 119,000 | 9,100 | 91,000 | 8,800 | 400 | 1,001,000 | 127,800 | 9,500 |
| Netherlands | 1,620,000 | 211,000 | 16,200 | 162,000 | 25,600 | 2,800 | 1,782,000 | 236,600 | 19,000 |
| Norway | 2,630,000 | 342,000 | 26,300 | 263,000 | 64,000 | 2,800 | 2,893,000 | 406,000 | 29,100 |
| Poland | 310,000 | 41,000 | 3,100 | 31,000 | 5,500 | 200 | 341,000 | 46,500 | 3,300 |
| Portugal | 730,000 | 95,000 | 7,300 | 73,000 | 12,400 | 100 | 803,000 | 107,400 | 7,400 |
| Slovakia | 280,000 | 36,000 | 2,800 | 28,000 | 6,100 | 200 | 308,000 | 42,100 | 3,000 |
| Slovenia | 690,000 | 90,000 | 6,900 | 69,000 | 9,000 | 400 | 759,000 | 99,000 | 7,300 |
| Spain | 1,020,000 | 132,000 | 10,200 | 102,000 | 6,900 | 300 | 1,122,000 | 138,900 | 10,500 |
| Sweden | 1,700,000 | 220,000 | 17,000 | 170,000 | 53,300 | 2,700 | 1,870,000 | 273,300 | 19,700 |
| Switzerland | 2,340,000 | 305,000 | 23,400 | 234,000 | 48,800 | 3,700 | 2,574,000 | 353,800 | 27,100 |
| United Kingdom | 1,650,000 | 215,000 | 16,500 | 165,000 | 20,100 | 2,100 | 1,815,000 | 235,100 | 18,600 |

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). * no country specific value available in European Commission (1994), therefore estimated from comparable countries. ** Benefit transfer from EU-value of €1.25 million based on GDP per capita ratios (income elasticity of 1.0)

**Table 5.3** Estimated values for casualties avoided (€2002 PPP, factor prices).

| Country | Fatality | Severe injury | Slight injury |
|---|---:|---:|---:|
| Austria | 1,685,000 | 230,100 | 18,200 |
| Belgium | 1,603,000 | 243,200 | 15,700 |
| Cyprus | 798,000 | 105,500 | 7,700 |
| Czech Republic | 932,000 | 125,200 | 9,100 |
| Denmark | 1,672,000 | 206,900 | 16,200 |
| Estonia | 630,000 | 84,400 | 6,100 |
| Finland | 1,548,000 | 205,900 | 15,400 |
| France | 1,548,000 | 216,300 | 16,200 |
| Germany | 1,493,000 | 206,500 | 16,700 |
| Greece | 1,069,000 | 139,700 | 10,700 |
| Hungary | 808,000 | 108,400 | 7,900 |
| Ireland | 1,836,000 | 232,600 | 17,800 |
| Italy | 1,493,000 | 191,900 | 14,700 |
| Latvia | 534,000 | 72,300 | 5,200 |
| Lithuania | 575,000 | 78,500 | 5,700 |
| Luxembourg | 2,055,000 | 320,200 | 19,300 |
| Malta | 1,445,000 | 183,500 | 13,700 |
| Netherlands | 1,672,000 | 221,500 | 17,900 |
| Norway | 2,055,000 | 288,300 | 20,700 |
| Poland | 630,000 | 84,500 | 6,100 |
| Portugal | 1,055,000 | 141,000 | 9,700 |
| Slovakia | 699,000 | 96,400 | 6,900 |
| Slovenia | 1,028,000 | 133,500 | 9,800 |
| Spain | 1,302,000 | 161,800 | 12,200 |
| Sweden | 1,576,000 | 231,300 | 16,600 |
| Switzerland | 1,809,000 | 248,000 | 19,100 |
| United Kingdom | 1,617,000 | 208,900 | 16,600 |

### 5.2.5 Treatment of values over time

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.

### 5.2.6 Calculation procedure

**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.

# 6 Environmental Costs

## 6.1 Purpose/role in project appraisal

Transport infrastructure projects and the associated changes in transport use lead to changes in the environmental burden and associated damages. Damages to the environment (incl. human health) cause utility losses and are therefore an important element to consider when assessing the costs and benefits of transport infrastructure projects.

Damages which will almost certainly occur, i.e. with a high probability, should be avoided or compensated as far as possible, e.g. loss of habitats due to constructing a road. Usually, this is ensured by the requirements for carrying out an Environmental Impact Assessment, or by obligations to meet certain target values (e.g. for noise levels) or thresholds (e.g. for airborne pollutants). However, even if such standards are met, the remaining burdens lead to environmental costs, which have to be considered as far as possible in a project appraisal.

The main focus of environmental effects covered in existing national CBA for infrastructure investment is on air pollution, noise and global warming. Other impacts such as vibration, severance, visual intrusion, loss of important sites, resource consumption, impairment of landscape, soil and water pollution are rarely covered by assigning a monetary value. Some of these categories are difficult to assess based on general values, because the impacts are to a high degree site specific (e.g. impairment of landscape). Such effects however are often included in environmental impact assessments, which are part of the project appraisal procedure.

In the following values for environmental costs due to air pollution, noise, and greenhouse gas emissions will be recommended.

## 6.2 General Valuation Methodology

Environmental costs from transport activities cover a broad range of different impacts, including the various impacts of emissions of a large number of pollutants and noise on human health, materials, ecosystems, flora and fauna. Impacts occur at the local, regional, European and global scale; damages caused by transport activities may be instantaneous, but also extend far into the future - up to several hundreds of years. The methods used to estimate environmental costs must be able to address these different scales, and it is furthermore necessary to select the most important among the large number of pollutants and damage categories for further analysis.

Most of the impacts of transport activities are highly site-specific, as can most obviously be seen for noise: noise emitted in densely populated areas affects many people and thus causes much higher impacts than noise emitted in sparsely populated areas. Furthermore, environmental costs vary considerably with the characteristics of the vehicles, trains, vessels or aircraft. A detailed bottom-up approach is required to be able to consider technology and site specific parameters, and variations of costs with time (e.g. day time versus night time noise).

The so-called Impact Pathway Approach (IPA) was designed to meet these requirements. The general idea of monetising environmental (incl. health) costs resulting from building and use of transport infrastructure based on welfare economics is illustrated in Figure 6.1. A transport activity causes changes in environmental pressures (e.g. air pollutant emissions), which are dispersed, leading to changes in environmental burdens and associated impacts on various receptors, such as human beings, crops, building materials or ecosystems (e.g. emissions of air pollutants leading to respiratory diseases). This change in impacts leads either directly or indirectly (e.g. through health effects caused by air pollutants) to a change in the utility of the affected persons. Welfare changes resulting from these impacts are transferred into monetary values. Based on the concepts of welfare economics, monetary valuation follows the approach of 'willingness-to-pay' for improved environmental quality. It is obvious that not all impacts can be modelled for all pollutants in detail. For this reason the most important pollutants and damage categories (so-called "priority impact pathways") are selected for detailed analysis.

One of the strengths and main principles of the IPA is the valuation of damages (e.g. additional respiratory hospital admissions) and not pressures or effects (e.g. emissions of fine particles). The monetary valuation of concrete casualties (e.g. hospital admissions) is more reliable and transparent than deriving a general willingness-to-pay for reducing air pollution.

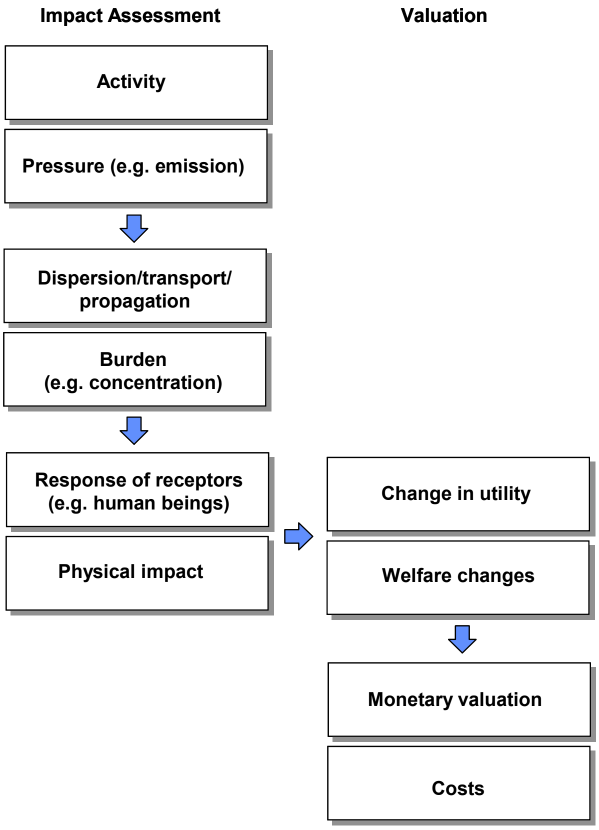

**Figure 6.1** The Impact Pathway Approach for the quantification of environmental costs.

The IPA was developed, made operational by providing the models required on each stage and updated for air pollution impacts in the ExternE project series (see e.g. Friedrich and Bickel, 2001; European Commission, 1999 and 2005). Models for assessing impacts from noise were provided in the projects UNITE (see Bickel et al., 2003) and RECORDIT (see Schmid et al., 2001).

Many of the impact pathways include non-linearities, due to air chemistry for example, therefore impacts and costs from two scenarios are calculated: a reference scenario reflecting the base case concerning the amount of pollutants or noise emitted, and a modified scenario, which is based on the reference scenario, but with changes in emissions due to the activity considered. For the marginal analysis this may be an additional vehicle, for the sectoral analysis this may be the emissions from a whole transport sector in one country. The difference in physical impacts and resulting damage costs of both scenarios represents the effect of the activity considered.

This principle of modelling the pressure (e.g. emissions), resulting burden (e.g. pollutant concentration increase), response of receptors (e.g. health damages, annoyance caused by noise) and monetary valuation can and should be applied for all impact categories. The main bottleneck of this procedure is the availability of the models required for the different stages. For instance the assessment of impacts due to climate change is very challenging and damage cost estimates show a high uncertainty range. In this case it appears appropriate to apply a second best approach and to analyse preferences revealed in (political) decisions. The avoidance costs to reach a socially accepted target can be used as a proxy for society's willingness-to-pay to avoid the risks of climate change impacts.

It is important to note, that, although only changes of one specific road or route segment may be considered, the pollutant or noise emissions from all other sources and the background burden influence the change due to non-linearities and therefore have to be accounted for in the framework. If emissions of pollutants and noise that occur in the future (or the past) have to be assessed, scenarios of the emissions and concentrations of pollutants at that time have to be used.

The principle of the Impact Pathway Approach can be applied to all modes. The character of a burden may differ by mode, as e.g. for noise: roads usually cause a rather constant noise level, while noise from railway lines and airports is characterised by single events with high noise levels. Such differences have to be taken into account and the models used on the respective stage have to be adjusted accordingly. The application of the same approach for all modes ensures consistency of the resulting estimates.

Carrying out bottom-up calculations for every potential transport infrastructure project appears unrealistic due to the amount of data and time required. Hence, we suggest to use simplified relationships between environmental costs and the most relevant parameters (e.g. amount of pollutant emission, vehicle mileage, etc.), which should be available in the project appraisal process anyway. These functions or values should, however, be based on the Impact Pathway Approach with consistent sets of dose-response functions and monetary values as given e.g. in European Commission (2005).

Our general recommendation is – wherever possible – to *value impacts, not pressures* 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.

## 6.3 Air pollution

The valuation of air pollution effects should be based on the damages caused by air pollutant emissions. The types of impacts for which dose-response relationships are established are human health impacts, agricultural and forestry production losses, as well as soiling and corrosion of building materials. Emission height (e.g. close to the ground from a car exhaust pipe or from a high power plant stack), local environment around the emission source, and geographical location within Europe have been identified as main parameters of the damage cost (see e.g. Bickel et al., 2005b). As a consequence, cost factors should take into account these parameters as a minimum. The estimated country-specific fall-back values that can be used if no state-of-the-art values are available were derived using the methodology developed and documented in the EU projects ExternE and UNITE (see e.g. European Commission, 2005 and 1999; Link et al., 2002).

Existing work identified damage to human health as the most important effect in terms of quantifiable costs. In particular losses in life expectancy in terms of Years of Life Lost (YOLL) contribute to health costs. For this reason they are a good indicator for physical impacts caused and impact factors are provided alongside the cost factors.

We recommend using country-specific values taking into account local population density. Cost factors 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 ($PM_{10}$ for emissions from power plants), $NO_x$ (as precursor of nitrate aerosols and ozone), $SO_2$ (direct effects and as precursor of sulphate aerosols), NMVOC (as precursor of ozone). The project related emissions should be calculated using national emission factors; if such are not available emission factors from international sources can be applied, taking into account national vehicle fleet compositions as far as possible.

Where available results from detailed exposure modelling (including pollutant dispersion modelling and estimation of changes in the population's exposure to the relevant pollutants) should be used. Besides the local effects (up to ca. 20 km from the emission source) Europe-wide effects should be considered to be consistent with the recommended approach.

### 6.3.1 Derivation of impact and cost factors per unit pollutant emitted

Country specific impact and cost factors were calculated using the EcoSense software tool developed and applied among others in the EU-projects ExternE and UNITE (a further description of the models and values is given in Annex D).

Impacts and resulting costs occurring in Europe were calculated for increasing the existing emissions of $NO_x$, $SO_2$, $PM_{2.5}$ and NMVOC by 10 percent in each country. Impacts and costs were compared to those calculated for the unchanged reference scenario; the difference between both scenarios is caused by the additional emissions. This procedure is necessary to take into account the pollutant concentrations caused by the background emissions from the reference scenario. This is an important issue, as the air chemistry processes are non-linear and depend on the available concentrations of reactive species in the atmosphere.

For the estimation of impacts and damages on human health in the environment close to the sources, sector and population density specific estimates were used which were derived from a number of calculations and results within former EC projects (Droste-Franke and Friedrich 2003, Link et al. 2001, Preiss et al. 2004, Schmid et al. 2001).

**Table 6.1** Health and environmental effects for which exposure-response functions are established (source: European Commission, 2005).

| Impact category | Pollutant | Effects included |
|---|---|---|
| Public health – mortality | $PM_{2.5}$, $PM_{10}$ 1) | Reduction in life expectancy due to acute and chronic effects |
| | $O_3$ | Reduction in life expectancy due to acute effects |
| Public health – morbidity | $PM_{2.5}$, $PM_{10}$ 1), $O_3$ | Respiratory hospital admissions<br>(Minor) Restricted activity days<br>Days of bronchodilator usage<br>Days of lower respiratory symptoms |
| | $PM_{2.5}$, $PM_{10}$ 1) only | New cases of chronic bronchitis<br>Cardiac hospital admissions |
| | $O_3$ only | Cough days |
| Material damage | $SO_2$, acid deposition | Ageing of galvanised steel, limestone, natural stone, mortar, sandstone, paint, rendering, zinc |
| Crops | $SO_2$ | Yield change for wheat, barley, rye, oats, potato, sugar beet |
| | $O_3$ | Yield loss for wheat, potato, rice, rye, oats, tobacco, barley |
| | Acid deposition | Increased need for liming |
| | N | Fertiliser effects |

1) including secondary particles (sulphate and nitrate aerosols).

Table 6.1 presents health and environmental effects for which exposure-response functions are established and monetary values are available.

Exposure-response functions come in a variety of functional forms. They may be linear or non-linear and contain thresholds (e.g. critical loads) or not. Those describing effects of various air pollutants on agriculture have proved to be particularly complex, incorporating both positive and negative effects, because of the potential for certain pollutants, e. g. those containing sulphur and nitrogen, to act as fertilisers.

When selecting exposure-response functions double counting of effects must be avoided. Two relevant aspects can be distinguished: (i) are different effects associated to one pollutant in different epidemiological studies additive (e.g. losses in life expectancy observed for long-term and short-term exposure)? And, (ii) are effects observed for different pollutants additive (e.g. losses in life expectancy from $PM_{2.5}$ and Ozone)? Answering these questions needs careful consideration of the underlying empirical studies. This effort has been undertaken in the context of the ExternE project series with the conclusion that consideration of all pollutants and effects listed in Table 6.1 does not imply double counting. Annex D gives the exposure-response functions used in the assessment.

Given the physical impacts, appropriate monetary values are needed to derive damage costs. For material damage and crop losses, market prices can be used. This is not the case for major aspects of health impacts, for which three components of welfare change can be distinguished (see e.g. European Commission 2005):

(a) Resource costs, i.e. medical costs paid by the health service
(b) Opportunity costs, i.e. mainly the costs in terms of productivity losses
(c) Disutility, i.e. other social and economic costs of the individual or others

Components (a) and (b) can be estimated using market prices and are known as "Cost of illness" (COI). The latter must be added to a measure of the individual's loss of welfare (c). This is important because the values for disutility are usually much larger than the cost of illness. They include any restrictions on or reduced enjoyment of desired leisure activities, discomfort or inconvenience (pain, suffering), anxiety about the future, and concern and inconvenience to family members and others. Stated preference methods are seen as the state of the art method for valuing component (c). Cost estimates can be based on the work done in ExternE and UNITE. Annex D presents the values underlying the values presented below.

Table 6.2 and Table 6.4 present cost factors in € per tonne of pollutant emitted by road and other ground level transport (e.g. diesel trains) and power plants (high stack emissions)[24]. The estimates are based on EcoSense calculations for ground level and high stack emissions respectively, using 1998 background emissions and meteorology. The values include estimates for local effects of $PM_{2.5}$ for transport and $PM_{10}$ for high stack emissions, the character of the local environment in terms of population density close to the emission source was assumed to be urban and outside urban areas. Table 6.6 and Table 6.7 show the corresponding impact factors in years of life lost per 1000 tonnes of pollutant emitted. Impacts (in years of life lost) and costs (in €) have to be calculated separately, applying the impact factors (Table 6.6 and Table 6.7) and the cost factors (Table 6.2 and Table 6.4) to the amount of pollutant emitted.

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[24] Table 6.3 and Table 6.5 give the corresponding values in PPP.

**Table 6.2** Cost factors for road transport emissions* per tonne of pollutant emitted in €$_{2002}$ (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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.

The PPP adjusted values in Table 6.3 differ from the values in Table 6.2 only for costs due to primary particle emissions. $NO_x$, NMVOC and $SO_2$ have virtually no local effects as most of their impact is caused after chemical transformation to other substances (ammoniumnitrates and –sulfates, 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 €. The same applies for Table 6.5 and Table 6.4 respectively. For the latter, differences are very small as the local share of impacts is much smaller for high level emission sources.

**Table 6.3** Cost factors for road transport emissions* per tonne of pollutant emitted in €$_{2002}$ PPS (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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.

The variation of the values presented in Table 6.2 to Table 6.7 illustrates the site specificity of the damage caused. Depending on meteorological conditions, background emissions and air chemistry processes, as well as population affected a unit of pollutant emitted may cause very different costs. Costs due to $NO_x$ emissions include damages caused by nitrates (secondary particles), ozone, nitrogen and acid deposition. NMVOC causes damages via ozone formation. For $SO_2$ damages arise from sulphates (secondary particles), acid deposition and directly on crops. Damages from primary particle emissions are given in the column "$PM_{2.5}$" and "$PM_{10}$" respectively.

The numbers provided 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 $SO_2$ between countries is mainly caused by air chemistry (incl. ozone formation) and the population affected. For primary particles no air chemistry is involved, therefore differences reflect the population affected, which is determined mainly by distance to the emission source and the prevailing wind direction.

**Table 6.4** Cost factors for electricity production emissions* per ton of pollutant emitted in $€_{2002}$ (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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 | 4,200 | 15,000 | 12,000 |
| Belgium | 2,700 | 1,100 | 5,700 | 17,000 | 14,000 |
| Cyprus** | 500 | 1,100 | 400 | 3,000 | 2,000 |
| Czech Republic | 2,900 | 1,100 | 4,200 | 9,000 | 8,000 |
| Denmark | 1,900 | 800 | 2,100 | 9,000 | 5,000 |
| Estonia | 1,400 | 500 | 1,200 | 3,000 | 2,000 |
| Finland | 900 | 200 | 800 | 6,000 | 3,000 |
| France | 4,800 | 800 | 4,400 | 14,000 | 11,000 |
| Germany | 2,800 | 1,100 | 4,300 | 12,000 | 9,000 |
| Greece | 2,300 | 600 | 1,200 | 4,000 | 3,000 |
| Hungary | 5,100 | 800 | 4,300 | 8,000 | 7,000 |
| Ireland | 1,800 | 400 | 1,600 | 8,000 | 4,000 |
| Italy | 3,000 | 1,600 | 1,700 | 9,000 | 7,000 |
| Latvia | 1,800 | 500 | 1,500 | 3,000 | 2,000 |
| Lithuania | 2,600 | 500 | 1,900 | 3,000 | 3,000 |
| Luxemburg | 4,700 | 1,400 | 5,200 | 17,000 | 12,000 |
| Malta ($O_3$ estimated) | 500 | 1,100 | 400 | 3,000 | 1,000 |
| Netherlands | 2,600 | 1,000 | 5,500 | 18,000 | 14,000 |
| Poland | 3,000 | 800 | 3,800 | 9,000 | 8,000 |
| Portugal | 2,500 | 1,000 | 1,700 | 6,000 | 5,000 |
| Slovakia | 4,600 | 1,100 | 4,000 | 7,000 | 6,000 |
| Slovenia | 4,400 | 700 | 4,200 | 7,000 | 6,000 |
| Spain | 2,400 | 500 | 1,900 | 6,000 | 4,000 |
| Sweden | 1,100 | 300 | 1,000 | 7,000 | 3,000 |
| Switzerland | 4,600 | 600 | 4,200 | 18,000 | 13,000 |
| United Kingdom | 1,400 | 700 | 3,000 | 13,000 | 10,000 |

Notes: Cost categories included are: human health, crop losses, material damages.
* Values are applicable to high stack emissions from power plants.
** Estimated values as Cyprus outside of modelling domain.

**Table 6.5** Cost factors for electricity production emissions* per ton of pollutant emitted in €$_{2002}$ PPS (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{10}$** | |
|---|---|---|---|---|---|
| **Effective pollutant** | **$O_3$, Nitrates, Crops** | **$O_3$** | **Sulphates, Acid deposition, Crops** | **Primary $PM_{10}$** | |
| **Local environment** | | | | **urban** | **outside built-up areas** |
| Austria | 4,300 | 600 | 4,200 | 15,000 | 12,000 |
| Belgium | 2,700 | 1,100 | 5,700 | 17,000 | 14,000 |
| Cyprus** | 500 | 1,100 | 400 | 4,000 | 2,000 |
| Czech Republic | 2,900 | 1,100 | 4,200 | 10,000 | 9,000 |
| Denmark | 1,900 | 800 | 2,100 | 8,000 | 5,000 |
| Estonia | 1,400 | 500 | 1,200 | 4,000 | 3,000 |
| Finland | 900 | 200 | 800 | 6,000 | 3,000 |
| France | 4,800 | 800 | 4,400 | 14,000 | 11,000 |
| Germany | 2,800 | 1,100 | 4,300 | 12,000 | 9,000 |
| Greece | 2,300 | 600 | 1,200 | 5,000 | 3,000 |
| Hungary | 5,100 | 800 | 4,300 | 9,000 | 7,000 |
| Ireland | 1,800 | 400 | 1,600 | 7,000 | 4,000 |
| Italy | 3,000 | 1,600 | 1,700 | 10,000 | 7,000 |
| Latvia | 1,800 | 500 | 1,500 | 3,000 | 2,000 |
| Lithuania | 2,600 | 500 | 1,900 | 4,000 | 3,000 |
| Luxemburg | 4,700 | 1,400 | 5,200 | 16,000 | 12,000 |
| Malta ($O_3$ estimated) | 500 | 1,100 | 400 | 4,000 | 2,000 |
| Netherlands | 2,600 | 1,000 | 5,500 | 17,000 | 14,000 |
| Poland | 3,000 | 800 | 3,800 | 9,000 | 8,000 |
| Portugal | 2,500 | 1,000 | 1,700 | 7,000 | 5,000 |
| Slovakia | 4,600 | 1,100 | 4,000 | 8,000 | 7,000 |
| Slovenia | 4,400 | 700 | 4,200 | 8,000 | 6,000 |
| Spain | 2,400 | 500 | 1,900 | 6,000 | 4,000 |
| Sweden | 1,100 | 300 | 1,000 | 6,000 | 3,000 |
| Switzerland | 4,600 | 600 | 4,200 | 16,000 | 12,000 |
| United Kingdom | 1,400 | 700 | 3,000 | 13,000 | 10,000 |

Notes: Cost categories included are: human health, crop losses, material damages.
* Values are applicable to high stack emissions from power plants.
** Estimated values as Cyprus outside of modelling domain.

**Table 6.6** 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** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **Effective pollutant** | **$O_3$, Nitrates** | **$O_3$** | **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.

**Table 6.7** Impact factors for electricity production emissions* (lost life expectancy in years of life lost per 1000 tonnes of pollutant emitted).

| **Pollutant emitted** | **NO$_x$** | **NMVOC** | **SO$_2$** | **PM$_{10}$** | |
|---|---|---|---|---|---|
| **Effective pollutant** | **O$_3$, Nitrates** | **O$_3$** | **Sulphates** | **Primary PM$_{10}$** | |
| **Local environment** | | | | **urban** | **outside built-up areas** |
| Austria | 62 | 0.6 | 62 | 210 | 180 |
| Belgium | 57 | 1.3 | 84 | 250 | 210 |
| Cyprus** | 9 | 0.5 | 7 | 60 | 30 |
| Czech Republic | 46 | 1.0 | 60 | 180 | 140 |
| Denmark | 31 | 0.9 | 31 | 100 | 70 |
| Estonia | 18 | 1.5 | 18 | 80 | 50 |
| Finland | 12 | 0.2 | 11 | 70 | 40 |
| France | 67 | 0.8 | 67 | 200 | 170 |
| Germany | 48 | 1.2 | 62 | 180 | 140 |
| Greece | 21 | 0.2 | 17 | 80 | 50 |
| Hungary | 63 | 0.6 | 62 | 160 | 120 |
| Ireland | 28 | 0.7 | 25 | 90 | 50 |
| Italy | 47 | 0.8 | 26 | 140 | 100 |
| Latvia | 22 | 0.9 | 22 | 80 | 50 |
| Lithuania | 29 | 0.9 | 28 | 90 | 60 |
| Luxemburg | 70 | 1.5 | 77 | 220 | 180 |
| Malta (O$_3$ estimated) | 9 | 0.5 | 7 | 60 | 30 |
| Netherlands | 55 | 1.1 | 81 | 250 | 220 |
| Poland | 45 | 0.8 | 53 | 170 | 140 |
| Portugal | 25 | 0.5 | 27 | 110 | 80 |
| Slovakia | 57 | 1.0 | 57 | 150 | 120 |
| Slovenia | 62 | 0.5 | 62 | 130 | 100 |
| Spain | 30 | 0.4 | 29 | 90 | 60 |
| Sweden | 14 | 0.4 | 14 | 70 | 40 |
| Switzerland | 70 | 0.7 | 64 | 220 | 190 |
| United Kingdom | 31 | 1.0 | 45 | 180 | 150 |

Notes: * Values are applicable to high stack emissions from power plants.
** Estimated values as Cyprus outside of modelling domain.

### 6.3.2 Treatment of values over time

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 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.

### 6.3.3 Calculation procedure

**Step 1**: quantification of change in pollutant emissions ($NO_x$, $SO_2$, NMVOC, $PM_{2.5}$/$PM_{10}$) 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.

## 6.4 Noise

The perception of sound follows a logarithmic scale, which results in considerable non-linearities of the impacts and associated costs due to a change in noise levels (in the following we refer to the equivalent noise level $L_{Aeq}$). The background noise level plays an important role: whereas in a quiet neighbourhood (40 dB(A)) an additional 40 dB(A), i.e. a doubling of the noise, results in a total level of 43 dB(A), the same noise increment of 40 dB(A) only leads to a total noise level of 60.04 dB(A) in a noisy environment with a background noise level of 60 dB(A). Besides this peculiarity of energetic addition of noise levels the perception, in particular the disturbance caused by changes in the noise level have to be considered. This, together with the very local character of noise makes impact assessment a challenging task; and the models used to quantify noise exposure must be able to map the environment (receptors, buildings), the vehicle technology (PC, HGV etc.) and the traffic situation (e.g. speed and traffic volume) adequately.

The general procedure for taking into account the site and technology specific characteristics is the same as for air pollution: Two scenarios are calculated: a reference scenario reflecting the present situation with traffic volume, speed distribution, vehicle technologies etc., and the case scenario which is based on the reference scenario, but includes the changes due to the project alternative considered. The difference in damage costs between both scenarios represents the noise costs due to the project assessed. It is important to quantify total exposure levels and not only exposure increments, because for certain impacts thresholds have to be considered. For instance, some exposure-response functions for health impacts are applicable only above a threshold of 70 dB(A) (see De Kluizenaar et al., 2001).

Depending on the exposure-response relationships available different noise indicators are required for the quantification of impacts. Examples of indicators that are commonly used are equivalent noise levels for different times of day, e.g. $L_{Aeq}$(7.00-19.00), $L_{Aeq}$(19.00-23.00), $L_{Aeq}$(23.00-7.00) and the compound day-evening-night noise indicator $L_{DEN}$ (see European Commission, 2000 for details on noise indicators). Usually noise levels are calculated as incident sound at the façade of the buildings. Empirical noise propagation models have been established in several member states (see e.g. Nordic Council of Ministers, 1996 or Arbeitsausschuß Immissionsschutz an Straßen, 1990), which can be used to model traffic noise exposure.

### 6.4.1 Noise impact assessment

Two major impacts are usually considered when assessing noise impacts:

- Annoyance, reflecting the disturbance which individuals experience when exposed to (traffic) noise.
- Health impacts, related to the long term exposure to noise, mainly stress related health effects like hypertension and myocardial infarction.

It can be assumed that these two effects are independent, i.e. the potential long term health risk is not taken into account in people's perceived noise annoyance.

A large amount of scientific literature on health and psychosocial effects considering a variety of potential effects of transport noise is available. For instance, De Kluizenaar et al. (2001) reviewed the state of the art, reporting risks due to noise exposure in the living environment. They identified quantitative functions for relative and absolute risks for the effect categories presented in Table 6.8.

**Table 6.8** Categorisation of effects and related impact categories (source: De Kluizenaar et al., 2001).

| Category | Measure given | Impacts |
|---|---|---|
| Stress related health effects | RR | Hypertension and ischemic heart disease |
| Psychosocial effects | AR | Annoyance |
| Sleep disturbance | AR | Awakenings and subjective sleep quality |
| RR = relative risk; AR = absolute risk | | |

A more recent study undertaken in Switzerland (Bundesamt für Raumentwicklung, 2004) reviewed additional empirical studies and concluded that for impacts from road and rail noise only few evidence has emerged in addition to De Kluizenaar et al. (2001)[25], which was the basis for calculations in the UNITE project (see Bickel et al. 2003).

Existing work has shown that quantifiable health effects are of minor importance compared to the WTP for reducing disamenity and annoyance (see e.g. Bickel et al. 2003). The uncertainty of exposure assessment is expected to be high, therefore no major revision of the UNITE

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[25] Bundesamt für Raumentwicklung (2004, p. 71)

assumptions and values were undertaken. The resulting values are to be interpreted as indication of possible costs due to health effects.

### 6.4.2 Monetary Valuation

The principles for monetary valuation have been outlined above in the section on air pollution impacts. These apply equally for impacts from noise. Given its high importance for the results and the challenges in its measurement, the value of annoyance caused by noise requires particular consideration. The main cost component of annoyance is disutility experienced, for which no market exists. Stated preference (SP) and revealed preference (RP) methods have been employed to estimate the economic value of changes in noise levels. The noise valuation literature is dominated by Hedonic Price (HP) studies (most of them old) on road traffic and aircraft noise of varying quality. HP studies analyse the housing market to explore the extent to which differences in property prices reflect individuals´ willingness-to-pay (WTP) for lower noise levels. Resulting values seem to be problematic to transfer, however, both theoretically and in practice (Day 2001).

There number of SP studies on road traffic noise is increasing, but only a few present WTP in terms of “euro per annoyed person per year” for different annoyance levels (little annoyed, annoyed and highly annoyed), which correspond to the endpoints of exposure-response functions. Due to the low number of studies that can be used for this approach, a “second-best” alternative was to evaluate the SP studies available with regards to quality (e.g. avoid using studies with scenarios based on changes in exposure rather than annoyance and health impacts), choose the best ones, and calculate a value in terms of “euro per dB per person per year”. This was done by Navrud (2002) to establish an EU-value.

To enable the application of the exposure-response functions predicting annoyance reactions on the population level as recommended by European Commission (2002), HEATCO’s Work Package 5 carried out stated preference surveys in five European countries (see Navrud et al. 2006). Based on surveys in Germany, Hungary, Norway, Spain, Sweden and the UK, values for application in Europe were derived for the annoyance levels highly annoyed, annoyed and little annoyed. As these values are still subject to peer review, they are recommended for sensitivity analysis (“new approach”). The same is the case for the values based on hedonic pricing studies as applied in UNITE (see Bickel et al. 2003) – the “high values”. Besides costs due to annoyance both sets of values consider quantifiable health costs – they are given in Annex E.

The country-specific “central values” per person exposed to a certain noise level given in Table 6.9 (€$_{2002}$) and in Table 6.10 (€$_{2002}$ PPP) comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003) and quantifiable costs of health effects.

The impact indicator suggested is the number of persons highly annoyed (total and by noise band) – see Table 6.11. The underlying functions and monetary values are given in Annex E. Impacts (in number of persons highly annoyed) and costs (in €) have to be calculated separately, applying the impact factors (Table 6.11) and the cost factors (Table 6.9) to the number of person exposed.

**Table 6.9** Cost factors (Central values) for noise exposure (€$_{2002}$, factor costs, per year per person exposed). High values and results for the new approach see Annex E.

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 10 | 0 | 16 | 10 | 0 | 15 | 6 | 0 | 9 | 3 | 0 | 5 | 13 | 0 | 20 | 2 | 0 | 3 | 10 | 0 | 16 |
| ≥52 | 21 | 0 | 32 | 19 | 0 | 30 | 12 | 0 | 18 | 6 | 0 | 9 | 26 | 0 | 40 | 4 | 0 | 6 | 20 | 0 | 32 |
| ≥53 | 31 | 0 | 48 | 29 | 0 | 45 | 18 | 0 | 27 | 9 | 0 | 14 | 39 | 0 | 60 | 6 | 0 | 10 | 31 | 0 | 47 |
| ≥54 | 41 | 0 | 64 | 39 | 0 | 60 | 24 | 0 | 37 | 12 | 0 | 18 | 52 | 0 | 80 | 8 | 0 | 13 | 41 | 0 | 63 |
| ≥55 | 52 | 0 | 80 | 48 | 0 | 75 | 29 | 0 | 46 | 15 | 0 | 23 | 64 | 0 | 100 | 10 | 0 | 16 | 51 | 0 | 79 |
| ≥56 | 62 | 10 | 96 | 58 | 10 | 90 | 35 | 6 | 55 | 18 | 3 | 27 | 77 | 13 | 120 | 12 | 2 | 19 | 61 | 10 | 95 |
| ≥57 | 72 | 21 | 112 | 67 | 19 | 104 | 41 | 12 | 64 | 21 | 6 | 32 | 90 | 26 | 140 | 14 | 4 | 22 | 71 | 20 | 110 |
| ≥58 | 83 | 31 | 128 | 77 | 29 | 119 | 47 | 18 | 73 | 23 | 9 | 36 | 103 | 39 | 160 | 16 | 6 | 26 | 81 | 31 | 126 |
| ≥59 | 93 | 41 | 144 | 87 | 39 | 134 | 53 | 24 | 82 | 26 | 12 | 41 | 116 | 52 | 180 | 19 | 8 | 29 | 92 | 41 | 142 |
| ≥60 | 103 | 52 | 160 | 96 | 48 | 149 | 59 | 29 | 91 | 29 | 15 | 46 | 129 | 64 | 200 | 21 | 10 | 32 | 102 | 51 | 158 |
| ≥61 | 114 | 62 | 176 | 106 | 58 | 164 | 65 | 35 | 100 | 32 | 18 | 50 | 142 | 77 | 220 | 23 | 12 | 35 | 112 | 61 | 174 |
| ≥62 | 124 | 72 | 192 | 116 | 67 | 179 | 71 | 41 | 110 | 35 | 21 | 55 | 155 | 90 | 240 | 25 | 14 | 38 | 122 | 71 | 189 |
| ≥63 | 134 | 83 | 208 | 125 | 77 | 194 | 77 | 47 | 119 | 38 | 23 | 59 | 168 | 103 | 260 | 27 | 16 | 41 | 132 | 81 | 205 |
| ≥64 | 144 | 93 | 224 | 135 | 87 | 209 | 82 | 53 | 128 | 41 | 26 | 64 | 181 | 116 | 280 | 29 | 19 | 45 | 143 | 92 | 221 |
| ≥65 | 155 | 103 | 240 | 144 | 96 | 224 | 88 | 59 | 137 | 44 | 29 | 68 | 193 | 129 | 300 | 31 | 21 | 48 | 153 | 102 | 237 |
| ≥66 | 165 | 114 | 256 | 154 | 106 | 239 | 94 | 65 | 146 | 47 | 32 | 73 | 206 | 142 | 320 | 33 | 23 | 51 | 163 | 112 | 252 |
| ≥67 | 175 | 124 | 272 | 164 | 116 | 254 | 100 | 71 | 155 | 50 | 35 | 77 | 219 | 155 | 340 | 35 | 25 | 54 | 173 | 122 | 268 |
| ≥68 | 186 | 134 | 288 | 173 | 125 | 269 | 106 | 77 | 164 | 53 | 38 | 82 | 232 | 168 | 360 | 37 | 27 | 57 | 183 | 132 | 284 |
| ≥69 | 196 | 144 | 304 | 183 | 135 | 284 | 112 | 82 | 173 | 56 | 41 | 87 | 245 | 181 | 380 | 39 | 29 | 61 | 193 | 143 | 300 |
| ≥70 | 206 | 155 | 320 | 193 | 144 | 298 | 118 | 88 | 183 | 59 | 44 | 91 | 258 | 193 | 400 | 41 | 31 | 64 | 204 | 153 | 316 |
| ≥71 | 274 | 222 | 393 | 256 | 208 | 367 | 156 | 127 | 224 | 78 | 63 | 112 | 342 | 278 | 491 | 55 | 44 | 78 | 270 | 219 | 388 |
| ≥72 | 291 | 240 | 416 | 272 | 224 | 388 | 166 | 137 | 237 | 83 | 68 | 118 | 364 | 299 | 520 | 58 | 48 | 83 | 287 | 236 | 410 |
| ≥73 | 308 | 257 | 439 | 288 | 240 | 410 | 176 | 147 | 251 | 88 | 73 | 125 | 385 | 321 | 549 | 61 | 51 | 88 | 304 | 253 | 433 |
| ≥74 | 326 | 274 | 462 | 304 | 256 | 431 | 186 | 156 | 264 | 93 | 78 | 131 | 407 | 343 | 577 | 65 | 55 | 92 | 321 | 270 | 456 |
| ≥75 | 343 | 291 | 485 | 320 | 272 | 452 | 196 | 166 | 277 | 98 | 83 | 138 | 429 | 364 | 606 | 68 | 58 | 97 | 338 | 287 | 478 |
| ≥76 | 360 | 309 | 508 | 336 | 288 | 474 | 206 | 176 | 290 | 103 | 88 | 145 | 450 | 386 | 635 | 72 | 62 | 101 | 355 | 305 | 501 |
| ≥77 | 378 | 326 | 531 | 352 | 304 | 495 | 215 | 186 | 303 | 107 | 93 | 151 | 472 | 407 | 663 | 75 | 65 | 106 | 372 | 322 | 524 |
| ≥78 | 395 | 343 | 554 | 368 | 320 | 517 | 225 | 196 | 316 | 112 | 98 | 158 | 493 | 429 | 692 | 79 | 68 | 110 | 390 | 339 | 546 |
| ≥79 | 412 | 361 | 577 | 384 | 336 | 538 | 235 | 206 | 329 | 117 | 103 | 164 | 515 | 450 | 721 | 82 | 72 | 115 | 407 | 356 | 569 |
| ≥80 | 429 | 378 | 600 | 401 | 352 | 559 | 245 | 216 | 342 | 122 | 108 | 171 | 537 | 472 | 749 | 86 | 75 | 120 | 424 | 373 | 592 |
| ≥81 | 447 | 395 | 623 | 417 | 369 | 581 | 255 | 225 | 355 | 127 | 112 | 177 | 558 | 494 | 778 | 89 | 79 | 124 | 441 | 390 | 614 |

Table 6.9 continued (Central values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 9 | 0 | 15 | 10 | 0 | 15 | 5 | 0 | 8 | 3 | 0 | 4 | 13 | 0 | 19 | 8 | 0 | 13 | 2 | 0 | 2 |
| ≥52 | 19 | 0 | 29 | 19 | 0 | 30 | 10 | 0 | 15 | 5 | 0 | 8 | 25 | 0 | 39 | 17 | 0 | 26 | 3 | 0 | 5 |
| ≥53 | 28 | 0 | 44 | 29 | 0 | 45 | 15 | 0 | 23 | 8 | 0 | 12 | 38 | 0 | 58 | 25 | 0 | 39 | 5 | 0 | 7 |
| ≥54 | 38 | 0 | 59 | 39 | 0 | 60 | 20 | 0 | 31 | 10 | 0 | 16 | 50 | 0 | 78 | 34 | 0 | 52 | 6 | 0 | 10 |
| ≥55 | 47 | 0 | 73 | 49 | 0 | 75 | 25 | 0 | 38 | 13 | 0 | 20 | 63 | 0 | 97 | 42 | 0 | 65 | 8 | 0 | 12 |
| ≥56 | 57 | 9 | 88 | 58 | 10 | 91 | 30 | 5 | 46 | 16 | 3 | 24 | 75 | 13 | 116 | 50 | 8 | 78 | 10 | 2 | 15 |
| ≥57 | 66 | 19 | 103 | 68 | 19 | 106 | 34 | 10 | 53 | 18 | 5 | 28 | 88 | 25 | 136 | 59 | 17 | 91 | 11 | 3 | 17 |
| ≥58 | 76 | 28 | 118 | 78 | 29 | 121 | 39 | 15 | 61 | 21 | 8 | 32 | 100 | 38 | 155 | 67 | 25 | 104 | 13 | 5 | 20 |
| ≥59 | 85 | 38 | 132 | 88 | 39 | 136 | 44 | 20 | 69 | 23 | 10 | 36 | 113 | 50 | 175 | 75 | 34 | 117 | 14 | 6 | 22 |
| ≥60 | 95 | 47 | 147 | 97 | 49 | 151 | 49 | 25 | 76 | 26 | 13 | 40 | 125 | 63 | 194 | 84 | 42 | 130 | 16 | 8 | 25 |
| ≥61 | 104 | 57 | 162 | 107 | 58 | 166 | 54 | 30 | 84 | 29 | 16 | 44 | 138 | 75 | 213 | 92 | 50 | 143 | 18 | 10 | 27 |
| ≥62 | 114 | 66 | 176 | 117 | 68 | 181 | 59 | 34 | 92 | 31 | 18 | 48 | 150 | 88 | 233 | 101 | 59 | 156 | 19 | 11 | 30 |
| ≥63 | 123 | 76 | 191 | 127 | 78 | 196 | 64 | 39 | 99 | 34 | 21 | 52 | 163 | 100 | 252 | 109 | 67 | 169 | 21 | 13 | 32 |
| ≥64 | 133 | 85 | 206 | 136 | 88 | 211 | 69 | 44 | 107 | 36 | 23 | 56 | 175 | 113 | 272 | 117 | 75 | 182 | 22 | 14 | 35 |
| ≥65 | 142 | 95 | 220 | 146 | 97 | 226 | 74 | 49 | 115 | 39 | 26 | 60 | 188 | 125 | 291 | 126 | 84 | 195 | 24 | 16 | 37 |
| ≥66 | 152 | 104 | 235 | 156 | 107 | 242 | 79 | 54 | 122 | 42 | 29 | 64 | 200 | 138 | 310 | 134 | 92 | 208 | 25 | 18 | 40 |
| ≥67 | 161 | 114 | 250 | 166 | 117 | 257 | 84 | 59 | 130 | 44 | 31 | 68 | 213 | 150 | 330 | 143 | 101 | 221 | 27 | 19 | 42 |
| ≥68 | 171 | 123 | 265 | 175 | 127 | 272 | 89 | 64 | 137 | 47 | 34 | 72 | 225 | 163 | 349 | 151 | 109 | 234 | 29 | 21 | 44 |
| ≥69 | 180 | 133 | 279 | 185 | 136 | 287 | 94 | 69 | 145 | 49 | 36 | 76 | 238 | 175 | 369 | 159 | 117 | 247 | 30 | 22 | 47 |
| ≥70 | 190 | 142 | 294 | 195 | 146 | 302 | 99 | 74 | 153 | 52 | 39 | 80 | 250 | 188 | 388 | 168 | 126 | 260 | 32 | 24 | 49 |
| ≥71 | 252 | 204 | 361 | 259 | 210 | 371 | 131 | 106 | 188 | 69 | 56 | 99 | 332 | 270 | 477 | 223 | 181 | 319 | 42 | 34 | 61 |
| ≥72 | 268 | 220 | 382 | 275 | 226 | 393 | 139 | 114 | 199 | 73 | 60 | 105 | 353 | 291 | 505 | 237 | 195 | 338 | 45 | 37 | 64 |
| ≥73 | 283 | 236 | 403 | 291 | 242 | 414 | 147 | 123 | 210 | 78 | 65 | 110 | 374 | 312 | 532 | 251 | 209 | 357 | 48 | 40 | 68 |
| ≥74 | 299 | 252 | 424 | 307 | 259 | 436 | 155 | 131 | 220 | 82 | 69 | 116 | 395 | 332 | 560 | 265 | 223 | 375 | 50 | 42 | 71 |
| ≥75 | 315 | 268 | 445 | 324 | 275 | 458 | 164 | 139 | 231 | 86 | 73 | 122 | 416 | 353 | 588 | 279 | 237 | 394 | 53 | 45 | 75 |
| ≥76 | 331 | 284 | 467 | 340 | 291 | 479 | 172 | 147 | 242 | 91 | 78 | 128 | 437 | 374 | 616 | 293 | 251 | 413 | 56 | 48 | 78 |
| ≥77 | 347 | 299 | 488 | 356 | 308 | 501 | 180 | 156 | 253 | 95 | 82 | 134 | 458 | 395 | 644 | 307 | 265 | 431 | 58 | 50 | 82 |
| ≥78 | 363 | 315 | 509 | 373 | 324 | 523 | 188 | 164 | 264 | 99 | 86 | 139 | 479 | 416 | 672 | 321 | 279 | 450 | 61 | 53 | 86 |
| ≥79 | 379 | 331 | 530 | 389 | 340 | 544 | 197 | 172 | 275 | 104 | 91 | 145 | 500 | 437 | 699 | 335 | 293 | 468 | 64 | 56 | 89 |
| ≥80 | 394 | 347 | 551 | 405 | 357 | 566 | 205 | 180 | 286 | 108 | 95 | 151 | 521 | 458 | 727 | 349 | 307 | 487 | 66 | 58 | 93 |
| ≥81 | 410 | 363 | 572 | 422 | 373 | 588 | 213 | 189 | 297 | 112 | 99 | 157 | 542 | 479 | 755 | 363 | 321 | 506 | 69 | 61 | 96 |

Table 6.9 continued (Central values for noise exposure in €2002 factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 2 | 0 | 3 | 14 | 0 | 21 | 4 | 0 | 6 | 10 | 0 | 16 | 2 | 0 | 3 | 5 | 0 | 7 | 2 | 0 | 3 |
| ≥52 | 3 | 0 | 5 | 27 | 0 | 42 | 8 | 0 | 13 | 21 | 0 | 32 | 4 | 0 | 6 | 9 | 0 | 15 | 4 | 0 | 6 |
| ≥53 | 5 | 0 | 8 | 41 | 0 | 64 | 12 | 0 | 19 | 31 | 0 | 49 | 6 | 0 | 9 | 14 | 0 | 22 | 5 | 0 | 8 |
| ≥54 | 6 | 0 | 10 | 55 | 0 | 85 | 17 | 0 | 26 | 42 | 0 | 65 | 8 | 0 | 13 | 19 | 0 | 29 | 7 | 0 | 11 |
| ≥55 | 8 | 0 | 13 | 68 | 0 | 106 | 21 | 0 | 32 | 52 | 0 | 81 | 10 | 0 | 16 | 24 | 0 | 37 | 9 | 0 | 14 |
| ≥56 | 10 | 2 | 15 | 82 | 14 | 127 | 25 | 4 | 38 | 63 | 10 | 97 | 12 | 2 | 19 | 28 | 5 | 44 | 11 | 2 | 17 |
| ≥57 | 11 | 3 | 18 | 96 | 27 | 149 | 29 | 8 | 45 | 73 | 21 | 114 | 14 | 4 | 22 | 33 | 9 | 51 | 13 | 4 | 20 |
| ≥58 | 13 | 5 | 20 | 110 | 41 | 170 | 33 | 12 | 51 | 84 | 31 | 130 | 16 | 6 | 25 | 38 | 14 | 59 | 14 | 5 | 22 |
| ≥59 | 15 | 6 | 23 | 123 | 55 | 191 | 37 | 17 | 58 | 94 | 42 | 146 | 18 | 8 | 28 | 43 | 19 | 66 | 16 | 7 | 25 |
| ≥60 | 16 | 8 | 25 | 137 | 68 | 212 | 41 | 21 | 64 | 105 | 52 | 162 | 20 | 10 | 31 | 47 | 24 | 73 | 18 | 9 | 28 |
| ≥61 | 18 | 10 | 28 | 151 | 82 | 234 | 45 | 25 | 70 | 115 | 63 | 179 | 22 | 12 | 35 | 52 | 28 | 81 | 20 | 11 | 31 |
| ≥62 | 19 | 11 | 30 | 164 | 96 | 255 | 50 | 29 | 77 | 126 | 73 | 195 | 24 | 14 | 38 | 57 | 33 | 88 | 22 | 13 | 34 |
| ≥63 | 21 | 13 | 33 | 178 | 110 | 276 | 54 | 33 | 83 | 136 | 84 | 211 | 26 | 16 | 41 | 61 | 38 | 95 | 23 | 14 | 36 |
| ≥64 | 23 | 15 | 35 | 192 | 123 | 297 | 58 | 37 | 90 | 147 | 94 | 227 | 28 | 18 | 44 | 66 | 43 | 103 | 25 | 16 | 39 |
| ≥65 | 24 | 16 | 38 | 205 | 137 | 318 | 62 | 41 | 96 | 157 | 105 | 243 | 30 | 20 | 47 | 71 | 47 | 110 | 27 | 18 | 42 |
| ≥66 | 26 | 18 | 40 | 219 | 151 | 340 | 66 | 45 | 102 | 168 | 115 | 260 | 32 | 22 | 50 | 76 | 52 | 117 | 29 | 20 | 45 |
| ≥67 | 28 | 19 | 43 | 233 | 164 | 361 | 70 | 50 | 109 | 178 | 126 | 276 | 34 | 24 | 53 | 80 | 57 | 125 | 31 | 22 | 48 |
| ≥68 | 29 | 21 | 45 | 247 | 178 | 382 | 74 | 54 | 115 | 188 | 136 | 292 | 37 | 26 | 57 | 85 | 61 | 132 | 32 | 23 | 50 |
| ≥69 | 31 | 23 | 48 | 260 | 192 | 403 | 78 | 58 | 122 | 199 | 147 | 308 | 39 | 28 | 60 | 90 | 66 | 139 | 34 | 25 | 53 |
| ≥70 | 32 | 24 | 50 | 274 | 205 | 425 | 83 | 62 | 128 | 209 | 157 | 325 | 41 | 30 | 63 | 95 | 71 | 147 | 36 | 27 | 56 |
| ≥71 | 43 | 35 | 62 | 364 | 295 | 522 | 110 | 89 | 157 | 278 | 226 | 399 | 54 | 44 | 77 | 125 | 102 | 180 | 48 | 39 | 69 |
| ≥72 | 46 | 38 | 65 | 386 | 318 | 552 | 117 | 96 | 167 | 295 | 243 | 422 | 57 | 47 | 82 | 133 | 110 | 191 | 51 | 42 | 73 |
| ≥73 | 48 | 40 | 69 | 409 | 341 | 583 | 123 | 103 | 176 | 313 | 261 | 445 | 61 | 50 | 86 | 141 | 118 | 201 | 54 | 45 | 77 |
| ≥74 | 51 | 43 | 72 | 432 | 364 | 613 | 130 | 110 | 185 | 331 | 278 | 469 | 64 | 54 | 91 | 149 | 126 | 212 | 57 | 48 | 81 |
| ≥75 | 54 | 46 | 76 | 455 | 387 | 644 | 137 | 117 | 194 | 348 | 296 | 492 | 67 | 57 | 95 | 157 | 133 | 222 | 60 | 51 | 85 |
| ≥76 | 56 | 48 | 80 | 478 | 410 | 674 | 144 | 124 | 203 | 366 | 313 | 515 | 71 | 61 | 100 | 165 | 141 | 233 | 63 | 54 | 89 |
| ≥77 | 59 | 51 | 83 | 501 | 433 | 704 | 151 | 130 | 212 | 383 | 331 | 539 | 74 | 64 | 104 | 173 | 149 | 243 | 66 | 57 | 93 |
| ≥78 | 62 | 54 | 87 | 524 | 456 | 735 | 158 | 137 | 222 | 401 | 348 | 562 | 78 | 67 | 109 | 181 | 157 | 254 | 69 | 60 | 97 |
| ≥79 | 65 | 57 | 90 | 547 | 478 | 765 | 165 | 144 | 231 | 418 | 366 | 585 | 81 | 71 | 113 | 189 | 165 | 264 | 72 | 63 | 101 |
| ≥80 | 67 | 59 | 94 | 570 | 501 | 796 | 172 | 151 | 240 | 436 | 383 | 608 | 84 | 74 | 118 | 197 | 173 | 275 | 75 | 66 | 105 |
| ≥81 | 70 | 62 | 98 | 593 | 524 | 826 | 179 | 158 | 249 | 453 | 401 | 632 | 88 | 78 | 122 | 205 | 181 | 285 | 78 | 69 | 109 |

Table 6.9 continued (Central values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 4 | 0 | 7 | 7 | 0 | 10 | 11 | 0 | 17 | 15 | 0 | 23 | 11 | 0 | 17 |
| ≥52 | 9 | 0 | 14 | 13 | 0 | 20 | 22 | 0 | 34 | 30 | 0 | 47 | 21 | 0 | 33 |
| ≥53 | 13 | 0 | 21 | 20 | 0 | 31 | 33 | 0 | 51 | 45 | 0 | 70 | 32 | 0 | 50 |
| ≥54 | 18 | 0 | 28 | 26 | 0 | 41 | 44 | 0 | 68 | 61 | 0 | 94 | 43 | 0 | 66 |
| ≥55 | 22 | 0 | 35 | 33 | 0 | 51 | 55 | 0 | 85 | 76 | 0 | 117 | 53 | 0 | 83 |
| ≥56 | 27 | 4 | 42 | 39 | 7 | 61 | 66 | 11 | 102 | 91 | 15 | 141 | 64 | 11 | 99 |
| ≥57 | 31 | 9 | 48 | 46 | 13 | 71 | 77 | 22 | 119 | 106 | 30 | 164 | 75 | 21 | 116 |
| ≥58 | 36 | 13 | 55 | 53 | 20 | 82 | 88 | 33 | 136 | 121 | 45 | 188 | 85 | 32 | 132 |
| ≥59 | 40 | 18 | 62 | 59 | 26 | 92 | 99 | 44 | 153 | 136 | 61 | 211 | 96 | 43 | 149 |
| ≥60 | 45 | 22 | 69 | 66 | 33 | 102 | 110 | 55 | 170 | 151 | 76 | 235 | 107 | 53 | 165 |
| ≥61 | 49 | 27 | 76 | 72 | 39 | 112 | 120 | 66 | 187 | 166 | 91 | 258 | 117 | 64 | 182 |
| ≥62 | 54 | 31 | 83 | 79 | 46 | 122 | 131 | 77 | 204 | 182 | 106 | 281 | 128 | 75 | 198 |
| ≥63 | 58 | 36 | 90 | 86 | 53 | 133 | 142 | 88 | 221 | 197 | 121 | 305 | 139 | 85 | 215 |
| ≥64 | 63 | 40 | 97 | 92 | 59 | 143 | 153 | 99 | 238 | 212 | 136 | 328 | 149 | 96 | 232 |
| ≥65 | 67 | 45 | 104 | 99 | 66 | 153 | 164 | 110 | 255 | 227 | 151 | 352 | 160 | 107 | 248 |
| ≥66 | 71 | 49 | 111 | 105 | 72 | 163 | 175 | 120 | 272 | 242 | 166 | 375 | 171 | 117 | 265 |
| ≥67 | 76 | 54 | 118 | 112 | 79 | 173 | 186 | 131 | 289 | 257 | 182 | 399 | 181 | 128 | 281 |
| ≥68 | 80 | 58 | 125 | 118 | 86 | 184 | 197 | 142 | 306 | 272 | 197 | 422 | 192 | 139 | 298 |
| ≥69 | 85 | 63 | 131 | 125 | 92 | 194 | 208 | 153 | 323 | 287 | 212 | 446 | 203 | 149 | 314 |
| ≥70 | 89 | 67 | 138 | 132 | 99 | 204 | 219 | 164 | 340 | 303 | 227 | 469 | 213 | 160 | 331 |
| ≥71 | 119 | 96 | 170 | 175 | 142 | 251 | 291 | 236 | 417 | 402 | 326 | 577 | 283 | 230 | 407 |
| ≥72 | 126 | 104 | 180 | 186 | 153 | 265 | 309 | 254 | 442 | 427 | 351 | 610 | 301 | 248 | 430 |
| ≥73 | 133 | 111 | 190 | 197 | 164 | 280 | 327 | 273 | 466 | 452 | 377 | 644 | 319 | 266 | 454 |
| ≥74 | 141 | 119 | 200 | 208 | 175 | 295 | 346 | 291 | 490 | 478 | 402 | 677 | 337 | 283 | 478 |
| ≥75 | 148 | 126 | 210 | 219 | 186 | 309 | 364 | 309 | 515 | 503 | 427 | 711 | 355 | 301 | 501 |
| ≥76 | 156 | 134 | 220 | 230 | 197 | 324 | 382 | 328 | 539 | 528 | 453 | 745 | 372 | 319 | 525 |
| ≥77 | 163 | 141 | 230 | 241 | 208 | 338 | 401 | 346 | 563 | 554 | 478 | 778 | 390 | 337 | 549 |
| ≥78 | 171 | 148 | 240 | 252 | 219 | 353 | 419 | 364 | 588 | 579 | 503 | 812 | 408 | 355 | 573 |
| ≥79 | 178 | 156 | 249 | 263 | 230 | 368 | 437 | 383 | 612 | 604 | 529 | 846 | 426 | 373 | 596 |
| ≥80 | 186 | 163 | 259 | 274 | 241 | 382 | 456 | 401 | 636 | 630 | 554 | 879 | 444 | 391 | 620 |
| ≥81 | 193 | 171 | 269 | 285 | 252 | 397 | 474 | 419 | 661 | 655 | 579 | 913 | 462 | 408 | 644 |

Notes: The central values comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003) and quantifiable costs of health effects.

**Table 6.10** Cost factors (Central values) for noise exposure (€$_{2002}$ PPP, factor costs, per year per person exposed). High values and results for the new approach see Annex E.

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 10 | 0 | 15 | 9 | 0 | 15 | 7 | 0 | 10 | 5 | 0 | 8 | 10 | 0 | 15 | 4 | 0 | 6 | 9 | 0 | 14 |
| ≥52 | 20 | 0 | 31 | 19 | 0 | 29 | 13 | 0 | 21 | 11 | 0 | 17 | 20 | 0 | 30 | 7 | 0 | 11 | 18 | 0 | 28 |
| ≥53 | 30 | 0 | 46 | 28 | 0 | 44 | 20 | 0 | 31 | 16 | 0 | 25 | 29 | 0 | 46 | 11 | 0 | 17 | 27 | 0 | 42 |
| ≥54 | 40 | 0 | 61 | 38 | 0 | 58 | 27 | 0 | 41 | 22 | 0 | 34 | 39 | 0 | 61 | 15 | 0 | 23 | 36 | 0 | 56 |
| ≥55 | 49 | 0 | 77 | 47 | 0 | 73 | 33 | 0 | 52 | 27 | 0 | 42 | 49 | 0 | 76 | 19 | 0 | 29 | 45 | 0 | 70 |
| ≥56 | 59 | 10 | 92 | 56 | 9 | 88 | 40 | 7 | 62 | 33 | 5 | 51 | 59 | 10 | 91 | 22 | 4 | 34 | 55 | 9 | 85 |
| ≥57 | 69 | 20 | 107 | 66 | 19 | 102 | 47 | 13 | 72 | 38 | 11 | 59 | 69 | 20 | 106 | 26 | 7 | 40 | 64 | 18 | 99 |
| ≥58 | 79 | 30 | 123 | 75 | 28 | 117 | 53 | 20 | 83 | 44 | 16 | 68 | 79 | 29 | 122 | 30 | 11 | 46 | 73 | 27 | 113 |
| ≥59 | 89 | 40 | 138 | 85 | 38 | 131 | 60 | 27 | 93 | 49 | 22 | 76 | 88 | 39 | 137 | 33 | 15 | 52 | 82 | 36 | 127 |
| ≥60 | 99 | 49 | 153 | 94 | 47 | 146 | 67 | 33 | 103 | 55 | 27 | 85 | 98 | 49 | 152 | 37 | 19 | 57 | 91 | 45 | 141 |
| ≥61 | 109 | 59 | 169 | 104 | 56 | 160 | 73 | 40 | 114 | 60 | 33 | 93 | 108 | 59 | 167 | 41 | 22 | 63 | 100 | 55 | 155 |
| ≥62 | 119 | 69 | 184 | 113 | 66 | 175 | 80 | 47 | 124 | 66 | 38 | 102 | 118 | 69 | 183 | 44 | 26 | 69 | 109 | 64 | 169 |
| ≥63 | 129 | 79 | 199 | 122 | 75 | 190 | 87 | 53 | 135 | 71 | 44 | 110 | 128 | 79 | 198 | 48 | 30 | 75 | 118 | 73 | 183 |
| ≥64 | 139 | 89 | 215 | 132 | 85 | 204 | 93 | 60 | 145 | 77 | 49 | 119 | 137 | 88 | 213 | 52 | 33 | 80 | 127 | 82 | 197 |
| ≥65 | 148 | 99 | 230 | 141 | 94 | 219 | 100 | 67 | 155 | 82 | 55 | 127 | 147 | 98 | 228 | 56 | 37 | 86 | 136 | 91 | 211 |
| ≥66 | 158 | 109 | 245 | 151 | 104 | 233 | 107 | 73 | 166 | 88 | 60 | 136 | 157 | 108 | 243 | 59 | 41 | 92 | 145 | 100 | 225 |
| ≥67 | 168 | 119 | 261 | 160 | 113 | 248 | 114 | 80 | 176 | 93 | 66 | 144 | 167 | 118 | 259 | 63 | 44 | 98 | 155 | 109 | 240 |
| ≥68 | 178 | 129 | 276 | 169 | 122 | 263 | 120 | 87 | 186 | 98 | 71 | 153 | 177 | 128 | 274 | 67 | 48 | 103 | 164 | 118 | 254 |
| ≥69 | 188 | 139 | 291 | 179 | 132 | 277 | 127 | 93 | 197 | 104 | 77 | 161 | 186 | 137 | 289 | 70 | 52 | 109 | 173 | 127 | 268 |
| ≥70 | 198 | 148 | 307 | 188 | 141 | 292 | 134 | 100 | 207 | 109 | 82 | 170 | 196 | 147 | 304 | 74 | 56 | 115 | 182 | 136 | 282 |
| ≥71 | 263 | 213 | 377 | 250 | 203 | 359 | 177 | 144 | 254 | 145 | 118 | 208 | 261 | 212 | 374 | 98 | 80 | 141 | 241 | 196 | 346 |
| ≥72 | 279 | 230 | 399 | 266 | 219 | 379 | 188 | 155 | 269 | 154 | 127 | 221 | 277 | 228 | 396 | 104 | 86 | 149 | 256 | 211 | 366 |
| ≥73 | 296 | 246 | 421 | 281 | 234 | 400 | 200 | 166 | 284 | 164 | 136 | 233 | 293 | 244 | 417 | 111 | 92 | 157 | 272 | 226 | 387 |
| ≥74 | 312 | 263 | 443 | 297 | 250 | 421 | 211 | 177 | 299 | 173 | 145 | 245 | 310 | 261 | 439 | 117 | 98 | 166 | 287 | 241 | 407 |
| ≥75 | 329 | 279 | 465 | 313 | 266 | 442 | 222 | 189 | 314 | 182 | 154 | 257 | 326 | 277 | 461 | 123 | 104 | 174 | 302 | 257 | 427 |
| ≥76 | 345 | 296 | 487 | 329 | 282 | 463 | 233 | 200 | 329 | 191 | 164 | 269 | 343 | 294 | 483 | 129 | 111 | 182 | 317 | 272 | 447 |
| ≥77 | 362 | 313 | 509 | 344 | 297 | 484 | 244 | 211 | 343 | 200 | 173 | 281 | 359 | 310 | 505 | 135 | 117 | 190 | 333 | 287 | 468 |
| ≥78 | 379 | 329 | 531 | 360 | 313 | 505 | 255 | 222 | 358 | 209 | 182 | 294 | 375 | 326 | 527 | 142 | 123 | 199 | 348 | 302 | 488 |
| ≥79 | 395 | 346 | 553 | 376 | 329 | 526 | 267 | 233 | 373 | 218 | 191 | 306 | 392 | 343 | 548 | 148 | 129 | 207 | 363 | 318 | 508 |
| ≥80 | 412 | 362 | 575 | 392 | 345 | 547 | 278 | 244 | 388 | 228 | 200 | 318 | 408 | 359 | 570 | 154 | 135 | 215 | 378 | 333 | 528 |
| ≥81 | 428 | 379 | 597 | 407 | 360 | 568 | 289 | 256 | 403 | 237 | 209 | 330 | 425 | 376 | 592 | 160 | 142 | 223 | 393 | 348 | 548 |

Table 6.10 continued (Central values for noise exposure in €<sub></sub>2002 PPP factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 9 | 0 | 14 | 9 | 0 | 14 | 6 | 0 | 10 | 5 | 0 | 7 | 11 | 0 | 17 | 9 | 0 | 14 | 3 | 0 | 5 |
| ≥52 | 18 | 0 | 28 | 18 | 0 | 27 | 13 | 0 | 19 | 9 | 0 | 15 | 22 | 0 | 33 | 18 | 0 | 27 | 6 | 0 | 10 |
| ≥53 | 27 | 0 | 42 | 26 | 0 | 41 | 19 | 0 | 29 | 14 | 0 | 22 | 32 | 0 | 50 | 26 | 0 | 41 | 9 | 0 | 15 |
| ≥54 | 36 | 0 | 56 | 35 | 0 | 54 | 25 | 0 | 39 | 19 | 0 | 29 | 43 | 0 | 67 | 35 | 0 | 54 | 13 | 0 | 19 |
| ≥55 | 45 | 0 | 70 | 44 | 0 | 68 | 31 | 0 | 49 | 24 | 0 | 37 | 54 | 0 | 84 | 44 | 0 | 68 | 16 | 0 | 24 |
| ≥56 | 55 | 9 | 85 | 53 | 9 | 82 | 38 | 6 | 58 | 28 | 5 | 44 | 65 | 11 | 100 | 53 | 9 | 82 | 19 | 3 | 29 |
| ≥57 | 64 | 18 | 99 | 61 | 18 | 95 | 44 | 13 | 68 | 33 | 9 | 51 | 75 | 22 | 117 | 61 | 18 | 95 | 22 | 6 | 34 |
| ≥58 | 73 | 27 | 113 | 70 | 26 | 109 | 50 | 19 | 78 | 38 | 14 | 59 | 86 | 32 | 134 | 70 | 26 | 109 | 25 | 9 | 39 |
| ≥59 | 82 | 36 | 127 | 79 | 35 | 122 | 56 | 25 | 88 | 43 | 19 | 66 | 97 | 43 | 150 | 79 | 35 | 122 | 28 | 13 | 44 |
| ≥60 | 91 | 45 | 141 | 88 | 44 | 136 | 63 | 31 | 97 | 47 | 24 | 74 | 108 | 54 | 167 | 88 | 44 | 136 | 31 | 16 | 49 |
| ≥61 | 100 | 55 | 155 | 96 | 53 | 149 | 69 | 38 | 107 | 52 | 28 | 81 | 119 | 65 | 184 | 96 | 53 | 149 | 35 | 19 | 53 |
| ≥62 | 109 | 64 | 169 | 105 | 61 | 163 | 75 | 44 | 117 | 57 | 33 | 88 | 129 | 75 | 200 | 105 | 61 | 163 | 38 | 22 | 58 |
| ≥63 | 118 | 73 | 183 | 114 | 70 | 177 | 82 | 50 | 126 | 62 | 38 | 96 | 140 | 86 | 217 | 114 | 70 | 177 | 41 | 25 | 63 |
| ≥64 | 127 | 82 | 197 | 123 | 79 | 190 | 88 | 56 | 136 | 66 | 43 | 103 | 151 | 97 | 234 | 123 | 79 | 190 | 44 | 28 | 68 |
| ≥65 | 136 | 91 | 211 | 132 | 88 | 204 | 94 | 63 | 146 | 71 | 47 | 110 | 162 | 108 | 251 | 132 | 88 | 204 | 47 | 31 | 73 |
| ≥66 | 145 | 100 | 225 | 140 | 96 | 217 | 100 | 69 | 156 | 76 | 52 | 118 | 172 | 119 | 267 | 140 | 96 | 217 | 50 | 35 | 78 |
| ≥67 | 155 | 109 | 240 | 149 | 105 | 231 | 107 | 75 | 165 | 81 | 57 | 125 | 183 | 129 | 284 | 149 | 105 | 231 | 53 | 38 | 83 |
| ≥68 | 164 | 118 | 254 | 158 | 114 | 245 | 113 | 82 | 175 | 85 | 62 | 132 | 194 | 140 | 301 | 158 | 114 | 245 | 56 | 41 | 88 |
| ≥69 | 173 | 127 | 268 | 167 | 123 | 258 | 119 | 88 | 185 | 90 | 66 | 140 | 205 | 151 | 317 | 167 | 123 | 258 | 60 | 44 | 92 |
| ≥70 | 182 | 136 | 282 | 175 | 132 | 272 | 125 | 94 | 195 | 95 | 71 | 147 | 216 | 162 | 334 | 175 | 132 | 272 | 63 | 47 | 97 |
| ≥71 | 241 | 196 | 346 | 233 | 189 | 334 | 167 | 135 | 239 | 126 | 102 | 181 | 286 | 232 | 411 | 233 | 189 | 334 | 83 | 68 | 120 |
| ≥72 | 256 | 211 | 366 | 247 | 204 | 354 | 177 | 146 | 253 | 134 | 110 | 191 | 304 | 250 | 435 | 247 | 204 | 354 | 89 | 73 | 126 |
| ≥73 | 272 | 226 | 387 | 262 | 218 | 373 | 188 | 156 | 267 | 142 | 118 | 202 | 322 | 268 | 459 | 262 | 218 | 373 | 94 | 78 | 133 |
| ≥74 | 287 | 241 | 407 | 277 | 233 | 393 | 198 | 167 | 281 | 150 | 126 | 212 | 340 | 286 | 483 | 277 | 233 | 393 | 99 | 83 | 140 |
| ≥75 | 302 | 257 | 427 | 291 | 248 | 412 | 209 | 177 | 295 | 158 | 134 | 223 | 358 | 304 | 507 | 291 | 248 | 412 | 104 | 89 | 147 |
| ≥76 | 317 | 272 | 447 | 306 | 262 | 432 | 219 | 188 | 309 | 166 | 142 | 234 | 376 | 322 | 530 | 306 | 262 | 432 | 110 | 94 | 154 |
| ≥77 | 333 | 287 | 468 | 321 | 277 | 451 | 230 | 198 | 323 | 174 | 150 | 244 | 394 | 340 | 554 | 321 | 277 | 451 | 115 | 99 | 161 |
| ≥78 | 348 | 302 | 488 | 335 | 292 | 471 | 240 | 209 | 337 | 182 | 158 | 255 | 412 | 359 | 578 | 335 | 292 | 471 | 120 | 104 | 168 |
| ≥79 | 363 | 318 | 508 | 350 | 306 | 490 | 251 | 219 | 351 | 190 | 166 | 265 | 430 | 377 | 602 | 350 | 306 | 490 | 125 | 110 | 175 |
| ≥80 | 378 | 333 | 528 | 365 | 321 | 509 | 261 | 230 | 365 | 197 | 174 | 276 | 448 | 395 | 626 | 365 | 321 | 509 | 131 | 115 | 182 |
| ≥81 | 393 | 348 | 548 | 379 | 336 | 529 | 272 | 240 | 379 | 205 | 182 | 286 | 467 | 413 | 650 | 379 | 336 | 529 | 136 | 120 | 189 |

Table 6.10 continued (Central values for noise exposure in €2002 PPP factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 3 | 0 | 5 | 12 | 0 | 19 | 6 | 0 | 9 | 10 | 0 | 15 | 4 | 0 | 6 | 6 | 0 | 10 | 4 | 0 | 6 |
| ≥52 | 7 | 0 | 10 | 24 | 0 | 37 | 12 | 0 | 18 | 20 | 0 | 30 | 7 | 0 | 11 | 12 | 0 | 19 | 8 | 0 | 13 |
| ≥53 | 10 | 0 | 16 | 36 | 0 | 56 | 18 | 0 | 28 | 29 | 0 | 46 | 11 | 0 | 17 | 19 | 0 | 29 | 12 | 0 | 19 |
| ≥54 | 14 | 0 | 21 | 48 | 0 | 75 | 24 | 0 | 37 | 39 | 0 | 61 | 15 | 0 | 23 | 25 | 0 | 38 | 16 | 0 | 25 |
| ≥55 | 17 | 0 | 26 | 60 | 0 | 94 | 30 | 0 | 46 | 49 | 0 | 76 | 19 | 0 | 29 | 31 | 0 | 48 | 21 | 0 | 32 |
| ≥56 | 20 | 3 | 31 | 72 | 12 | 112 | 36 | 6 | 55 | 59 | 10 | 91 | 22 | 4 | 34 | 37 | 6 | 58 | 25 | 4 | 38 |
| ≥57 | 24 | 7 | 37 | 84 | 24 | 131 | 42 | 12 | 65 | 69 | 20 | 106 | 26 | 7 | 40 | 43 | 12 | 67 | 29 | 8 | 45 |
| ≥58 | 27 | 10 | 42 | 97 | 36 | 150 | 48 | 18 | 74 | 79 | 29 | 122 | 30 | 11 | 46 | 50 | 19 | 77 | 33 | 12 | 51 |
| ≥59 | 30 | 14 | 47 | 109 | 48 | 168 | 54 | 24 | 83 | 88 | 39 | 137 | 33 | 15 | 52 | 56 | 25 | 86 | 37 | 16 | 57 |
| ≥60 | 34 | 17 | 52 | 121 | 60 | 187 | 60 | 30 | 92 | 98 | 49 | 152 | 37 | 19 | 57 | 62 | 31 | 96 | 41 | 21 | 64 |
| ≥61 | 37 | 20 | 58 | 133 | 72 | 206 | 65 | 36 | 101 | 108 | 59 | 167 | 41 | 22 | 63 | 68 | 37 | 106 | 45 | 25 | 70 |
| ≥62 | 41 | 24 | 63 | 145 | 84 | 224 | 71 | 42 | 111 | 118 | 69 | 183 | 44 | 26 | 69 | 74 | 43 | 115 | 49 | 29 | 76 |
| ≥63 | 44 | 27 | 68 | 157 | 97 | 243 | 77 | 48 | 120 | 128 | 79 | 198 | 48 | 30 | 75 | 81 | 50 | 125 | 53 | 33 | 83 |
| ≥64 | 47 | 30 | 73 | 169 | 109 | 262 | 83 | 54 | 129 | 137 | 88 | 213 | 52 | 33 | 80 | 87 | 56 | 134 | 57 | 37 | 89 |
| ≥65 | 51 | 34 | 79 | 181 | 121 | 281 | 89 | 60 | 138 | 147 | 98 | 228 | 56 | 37 | 86 | 93 | 62 | 144 | 62 | 41 | 95 |
| ≥66 | 54 | 37 | 84 | 193 | 133 | 299 | 95 | 65 | 148 | 157 | 108 | 243 | 59 | 41 | 92 | 99 | 68 | 154 | 66 | 45 | 102 |
| ≥67 | 57 | 41 | 89 | 205 | 145 | 318 | 101 | 71 | 157 | 167 | 118 | 259 | 63 | 44 | 98 | 105 | 74 | 163 | 70 | 49 | 108 |
| ≥68 | 61 | 44 | 94 | 217 | 157 | 337 | 107 | 77 | 166 | 177 | 128 | 274 | 67 | 48 | 103 | 111 | 81 | 173 | 74 | 53 | 114 |
| ≥69 | 64 | 47 | 99 | 229 | 169 | 355 | 113 | 83 | 175 | 186 | 137 | 289 | 70 | 52 | 109 | 118 | 87 | 182 | 78 | 57 | 121 |
| ≥70 | 68 | 51 | 105 | 241 | 181 | 374 | 119 | 89 | 185 | 196 | 147 | 304 | 74 | 56 | 115 | 124 | 93 | 192 | 82 | 62 | 127 |
| ≥71 | 90 | 73 | 129 | 320 | 260 | 460 | 158 | 128 | 227 | 261 | 212 | 374 | 98 | 80 | 141 | 164 | 133 | 236 | 109 | 88 | 156 |
| ≥72 | 95 | 78 | 136 | 340 | 280 | 486 | 168 | 138 | 240 | 277 | 228 | 396 | 104 | 86 | 149 | 175 | 144 | 250 | 116 | 95 | 165 |
| ≥73 | 101 | 84 | 144 | 361 | 300 | 513 | 178 | 148 | 253 | 293 | 244 | 417 | 111 | 92 | 157 | 185 | 154 | 264 | 123 | 102 | 175 |
| ≥74 | 107 | 90 | 151 | 381 | 321 | 540 | 188 | 158 | 266 | 310 | 261 | 439 | 117 | 98 | 166 | 196 | 165 | 277 | 129 | 109 | 184 |
| ≥75 | 112 | 95 | 159 | 401 | 341 | 567 | 198 | 168 | 280 | 326 | 277 | 461 | 123 | 104 | 174 | 206 | 175 | 291 | 136 | 116 | 193 |
| ≥76 | 118 | 101 | 166 | 421 | 361 | 594 | 208 | 178 | 293 | 343 | 294 | 483 | 129 | 111 | 182 | 216 | 185 | 305 | 143 | 123 | 202 |
| ≥77 | 124 | 107 | 174 | 441 | 381 | 621 | 218 | 188 | 306 | 359 | 310 | 505 | 135 | 117 | 190 | 227 | 196 | 319 | 150 | 130 | 211 |
| ≥78 | 129 | 112 | 181 | 462 | 401 | 647 | 228 | 198 | 319 | 375 | 326 | 527 | 142 | 123 | 199 | 237 | 206 | 332 | 157 | 136 | 220 |
| ≥79 | 135 | 118 | 189 | 482 | 422 | 674 | 238 | 208 | 333 | 392 | 343 | 548 | 148 | 129 | 207 | 247 | 216 | 346 | 164 | 143 | 229 |
| ≥80 | 141 | 124 | 196 | 502 | 442 | 701 | 248 | 218 | 346 | 408 | 359 | 570 | 154 | 135 | 215 | 258 | 227 | 360 | 171 | 150 | 238 |
| ≥81 | 146 | 129 | 204 | 522 | 462 | 728 | 258 | 228 | 359 | 425 | 376 | 592 | 160 | 142 | 223 | 268 | 237 | 374 | 178 | 157 | 248 |

Table 6.10 continued (Central values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 6 | 0 | 9 | 8 | 0 | 12 | 9 | 0 | 14 | 11 | 0 | 16 | 9 | 0 | 15 |
| ≥52 | 12 | 0 | 19 | 15 | 0 | 24 | 19 | 0 | 29 | 21 | 0 | 33 | 19 | 0 | 29 |
| ≥53 | 18 | 0 | 28 | 23 | 0 | 36 | 28 | 0 | 43 | 32 | 0 | 49 | 28 | 0 | 44 |
| ≥54 | 24 | 0 | 37 | 31 | 0 | 47 | 37 | 0 | 57 | 42 | 0 | 66 | 38 | 0 | 59 |
| ≥55 | 30 | 0 | 47 | 38 | 0 | 59 | 46 | 0 | 72 | 53 | 0 | 82 | 47 | 0 | 74 |
| ≥56 | 36 | 6 | 56 | 46 | 8 | 71 | 56 | 9 | 86 | 64 | 11 | 99 | 57 | 9 | 88 |
| ≥57 | 42 | 12 | 65 | 53 | 15 | 83 | 65 | 19 | 100 | 74 | 21 | 115 | 66 | 19 | 103 |
| ≥58 | 48 | 18 | 75 | 61 | 23 | 95 | 74 | 28 | 115 | 85 | 32 | 132 | 76 | 28 | 118 |
| ≥59 | 54 | 24 | 84 | 69 | 31 | 107 | 83 | 37 | 129 | 96 | 42 | 148 | 85 | 38 | 132 |
| ≥60 | 60 | 30 | 94 | 76 | 38 | 118 | 93 | 46 | 143 | 106 | 53 | 165 | 95 | 47 | 147 |
| ≥61 | 66 | 36 | 103 | 84 | 46 | 130 | 102 | 56 | 158 | 117 | 64 | 181 | 104 | 57 | 162 |
| ≥62 | 72 | 42 | 112 | 92 | 53 | 142 | 111 | 65 | 172 | 127 | 74 | 198 | 114 | 66 | 177 |
| ≥63 | 78 | 48 | 122 | 99 | 61 | 154 | 120 | 74 | 186 | 138 | 85 | 214 | 123 | 76 | 191 |
| ≥64 | 84 | 54 | 131 | 107 | 69 | 166 | 130 | 83 | 201 | 149 | 96 | 230 | 133 | 85 | 206 |
| ≥65 | 90 | 60 | 140 | 115 | 76 | 178 | 139 | 93 | 215 | 159 | 106 | 247 | 142 | 95 | 221 |
| ≥66 | 97 | 66 | 150 | 122 | 84 | 190 | 148 | 102 | 229 | 170 | 117 | 263 | 152 | 104 | 235 |
| ≥67 | 103 | 72 | 159 | 130 | 92 | 201 | 157 | 111 | 244 | 181 | 127 | 280 | 161 | 114 | 250 |
| ≥68 | 109 | 78 | 168 | 138 | 99 | 213 | 167 | 120 | 258 | 191 | 138 | 296 | 171 | 123 | 265 |
| ≥69 | 115 | 84 | 178 | 145 | 107 | 225 | 176 | 130 | 272 | 202 | 149 | 313 | 180 | 133 | 280 |
| ≥70 | 121 | 90 | 187 | 153 | 115 | 237 | 185 | 139 | 287 | 212 | 159 | 329 | 190 | 142 | 294 |
| ≥71 | 160 | 130 | 230 | 203 | 165 | 291 | 246 | 199 | 352 | 282 | 229 | 405 | 252 | 205 | 362 |
| ≥72 | 170 | 140 | 243 | 216 | 177 | 308 | 261 | 215 | 373 | 300 | 247 | 428 | 268 | 220 | 383 |
| ≥73 | 180 | 150 | 257 | 228 | 190 | 325 | 277 | 230 | 394 | 317 | 264 | 452 | 284 | 236 | 404 |
| ≥74 | 190 | 160 | 270 | 241 | 203 | 342 | 292 | 246 | 414 | 335 | 282 | 475 | 300 | 252 | 425 |
| ≥75 | 201 | 170 | 283 | 254 | 216 | 359 | 307 | 261 | 435 | 353 | 300 | 499 | 316 | 268 | 446 |
| ≥76 | 211 | 180 | 297 | 267 | 229 | 376 | 323 | 277 | 455 | 371 | 318 | 523 | 331 | 284 | 467 |
| ≥77 | 221 | 191 | 310 | 280 | 241 | 393 | 338 | 292 | 476 | 388 | 335 | 546 | 347 | 300 | 488 |
| ≥78 | 231 | 201 | 324 | 292 | 254 | 410 | 354 | 308 | 496 | 406 | 353 | 570 | 363 | 316 | 509 |
| ≥79 | 241 | 211 | 337 | 305 | 267 | 427 | 369 | 323 | 517 | 424 | 371 | 593 | 379 | 332 | 530 |
| ≥80 | 251 | 221 | 351 | 318 | 280 | 444 | 385 | 339 | 538 | 442 | 389 | 617 | 395 | 347 | 552 |
| ≥81 | 261 | 231 | 364 | 331 | 293 | 461 | 400 | 354 | 558 | 460 | 406 | 641 | 411 | 363 | 573 |

Notes: The Central values comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003) and quantifiable costs of health effects.

**Table 6.11** Impact indicator for noise exposure: percentage of adult persons highly annoyed per person (all ages) exposed – based on functions 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 |

### 6.4.3 Treatment of values over time

We recommend increasing 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 overestimate benefits from a transport project, as vehicle emissions are likely to decrease in the future.

### 6.4.4 Calculation procedure

**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).

## 6.5 Global warming

### 6.5.1 General approach

The method of calculating costs due to the emission of greenhouse gases (usually expressed as $CO_2$ equivalents) basically consists of multiplying the amount of $CO_2$ equivalents emitted by 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.

The $CO_2$ 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 $CO_2$ it is 1.

In high altitudes other emissions from aircraft than $CO_2$ 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 $CO_2$ 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 $CO_2$ emissions by a factor of 2 to consider the warming effect of other species than $CO_2$.

### 6.5.2 Monetary values

In the ideal case the cost factor would be calculated as damage cost using the principles outlined in section 6.2 above. However, there is a lack of exact knowledge about the impacts caused by climate change. Furthermore, uncertainties about scenarios of future developments and about the workings of the climate system are tremendous. Models have been developed to assess the impact of climate change on human health, agriculture, water availability, etc., and quantitative estimates of damage costs have been provided. In a review of valuation literature Tol (2005) found a median estimate of €4/t $CO_2$, a mean of €25/t $CO_2$ and a 95 percentile of €96/t $CO_2$ [26]. These figures are conservative in the sense that only damage that can be estimated with a reasonable certainty is included; for instance impacts such as extended floods and more frequent hurricanes with higher energy density are not taken into account, as there is not enough information about the possible relationship between global warming and these impacts. The literature review revealed a trend towards lower values over time, i.e. that more recent estimates tend to result in lower values than earlier estimates.

Due to the uncertainties in damage cost estimates often abatement costs have been used as a second best option (e.g. the cost to reach the Kyoto targets for reducing greenhouse gas emissions) to value costs from greenhouse gas emissions. Abatement costs are inferred from reduction targets or constraints for emissions and estimate the opportunity costs of environmentally harmful activities assuming that a specified reduction target is socially desired.

A European abatement cost of €20 per tonne of $CO_2$ represents a central estimate of the range of values for meeting the Kyoto targets in 2010 in the EU based on estimates by Capros and Mantzos (2000). They report a value of €5 per tonne of $CO_2$ avoided for reaching the Kyoto targets for the EU, assuming a full trade flexibility scheme involving all regions of the world. For the case that no trading of $CO_2$ emissions with countries outside the EU is permitted, they calculate a value of €38 per tonne of $CO_2$ avoided. It is assumed that measures for a reduction in $CO_2$ emissions are taken in a cost effective way. This implies that reduction targets are not set per sector, but that the cheapest measures are implemented, no matter in which sector.

However, there is a need to strive for more stringent reduction targets than Kyoto. The EU target of limiting global warming to an increase of 2°C of the earth's average temperature above pre-industrial levels may lead to marginal abatement costs as high as about €95/t $CO_2$. However it is an open question whether such an ambitious goal with such high costs will be accepted by the general population.

Recent work has confirmed the assumption that emissions in future years will have greater total impacts than emissions today (see e.g. Watkiss et al.; 2005a). Consequently for transport project appraisal we need value estimates that include future increases. In a recent report for

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[26] Values cited from Watkiss et al. (2005a), p. 29.

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 $CO_2$ 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 the UK's government long-term goal of meeting a 60% $CO_2$ reduction in 2050 (which is broadly consistent with the EU's 2°C target). On the 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 central guidance value given in Table 6.12 as central estimate, with the lower and upper central estimate for sensitivity analysis.

**Table 6.12** Shadow prices based on Watkiss et al. (2005b), converted from $£_{2000}$/t C to $€_{2002}$ (factor prices) per tonne of $CO_2$ equivalent emitted.

| | **Central guidance** | **For sensitivity analysis** | |
|---|---|---|---|
| **Year of emission** | | **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).

### 6.5.3 Treatment of values over time

We do not recommend increasing the values in Table 6.12 additionally 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 growing values over time clearly require 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.

### 6.5.4 Calculation procedure

**Step 1**: quantification of change in greenhouse gas emissions ($CO_2$, $CH_4$, $N_2O$; 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 $CO_2$ equivalents of ground level emissions; multiplication of high altitude aircraft $CO_2$ emissions with a factor of 2 (to consider warming effects of other species).

**Step 3**: multiplication of $CO_2$ equivalents with cost factor for year of emission.

**Step 4**: reporting of emissions and costs.

## 6.6 Other effects

Air pollution, global warming and noise represent the most important and relevant cost categories that can currently be assessed in 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 considered beside the CBA. However, it is beyond the scope of HEATCO to suggest concrete values or detailed methods in these areas.

# 7 Costs and Indirect Costs of Infrastructure Investment

## 7.1 Introduction

This chapter focuses on a framework for including costs and indirect costs of infrastructure investment in a cost-benefit analysis framework.

More specifically, this chapter discusses five elements related to the assessment of infrastructure costs of a project:
- Capital costs of the infrastructure project
- Residual value
- Optimism-bias
- Costs of maintenance, operation and administration
- Changes in infrastructure costs on existing network

The recommendations on how to treat each of these elements are set out below, following a short description of the overall framework of "whole life costing".

## 7.2 Whole life costing

One of the distinguishing features of infrastructure investment is that engineering and system running costs are spread across the lifetime of the scheme. Whilst a large proportion of the engineering costs will be in the form of initial capital outlay, the cost inventory also has to account for those items of expenditure involved in operating the investment over the appraisal period. Some of these may be small items that occur frequently or almost continuously (e.g. cleaning), whilst others will be larger and may happen only in a few specific years over the scheme's lifetime (e.g. road resurfacing). In order to represent all these items of expenditure in the cost-benefit analysis, a whole life costing framework should be used. This allows the full engineering costs of alternative transport investment options to be compared, thereby making explicit any trade-off between the initial capital outlay and the size of maintenance expenditure. An investment strategy with a high initial capital outlay resulting in lower maintenance costs may therefore be preferred to a strategy with lower initial capital costs and high maintenance costs. It is also important to realise that the most 'efficient' investment strategy in terms of total engineering costs may not be the optimum economic strategy due to the impact of construction and maintenance engineering works on accidents, vehicle operating costs and travel time delays.

In summary the principal advantages of the whole life costing approach are[27]:
- It allows the comparison of projects on the basis of lifetime costs
- It provides greater awareness of the total costs involved
- It allows more accurate forecasting of future expenditure

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[27] See for example Office of Government and Commerce (2004).

- It allows for a cost trade-off to be made against the attributes of the benefits from the project.

The focus of this section is, as mentioned, on the costs related to the infrastructure.

Figure 7.1 provides the structure for this whole life costing approach. The inputs to the framework are the costs associated with the investment in the new infrastructure (capital and future maintenance costs) plus the changes to the maintenance costs on the existing network over the lifetime of the project. These costs should then be adjusted for uncertainty and risk. Furthermore, it has to be considered whether optimism-bias is an issue.

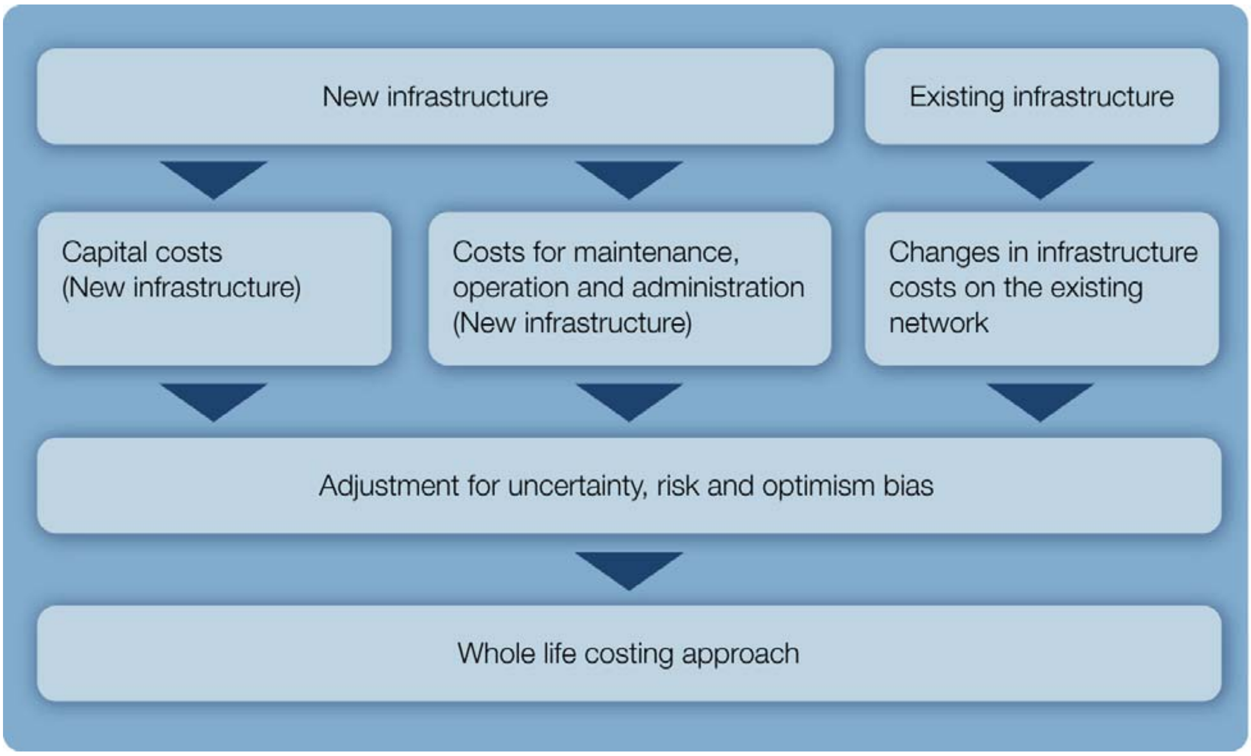

**Figure 7.1** Whole life costing approach

## 7.3 Capital costs of the infrastructure investment

The recommendations on how to treat the capital costs of the investment are presented below. The recommendations are given on the basis of the current practice in EU Member States and general considerations on which costs to include in a cost-benefit analysis.

**Recommendation**
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.

This definition is generally in line with the definition used in the EUNET study and country practice, as documented in Odgaard et al (2005).

**General principles**
There are two general principles for assessing the *capital costs of the infrastructure project.*

First[28], costs should be attributed to the project year in which the resources become unavailable to alternative uses. The year in which the resource becomes unavailable to alternative uses is not necessarily the year in which the resource is purchased or even the year in which the resource is used. This can be illustrated by two examples:

- If agricultural land has been purchased before the construction begins, cattle may graze the land up until the day before the engineering works begin. Under such circumstances the costs of the land should be charged in the cost-benefit analysis when the land is no longer used for grazing.
- If residential property is purchased long before the construction period, but for some reason becomes unsafe for occupation at some time, the value of the property should be included in the year in which it is taken out of use.

Second, it is necessary to distinguish between:

- Costs incurred before and after the decision whether to go ahead with the project or not
- 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.

**Specific recommendations**
The implications of these general principles are discussed below for each of the elements of capital costs together with element-specific issues.

*Construction costs* are generally incurred after the decision to go ahead with the project and should as such be included in the cost-benefit analysis. In the event that some of the costs have been incurred prior to the decision, a case-by-case judgement has to be made as to whether the costs are retrievable.

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[28] British Department for Transport, 2004a

Parts of *planning costs* are normally incurred prior to the date of decision whether to go ahead with the project. As these costs are non-retrievable they should not be included in the cost-benefit analysis. This also means that if a cost-benefit analysis is updated, some of the planning costs should possibly be ignored in the new assessment (i.e. the planning costs incurred in the time between the original assessment and the update).

How the *costs of land and property purchase* should be included in the project appraisal was outlined above. However, in some cases it can be relevant to consider the various components of the costs of land and property purchase.

The UK approach to subdividing the costs of land and property purchase seems reasonable.

The UK guidelines refer to four different cost categories:

- Acquisition costs (not necessarily the money paid to the previous owner, but the opportunity costs of the land/property)
- Legal transaction costs which refer to the amount paid to for example estate agents to deal with paperwork etc.
- Property management costs, i.e. the costs of managing and maintaining the land and property before it is used for the scheme (e.g. the costs of renting out farming land prior to the use of the land for the infrastructure project)
- Resale value (only relevant for off-line land and property).

Acquisition costs are normally retrievable, as the land and property can be resold if it is decided not to go ahead with the investment. Hence acquisition costs should generally be included in the project appraisal, even if the purchase has been paid for prior to the appraisal. If the land is used for farming or the property is occupied from purchase to construction, the costs should be included in the cost-benefit analysis at the time when it becomes unavailable to alternative use. If the land/property becomes unavailable prior the decision, the costs should be included at the time of decision at the earliest.

Transaction costs related to acquiring the land/property are generally non-retrievable. Hence, transaction costs should only be included if the land is acquired after the decision on whether to go ahead with the project29. The same goes for property management costs.

The resale value is included in the cost-benefit analysis as a negative cost at the time of resale. In addition to the costs set out above, compensation costs should be included in the project appraisal (for all land/property affected by the project).

The costs of *disruption from construction* may consist of several elements, including:

- Delays to private traffic
- Delays to public transport/scheduled services
- Effect on neighbours (noise, dust etc.)

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[29] The costs should exclude taxes and stamp duty

– Changes in risk of accidents.

The quantification of these effects has to be made on a case-by-case basis. The valuation of the effects should be made in accordance with the general valuation of time, accidents etc.

## 7.4 Residual value

In theory, the time horizon of the project appraisal should equal the lifetime of the infrastructure[30] in order to capture the full benefits of the project. However, the evaluation period is often limited to the period over which demand can be foreseen with reasonable accuracy (see section 3.5 for a discussion of the appraisal period). Thus, due to uncertainty about traffic, impacts on the environment, safety issues etc., the evaluation period is often shorter than the lifetime of the infrastructure. This introduces the issue of the residual value of the infrastructure.

The residual value is an item in the appraisal which captures net benefits beyond the formal appraisal period.

### 7.4.1 Justification/motivation

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.

The examples presented later illustrate that the residual value is often of relatively little importance to the results of the cost-benefit analysis.

The recommended approach is generally in line with country practice, as documented in Odgaard et al (2005).

### 7.4.2 Recommendation

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 'allowed'.

A range of recommended lifetimes is provided in Table 7.1 for road and rail projects. For other modes the recommended lifetimes can be used as inspiration. If the appraiser uses life-

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[30] In reality the infrastructure consists of several parts with different lifetimes.

times outside the ranges presented in Table 7.1, it must be explicitly stated why such an approach is taken.

For short-lived sub-components reinvestments may be necessary during the evaluation period (see Example 2 below and discussion on the costs of maintenance, operation and administration).

**Table 7.1** Lifetimes in years by mode and group of components (road and rail).

| Mode | Group of components | Min | Main | Max |
|---|---|---|---|---|
| General | Bridges | 50 | 75 | 100 |
| | Tunnels | 50 | 75 | 100 |
| | Land | Infinite | Infinite | Infinite |
| 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 |
| Rail | Substructures | 40 | 60 | 80 |
| | Tracks | 20 | 30 | 40 |
| | Tech. equip., | 10 | 20 | 30 |
| | Power supply | 20 | 30 | 40 |
| | Environmental installations | 10 | 30 | 50 |

**Illustrative examples**

Two illustrative examples on how to deal with the residual value in a cost-benefit framework are presented below.

Example 1: "No re-investments"

The table below shows the NPV assessment of a bridge. The assessment is based on the following parameters/assumptions:

- Capital costs of the infrastructure project: 150 million € (distributed equally over three years)
- Lifetime of bridge: 75 years
- Linear depreciation profile
- Discount rate: 3%
- Appraisal period: 40 years (operational phase)

After 40 years of operation the residual value can be determined as:

Residual value = (remaining lifetime/total lifetime)*capital costs = (35 years/75 years)*150 million € = 70 million €. As can be seen the capital costs of the infrastructure are reduced by the net present value of the residual value.

**Table 7.2** Example 1: "No re-investments" (million €)

| **Element** | **NPV** | **Planning and construction phase** | | | **Operational phase** | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | … | 44 |
| Construction costs | 141 | 50 | 50 | 50 | 0 | 0 | … | 0 |
| Residual value | -19 | 0 | 0 | 0 | 0 | 0 | … | -70 |
| Total | 122 | 50 | 50 | 50 | 0 | 0 | … | -70 |

Example 2: "Re-investments"

Consider the same example as above, but in addition the project includes investments in new tracks for 12 million €. The tracks are assumed to have a lifetime of 30 years. This means that the tracks have to be replaced after 30 years in operation. The table below shows the NPV assessment for such a project.

The residual value of the tracks can be assessed on the basis of the formula presented above, i.e.: Residual value = (20 years/30 years)* 12 million € = 8 million €.

Again, the capital costs of the infrastructure are reduced by the net present value of the residual value.

**Table 7.3** Example 2: "Re-investments" (million €)

| **Element** | **NPV** | **Planning and construction phase** | | | **Operational phase** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | … | 34 | … | 44 |
| Construction costs - bridge | 141 | 50 | 50 | 50 | 0 | … | 0 | … | 0 |
| Residual value - bridge | -19 | 0 | 0 | 0 | 0 | … | 0 | … | -70 |
| Construction costs - tracks | 11 | 4 | 4 | 4 | 0 | … | 0 | … | 0 |
| Re-investments - tracks | 4 | 0 | 0 | 0 | 0 | … | 12 | … | 0 |
| Residual value - tracks | -2 | 0 | 0 | 0 | 0 | … | 0 | … | -8 |
| Total | 136 | 54 | 54 | 54 | 0 | … | 12 | … | -78 |

## 7.5 Optimism-bias

At the early stages of the project life-cycle the estimates of construction costs are naturally uncertain. This uncertainty is known and should therefore be accounted for in the construction cost estimates.

### 7.5.1 Justification/motivation

The problem is however that several studies have documented a systematic tendency for project appraisers to underestimate construction costs. For example, Flyvbjerg et al (2003) show that:

- Cost escalation occurs in almost nine out of ten projects
- *Actual costs* are on average 28% higher than *estimated/forecast costs.*

- Cost overrun seems to be a global phenomenon.

The cause of the cost overrun is cost underestimation[31]. On the basis of the evidence of cost underestimation, it is recommended that the issue of optimism-bias is dealt with in the project appraisal. Bent Flyvbjerg (2005a) presented 10 points to reduce uncertainty/cures to optimism-bias at the first HEATCO conference in Brussels in April 2005. The 10 ideas are presented in Table 7.4, where they have been grouped into three categories:

- Ideas relating to the content of the *guidelines*
- Ideas relating to the *process of project appraisal*
- Ideas relating to the *organisation of risks/incentives*.

**Table 7.4** Ideas to reduce uncertainty/cures to optimism-bias.

| Guidelines | Process of project appraisal | Organisation of risks/incentives |
|---|---|---|
| ▪Benchmark projects<br>▪Use reference class forecasting | ▪Get independent reviews of all cost and benefit estimates<br>▪Engage stakeholders and civil society<br>▪Make all documents and other info publicly available, e.g. at website<br>▪Make sure guidelines are applied consistently across member states | ▪Change incentive structure<br>▪Make forecasters share financial responsibility for covering cost overruns and benefit shortfalls<br>▪Make go-ahead contingent on 1/3 private risk capital, also in subsidised projects<br>▪In PPPs, make size of subsidy dependent on accuracy of forecasts |

Source: Flyvbjerg (2005a), own categorisation

It is outside the scope of this project to deal with the ideas relating to the process of project appraisal and organisation of risks/incentives. It is however recommended that projects are benchmarked and that reference forecasting is used. The procedure for this is described below. The recommendation draws heavily on the recommendation prepared by Bent Flyvbjerg in association with COWI for the British Department for Transport (British Department for Transport, 2004b), which again draws on Mott Macdonald (2002) and Flyvbjerg et al (2002, 2003).

### 7.5.2 Recommendation

It is recommended that a side-analysis is conducted where optimism-bias uplifts are applied to the estimated budgets (see below for description on how to apply the uplifts).

- 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 cost estimates applied in the study must be benchmarked to the realised costs of similar projects.

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[31] For a discussion of what causes cost overrun see Flyvbjerg et al (2004).

- If it can be documented that the original cost estimates are in line with the realised costs of similar projects, the project appraisal process can continue. If not, it must either be explicitly justified why the cost estimates are lower and/or the construction cost estimates must be revised.

The main reason why it is 'only' recommended to apply the uplifts in a side-analysis is that part of the estimates on average cost escalation (which are presented below) can be attributed to benefit-generating improvements. This could for example be the costs of upgrading the quality (e.g. safety improvements) of the infrastructure between the time of 'decision to build' and the time of 'completing the project'. An upgrade of the infrastructure is likely to generate additional benefits. Hence, if the figures on the average cost escalation are used as a proxy for the 'level of optimism-bias', then the effect is overestimated. Unfortunately, the data does not allow separating the cost escalation on the effects of optimism-bias and the effect of benefit-generating upgrades.

**Applying the optimism-bias uplifts**
The basic idea behind the reference forecasting approach is that the "*…information on a class of similar or comparable projects is used to derive information on the extent to which likely - but presently unknown - future events may increase project costs, delay project time schedule or reduce project benefits compared to the base scenario*"[32]. This means that no attempt is made to forecast specific risks to a project. On the contrary, reference is made to a set of relevant and similar past transport infrastructure projects. The first step is to define a reference class of past transport projects, which can be considered as "similar" to the project under consideration.

When the reference class has been defined, the historically observed budget increase is used to form a probability distribution. An example of such a probability distribution is shown in Figure 7.2 below. The figure illustrates how the information on historically observed budget increases can be used to correct the estimate on construction costs of new projects for optimism-bias.

Given that the probability distribution has been formed on the basis of similar projects, the new project should be placed at the point 'initial budget'. The point 'average construction costs' refers to average realised costs of a 'similar project'. The 'applicable capital expenditure uplift' refers to the uplift necessary to ensure that on average the realised costs will be on budget.

It is recommended here that a side-analysis is made on the basis of the average realised costs of similar projects (initial budget + 'applicable capital expenditure uplift'). The initial budget should include contingencies.

Table 7.5 shows the recommended optimism-bias uplifts for selected reference classes (e.g. fixed links). If a project includes elements of different categories of project types, the relative

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[32] The British Ministry of Transport (2004, page 8).

size of each sub-project should be identified and the relevant uplift applied before aggregation to establish the total budget.

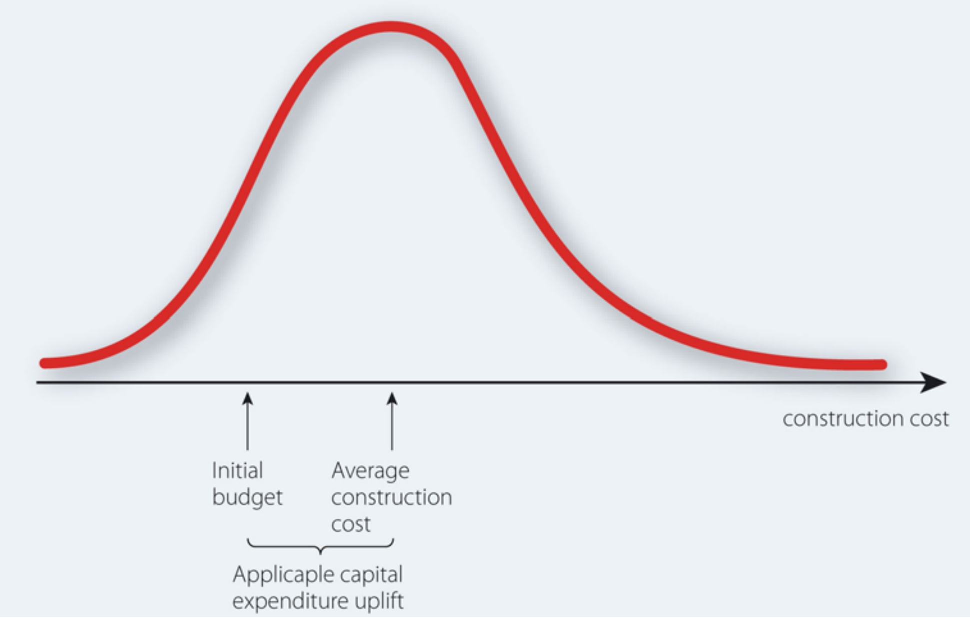

**Figure 7.2** Definition of optimism-bias uplifts within a certain class.
Source: Based on the British Department for Transport (2004b, page 11)

**Table 7.5** Applicable capital expenditure uplift (average cost escalation)

| Category | Types of projects | Uplift |
|---|---|---|
| Roads | Motorway<br>Trunk roads<br>Local roads<br>Bicycle facilities<br>Pedestrian facilities<br>Park and ride<br>Bus lane schemes<br>Guided buses on wheels | 22%* |
| Rail | Metro<br>Light rail<br>Guided buses on tracks<br>Conventional rail<br>High speed rail | 34%* |
| Fixed links | Bridges<br>Tunnels | 43%* |
| Building projects | Stations<br>Terminal buildings | 25%** |
| IT projects | IT system development | 100%** |

Source: British Department for Transport (2004b), Mott MacDonald (2002), Flyvbjerg et al (2002)
* Based on data for average cost escalation in Europe presented in Flyvbjerg et al (2002)
** Pragmatic estimate based on range given in Mott MacDonald (2002), See British Department for Transport (2004b, page 30-32) for discussion of the figures presented in Mott MacDonald (2002).

I might be the case that the level of optimism-bias depends on the phase of the planning. This is however - due to data limitations - not considered here.

A simple example[33] illustrates how the optimism-bias uplifts can be used in practice. To secure that on average the realised costs will be on budget, the planners should use an uplift of 22% on their estimated capital expenditure budget for a road project. Thus, if the initially estimated budget were € 100 million, then the final budget taking into account optimism-bias would be € 122 million.

## 7.6 "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 the parts of the network which are not changed by the project. Changes in costs of the existing network refer to changes in costs due to changes in traffic volumes. Accordingly, non-traffic related costs of the existing network will by definition be identical for the relevant alternatives for the cost-benefit analysis, and can therefore be ignored.

It is a 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
- Approaches to cost accounting
- Climate and topographical conditions
- Classification of vehicles.

This means not only that it is impossible to generalise/transfer cost estimates, but also that the 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.

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[33] Based on the British Ministry of Transport (2004, page 31).

### 7.6.1 Justification/motivation

The recommendations are given on the basis of the current country practice (see Odgaard et al 2005), general considerations on which costs to include in a cost-benefit analysis and state-of-the-art considerations.

### 7.6.2 Recommendation

**Definition**
The EUNET study defined the related *system operating costs and maintenance costs* as; *"costs consisting of the costs of infrastructure operation (e.g. signalling/traffic control), the costs of maintenance (e.g. cleaning, minor repairs, winter servicing) and the costs of renewal (e.g. road surfacing)"*[34]. It is recommended to use the same definition here.

A number of methods are used for determining the costs of maintenance, operation and administration. These methods need to both determine what maintenance strategy is required (depending on vehicle use) and how much this will cost for input into the cost-benefit analysis.

Most studies agree that the preferable state-of-the-art technique for assessing running costs entails the estimation of a total cost function. However, this is quite complicated, as not only must the future number of vehicles and type of vehicles be forecast, but the form of the total cost function must also be known. Furthermore, the problem that the chosen time horizon has an impact on the definition/delimitation of cost categories has to be dealt with. Hence, such an approach is in general not feasible for project appraisal. This calls for a more simple approach.

**First best**
The recommended approach is to use national default values if they are available. This is recommended to secure transparency, even if empirical evidence shows that running costs are highly dependent on circumstances surrounding the observed pieces of infrastructure, and that the variation in costs can be large[35]. It has to be carefully considered if the national standard figures are applicable to the infrastructure under consideration.

**Second best**
The second best option is to use a pragmatic approach based on aggregate cost data which is available in many 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

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[34] EUNET, D9, page 15.

[35] See for example DIW et al, 1998

The distinction between (short run) fixed costs and 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 7.6 shows the recommended spilt into fixed and variable costs for road and rail.

**Table 7.6** 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 treatmens 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 maintanance** | | | |
| | Removal of pot-holes, spilling of joints | | No | Yes |
| | Minor repairs | Minor repairs | Partly | Partly |
| | Pavement renewal | Ballast cleaning, compression | No | Yes |
| Ongoing maintanance and operation | **Operation, servicing and ongoing maintanance** 1) | | | |
| | Winter maintanance (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.

What is left is 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).

To estimate these costs it is - for pragmatic reasons - recommended 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[36]).

Then 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 7.7 for the cost categories which were categorised as 'variable' or 'partly variable' in Table 7.6.

**Table 7.7** 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)[37]. 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)

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[36] This is generally not supported by the empirical evidence.

[37] See for example Transport and Road Research Laboratory, 1998.

For rail more research is needed on the cost allocation, as virtually no studies exist. With respect to classification, trains should be classified according to wagon weight and speed, as these are the cost drivers (Link et al, 1999). Link et al (1999) suggest the following classification:

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

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

# 8 Vehicle Operating Costs

## 8.1 Purpose/role in project appraisal

Vehicle operating costs form an element of user benefit (cost) for private road users and form an element of the operating cost of a public transport service. Along with user charges and fares they are one of the handful of components of a cost benefit analysis that have market values, and for which prices do not have to be inferred using non-market valuation techniques. In the EC, which has a well developed transport network of reasonable quality, vehicle operating costs would not typically form a large component of the economic benefit of a new transport project. However, there may be some projects in which the transport network is of particularly poor quality and existing vehicle operating costs are very large (e.g. gravel roads in a mountainous region). In such circumstances the provision of high quality infrastructure may give significant vehicle operating cost savings.

## 8.2 Definition

There is a high degree of consensus within the EU regarding the definition of vehicle operating costs (Odgaard *et al.*, 2005). Out of 18 countries that have a definition for vehicle operating costs, only two have a definition that is not fully consistent with that recommended by EUNET. Neither of these two countries have a definition that deviates materially from that definition. Therefore, we recommend that vehicle operating costs are defined as *comprising the standing costs, which are invariant with distance, and operating costs, which vary with distance, of the transport vehicle*.

There are two potential ways in which vehicle operating costs can be double counted within a transport cost benefit analysis:

- The first is potential double counting with system operating costs. System operating costs are incurred by the owner of the infrastructure and are described in section 7 of these guidelines. In some situations the owner of the infrastructure may also own the transport vehicle (e.g. a publicly owned and operated railway or port). In such situations it may be simpler to consider vehicle operating and system operating costs simultaneously.
- The second area is the treatment of personnel costs and other time related components of cost within the operation of public transport vehicles and commercial goods traffic vehicles, as this can potentially lead to some double counting of benefits with travel time savings. If the vehicle operating cost model used in the appraisal does *not* include such time related costs then the travel time savings for personnel costs (and time related costs for goods transported) should be included in the appraisal and vice versa.

Clearly all forms of double counting should be avoided.

## 8.3 Valuation Methodology

### 8.3.1 Core Issues

Operating costs are clearly dependent on the prices of goods within a region (e.g. price of fuel, vehicle parts, etc.). However, operating costs can also be influenced by the regulatory and institutional characteristics of the environment in which the transport industry in a particular country 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 0 of these guidelines);
- Depreciation (distance related share)
- Fuel and lubricants

In the case of all economic appraisals of transport investment projects the key input with respect to operating costs is the change in operating costs with and without the project. However, the nature that this change is brought about will determine whether an incremental or absolute operating cost model is required.

- *An incremental model* will be sufficient for majority of TEN-T projects. Within an incremental model it is expected that unit costs of operation will not alter significantly after the investment.
- *An absolute model:* would be required where the unit costs of operation are expected to alter significantly after the investment. An example would be the replacement or purchase of a new fleet of high speed trains, which may also coincide with an associated expansion of the high speed train network.

Operating costs accrue throughout a project's life and as such should reflect the manner that resource costs will vary during the lifetime of a project. Consideration will need to be given to the derivation of future year resource costs. Comparability should be maintained with the assumptions regarding other future year costs (e.g. value of time – section 4.4.8 - and accident costs – section 5.2.5).

### 8.3.2 Road vehicle operating costs

Operating costs for road vehicles comprise of those incurred by road users and road service providers (e.g. road haulage firm). The nature of these costs is that they are distance dependent, however, some vary linearly with distance travelled (e.g. fuel costs) whilst others vary in a step like or lumpy manner (e.g. vehicle purchases and maintenance schedules). Road vehicle costs vary by vehicle type, the condition of the road surface, the road gradient and vehicle speed. Road vehicle operating costs are therefore correlated with the proposed road design standard (e.g. bitumen, concrete or gravel surface), the road maintenance strategy, environmental impacts, the composition of the traffic flow and road congestion (through speed).

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. It should be noted that such a model is incremental in nature. The HDM model needs to be populated with some local data reflecting road and vehicle characteristics (including the price of replacement parts).

### 8.3.3 Train operating costs

The operating costs for a train are those incurred by the service provider. These costs vary as follows:

- Between freight and passenger services
- By the type of freight carried. If the freight is high volume low density than the cost per tonne will be higher than if it is low volume high density (operating costs vary by the number of cars used per train and there maybe weight restrictions that limit freight train sizes).
- By the length of the journey (costs per mile decline with distance)
- By track alignment (it takes more power and fuel to climb mountains than it does to cross flat country)
- By train vehicle utilisation which in turn depends on:
  - operational characteristics (a returning empty freight train costs less per mile than a full outbound train)
  - the physical characteristics of the rail network (including train depot locations);
  - the regulatory and labour market framework between countries (e.g. working time directives); and
  - congestion effects: should the railway under consideration operate at or close to capacity in certain locations delays maybe experienced within the system.

> Utilisation rates for the train vehicles will therefore decrease as delays increase thereby increasing unit costs

As with road vehicles, the nature of train operating costs are that some cost items are "lumpy", such as replacement costs for locomotives, whilst others are proportional to distance (e.g. train fuel costs).

Railway operating cost models derived from existing cost data contain an implicit assumption that the cost base will not be affected by the transport investment proposed. The following situations, however, may result in a change in the cost base:

- The use of a new type of locomotive with unknown operating costs and reliability (an engineering unit cost may have to be used);
- A step change in the level of service provision at a regional level (congestion effects maybe incurred and new infrastructure with different utilisation rates maybe required); and
- Railway reform (e.g. privatisation or commercialisation) may alter the cost base.

### 8.3.4 Ship and aircraft operating costs

Ship and aircraft operating costs vary in a similar manner to train operating costs. They are heavily dependent on vessel or aircraft type, manner of operation, utilisation and maintenance strategies, as well as the regulatory framework in which the vessel or craft operates.

## 8.4 Implementation of vehicle operating cost guidelines

### 8.4.1 Deriving vehicle operating costs for use in an appraisal

As with other components of the cost benefit analysis the underlying principle regarding the implementation of the above guidelines is that vehicle operating costs used in an appraisal should:

(i) Be developed in a manner that reflects the core determinants of vehicle operating costs as set out above; and

(ii) Reflect the underlying resource costs associated with operating vehicles on 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, ideally, as different vehicle operating costs are faced by different users of the transport system this should be reflected within the appraisal. Clearly the extent to which this can be undertaken depends on the detail of the transport modelling and the appraisal (e.g. disaggregation by HGV types and train utilisation rates). Obviously greater efforts should be made for large schemes with significant capital costs than for small schemes, where reasonable approximations to the underlying resource costs may be made. Some EU countries have well developed appraisal frameworks with a lot 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. Table 8.1 sets out methods that can be used to approximate vehicle operating costs where the nationality or true origins and destinations of traffic may not be known.

### 8.4.2 Vehicle operating cost data requirements

The calculation of the economic benefit (cost) 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:

(i) Demand - the number of vehicles making a particular origin-destination trip for the Do-Minimum and the Do-Something cases;

(ii) 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

(iii) The unit cost of a vehicle kilometre – this in turn will require data on:

   a. the transport network characteristics (e.g. gradient)
   b. vehicle characteristics (e.g. vehicle type, speed, cost of replacement parts and maintenance, load, etc.)
   c. 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 should be local to the appraisal. 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.

**Table 8.1** Approximating the underlying resource costs for operating vehicles on the TEN-T.

| TEN-T Project | Passenger traffic | Goods traffic |
|---|---|---|
| **TEN-T schemes located wholly within a single nation state** | The majority of the passenger traffic will be related to trips within that nation state. In such a situation use of that nation's vehicle operating cost methodology for all passenger trips may be reasonable. | On TEN-T projects a significant amount of goods traffic may be international:<br>• In the (probably) rare circumstances that the nationality of the haulier is known a vehicle operating cost value consistent with that nationality should be used.<br>• Where identification of the origins and destinations of the goods traffic can be made (e.g. Milan to Munich) but the nationality of the traffic is unknown (e.g. French or British) a pragmatic option is to use a vehicle operating cost consistent with the country of the trip origin.<br>• Where the identification of the origins and destinations of the goods traffic is unknown all traffic should be allocated the vehicle operating cost of the host nation. |
| **Cross-Border TEN-T schemes** | The majority of the passenger traffic will be related to trips between the nation states. In such a situation use of the respective nations' vehicle operating cost methodology for trips that originate in that country maybe reasonable. | As for TEN-T schemes located wholly within a single nation state. |

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# Overview of Annexes

**Please note: the original annexes have been prepared as separate documents, therefore the page numbering for each annex starts with 1. The page numbers mentioned below refer to the numbers shown in the pdf reading programme used.**

# An international meta-analysis of values of time

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16 March 2006

## 1. Introduction

Meta-analysis can be defined as: the statistical analysis of analyses. A number, usually large, of previous research studies is analysed using statistical methods. The origin of the method is in medicine, where often large numbers of studies, carried out in similar ways (e.g. double-blind treatment experiments), are available on some topic, and where meta-analysis has proven to be a valuable tool for synthesising the available research outcomes. It does not use the data sets of the individual studies, but analyses a data set at a higher level (this explains the name ‘meta-analysis’). What meta-analysis does is looking for patterns in the outcomes of past studies, by regressing their findings on variables such as: attributes of the countries where the study took place, the segments of the population studied and the method used. Once this regression has been carried out, the results can be used both for interpreting the outcomes of the individual past studies and the overall evidence, and for predicting other situations. In the case of value of time (VoT) studies, a meta-regression can be estimated on study outcomes for countries where VoT studies have been carried out, and then applied to countries (using explanatory variables for these countries) where such studies are lacking. For a general introduction we refer to Button et al., (1999).

Meta-analysis has been applied in transport research, though not very often. It has been used to study elasticities (Nijkamp and Pepping, 1998), to generate transport demand forecasts (de Jong et al., 2004a) and also a meta-analysis has been performed on a database of a large number of UK VoT studies (Wardman, 2004).

Within the HEATCO project for the European Commission on harmonised European approaches for transport costing and project assessment, a meta-analysis of international VoT studies has been carried out. The objectives of this meta-analysis were:

- To provide input for the HEATCO benefit-transfer procedure for values of travel time savings (VTTS): derive values for countries
    - Without VTTS guidelines.
    - With limited segmentation in VTTS.
- To investigate variation in VTTS:
    - How much of the variation between countries can be explained by variation in GDP/capita?
    - What is the role of the valuation method (e.g. cost savings, willingness to pay (WTP)), distance, mode?
    - What evidence can it provide on the variation of the VTTS over time?
- To provide consistency of national results with the benefit-transfer method.

## 2. The data sets used

To some degree, the data collection for the HEATCO VTTS meta-analysis could build on earlier data collection efforts (e.g. TRACE, 1998; de Jong et al, 2004b). But several fairly recent studies have been added as well. For passenger transport we collected 77 studies (some investigating one specific mode, some with multiple modes), with 1,299 values of time in total. A study can provide several V0Ts, e.g. for different travel purposes, population groups and/or travel modes. The 77 studies cover 30 countries around the world, mainly in OECD countries, with some emphasis on European countries. We focussed on national studies (so we did not re-use Wardman's data set with many local/regional UK studies) and on recent studies (defined as 1990 and later; only for countries that had limited recent material did we use older studies). The distribution of values over countries is given in Appendix I.

For freight transport we created a separate data set, with values from 33 studies in 18 countries (mainly in Western-Europe). This data set contains 139 values in total. We only included values of time by road and rail, because there were insufficient values for other modes to include specific coefficients for these. The distribution of values over countries is given in Appendix II

We brought all the data in a common format:

- The VTTS is in 2003 Euros. We used currency exchange rates and national price indices; with regards to market or factor prices, we use the units as in the original surveys; generally speaking non-work values are in market prices and the work and freight values are in factor prices. Purchasing power parities (PPP) were not used. In our analysis, both the values of time and the GDP/capita used refer to the year of the original survey (but in prices of 2003).
- We created from the underlying studies a common set of explanatory variables on countries, segments of population, method used, year, etc.

## 3. Regression results

### 3.1 Passenger transport

We tried different functional forms (linear, logarithmic, double logarithmic) and found that the best results (in terms of $R^2$, t-ratios, sign and size of coefficients) were obtained by using double logarithmic models. In these models, the dependent variable is the natural logarithm of the VoT and the explanatory variables are the natural logarithm of GDP per capita (of the country and year studied) and a number of dummy variables. Wardman (2004) also found that this specification performed best in his regression analysis on UK VoT studies. In these double logarithmic models, or constant elasticity of substitution models, the estimated coefficient for the natural logarithm of GDP per capita will be the GDP per capita ('income') elasticity of the VoT.

Models were estimated for all travel purposes together and separately for travelling on employer's business (EB) on the one hand and commuting and other purposes on the other hand. The estimation results for all travel purposes together, using the least squares regression facility in SPSS, are in Table A1.

**Table A1**. Least squares regression estimation results for passenger VTTS, all purposes; dependent variable: log of the VoT; n=1250

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (constant) | -4.249 | .495 | | -8.585 | .000 |
| rpdummy | .013 | .066 | .004 | .193 | .847 |
| sprpdum | -.222 | .042 | -.124 | -5.322 | .000 |
| spdummy | -.254 | .042 | -.165 | -6.109 | .000 |
| traindum | .083 | .044 | .046 | 1.912 | .056 |
| airdum | .389 | .071 | .121 | 5.507 | .000 |
| busdum | -.189 | .044 | -.102 | -4.272 | .000 |
| carpass | .149 | .042 | .092 | 3.558 | .000 |
| longdisdum | .163 | .036 | .087 | 4.478 | .000 |
| lngdpcap | .619 | .049 | .394 | 12.528 | .000 |
| pre90 | .250 | .108 | .040 | 2.323 | .020 |
| yr9094 | .071 | .042 | .031 | 1.687 | .092 |
| yr0005 | .244 | .053 | .080 | 4.571 | .000 |
| seurope | .348 | .048 | .183 | 7.230 | .000 |
| bseurop | -.265 | .063 | -.096 | -4.232 | .000 |
| beast | -.221 | .136 | -.034 | -1.625 | .104 |
| row | .266 | .059 | .085 | 4.520 | .000 |
| eastbloc | .608 | .133 | .148 | 4.564 | .000 |
| comdum | .145 | .033 | .079 | 4.365 | .000 |
| busidum | 1.172 | .037 | .723 | 31.821 | .000 |
| brow | -.621 | .167 | -.064 | -3.711 | .000 |

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .831(a) | .690 | .685 | .43324 |

The explanatory variables in this model are:

**rpdummy**: dummy variable that takes the value of 1 if VoT from model estimated on revealed preference (RP) data; 0 otherwise (base=cost savings approach).

**sprpdum**: dummy variable that takes the value of 1 if VoT from model estimated jointly on RP and stated preference (SP) data (base=cost savings approach); 0 otherwise.

**spdummy**: dummy variable that takes the value of 1 if VoT from model estimated on SP data (base=cost savings approach); 0 otherwise.

**traindum**: dummy variable that takes the value of 1 if VoT for travel by train (base=car driver); 0 otherwise.

**airdum**: dummy variable that takes the value of 1 if VoT for travel by airplane (base=car driver); 0 otherwise

**busdum**: dummy variable that takes the value of 1 if VoT for travel by bus (base=car driver); 0 otherwise.

**carpass**: dummy variable that takes the value of 1 if VoT for travel as car passenger (base=car driver); 0 otherwise.
**longdisdum**: dummy variable that takes the value of 1 if VoT for long distance travel (base =short distance); 0 otherwise.
**lngdpcap**: natural logarithm of GDP per capita (in 2003 Euros).
**pre90**: dummy variable that takes the value of 1 if VoT for a year before 1990 (base=1995-1999); 0 otherwise.
**yr9094**: dummy variable that takes the value of 1 if VoT for a year from 1990 until 1994 (base=1995-1999); 0 otherwise.
**yr0005**: dummy variable that takes the value of 1 if VoT for a year from 2000 until 2005 (base=1995-1999); 0 otherwise.
**seurope**; dummy variable that takes the value of 1 if VoT for a country in Southern-Europe (base is Northwest-Europe); 0 otherwise.
**bseurope**: interaction dummy variable that takes the value of 1 if VoT for business travel and for Southern-Europe; 0 otherwise.
**beast**: interaction dummy variable that takes the value of 1 if VoT for business travel and for Eastern-Europe; 0 otherwise.
**row**: dummy variable that takes the value of 1 if VoT for a country outside Europe (base is Northwest-Europe); 0 otherwise.
**eastbloc**: dummy variable that takes the value of 1 if VoT for a country in Eastern-Europe (base is Northwest-Europe); 0 otherwise.
**comdum**: dummy variable that takes the value of 1 if VoT for commuting (base is ‘other’ purposes); 0 otherwise.
**busidum**: dummy variable that takes the value of 1 if VoT for business travel (base is ‘other’ purposes); 0 otherwise.
**brow**: interaction dummy variable that takes the value of 1 if VoT for business travel and for non-Europe; 0 otherwise.

From Table A1, we conclude the following:

- There is a large degree of variation in the value of time. The model is able to explain around 70% (the R square at the bottom of the table) of that variation, which is a reasonably good outcome for a model on 1,250 observations. The other 30% of the variation will depend on other attributes of the countries and the methods used in the individual studies, for which we have no variables to include in the model.
- Studies that estimate a model on RP data do not produce a significantly different VoT from resource-based (cost savings) studies. SP and combined SP-RP studies produce significantly lower VoTs for passenger transport. This has also been found for walk and wait time in the UK by Wardman (2004), but here we are studying in-vehicle-times or main-mode travel times. Or course it is hard to say whether the SP and SP-RP studies or the RP and resource-based studies give the correct VoTs. Some authors (e.g. Wardman) have argued that it’s likely that in the SP there is a lack of realism in terms of time constraints and presentation of cost and time values, that could lead to underestimation of the VoT.
- The VoTs for train are slightly higher than those for car driver; those for air travel are considerably higher and those for bus are somewhat lower and for car passenger somewhat higher. These are presumably mostly effects of different user groups for these modes (see the discussion on the effects of mode in section 5.

- Long distance travel has a significantly higher VoT. This was also found in the UK and Dutch national VoT studies (e.g. Gunn et al., 1996) and in Wardman's (2004) meta-analysis on UK sources. Please note that our model only includes a dummy variable for long distance travel. We do not have information from the underlying studies that would allow us to construct a continuous distance variable. The present dummy-variable indicates interurban travel (as opposed to urban). This dummy is not just picking up the fact that longer trips might relatively frequently be business trips: a business dummy is included in this model as well, and the long-distance dummy is also significant in the model for commuting and other that will be presented below (but not in the business model).
- GDP per capita influences the VoT positively, with an elasticity value of 0.62. This is one of the most significant variables (see the t-ratios) and also one of the most important variables in explaining the VoT (see the Beta coefficients). The other most important variables are the air dummy and the business dummy.
- The time dummies do not show a linear trend of the VoT over time, but rather relatively high values (after having corrected for other things such as the GDP increase) before the period 1995-1999 and after 1999. 1995-1999 was a period of fast growth in GDP per capita for most countries studied and apparently the VoT did not grow that fast in these years, but rather increased more steadily over time.
- The values of time from Southern-European studies for commuting and other are higher than in Northwest-Europe but for business travel the VoTs are practically the same. Please note that the *ceteris paribus* condition applies here: the commuting and other VoTs in Southern-Europe need not be higher than in Northwest-Europe, but when controlling for other effects, including differences in GDP per capita, we get a higher commuting and other VoT in Southern-Europe. This could be seen as a behavioural difference between nations, or as a correction on the income elasticity. For Eastern-Europe we also find higher values, especially for commuting and other travel. We interpret this as a sort of correction for the impact of GDP per capita, which by itself seems to lead to an 'overcorrection' of VoTs for Southern and Eastern-Europe. This also goes for the non-European countries (commuting, other), but here the business values are lower than for Northwest-Europe.
- The commuting values are slightly higher than for 'other' purposes, and the business values are higher than those for other by a very substantial amount.

One of the most important findings from these regression is the income elasticity of 0.62. In several countries the VoT for future years is calculated by using the change of the wage rate over time[1]. However, at least for non-work travel, there is no theoretical justification for assuming proportionality between the VoT and the wage rate (of GDP per capita). The VoT is a ratio of the marginal utility of time and the marginal utility of money. The latter is expected to decrease with income, the former might decrease with income as well. Both derivatives are also

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[1] In The Netherlands, the VoTs for commuting and other purposes for future years are corrected using the general price index and the one for business travel is adjusted using the wage rate increase (CPB/NEI, 2000).

influenced by many circumstantial factors. The net effect of income increases on the VoT will probably be positive (dominance of the denominator effect), but this need not be proportional (Hensher and Goodwin, 2004).

Recent empirical evidence also does not support the income proportionality assumption. In both the 1985 and the 1994/1995 UK national VoT survey, a monotonically increasing relationship between income and VoT was found, but is was not proportional. At the same income levels, the 1994/1995 VoTs were even lower than in 1985, but this is believed to be largely due to the longer distances studied in 1985 (in passenger transport, VoT clearly increases with distance). Based on the 1994/1995 data, income elasticities of the VoT were calculated from cross-sectional analysis (also taking into account other socioeconomic variables and travel conditions). For business travel the average income elasticity was 0.45, for commuting 0.65 and other travel 0.35 (Gunn et al., 1996). This income elasticity of around 0.5 is also supported by evidence from the transfer of the VoT in The Netherlands over 10 years (the VoT studies of 1988 and 1997) period (Gunn, 2000) and the meta-analysis of British VoTs in Wardman (2004), who found an (largely intertemporal) income elasticity of 0.72. It has been suggested (Gunn, 2001) that the cause for this less than proportional growth of the VoT with income over time may be the change that has occurred in the disutility of travel time and the productivity of travel time, mainly through the introduction of new technology that can be used while travelling (mobile phones, laptop computers, audio and video equipment). In our regression analyses we also find coefficients around 0.6 for GDP/capita in double-logarithmic models. Price elasticity studies do not show any sign of price elasticity declining over time in a way, which would be expected if VoTs increased with income (Hensher and Goodwin, 2004). The latter authors conclude by warning against using the proportionality assumption; it is overoptimistic on revenue and potentially underestimates the behavioural response.

The income elasticities of the VoT could be different for comparing countries at one point in time (cross-section elasticity) and for a single country over time (intertemporal or time-series elasticity). The GDP per capita elasticities in this note are of mixture of both: they are based on values for several countries and for several years. This is true both for the least squares regression models and the panel models that follow later in this note. However it can safely be assumed that the cross-sectional variation will be dominating in the estimation results, since that variation in the VoT between countries in the data set is much larger than within countries. By including dummy-variables for time periods, we have removed some of the time series element from the income elasticities, making them even more like cross-sectional elasticities (but please note that this didn’t make much difference: the income elasticities are practically the same in models with and without time period dummies). Consequently, the estimation results from our meta-analysis provide evidence for an income elasticity that might be used for a transfer of VoTs from one country to another for the year 2003 (and more generally a VoT equation that can be applied for all EU countries to get VoTs for 2003). Whether the estimation results from the meta-analysis can also be used for deciding on how future VoTs can be calculated from present VoTs depends on the agreement with *à priori* expectations (and other literature) on the intertemporal income elasticity of the VoT. These expectations are different for business and non-work travel and will be discussed below after having presented the estimation results for panel models (section 4).

For prediction (e.g. for countries without a VoT) we judged that separate models for business travel on the one hand and commuting and other purposes on the other hand would be better than one overall model with only a business travel dummy (and some interaction effects) to distinguish business travel from the rest. Therefore we estimated two separate models: one for travelling on employer's business and one for commuting and other purposes. The estimation results are reported in Tables A2 and A3.

**Table A2**. Least squares regression estimation results for passenger VTTS, travelling on employer's business; dependent variable: log of the VoT; n=436

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (constant) | -1.526 | .912 | | -1.674 | .095 |
| rpdummy | -.431 | .172 | -.104 | -2.509 | .012 |
| sprpdum | -.217 | .055 | -.195 | -3.908 | .000 |
| spdummy | -.400 | .062 | -.299 | -6.481 | .000 |
| traindum | -.063 | .069 | -.055 | -.911 | .363 |
| Airdum | .250 | .102 | .149 | 2.442 | .015 |
| Busdum | -.266 | .073 | -.209 | -3.652 | .000 |
| carpass | -.008 | .072 | -.007 | -.113 | .910 |
| longdisdum | .028 | .066 | .024 | .427 | .669 |
| lngdpcap | .485 | .091 | .438 | 5.353 | .000 |
| pre90 | .640 | .183 | .155 | 3.502 | .001 |
| yr9094 | -.126 | .078 | -.074 | -1.613 | .108 |
| yr0005 | .295 | .139 | .089 | 2.116 | .035 |
| seurope | -.048 | .070 | -.040 | -.690 | .491 |
| Row | -.362 | .155 | -.094 | -2.335 | .020 |
| eastbloc | .131 | .201 | .047 | .651 | .515 |

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .608(a) | .370 | .347 | .41939 |

Some observation from Table A2:

- The variation in business VoTs is relatively large and difficult to explain well.
- As before the SP and SP/RP dummies are negative and significant, but now also the RP dummy is significant: models on RP data also produce lower VoTs for business travel than the cost savings approach.
- The train and car passenger dummies are no longer significant, but the air dummy still is, as is the bus dummy. Please note that the air dummy is not so important within business travel than for all purposes (or for commuting and other, see next table).
- There no longer is a long distance effect.

- The pattern over time now has relatively high values before 1990 and after 1999, but the period 1990-1994 has a lower VoT than the period 1995-1999 (though not significant at the 95% confidence level).
- The GDP/capita elasticity of the business VoT is 0.49, somewhat lower than the overall elasticity of 0.62.
- Countries outside Europe have a lower business VoT. We tried dummies for various regions of Europe (e.g. East, South), but these were not significant for this travel purpose

**Table A3**. Least squares regression estimation results for passenger VTTS, commuting and other purposes; dependent variable: log of the VoT; n=814

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (constant) | -4.842 | .576 | | -8.407 | .000 |
| spdummy | -.286 | .049 | -.232 | -5.841 | .000 |
| sprpdum | -.320 | .059 | -.221 | -5.439 | .000 |
| traindum | .153 | .055 | .106 | 2.794 | .005 |
| airdum | .613 | .101 | .195 | 6.099 | .000 |
| busdum | -.162 | .054 | -.118 | -3.015 | .003 |
| carpass | .217 | .050 | .181 | 4.311 | .000 |
| longdisdum | .217 | .045 | .146 | 4.840 | .000 |
| pre90 | .123 | .130 | .025 | .944 | .345 |
| yr9094 | .148 | .049 | .090 | 3.019 | .003 |
| yr0005 | .224 | .057 | .111 | 3.944 | .000 |
| seurope | .386 | .050 | .260 | 7.776 | .000 |
| row | .245 | .060 | .120 | 4.097 | .000 |
| eastbloc | .691 | .143 | .223 | 4.841 | .000 |
| comdum | .161 | .033 | .132 | 4.861 | .000 |
| lngdpcap | .674 | .057 | .581 | 11.776 | .000 |

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .692(a) | .479 | .469 | .42586 |

The estimation results for commuting and other purposes in Table A3 are very similar in terms of sign, size and significance to those for all purposes in Table A1. We think that the long distance dummy for commuting and other is picking up a different mix of purposes within non-work travel (e.g. more holiday trips and less shopping and commuting trips for longer distances), together with an increasing disutility of long trips (travellers getting tired and/or bored).

The GDP/capita elasticity of the commuting and other VoT is 0.67, slightly higher than for all purposes (0.62) and the one for business (0.49). Countries outside Europe and countries in Southern and Eastern-Europe have higher commuting and other VoTs than in Northwest-Europe. The significant commuting dummy indicates a higher VoT for commuting than for other non-work purposes.

## 3.2 Freight transport

In Table A4 are estimation results for freight transport (road and rail VoTs). For freight we have considerably less observations than for passenger transport, which makes it harder to obtain significant coefficients.

**Table A4**. Least squares regression estimation results for freight VTTS, road and rail transport; dependent variable: log of the VoT; n=137

| | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (constant) | -3.458 | 1.895 | | -1.825 | .070 |
| lngdpcap | .392 | .191 | .176 | 2.054 | .042 |
| spdum | -.047 | .143 | -.038 | -.328 | .743 |
| roaddum | .856 | .151 | .457 | 5.682 | .000 |
| sprpdum | -.524 | .297 | -.159 | -1.765 | .080 |
| hgvdum | .043 | .146 | .023 | .294 | .769 |
| pre90 | -.497 | .328 | -.118 | -1.515 | .132 |
| yr90to94 | -.032 | .148 | -.023 | -.216 | .830 |
| yr2000 | .067 | .164 | .038 | .408 | .684 |
| seuropdu | .102 | .149 | .062 | .688 | .492 |
| rowdum | .095 | .156 | .054 | .608 | .544 |

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .555(a) | .308 | .253 | .53608 |

The variable names used are the same as for passenger transport, with the following freight-specific explanatory variables added:

**roaddum**: dummy variable that takes the value of 1 if VoT for road transport (base=rail); 0 otherwise.

**hgvdum**: dummy variable that takes the value of 1 if VoT for transport by HGV (base=LGV or combined LGV/HGV); 0 otherwise.

In Table A4 we see the following:

- The degree of explained variation for freight transport is relatively low, indicating a very large variation in the freight VoT that can only be partially explained by the explanatory variables.
- The GDP per capita elasticity of the freight VoT is 0.39.
- SP studies do not lead to significantly different values of time for freight than the costs savings approach (as opposed to passenger transport, where SP VoTs were significantly lower). For the (few) SP-RP study around, the estimated coefficient, which has a negative sign, is almost significant at the 95% confidence level.
- Road transport VoTs are higher than rail values. This is the most important coefficient in this model (even more important in terms of t-ratio and beta-coefficient than GDP per capita).

- There are no significant differences between time periods and between country groups (at least for this limited amount of observations).

We removed the clearly non-significant coefficients and estimated the freight transport model again. The estimation results are in Table A5. This gives a slightly lower R square, an income elasticity of 0.33, and values before 1990 that are lower than for 1995-1999 (significant at the 90% confidence level, not at 95%).

**Table A5**. Least squares regression estimation results for freight VTTS, road and rail transport; dependent variable: log of the VoT; n=137

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (constant) | -2.880 | 1.631 | | -1.766 | .080 |
| lngdpcap | .332 | .164 | .149 | 2.025 | .045 |
| roaddum | .890 | .139 | .475 | 6.407 | .000 |
| sprpdum | -.371 | .244 | -.112 | -1.519 | .131 |
| pre90 | -.549 | .310 | -.130 | -1.770 | .079 |

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .546(a) | .298 | .277 | .52760 |

We also estimated a model for road transport only (Table A6). There were not enough observations for a model for rail transport only. The road transport model has a low R-square (due to dropping the road dummy). Its income elasticity is 0.38 and SP/RP studies give a significantly lower VoT than resource-based (and SP) studies. This income elasticity of 0.38 and the one for road and rail of 0.33 are rather low, also compared to the passenger ones. The variation in freight transport costs or rates between countries will be smaller than that in the GDP/capita between the same countries (because the transport markets are relatively open, international and competitive markets). Therefore differences between countries in GDP per capita do not fully translate into differences in the VoT. These findings can be used for calculating the base-year freight VoT for countries without such values, but do not necessarily apply to future versus current VoTs.

**Table A6**. Least squares regression estimation results for freight VTTS, road transport only; dependent variable: log of the VoT; n=120

| | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (constant) | -2.443 | 1.810 | | -1.350 | .180 |
| lngdpcap | .378 | .182 | .185 | 2.081 | .040 |
| sprpdum | -.662 | .320 | -.182 | -2.064 | .041 |
| pre90 | -.548 | .321 | -.151 | -1.705 | .091 |

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .316(a) | .100 | .077 | .54615 |

## 4. Panel models

### 4.1 The model specification

Our data sets contain multiple observations for several countries (e.g. different studies for the same country or even different values for different purposes from the same study). One of the assumptions underlying the ordinary least squares regressions models presented above is that the different observations are not correlated. It is very likely however that observations from the same country will be correlated, and this will bias the estimation results.

We now use panel data models to take the correlation between observations from the same country into account and remove the bias. A panel is a data set with multiple respondents each of which are observed multiple times (e.g. a sample of persons is interviewed every year for five consecutive years). In our case, the 'respondents' are the different countries for which we have VoTs from several studies.

The general model is:

$$y_{it} = \mathbf{x}'_{it}\beta + u_{it} \qquad (1)$$

with y denoting VoTs, explanatory variables in **x**, coefficients to be estimated in β and error term u. The subscript i (i=1, 2, …, N) gives the countries and t the different observations (e.g. for different years) per country (t=1, 2, …, T). We have an unbalanced panel, meaning that the number of observations per country can differ between countries.

We can decompose the error term u into two components:

$$u_{it} = \mu_i + \varepsilon_{it} \qquad (2)$$

The first error component is country-specific (in a panel context this would be a cross-section-specific component), the latter is the usual identical and independently normally distributed error component (which it can be because of the presence of the first component that takes account of the correlation within a country).

Now there are two ways of estimating this panel model:

- The fixed effect model; which estimates a constant for every i (every country)
- The random effects model, which starts out by assuming a normal distribution for the first error component with a zero mean and a standard error to be estimated (one can also specify more complicated covariance structures).

We estimated both models by Maximum Likelihood in SAS. The fixed effects model gives as many extra coefficients as there are countries (30 for passengers, 18 for freight). In estimation many of these fixed effects are not significant. The random coefficients model is much more parsimonious and has one extra coefficient compared to ordinary least squares: the variance or the standard error of the country-specific effect. Below we only report the estimation results for the random effects panel models. We removed the country group dummies before estimating the panel models, because these deal with similar effects as the country-specific constants.

## 4.2 Results for passenger transport

The random effects model estimation results are in the Tables A7-A12. We estimated all models with and without time period dummies.

**Table A7**. Random effects panel model estimation results for passenger VTTS, all purposes; dependent variable: log of the VoT; n=1250

| | coefficient | t-ratio |
|---|---:|---:|
| (constant) | -.694 | -2.2 |
| rpdummy | .130 | 2.0 |
| sprpdum | -.246 | -6.0 |
| spdummy | -.245 | -5.9 |
| traindum | .117 | 2.6 |
| airdum | .420 | 5.8 |
| busdum | -.188 | -4.1 |
| carpass | .197 | 4.7 |
| longdisdum | .174 | 4.7 |
| lngdpcap | .434 | 16.5 |
| comdum | .185 | 5.5 |
| busidum | 1.089 | 31.8 |
| variance country | .198 | 25.0 |

**Table A8**. Random effects panel model estimation results for passenger VTTS, all purposes; dependent variable: log of the VoT; n=1250

| | coefficient | t-ratio |
|---|---|---|
| (constant) | -0.350 | -1.0 |
| Rpdummy | .102 | 1.6 |
| Sprpdum | -.253 | -6.1 |
| Spdummy | -.265 | -6.4 |
| Traindum | .099 | 2.2 |
| Airdum | .410 | 5.7 |
| Busdum | -.187 | -4.2 |
| Carpass | .186 | 4.4 |
| Longdisdum | .174 | 4.7 |
| Lngdpcap | .415 | 15.6 |
| Comdum | .176 | 5.2 |
| Busidum | 1.087 | 31.9 |
| pre90 | .074 | .7 |
| yr9094 | -.036 | -.9 |
| yr0005 | .211 | 3.9 |
| variance country | .196 | 25.0 |

Many of the estimated coefficients in Table A7 and A8 for all purposes are quite similar to those of Table A1 (OLS). The main differences are that the constant is no longer significant (the country-specific effect is correlated with the general intercept term), that the RP dummy is positive and significant now (higher VOTs from RP studies) and that the income elasticity has dropped from 0.62 to 0.43 (or 0.42 with time period dummies). We conclude that not properly accounting for the panel nature of the data has led to an overestimation of the income elasticity. The only significant time period dummy is for the most recent period (higher VoT than for 1995-1999). The estimate for the country-specific random effect is highly significant.

**Table A9**. Random effects panel model estimation results for passenger VTTS, business travel; dependent variable: log of the VoT; n=436

| | coefficient | t-ratio |
|---|---|---|
| (constant) | -2.265 | -4.1 |
| rpdummy | -.272 | -1.6 |
| sprpdum | -.201 | -3.8 |
| spdummy | -.374 | -6.3 |
| traindum | -.053 | -.7 |
| airdum | .200 | 1.9 |
| busdum | -.277 | -3.7 |
| carpass | .007 | .1 |
| longdisdum | .104 | 1.6 |
| lngdpcap | .467 | 10.2 |
| variance country | .182 | 14.8 |

**Table A10**. Random effects panel model estimation results for passenger VTTS, business travel; dependent variable: log of the VoT; n=436

| | coefficient | t-ratio |
|---|---:|---:|
| (constant) | -1.622 | -2.91 |
| rpdummy | -.422 | -2.4 |
| sprpdum | -.225 | -4.3 |
| spdummy | -.418 | -6.9 |
| traindum | -.053 | -.7 |
| airdum | .249 | 2.4 |
| busdum | -.263 | -3.6 |
| carpass | .004 | .1 |
| longdisdum | .040 | 0.6 |
| lngdpcap | .467 | 10.4 |
| pre90 | .642 | 3.6 |
| yr9094 | -.120 | -1.6 |
| yr0005 | .325 | 2.3 |
| variance country | .173 | 14.8 |

The estimated coefficients for business are all very similar to those of the least squares regression model, including the income elasticity, which was 0.49 and is 0.47 now. Here too, the estimate for the country-specific random effect is highly significant.

**Table A11**. Random effects panel model estimation results for passenger VTTS, commuting and other purposes; dependent variable: log of the VoT; n=814

| | Coefficient | t-ratio |
|---|---:|---:|
| (constant) | -1.536 | -4.2 |
| sprpdum | -.421 | -7.5 |
| spdummy | -.348 | -7.3 |
| traindum | .200 | 3.6 |
| airdum | 0.664 | 6.4 |
| busdum | -.149 | -2.7 |
| carpass | .285 | 5.6 |
| longdisdum | .241 | 5.2 |
| lngdpcap | .425 | 13.3 |
| comdum | .201 | 6.0 |
| variance country | .197 | 20.2 |

**Table A12**. Random effects panel model estimation results for passenger VTTS, commuting and other purposes; dependent variable: log of the VoT; n=814

| | Coefficient | t-ratio |
|---|---:|---:|
| (constant) | -1.249 | -3.1 |
| sprpdum | -.418 | -7.3 |
| spdummy | -.358 | -7.3 |
| traindum | .176 | 3.1 |
| airdum | .659 | 6.4 |
| busdum | -.148 | -2.7 |
| carpass | .269 | 5.2 |
| longdisdum | .237 | 5.1 |
| lngdpcap | .401 | 12.4 |
| comdum | .197 | 5.8 |
| pre90 | -.088 | -.7 |
| yr9094 | .002 | .05 |
| yr0005 | .196 | 3.4 |
| variance country | .194 | 20.2 |

Compared to the OLS model for commuting and other, the estimate for the constant has changed noticeably, and the income elasticity has decreased from 0.67 to 0.43 (or even to 0.40 with time period dummies). Whereas in the OLS estimation results business travel had a lower income elasticity than commuting and other, in the panel models (which are to be preferred) business has a slightly higher GDP elasticity of the VoT (0.47 versus 0.43). The time period dummy for the most recent period is significantly positive and the random effect is very significant. The positive time dummy indicates an increase in the VoTs after 1999 (compared to 1995-1999). This could be a sign of an upward trend that needs to be added to the GDP effect when applied to future years.

### 4.3 Results for freight transport

**Table A13**. Random effects panel model estimation results for freight VTTS, road and rail transport; dependent variable: log of the VoT; n=137

| | coefficient | t-ratio |
|---|---:|---:|
| (constant) | -2.663 | -1.6 |
| lngdpcap | .361 | 2.2 |
| roaddum | .876 | 6.4 |
| sprpdum | -.362 | -1.5 |
| variance country | .275 | 8.28 |

**Table A14**. Random effects panel model estimation results for freight VTTS, road and rail transport; dependent variable: log of the VoT; n=137

| | coefficient | t-ratio |
|---|---|---|
| (constant) | -2.933 | -1.7 |
| lngdpcap | .322 | 1.9 |
| roaddum | .866 | 6.1 |
| sprpdum | -.436 | -1.7 |
| Pre90 | -.570 | -1.9 |
| yr9094 | -.092 | -0.9 |
| yr0005 | .041 | 0.3 |
| variance country | .266 | 8.28 |

**Table A15**. Random effects panel model estimation results for freight VTTS, road transport only; dependent variable: log of the VoT; n=120

| | coefficient | t-ratio |
|---|---|---|
| (constant) | -3.669 | -2.1 |
| lngdpcap | .379 | 2.1 |
| sprpdum | -.665 | -2.1 |
| pre90 | -.548 | -1.7 |
| variance country | .288 | 7.75 |

The panel results for freight are quite similar to those from the OLS estimation. The income elasticity was 0.33 and is 0.36 now (0.33 with time period dummies). For road transport only it was 0.38 and still is (here only the pre-1990 time dummy was significant at 90%, the others were removed). The VoT studies before 1990 give significantly lower values. The country-specific random effect is clearly significant.

### 4.4 Discussion on income elasticities

Goods with an income elasticity between 0 and 1 are called ‘normal goods’ in micro-economics, and ‘luxuries’ if the income elasticity is greater than 1. For commuting and other purposes the relevant theoretical economic models allow for income elasticities (cross-sectional as well as intertemporal) that are smaller than one.  There is more cross-sectional evidence (e.g. several analyses on the national UK VoT study data of 1994; the Swiss national VoT study of 2003) to support income elasticities below 1.

For business travel there is the theory of the firm that implies an income (or rather marginal productivity of labour) elasticity of the VoT of 1. Hensher’s approach extends this theoretical model from the perspective of the employer to include the valuation of the traveller. As a result, the income elasticity can differ from 1. However it is unlikely that this value will be very different from 1, since the contribution of the employer to the total VoT in Hensher’s formula is substantial (more than half in the 1988 and 1997 national Dutch VoT surveys).

There is limited empirical evidence on intertemporal VoTs. Analysis of the changes between the two Dutch national VoT studies gave an income elasticity (all purposes) of about 0.5. The difference from 1 is explained by technological innovations that can be used while travelling (Gunn, 2001). It is difficult to say whether these constitute a once-and-for-all downward shift of the VoT or a structural trend that will continue in the future. The income elasticity from the meta-analysis for the UK by Wardman (2004) will also be mostly an intertemporal elasticity (one country studied for 1963-2000). The value (all purposes) he found was 0.72.

Weighting all the theoretical and empirical evidence, we recommend using a cross-sectional income elasticity of 0.5 for business, 0.65 for commuting and other, and 0.3-0.4 for freight for transfer to other countries (e.g. with missing VoTs) in the base year, and using an elasticity of 0.7 (all purposes, also for freight) for calculating future year VOTs from current VoTs.

Furthermore we recommend to perform sensitivity analyses for assumptions on evolution of the VoT over time.

5. The effect of mode of travel

The estimated coefficients for specific modes consists of two effects:

- the users of some mode may have different socio-economic characteristics than the users of another mode (e.g. car users on average have higher incomes than bus users). This is the **user type** effect.

- Travelling by some mode may be more productive or less unpleasant than travelling by some other mode (e.g. possibility to read things or use a laptop on a train). This is the **real mode-specific** effect.

Furthermore there could be other attributes of the modes involved in the second type of effect (e.g. one mode could be more reliable than another), and in an SP respondents could be trying to justify their actual choices (justification bias).

In most SP VoT studies these effects cannot be separated, because car users have been asked to choose between car alternatives and public transport users to choose between public transport alternatives. In four of the international studies included in this meta-analysis, users of some mode were not only asked to trade between choice alternatives for the mode actually used, but also for a mode not actually used for the trip studied:

- The Dutch national VoT study of 1989 (e.g. reported in Gunn and Rohr, 1996)
- The Swedish national VoT study (Algers et al. 1996)
- The Norwegian national VoT study (Ramjerdi et al, 1997)
- The Swiss national VoT study (Axhausen et al., 2003).

This does not provide enough observations to make the distinction between user type and real mode-specific effects in the meta-analysis, but we can draw on the above-mentioned literature to reach –tentative- conclusions on this.

In the first Dutch national VoT study (see Gunn and Rohr, 1996), apart from the main study, a number of additional analyses was carried out. One of these concerned the impact of user type versus mode on the value of time. The main outcomes are in Table A16.

**Table A16.** Values of time relative (% difference) to car driver values of car time, 1989 Dutch national VoT study

| | commuting | business | Other |
|---|---|---|---|
| Train in-vehicle-time valued | +32.7 | +20.4 | +1.7 |
| Train user | +14.2 | -2.7 | +1.2 |
| Rejected mode | +12.4 | +7.7 | +1.0 |

From this table we can calculate that a car driver's value of train time for commuting is 1.327x1.124=1.492 times higher than the car driver's value of car time. The train user's value of car time is 1.142x1.124=1.284 higher than the car driver's value of car time for commuting. Generally speaking train as a mode (first row) has a higher VoT than car. Also train users in most cases have higher values than car users (second row). User type is less important here than the mode-specific effect. Wardman (2004) remarked that this could change when bus and air users would be included. The higher values for the rejected mode (the mode not actually used) point at the presence of a self-selectivity effect.

Another additional SP analysis within the first Dutch national VoT study looked at urban travel, also including bus and tram. For bus and tram users, it was found that the user type effect dominates the mode effect.

In the national Swedish VoT study (Algers et al, 1996), all respondents except those using long distance trains, were presented two choice experiments, one with alternatives in terms of the actually chosen mode and one with alternatives referring to an alternative mode. The outcome was that the VoTs for the alternative mode are generally higher than for mode actually used. This was interpreted as a self-selection effect. The report stated that it was difficult to conclude that there was a real mode-specific effect.

In the Norwegian national VoT study (Ramjerdi et al., 1997), there were also two within-mode experiments per respondent, one for the chosen mode and one for an alternative mode. For car users, the car VoT and the public transport in-vehicle VoT were higher than for travellers who had actually used public transport. This was explained by the fact that car users have on average a higher income than users of other modes (user type effect).

In the Swiss national VOT study (Axhausen et al, 2003), there were three SP experiments for car drivers:

- Mode choice
- Route choice for car
- Route choice for public transport.

Car route choice for public transport users and destination choice had been discarded after the pre-tests. However, we have not seen model estimation results that distinguish between user type effects and real mode-specific effects.

In his meta-analysis of the VoT from UK studies, Wardman (2004) was able to separate the user type and the real mode-specific effect (a large number of his sources consisted of SP experiments for actually used as well as alternative modes). He found that air travellers and combined air and rail travellers have the highest VoTs (after having included a distance effect and journey purpose effects), presumably because the business travellers in these categories are more senior and the leisure travellers have relatively high incomes. Within the other modes, rail users have the highest values (especially in the UK these are travellers with relatively high incomes). Car users have much higher values than bus users (again an income effect). For car users, rail (in-vehicle) and car time are valued similarly, and bus is regarded as somewhat inferior to train and car travel.

Evidence of the real mode-specific effect is also provided in Mackie et al. (2003), who report that the VoT for rail is smaller than the VoT for car, which is smaller than the VoT for bus for persons that actually use the car.

Our tentative conclusion is that when air, train, bus and car are studied, the user type effects are probably stronger than the real mode-specific effects. Bus users have the lowest value of time and air travellers the highest, mainly because of differences between the users of these modes. But for car users, time in the car and on the train has a lower mode-specific cost than time on the bus.

## 6. Application of the estimated models

One of the reasons for estimating the meta-models is the application of the equations found to all countries of the EU and Switzerland, to obtain VoTs by purpose (the benefit-transfer procedure). For countries with proper VoTs, this is for comparison between the values form the meta-analysis and the national values. For countries without VoTs or that are lacking the minimally required segmentation, the values from the meta-analysis can be the basis for our recommendations. Before applying the models to the countries, we re-estimated the random effects panel models, removing the coefficients that were clearly insignificant. This gives the following three models, which have been used in application.

**Table A17**. Random effects panel model estimation results for passenger VTTS, business travel, as used in application; dependent variable: log of the VoT; n=436

| | Coefficient | t-ratio |
|---|---:|---:|
| (constant) | -1.75 | 3.19 |
| rpdummy | -0.47 | 2.85 |
| sprpdum | -0.22 | 4.68 |
| spdummy | -0.40 | 6.63 |
| airdum | 0.32 | 4.77 |
| busdum | -0.22 | 4.30 |
| lngdpcap | 0.47 | 10.58 |
| pre90 | 0.71 | 4.29 |
| yr0005 | 0.31 | 2.32 |
| row | -0.33 | 2.21 |
| variance country | 0.17 | 14.76 |

**Table A18**. Random effects panel model estimation results for passenger VTTS, commuting and other purposes, as used in application; dependent variable: log of the VoT; n=814

| | coefficient | t-ratio |
|---|---:|---:|
| (constant) | -3.25 | 6.88 |
| sprpdum | -0.40 | 7.10 |
| spdummy | -0.31 | 6.37 |
| airdum | 0.40 | 4.39 |
| busdum | -0.33 | 8.57 |
| longdistdum | 0.25 | 5.65 |
| lngdpcap | 0.65 | 11.74 |
| comdum | 0.16 | 4.65 |
| row | 0.24 | 4.06 |
| seurope | 0.34 | 7.18 |
| eastbloc | 0.59 | 4.30 |
| yr0005 | 0.22 | 3.92 |
| variance country | 0.19 | 20.17 |

**Table A19**. Random effects panel model estimation results for freight VTTS, road and rail transport, as used in application; dependent variable: log of the VoT; n=137

| | Coefficient | t-ratio |
|---|---:|---:|
| (constant) | -2.93 | 1.8 |
| lngdpcap | 0.33 | 2.1 |
| roaddum | 0.89 | 6.5 |
| sprpdum | -0.37 | 1.6 |
| pre90 | -0.55 | 1.8 |
| variance country | 0.27 | 8.3 |

The application refers to the year 2003. In application, we used the GDP per capita (for 2003) of each country. The dummies for methods, period before 1990 and the variance of the country were set to 0. The role of these variables is to get the coefficients for the other variables in the model right. The dummy for the period 2000-2005 was put on. For Cyprus, France, Greece, Italy, Malta, Portugal and Spain, the dummy for Southern Europe is used, whereas the dummy for Eastern Europe is invoked for the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. Dummies for mode, purpose and distance were put on or off depending on the VTTS sought. This gives the following values for the 25 EU countries plus Switzerland for 2003.

**Table A20**. VTTS for 25 EU countries and Switzerland in 2003 (2003 Euro per Hour): business travel

| | **Business** | | |
|---|---|---|---|
| **Country** | **Air** | **Bus** | **Other modes (car, train)** |
| Austria | 39.30 | 22.90 | 28.54 |
| Belgium | 38.00 | 22.15 | 27.59 |
| Cyprus | 29.20 | 17.01 | 21.20 |
| Czech Republic | 20.24 | 11.79 | 14.70 |
| Denmark | 43.64 | 25.43 | 31.69 |
| Estonia | 18.44 | 10.75 | 13.39 |
| Finland | 39.31 | 22.91 | 28.54 |
| France | 38.14 | 22.23 | 27.70 |
| Germany | 38.26 | 22.29 | 27.78 |
| Greece | 27.64 | 16.11 | 20.07 |
| Hungary | 18.91 | 11.02 | 13.73 |
| Ireland | 42.03 | 24.49 | 30.52 |
| Italy | 35.14 | 20.48 | 25.52 |
| Latvia | 17.09 | 9.96 | 12.41 |
| Lithuania | 17.07 | 9.94 | 12.39 |
| Luxembourg | 53.17 | 30.98 | 38.61 |
| Malta | 25.22 | 14.70 | 18.31 |
| Netherlands | 38.34 | 22.34 | 27.84 |
| Poland | 18.07 | 10.53 | 13.12 |
| Portugal | 26.28 | 15.31 | 19.08 |
| Slovakia | 17.35 | 10.11 | 12.60 |
| Slovenia | 26.41 | 15.39 | 19.18 |
| Spain | 31.07 | 18.11 | 22.56 |
| Sweden | 42.07 | 24.52 | 30.55 |
| UK | 40.45 | 23.57 | 29.37 |
| **EU Average** | **33.05** | **19.26** | **24.00** |
| Switzerland | 45.95 | 26.78 | 33.36 |

**Table A21**. VTTS for 25 EU countries and Switzerland in 2003 (2003 Euro per hour): Short Distance Commute Travel

| **Country** | **Air** | **Bus** | **Other modes (car, train)** |
|---|---|---|---|
| Austria | 14.68 | 7.08 | 9.84 |
| Belgium | 14.02 | 6.75 | 9.40 |
| Cyprus | 13.68 | 6.59 | 9.17 |
| Czech Republic | 10.58 | 5.10 | 7.09 |
| Denmark | 16.97 | 8.18 | 11.38 |
| Estonia | 9.30 | 4.48 | 6.24 |
| Finland | 14.69 | 7.08 | 9.85 |
| France | 19.80 | 9.54 | 13.27 |
| Germany | 14.15 | 6.82 | 9.48 |
| Greece | 12.68 | 6.11 | 8.50 |
| Hungary | 9.63 | 4.64 | 6.46 |
| Ireland | 16.11 | 7.76 | 10.80 |
| Italy | 17.68 | 8.52 | 11.85 |
| Latvia | 8.37 | 4.03 | 5.61 |
| Lithuania | 8.36 | 4.03 | 5.60 |
| Luxembourg | 22.30 | 10.79 | 14.95 |
| Malta | 11.17 | 5.38 | 7.49 |
| Netherlands | 14.19 | 6.84 | 9.51 |
| Poland | 9.04 | 4.36 | 6.06 |
| Portugal | 11.82 | 5.70 | 7.93 |
| Slovakia | 8.55 | 4.12 | 5.73 |
| Slovenia | 15.29 | 7.37 | 10.25 |
| Spain | 14.91 | 7.18 | 9.99 |
| Sweden | 16.14 | 7.78 | 10.82 |
| UK | 15.28 | 7.36 | 10.24 |
| **EU Average** | **15.35** | **7.40** | **10.29** |
| Switzerland | 18.23 | 8.78 | 12.22 |

**Table A22**. VTTS for 25 EU countries and Switzerland in 2003 (2003 Euro per hour): Long Distance Commute Travel

| | **Other-Long Distance** | | |
|---|---|---|---|
| **Country** | **Air** | **Bus** | **Other modes (car, train)** |
| Austria | 18.86 | 9.09 | 12.64 |
| Belgium | 18.00 | 8.67 | 12.06 |
| Cyprus | 17.56 | 8.46 | 11.77 |
| Czech Republic | 13.58 | 6.55 | 9.11 |
| Denmark | 21.79 | 10.50 | 14.61 |
| Estonia | 11.95 | 5.76 | 8.01 |
| Finland | 18.86 | 9.09 | 12.64 |
| France | 25.42 | 12.25 | 17.04 |
| Germany | 18.67 | 8.75 | 12.18 |
| Greece | 16.28 | 7.85 | 10.91 |
| Hungary | 12.37 | 5.96 | 8.29 |
| Ireland | 20.69 | 9.97 | 13.87 |
| Italy | 22.70 | 10.94 | 15.21 |
| Latvia | 10.75 | 5.18 | 7.21 |
| Lithuania | 10.73 | 5.17 | 7.19 |
| Luxembourg | 28.64 | 13.80 | 19.20 |
| Malta | 14.34 | 6.91 | 9.61 |
| Netherlands | 18.22 | 8.78 | 12.21 |
| Poland | 11.61 | 5.60 | 7.78 |
| Portugal | 15.18 | 7.32 | 10.18 |
| Slovakia | 10.98 | 5.29 | 7.36 |
| Slovenia | 19.63 | 9.46 | 13.16 |
| Spain | 19.14 | 9.23 | 12.83 |
| Sweden | 20.72 | 9.99 | 13.89 |
| UK | 19.62 | 9.45 | 13.15 |
| **EU Average** | **19.61** | **9.50** | **13.21** |
| Switzerland | 23.40 | 11.28 | 15.69 |

**Table A23**. VTTS for 25 EU countries and Switzerland in 2003 (2003 Euro per hour): Other-short distance travel

| | **Other-Short Distance** | | |
|---|---|---|---|
| **Country** | **Air** | **Bus** | **Other modes (car, train)** |
| Austria | 12.31 | 5.93 | 8.25 |
| Belgium | 11.75 | 5.66 | 7.88 |
| Cyprus | 11.47 | 5.53 | 7.69 |
| Czech Republic | 8.87 | 4.27 | 5.95 |
| Denmark | 14.23 | 6.86 | 9.54 |
| Estonia | 7.80 | 3.76 | 5.23 |
| Finland | 12.32 | 5.93 | 8.26 |
| France | 16.60 | 8.0 | 11.13 |
| Germany | 11.86 | 5.72 | 7.95 |
| Greece | 10.63 | 5.12 | 7.13 |
| Hungary | 8.07 | 3.89 | 5.41 |
| Ireland | 13.51 | 6.51 | 9.06 |
| Italy | 14.82 | 7.14 | 9.93 |
| Latvia | 7.02 | 3.38 | 4.71 |
| Lithuania | 7.01 | 3.38 | 4.70 |
| Luxembourg | 18.70 | 9.01 | 12.54 |
| Malta | 9.37 | 4.51 | 6.28 |
| Netherlands | 11.90 | 5.73 | 7.98 |
| Poland | 7.58 | 3.65 | 5.08 |
| Portugal | 9.91 | 4.78 | 6.65 |
| Slovakia | 7.17 | 3.46 | 4.81 |
| Slovenia | 12.82 | 6.18 | 8.59 |
| Spain | 12.50 | 6.02 | 8.38 |
| Sweden | 13.53 | 6.52 | 9.07 |
| UK | 12.81 | 6.17 | 8.59 |
| **EU Average** | **12.87** | **6.20** | **8.63** |
| Switzerland | 15.28 | 7.36 | 10.24 |

**Table A24**. VTTS for 25 EU countries and Switzerland in 2003 (2003 Euro per hour): Other-long distance travel

| | **Other Long Distance** | | |
|---|---|---|---|
| **Country** | **Air** | **Bus** | **Other modes (car, train)** |
| Austria | 15.81 | 7.62 | 10.60 |
| Belgium | 15.09 | 7.27 | 10.12 |
| Cyprus | 14.73 | 7.10 | 9.87 |
| Czech Republic | 11.39 | 5.49 | 7.63 |
| Denmark | 18.27 | 8.81 | 12.25 |
| Estonia | 10.02 | 4.83 | 6.71 |
| Finland | 15.81 | 7.62 | 10.60 |
| France | 21.31 | 10.27 | 14.29 |
| Germany | 15.23 | 7.34 | 10.21 |
| Greece | 13.65 | 6.58 | 9.15 |
| Hungary | 10.37 | 5.00 | 6.95 |
| Ireland | 17.35 | 8.36 | 11.63 |
| Italy | 19.03 | 9.17 | 12.76 |
| Latvia | 9.01 | 4.34 | 6.04 |
| Lithuania | 9.00 | 4.34 | 6.03 |
| Luxembourg | 24.01 | 11.57 | 16.10 |
| Malta | 12.03 | 5.80 | 8.06 |
| Netherlands | 15.28 | 7.36 | 10.24 |
| Poland | 9.74 | 4.69 | 6.53 |
| Portugal | 12.73 | 6.13 | 8.53 |
| Slovakia | 9.21 | 4.44 | 6.17 |
| Slovenia | 16.46 | 7.93 | 11.03 |
| Spain | 16.05 | 7.73 | 10.76 |
| Sweden | 17.37 | 8.37 | 11.65 |
| UK | 16.45 | 7.93 | 11.03 |
| **EU Average** | **16.53** | **7.96** | **11.08** |
| Switzerland | 19.62 | 9.46 | 13.15 |

**Table A25**. VTTS for 25 EU countries and Switzerland in 2003 (2003 Euro per tonne per hour): Freight

| | **Freight** | |
|---|---|---|
| **Country** | **Road** | **Rail** |
| Austria | 3.39 | 1.39 |
| Belgium | 3.31 | 1.36 |
| Cyprus | 2.75 | 1.13 |
| Czech Republic | 2.12 | 0.87 |
| Denmark | 3.65 | 1.50 |
| Estonia | 1.98 | 0.81 |
| Finland | 3.39 | 1.39 |
| France | 3.32 | 1.36 |
| Germany | 3.33 | 1.37 |
| Greece | 2.64 | 1.09 |
| Hungary | 2.02 | 0.83 |
| Ireland | 3.56 | 1.46 |
| Italy | 3.13 | 1.29 |
| Latvia | 1.88 | 0.77 |
| Lithuania | 1.88 | 0.77 |
| Luxembourg | 4.20 | 1.73 |
| Malta | 2.48 | 1.02 |
| Netherlands | 3.33 | 1.37 |
| Poland | 1.96 | 0.80 |
| Portugal | 2.55 | 1.05 |
| Slovakia | 1.90 | 0.78 |
| Slovenia | 2.56 | 1.05 |
| Spain | 2.87 | 1.18 |
| Sweden | 3.56 | 1.46 |
| UK | 3.46 | 1.42 |
| **EU Average** | **3.00** | **1.23** |
| Switzerland | 3.79 | 1.56 |

For a number of these countries HEATCO has obtained the national values. In Table A26 these are compared to the values from the HEATCO meta-analysis for car driver, and in Table A27 for HGV. The variation between the national values for work time is quite large, even within Western Europe (ranging from 12.5 Euros per hour for France to 43.80 Euros for the UK. These national values for business travel are mostly based on direct proportionality with income. The meta-model for business, which has an income elasticity of 0.47, produces values for the different countries that are closer together (smaller spread). So for countries with a relatively high business VTTS we get a ratio of the meta-model value to the national value below one (e.g. UK) and for countries with a relatively low national business VTTS we obtain a ratio above one (e.g. France). Additionally, the meta-analysis model has been applied to estimate values as derived from the cost saving approach to valuing business time. This gives higher values of time than SP or joint SP-RP methods as used in the Netherlands and Sweden.

For non-work (this refers to short-distance commuting in the meta-model), the meta-model values are mostly higher than the national values, with the exception of France and Switzerland. This indicates that in the data base used for the meta-model, we had many values of time that were high relative to the ones for the countries for which HEATCO found national values. Amongst the reasons for this are that the meta-analysis identified that values of time surveyed between 2000-2005 are higher, all other things being equal, than those surveyed in the 1990s. The meta-analysis model values presented above have been calculated for 2002, whilst all the national value of time studies (except Switzerland's) were undertaken in the 1990s. The meta-analysis model also clearly identifies that countries in the southern and eastern regions of the EU have higher values of time, all else being equal, compared to countries in the north and west of the EU. This is reflected in the meta-analysis model forecasts. However, values of time used for appraisal in these countries have typically been derived by transferring a relationship from a national VTTS study associated with countries in the north and west of Europe with an adjustment for national income.

**Table A26.** Car Trip Values of Time for 2003 (in prices and GDP)

| | Currency | Numeraire | Price Base | Unit | National Work | National Non Work | Overall Factor | National Work in Euros | National Non-work in Euros | Meta-model Forecasts<br>Work[3] | Meta-model Forecasts<br>Non work[3] | VTTS Values relate to |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Denmark | DKK | Market | 2001 | Person-hr | 252 | 56 | 0.146 | 36.87 | 8.194 | 31.69<br>*0.86* | 11.38<br>*1.39* | Average road vehicle, non work=commute |
| Finland | Euro | factor | 2000 | Person-hr | 24.08 | 4.07 | 1.450 | 34.91 | 5.901 | 28.54<br>*0.82* | 9.85<br>*1.67* | |
| France | Euro | Market | 2000 | Person-hr | 11.1 | 10 | 1.128 | 12.52 | 11.284 | 27.70<br>*2.21* | 13.27<br>*1.18* | All modes urban only, Non-work=commute |
| Germany | Euro | Factor | 1998 | Person-hr | 27.92 | 3.83 | 1.317 | 36.78 | 5.046 | 27.78<br>*0.76* | 9.48<br>*1.88* | |
| Ireland | Euro | Market | 2002 | Person-hr | 26.5 | 8.1 | 1.126 | 29.85 | 9.123 | 30.52<br>*1.02* | 10.80<br>*1.18* | Non-work=commute |
| Netherlands | NLG | Market | 1997 | Person-hr | 48.4 | 14.4 | 0.623 | 30.16 | 8.973 | 27.84<br>*0.92* | 9.51<br>*1.06* | Non-work=commute |
| Sweden | SEK | Market | 2001 | Person-hr | 238 | 42 | 0.120 | 28.66 | 5.057 | 30.55<br>*1.07* | 10.82<br>*2.14* | Values are for all income grps, non-work=commute |
| UK | GBP | Market | 2002 | Person-hr | 26.43 | 5.04 | 1.657 | 43.80 | 8.352 | 29.37<br>*0.67* | 10.24<br>*1.23* | Work value=drivers of cars, non-work=commute |
| Latvia | LVL | Market | 2002 | Veh-hr | 2.98 | 0.45 | 1.867 | 5.56 | 0.840 | 12.41<br>(6.21)[1]<br>*1.12* | 5.61<br>(2.81)[1]<br>*3.35* | Average road vehicle, work trips=biz/managers, non-work=commuting |
| Malta | Euro | Market | 2004 | Veh-hr | 11.89 | 3.48 | 0.958 | 11.39 | 3.334 | 18.31<br>(10.46)[2]<br>*0.92* | 7.49<br>(4.28)[2]<br>*1.28* | |
| Switzerland | CHF | Market | 2003 | Person-hr | 32.5 | 21.36 | 0.682 | 22.17 | 14.57 | 33.36<br>*1.50* | 12.22<br>*0.84* | Average road vehicle, non-work=commute |

Notes: [1] assumed a car occupancy of 2; [2] assumed a car occupancy of 1.75;[3] ratio of meta-model to national 2003 values.

**Table A27**. Comparison of Freight Values Per Tonne Per Hour (2003 Prices & GDP)

| Country | Currency | Numeraire | Price Base | Unit | National HGV (>3.5 t) | Overall Factor | National HGV in Euros | National HGV in Euros per tonne | Meta-model Fore-casts[1] | VTTS Values Relate to |
|---|---|---|---|---|---|---|---|---|---|---|
| Austria | Euro | Market | 1995 | Vehicle-hr | 21.08 | 1.596 | 33.64 | 2.80 | 3.39<br>(1.21) | Road: HGV>3.5t |
| Belgium | BEF | Market | 1996 | Person-hr | 900 | 0.039 | 35.26 | 2.94 | 3.31<br>(1.13) | Road: "Heavy vehicles" (Walloon) |
| Denmark | DKK | Market | 2001 | Vehicle-hr | 156 | 0.146 | 22.82 | 1.90 | 3.65<br>(1.92) | Road: Truck (3.5+t) |
| Finland | Euro | Market | 2000 | Person-hr | 17.31 | 1.522 | 26.34 | 2.19 | 3.39<br>(1.55) | HGV |
| France | Euro | Market | 2000 | Vehicle-hr | 31.4 | 1.128 | 35.43 | 2.95 | 3.32<br>(1.13) | Road: Driver VOT |
| Germany | Euro | Market | 1998 | Vehicle-hr | 22.76 | 1.342 | 30.55 | 2.55 | 3.33<br>(1.31) | Road: HGV>3.5t |
| Ireland | Euro | Market | 2002 | Person-hr | 26.5 | 1.126 | 29.85 | 2.49 | 3.56<br>(1.43) | Working time value |
| Netherlands | Euro | Market | 2002 | Vehicle-hr | 38 | 1.301 | 49.44 | 4.12 | 3.33<br>(0.81) | |
| Switzerland | CHF | Market | 1998 | Vehicle-hr | 100 | 0.714 | 71.42 | 5.95 | 3.79<br>(0.64) | Average Road freight |
| UK | GBP | Market | 2002 | Person-hr | 10.18 | 1.657 | 16.87 | 1.41 | 3.46<br>(2.45) | OGV |
| Czech Republic | CZK | Market | 2003 | Vehicle-hr | 113 | 0.038 | 4.35 | 0.36 | 2.12<br>(5.89) | Road |
| Hungary | HUF | Market | 2005 | Vehicle-hr | 6847 | 0.004 | 27.66 | 2.31 | 2.02<br>(0.87) | Road: Heavy vehicle |
| Latvia | LVL | Market | 2002 | Vehicle-hr | 5.71 | 1.867 | 10.66 | 0.89 | 1.88<br>(2.11) | Truck >16.0t |
| Lithuania | LTL | Market | 2003 | Vehicle-hr | 22.7 | 0.289 | 6.56 | 0.55 | 1.88<br>(3.42) | HGV |
| Malta | Euro | Market | 2004 | Vehicle-hr | 4.25 | 0.973 | 4.14 | 0.34 | 2.48<br>(7.3) | OGV (>3.5t GVW) |
| Portugal | Euro | Market | 2004 | Vehicle-hr | 8.7 | 0.950 | 8.26 | 0.69 | 1.96<br>(2.8) | OGV (>3.5t GVW) |
| Spain | ESP | Market | 1992 | Vehicle-hr | 2500 | 0.012 | 30.74 | 2.56 | 2.87<br>(1.12) | HGV |

Notes: [1]Ratio of meta-model to national 2003 values

For HGVs we find a similar pattern as for commuting. Most national values (per tonne per hour) are lower than the meta-model values, except the ones for The Netherlands, Switzerland and Hungary. The data base used in estimating the meta-model predominantly contains VoTs that are higher than the national values for the countries in Table A27.

In Tables A28-A31, a number of sense-checks on the VoTs from the meta-analysis are carried out. The ratios of commuting to business VoT is around 0.4 for short distance and 0.5 for long distance, which is in line with our expectations. The ratio of the other VoT to the commute VoT is 0.84, which also seems plausible. The interurban (long distance) VoT is 1.28 times the urban (short distance) VoT, which is a rather small difference, but still quite acceptable. The bus VoTs are slightly lower than the car driver and train VoTs. The VoT for air transport can be up to 1.5 times the car driver VoT. As discussed in section 5, these will mostly be the effect of different user types that have not fully been represented by other variables in the model.

**Table A28.** Ratio of Commute to Business (EU Average)

| **Short Distance** | | |
|---|---|---|
| ***Air*** | ***Bus*** | ***Car driver, car passenger, train*** |
| - | 0.38 | 0.43 |
| **Long Distance** | | |
| ***Air*** | ***Bus*** | ***Car driver, car passenger, train*** |
| - | 0.49 | 0.55 |

**Table A29**. Ratio of Other to Commute (EU Average)

| **Short Distance** | | |
|---|---|---|
| ***Air*** | ***Bus*** | ***Car driver, car passenger*** |
| 0.84 | 0.84 | 0.84 |
| **Long Distance** | | |
| ***Air*** | ***Bus*** | ***Car driver, car passenger*** |
| 0.84 | 0.84 | 0.84 |

**Table A30**. Ratio of Long to Short Distance – Other Non-Work

| ***Air*** | ***Bus*** | ***Car driver, car passenger*** |
|---|---|---|
| 1.28 | 1.28 | 1.28 |

**Table A31**. Ratio of Modes vs Car

| | | |
|---|---|---|
| **Business** | | |
| ***Air*** | ***Bus*** | ***Train*** |
| 1.38 | 0.80 | 1.00 |
| **Commute Short Distance** | | |
| ***Air*** | ***Bus*** | ***Train*** |
| 1.49 | 0.72 | 1.00 |
| **Commute Long Distance** | | |
| ***Air*** | ***Bus*** | ***Train*** |
| 1.49 | 0.72 | 1.00 |
| **Other Short Distance** | | |
| ***Air*** | ***Bus*** | ***Train*** |
| 1.49 | 0.72 | 1.00 |
| **Other Long Distance** | | |
| ***Air*** | ***Bus*** | ***Train*** |
| 1.49 | 0.72 | 1.00 |
| | | |

## 7. Summary and conclusions

In the HEATCO meta-analysis we have estimated regression equations on almost 1,300 values of time from studies around the world, mostly studies conducted after 1990. We also estimated models on more than 130 values of time for freight transport. For both passenger and freight transport, we estimated double logarithmic models with ordinary least squares, but also models that account for the fact that we have repeated observations for the same country (fixed effects and random effects panel models). The estimation results lead to the following general conclusions:

- We find a (largely cross-sectional) income elasticity of the VoT of about 0.5 for business travel, 0.7 for other passenger transport and 0.3 for freight.
- Long distances lead to higher VTTS for commuting and other purposes. SP and SP-RP studies give somewhat lower passenger VoTs than the cost savings approach. We found no significant effect of study method (SP) for freight transport.
- We find significant effects for purpose (business, commuting) and mode (especially for air; less so for bus relative to car and train).
- We obtain higher values of time in Southern and Eastern European countries, all other things (including GDP/capita) being equal.

Furthermore, the estimation results have been applied to each of the 25 EU countries to get VTTS by purpose, either for comparison against existing national values, or as a basis for our recommendations for countries with missing VTTS.

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## Appendix I. Distribution of values of time in the passenger transport data base over countries

| | Number of Values | Percent |
|---|---:|---:|
| Australia | 10 | .8 |
| Austria | 48 | 3.7 |
| Belarus | 1 | .1 |
| Belgium | 45 | 3.5 |
| Chili | 2 | .2 |
| Denmark | 72 | 5.5 |
| Estonia | 21 | 1.6 |
| Finland | 59 | 4.5 |
| France | 78 | 6.0 |
| Germany | 54 | 4.2 |
| Greece | 46 | 3.5 |
| Hungary | 21 | 1.6 |
| Ireland | 50 | 3.8 |
| Israel | 9 | .7 |
| Italy | 46 | 3.5 |
| Japan | 4 | .3 |
| Korea | 3 | .2 |
| Luxembourg | 23 | 1.8 |
| Moldova | 2 | .2 |
| Netherlands | 84 | 6.5 |
| New Zealand | 10 | .8 |
| Norway | 60 | 4.6 |
| Portugal | 48 | 3.7 |
| Russia | 2 | .2 |
| Spain | 46 | 3.5 |
| Sweden | 128 | 9.9 |
| Switzerland | 69 | 5.3 |
| UK | 201 | 15.5 |
| Ukraine | 1 | .1 |
| US | 56 | 4.3 |
| Total | 1299 | 100.0 |

## Appendix II. Distribution of values of time in the freight transport data base over countries

| | Number of Values | Percent |
|---|---|---|
| Austria | 3 | 2.2 |
| Belgium | 3 | 2.2 |
| Denmark | 5 | 3.6 |
| Finland | 6 | 4.3 |
| France | 11 | 7.9 |
| Germany | 6 | 4.3 |
| Greece | 3 | 2.2 |
| Ireland | 3 | 2.2 |
| Israel | 3 | 2.2 |
| Italy | 3 | 2.2 |
| Netherlands | 17 | 12.2 |
| New Zealand | 3 | 2.2 |
| Norway | 3 | 2.2 |
| Portugal | 3 | 2.2 |
| Spain | 3 | 2.2 |
| Sweden | 28 | 20.1 |
| UK | 21 | 15.1 |
| US | 15 | 10.8 |
| Total | 139 | 100.0 |

## Appendix III Classification of Countries Used in Forecasts into Country Groups

| Country | Country Group |
|---|---|
| Austria | N Europe |
| Belgium | N Europe |
| Cyprus | S Europe |
| Czech Republic | Eastern Bloc |
| Denmark | N Europe |
| Estonia | Eastern Bloc |
| Finland | N Europe |
| France | S Europe |
| Germany | N Europe |
| Greece | S Europe |
| Hungary | Eastern Bloc |
| Ireland | N Europe |
| Italy | S Europe |
| Latvia | Eastern Bloc |
| Lithuania | Eastern Bloc |
| Luxembourg | N Europe |
| Malta | S Europe |
| Netherlands | N Europe |
| Poland | Eastern Bloc |
| Portugal | S Europe |
| Slovakia | Eastern Bloc |
| Slovenia | Eastern Bloc |
| Spain | S Europe |
| Sweden | N Europe |
| UK | N Europe |
| EU Average | Na |
| Switzerland | N Europe |

## Appendix IV GDP/capita Countries Used in Forecasts (2003 Euros & Prices)

| Country | Euros |
|---|---:|
| Austria | 22,926 |
| Belgium | 21,342 |
| Cyprus | 12,181 |
| Czech Republic | 5,585 |
| Denmark | 28,649 |
| Estonia | 4,583 |
| Finland | 22,934 |
| France | 21,512 |
| Germany | 21,649 |
| Greece | 10,839 |
| Hungary | 4,833 |
| Ireland | 26,443 |
| Italy | 18,072 |
| Latvia | 3,897 |
| Lithuania | 3,886 |
| Luxembourg | 43,611 |
| Malta | 8,920 |
| Netherlands | 21,748 |
| Poland | 4,387 |
| Portugal | 9,736 |
| Slovakia | 4,027 |
| Slovenia | 9,842 |
| Spain | 13,908 |
| Sweden | 26,505 |
| UK | 24,370 |
| EU Average | 15,855 |
| Switzerland | 31,965 |

## APPENDIX V – COMPARISON OF COUNTRY APPRAISAL VALUES AND META-ANALYSIS VALUES (2002 EUROS, FACTOR PRICES)

**Table A-V-1: Comparison of country appraisal values and meta-analysis values (Car, business, 2002 euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 23.82 | 23.82 |
| | | | | |
| Austria | 10.74 | 10.74 | 28.40 | 28.40 |
| Belgium | | | 27.44 | 27.44 |
| Denmark | 26.50 | 26.50 | 31.54 | 31.54 |
| Finland | 26.64 | 27.06 | 28.15 | 28.15 |
| France | 10.21 | 12.60 | 27.70 | 27.70 |
| Germany | 22.17 | 22.17 | 27.86 | 27.86 |
| Ireland | 21.07 | 21.07 | 29.87 | 29.87 |
| Luxembourg | | | 38.02 | 38.02 |
| Netherlands | 8.41 | 35.37 | 28.00 | 28.00 |
| Sweden | 21.02 | 21.02 | 30.30 | 30.30 |
| Switzerland | 20.07 | 20.07 | 32.97 | 32.97 |
| United Kingdom | 24.82 | 35.03 | 29.02 | 29.02 |
| | | | | |
| Czech Republic | | | 14.27 | 14.27 |
| Estonia | | | 12.82 | 12.82 |
| Hungary | | | 13.52 | 13.52 |
| Latvia | 4.34 | 4.35 | 11.73 | 11.73 |
| Lithuania | 3.44 | 3.44 | 11.58 | 11.58 |
| Poland | | | 12.87 | 12.87 |
| Slovakia | | | 12.36 | 12.36 |
| Slovenia | | | 18.80 | 18.80 |
| | | | | |
| Cyprus | | | 21.08 | 21.08 |
| Greece | | | 19.42 | 19.42 |
| Italy | 26.70 | 26.70 | 25.63 | 25.63 |
| Malta (*) | 14.38 | 14.38 | 18.64 | 18.64 |
| Portugal | 10.15 | 10.15 | 19.34 | 19.34 |
| Spain | | | 22.34 | 22.34 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-2: Comparison of country appraisal values and meta-analysis values (Car, non-work, 2002 euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 7.11 | 10.89 |
| | | | | |
| Austria | 1.93 | 1.93 | 6.73 | 10.32 |
| Belgium | | | 6.43 | 9.84 |
| Denmark | 3.58 | 5.89 | 7.11 | 10.88 |
| Finland | 4.57 | 4.57 | 6.36 | 9.73 |
| France | 5.06 | 11.22 | 9.18 | 14.06 |
| Germany | 4.26 | 4.26 | 6.74 | 10.32 |
| Ireland | 5.80 | 6.44 | 7.04 | 10.77 |
| Luxembourg | | | 9.99 | 15.30 |
| Netherlands | 3.67 | 9.57 | 6.52 | 9.97 |
| Sweden | 3.71 | 7.42 | 6.88 | 10.53 |
| Switzerland | 7.57 | 13.19 | 9.40 | 14.41 |
| United Kingdom | 5.85 | 6.61 | 6.99 | 10.70 |
| | | | | |
| Czech Republic | | | 4.82 | 7.38 |
| Estonia | | | 4.18 | 6.40 |
| Hungary | | | 4.23 | 6.48 |
| Latvia | 0.43 | 0.69 | 3.82 | 5.85 |
| Lithuania | 0.85 | 0.85 | 3.72 | 5.69 |
| Poland | | | 4.14 | 6.34 |
| Slovakia | | | 3.86 | 5.91 |
| Slovenia | | | 6.74 | 10.33 |
| | | | | |
| Cyprus | | | 6.65 | 10.18 |
| Greece | 1.93 | 3.86 | 5.82 | 8.90 |
| Italy | 5.50 | 11.01 | 8.52 | 13.04 |
| Malta (*) | 4.21 | 4.21 | 5.47 | 8.37 |
| Portugal | 1.62 | 1.62 | 5.61 | 8.59 |
| Spain | | | 7.15 | 10.94 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-3: Comparison of country appraisal values and meta-analysis values (Train, business trips, 2002 euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 23.82 | 23.82 |
| | | | | |
| Austria | 59.87 | 59.87 | 28.40 | 28.40 |
| Belgium | | | 27.44 | 27.44 |
| Denmark | 26.61 | 26.61 | 31.54 | 31.54 |
| Finland | | | 28.15 | 28.15 |
| France | 10.21 | 12.60 | 27.70 | 27.70 |
| Germany | 22.17 | 22.17 | 27.86 | 27.86 |
| Ireland | 21.07 | 21.07 | 29.87 | 29.87 |
| Luxembourg | | | 38.02 | 38.02 |
| Netherlands | 8.41 | 35.37 | 28.00 | 28.00 |
| Sweden | 11.92 | 15.19 | 30.30 | 30.30 |
| Switzerland | 18.68 | 18.68 | 32.97 | 32.97 |
| United Kingdom | 35.03 | 48.44 | 29.02 | 29.02 |
| | | | | |
| Czech Republic | | | 14.27 | 14.27 |
| Estonia | | | 12.82 | 12.82 |
| Hungary | | | 13.52 | 13.52 |
| Latvia | | | 11.73 | 11.73 |
| Lithuania | | | 11.58 | 11.58 |
| Poland | | | 12.87 | 12.87 |
| Slovakia | | | 12.36 | 12.36 |
| Slovenia | | | 18.80 | 18.80 |
| | | | | |
| Cyprus | | | 21.08 | 21.08 |
| Greece | | | 19.42 | 19.42 |
| Italy | 26.70 | 26.70 | 25.63 | 25.63 |
| Malta (*) | | | 18.64 | 18.64 |
| Portugal | | | 19.34 | 19.34 |
| Spain | | | 22.34 | 22.34 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-4: Comparison of country appraisal values and meta-analysis values (Train, non-work trips, 2002 euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 7.11 | 10.89 |
| | | | | |
| Austria | 14.97 | 14.97 | 6.73 | 10.32 |
| Belgium | | | 6.43 | 9.84 |
| Denmark | 3.58 | 5.99 | 7.11 | 10.88 |
| Finland | | | 6.36 | 9.73 |
| France | 5.06 | 11.22 | 9.18 | 14.06 |
| Germany | 6.08 | 6.08 | 6.74 | 10.32 |
| Ireland | 5.80 | 6.44 | 7.04 | 10.77 |
| Luxembourg | | | 9.99 | 15.30 |
| Netherlands | 3.67 | 9.57 | 6.52 | 9.97 |
| Sweden | 3.71 | 7.42 | 6.88 | 10.53 |
| Switzerland | 5.97 | 10.93 | 9.40 | 14.41 |
| United Kingdom | 5.85 | 6.61 | 6.99 | 10.70 |
| | | | | |
| Czech Republic | | | 4.82 | 7.38 |
| Estonia | | | 4.18 | 6.40 |
| Hungary | | | 4.23 | 6.48 |
| Latvia | | | 3.82 | 5.85 |
| Lithuania | | | 3.72 | 5.69 |
| Poland | | | 4.14 | 6.34 |
| Slovakia | | | 3.86 | 5.91 |
| Slovenia | | | 6.74 | 10.33 |
| | | | | |
| Cyprus | | | 6.65 | 10.18 |
| Greece | | | 5.82 | 8.90 |
| Italy | 5.50 | 11.01 | 8.52 | 13.04 |
| Malta (*) | | | 5.47 | 8.37 |
| Portugal | | | 5.61 | 8.59 |
| Spain | | | 7.15 | 10.94 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-5: Comparison of country appraisal values and meta-analysis values (Bus, business trips, 2002 euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 19.11 | 19.11 |
| | | | | |
| Austria | | | 22.79 | 22.79 |
| Belgium | | | 22.03 | 22.03 |
| Denmark | 26.61 | 26.61 | 25.31 | 25.31 |
| Finland | | | 22.59 | 22.59 |
| France | 10.21 | 12.60 | 22.23 | 22.23 |
| Germany | 23.87 | 23.87 | 22.35 | 22.35 |
| Ireland | 21.07 | 21.07 | 23.97 | 23.97 |
| Luxembourg | | | 30.51 | 30.51 |
| Netherlands | 8.41 | 35.37 | 22.47 | 22.47 |
| Sweden | 11.92 | 11.92 | 24.32 | 24.32 |
| Switzerland | 18.68 | 18.68 | 26.47 | 26.47 |
| United Kingdom | 13.34 | 35.03 | 23.29 | 23.29 |
| | | | | |
| Czech Republic | | | 11.45 | 11.45 |
| Estonia | | | 10.30 | 10.30 |
| Hungary | | | 10.85 | 10.85 |
| Latvia | | | 9.41 | 9.41 |
| Lithuania | | | 9.29 | 9.29 |
| Poland | | | 10.33 | 10.33 |
| Slovakia | | | 9.92 | 9.92 |
| Slovenia | | | 15.08 | 15.08 |
| | | | | |
| Cyprus | | | 16.92 | 16.92 |
| Greece | | | 15.59 | 15.59 |
| Italy | 26.70 | 26.70 | 20.57 | 20.57 |
| Malta (*) | | | 14.96 | 14.96 |
| Portugal | | | 15.52 | 15.52 |
| Spain | | | 17.93 | 17.93 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-6: Comparison of country appraisal values and meta-analysis values (Bus, non-work trips, 2002 euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 5.11 | 7.83 |
| | | | | |
| Austria | | | 4.84 | 7.42 |
| Belgium | | | 4.62 | 7.07 |
| Denmark | 3.58 | 5.99 | 5.11 | 7.82 |
| Finland | | | 4.57 | 7.00 |
| France | 5.06 | 11.22 | 6.60 | 10.11 |
| Germany | | | 4.85 | 7.42 |
| Ireland | 5.80 | 6.44 | 5.06 | 7.74 |
| Luxembourg | | | 7.18 | 11.00 |
| Netherlands | 3.67 | 9.57 | 4.68 | 7.17 |
| Sweden | 3.71 | 7.42 | 4.94 | 7.57 |
| Switzerland | 5.97 | 10.93 | 6.76 | 10.36 |
| United Kingdom | 5.85 | 6.61 | 5.02 | 7.69 |
| | | | | |
| Czech Republic | | | 3.46 | 5.31 |
| Estonia | | | 3.01 | 4.60 |
| Hungary | | | 3.04 | 4.66 |
| Latvia | | | 2.74 | 4.20 |
| Lithuania | | | 2.67 | 4.09 |
| Poland | | | 2.97 | 4.56 |
| Slovakia | | | 2.78 | 4.25 |
| Slovenia | | | 4.85 | 7.42 |
| | | | | |
| Cyprus | | | 4.78 | 7.32 |
| Greece | 1.93 | 3.37 | 4.18 | 6.40 |
| Italy | 5.50 | 11.01 | 6.12 | 9.38 |
| Malta (*) | | | 3.93 | 6.02 |
| Portugal | | | 4.03 | 6.18 |
| Spain | | | 5.13 | 7.87 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-7: Comparison of country appraisal values and meta-analysis values (Car, business trips, 2002 PPP euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | **Existing country appraisal values** | | **Meta-analysis values** | |
| | **Lowest** | **Highest** | **Lowest** | **Highest** |
| EU (25 countries) | | | 23.82 | 23.82 |
| | | | | |
| Austria | 10.30 | 10.30 | 27.23 | 27.23 |
| Belgium | | | 26.82 | 26.82 |
| Denmark | 20.17 | 20.17 | 24.00 | 24.00 |
| Finland | 23.78 | 24.16 | 25.13 | 25.13 |
| France | 9.79 | 12.08 | 26.56 | 26.56 |
| Germany | 19.95 | 19.95 | 25.07 | 25.07 |
| Ireland | 18.14 | 18.14 | 25.73 | 25.73 |
| Luxembourg | | | 33.50 | 33.50 |
| Netherlands | 7.88 | 33.15 | 26.24 | 26.24 |
| Sweden | 17.76 | 17.76 | 25.59 | 25.59 |
| Switzerland | 14.08 | 14.08 | 23.14 | 23.14 |
| United Kingdom | 22.09 | 31.17 | 25.82 | 25.82 |
| | | | | |
| Czech Republic | | | 26.57 | 26.57 |
| Estonia | | | 23.07 | 23.07 |
| Hungary | | | 24.72 | 24.72 |
| Latvia | 8.54 | 8.56 | 23.09 | 23.09 |
| Lithuania | 7.18 | 7.18 | 24.17 | 24.17 |
| Poland | | | 23.48 | 23.48 |
| Slovakia | | | 28.09 | 28.09 |
| Slovenia | | | 25.40 | 25.40 |
| | | | | |
| Cyprus | | | 23.90 | 23.90 |
| Greece | | | 24.74 | 24.74 |
| Italy | 27.93 | 27.93 | 26.81 | 26.81 |
| Malta (*) | 20.72 | 20.72 | 26.85 | 26.85 |
| Portugal | 13.30 | 13.30 | 25.34 | 25.34 |
| Spain | | | 25.95 | 25.95 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-8: Comparison of country appraisal values and meta-analysis values (Car, non-work trips, 2002 PPP euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 7.11 | 10.89 |
| | | | | |
| Austria | 1.85 | 1.85 | 6.46 | 9.89 |
| Belgium | | | 6.28 | 9.62 |
| Denmark | 2.72 | 4.48 | 5.41 | 8.28 |
| Finland | 4.08 | 4.08 | 5.68 | 8.69 |
| France | 4.85 | 10.76 | 8.80 | 13.48 |
| Germany | 3.83 | 3.83 | 6.07 | 9.29 |
| Ireland | 5.00 | 5.55 | 6.06 | 9.28 |
| Luxembourg | | | 8.80 | 13.48 |
| Netherlands | 3.44 | 8.97 | 6.11 | 9.35 |
| Sweden | 3.13 | 6.27 | 5.81 | 8.89 |
| Switzerland | 5.31 | 9.26 | 6.60 | 10.11 |
| United Kingdom | 5.20 | 5.88 | 6.22 | 9.52 |
| | | | | |
| Czech Republic | | | 8.98 | 13.75 |
| Estonia | | | 7.52 | 11.52 |
| Hungary | | | 7.74 | 11.86 |
| Latvia | 0.85 | 1.35 | 7.52 | 11.51 |
| Lithuania | 1.78 | 1.78 | 7.76 | 11.88 |
| Poland | | | 7.55 | 11.56 |
| Slovakia | | | 8.78 | 13.44 |
| Slovenia | | | 9.11 | 13.96 |
| | | | | |
| Cyprus | | | 7.54 | 11.54 |
| Greece | 2.46 | 4.91 | 7.41 | 11.34 |
| Italy | 5.75 | 11.52 | 8.91 | 13.64 |
| Malta (*) | 6.06 | 6.06 | 7.89 | 12.07 |
| Portugal | 2.12 | 2.12 | 7.35 | 11.26 |
| Spain | | | 8.30 | 12.71 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-9: Comparison of country appraisal values and meta-analysis values (Train, business trips, 2002 PPP euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 23.82 | 23.82 |
| | | | | |
| Austria | 57.40 | 57.40 | 27.23 | 27.23 |
| Belgium | | | 26.82 | 26.82 |
| Denmark | 20.25 | 20.25 | 24.00 | 24.00 |
| Finland | | | 25.13 | 25.13 |
| France | 9.79 | 12.08 | 26.56 | 26.56 |
| Germany | 19.95 | 19.95 | 25.07 | 25.07 |
| Ireland | 18.14 | 18.14 | 25.73 | 25.73 |
| Luxembourg | | | 33.50 | 33.50 |
| Netherlands | 7.88 | 33.15 | 26.24 | 26.24 |
| Sweden | 10.07 | 12.83 | 25.59 | 25.59 |
| Switzerland | 13.11 | 13.11 | 23.14 | 23.14 |
| United Kingdom | 31.17 | 43.10 | 25.82 | 25.82 |
| | | | | |
| Czech Republic | | | 26.57 | 26.57 |
| Estonia | | | 23.07 | 23.07 |
| Hungary | | | 24.72 | 24.72 |
| Latvia | | | 23.09 | 23.09 |
| Lithuania | | | 24.17 | 24.17 |
| Poland | | | 23.48 | 23.48 |
| Slovakia | | | 28.09 | 28.09 |
| Slovenia | | | 25.40 | 25.40 |
| | | | | |
| Cyprus | | | 23.90 | 23.90 |
| Greece | | | 24.74 | 24.74 |
| Italy | 27.93 | 27.93 | 26.81 | 26.81 |
| Malta (*) | | | 26.85 | 26.85 |
| Portugal | | | 25.34 | 25.34 |
| Spain | | | 25.95 | 25.95 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-10: Comparison of country appraisal values and meta-analysis values (Train, non-work trips, 2002 PPP euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 7.11 | 10.89 |
| | | | | |
| Austria | 14.35 | 14.35 | 6.46 | 9.89 |
| Belgium | | | 6.28 | 9.62 |
| Denmark | 2.72 | 4.56 | 5.41 | 8.28 |
| Finland | | | 5.68 | 8.69 |
| France | 4.85 | 10.76 | 8.80 | 13.48 |
| Germany | 5.47 | 5.47 | 6.07 | 9.29 |
| Ireland | 5.00 | 5.55 | 6.06 | 9.28 |
| Luxembourg | | | 8.80 | 13.48 |
| Netherlands | 3.44 | 8.97 | 6.11 | 9.35 |
| Sweden | 3.13 | 6.27 | 5.81 | 8.89 |
| Switzerland | 4.19 | 7.67 | 6.60 | 10.11 |
| United Kingdom | 5.20 | 5.88 | 6.22 | 9.52 |
| | | | | |
| Czech Republic | | | 8.98 | 13.75 |
| Estonia | | | 7.52 | 11.52 |
| Hungary | | | 7.74 | 11.86 |
| Latvia | | | 7.52 | 11.51 |
| Lithuania | | | 7.76 | 11.88 |
| Poland | | | 7.55 | 11.56 |
| Slovakia | | | 8.78 | 13.44 |
| Slovenia | | | 9.11 | 13.96 |
| | | | | |
| Cyprus | | | 7.54 | 11.54 |
| Greece | | | 7.41 | 11.34 |
| Italy | 5.75 | 11.52 | 8.91 | 13.64 |
| Malta (*) | | | 7.89 | 12.07 |
| Portugal | | | 7.35 | 11.26 |
| Spain | | | 8.30 | 12.71 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-11: Comparison of country appraisal values and meta-analysis values (Bus, business trips, 2002 PPP euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 19.11 | 19.11 |
| | | | | |
| Austria | | | 21.85 | 21.85 |
| Belgium | | | 21.53 | 21.53 |
| Denmark | 20.25 | 20.25 | 19.26 | 19.26 |
| Finland | | | 20.17 | 20.17 |
| France | 9.79 | 12.08 | 21.31 | 21.31 |
| Germany | 21.49 | 21.49 | 20.12 | 20.12 |
| Ireland | 18.14 | 18.14 | 20.65 | 20.65 |
| Luxembourg | | | 26.88 | 26.88 |
| Netherlands | 7.88 | 33.15 | 21.06 | 21.06 |
| Sweden | 10.07 | 10.07 | 20.54 | 20.54 |
| Switzerland | 13.11 | 13.11 | 18.57 | 18.57 |
| United Kingdom | 11.87 | 31.17 | 20.72 | 20.72 |
| | | | | |
| Czech Republic | | | 21.31 | 21.31 |
| Estonia | | | 18.52 | 18.52 |
| Hungary | | | 19.84 | 19.84 |
| Latvia | | | 18.53 | 18.53 |
| Lithuania | | | 19.39 | 19.39 |
| Poland | | | 18.85 | 18.85 |
| Slovakia | | | 22.54 | 22.54 |
| Slovenia | | | 20.38 | 20.38 |
| | | | | |
| Cyprus | | | 19.18 | 19.18 |
| Greece | | | 19.86 | 19.86 |
| Italy | 27.93 | 27.93 | 21.51 | 21.51 |
| Malta (*) | | | 21.56 | 21.56 |
| Portugal | | | 20.34 | 20.34 |
| Spain | | | 20.83 | 20.83 |

(*) Malta country appraisal value based on VTTS per vehicle

**Table A-V-12: Comparison of country appraisal values and meta-analysis values (Bus, non-work trips, 2002 PPP euros per passenger per hour, factor prices)**

| | Range of VTTS estimates | | | |
|---|---|---|---|---|
| | Existing country appraisal values | | Meta-analysis values | |
| | Lowest | Highest | Lowest | Highest |
| EU (25 countries) | | | 5.11 | 7.83 |
| | | | | |
| Austria | | | 4.64 | 7.11 |
| Belgium | | | 4.51 | 6.91 |
| Denmark | 2.72 | 4.56 | 3.89 | 5.95 |
| Finland | | | 4.08 | 6.25 |
| France | 4.85 | 10.76 | 6.33 | 9.69 |
| Germany | | | 4.36 | 6.68 |
| Ireland | 5.00 | 5.55 | 4.36 | 6.67 |
| Luxembourg | | | 6.33 | 9.69 |
| Netherlands | 3.44 | 8.97 | 4.39 | 6.72 |
| Sweden | 3.13 | 6.27 | 4.17 | 6.40 |
| Switzerland | 4.19 | 7.67 | 4.74 | 7.27 |
| United Kingdom | 5.20 | 5.88 | 4.47 | 6.84 |
| | | | | |
| Czech Republic | | | 6.44 | 9.88 |
| Estonia | | | 5.41 | 8.28 |
| Hungary | | | 5.56 | 8.52 |
| Latvia | | | 5.40 | 8.27 |
| Lithuania | | | 5.58 | 8.54 |
| Poland | | | 5.43 | 8.32 |
| Slovakia | | | 6.32 | 9.66 |
| Slovenia | | | 6.55 | 10.03 |
| | | | | |
| Cyprus | | | 5.42 | 8.29 |
| Greece | 2.46 | 4.29 | 5.32 | 8.16 |
| Italy | 5.75 | 11.52 | 6.40 | 9.81 |
| Malta (*) | | | 5.66 | 8.68 |
| Portugal | | | 5.29 | 8.10 |
| Spain | | | 5.96 | 9.14 |

(*) Malta country appraisal value based on VTTS per vehicle

**Figure A-V-1**

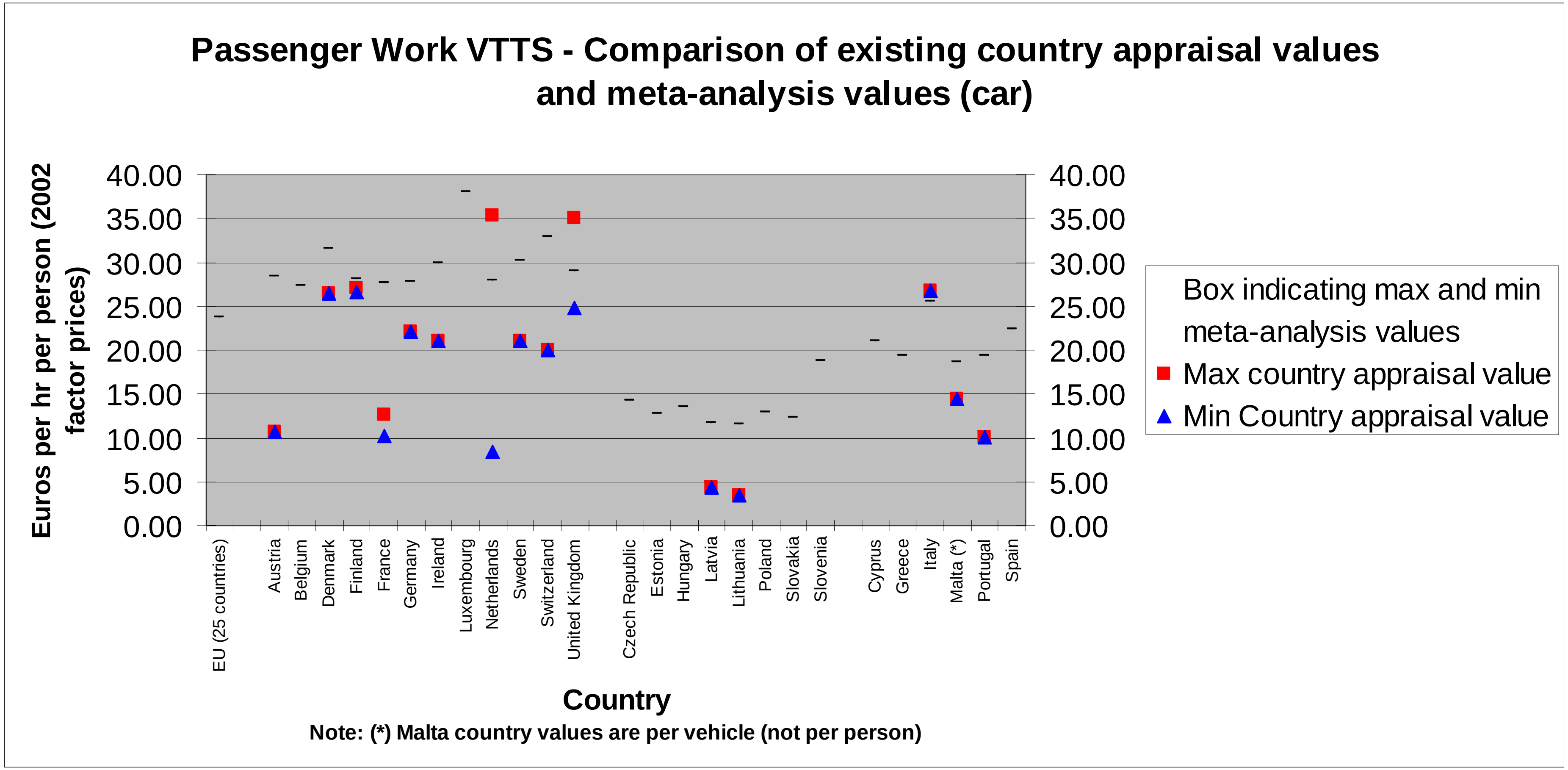
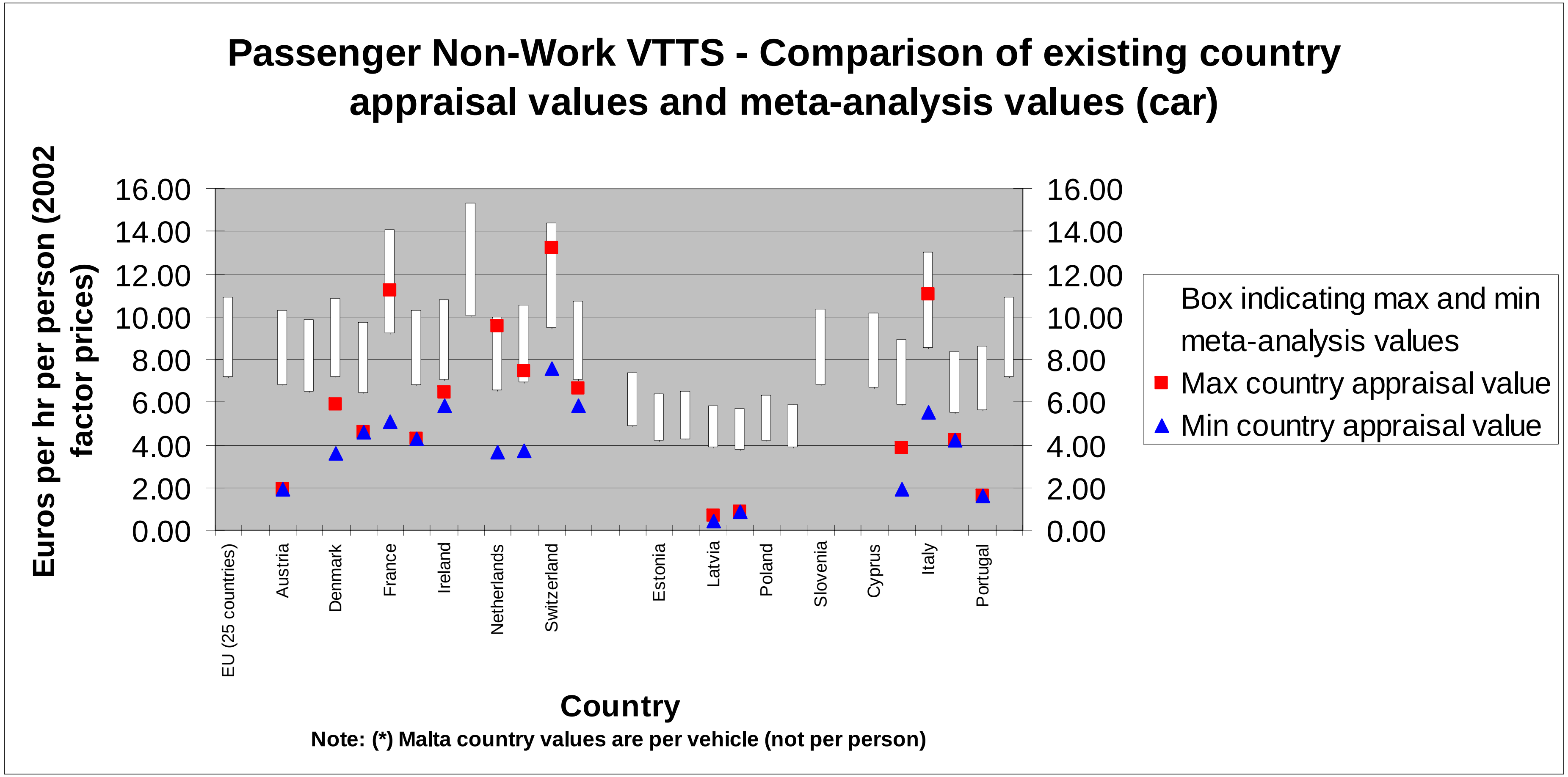

Passenger Work VTTS - Comparison of existing country appraisal values and meta-analysis values (car)
Euros per hr per person (2002 factor prices)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
EU (25 countries)
Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Luxembourg
Netherlands
Sweden
Switzerland
United Kingdom
Czech Republic
Estonia
Hungary
Latvia
Lithuania
Poland
Slovakia
Slovenia
Cyprus
Greece
Italy
Malta (*)
Portugal
Spain
Country
Note: (*) Malta country values are per vehicle (not per person)
Box indicating max and min meta-analysis values
Max country appraisal value
Min Country appraisal value

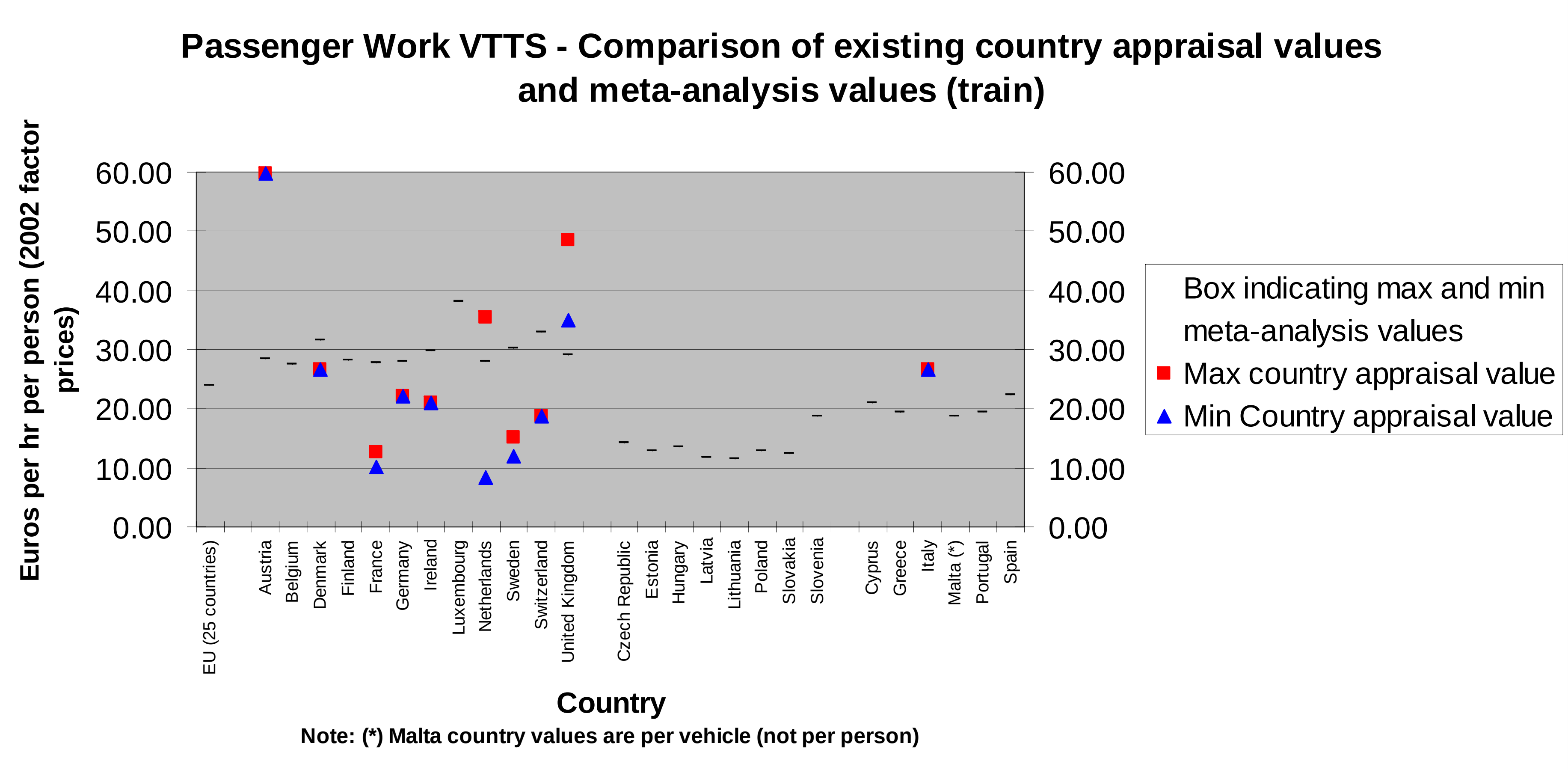
**Figure A-V-2**



Passenger Non-Work VTTS - Comparison of existing country appraisal values and meta-analysis values (car)

Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-3**



Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-4**

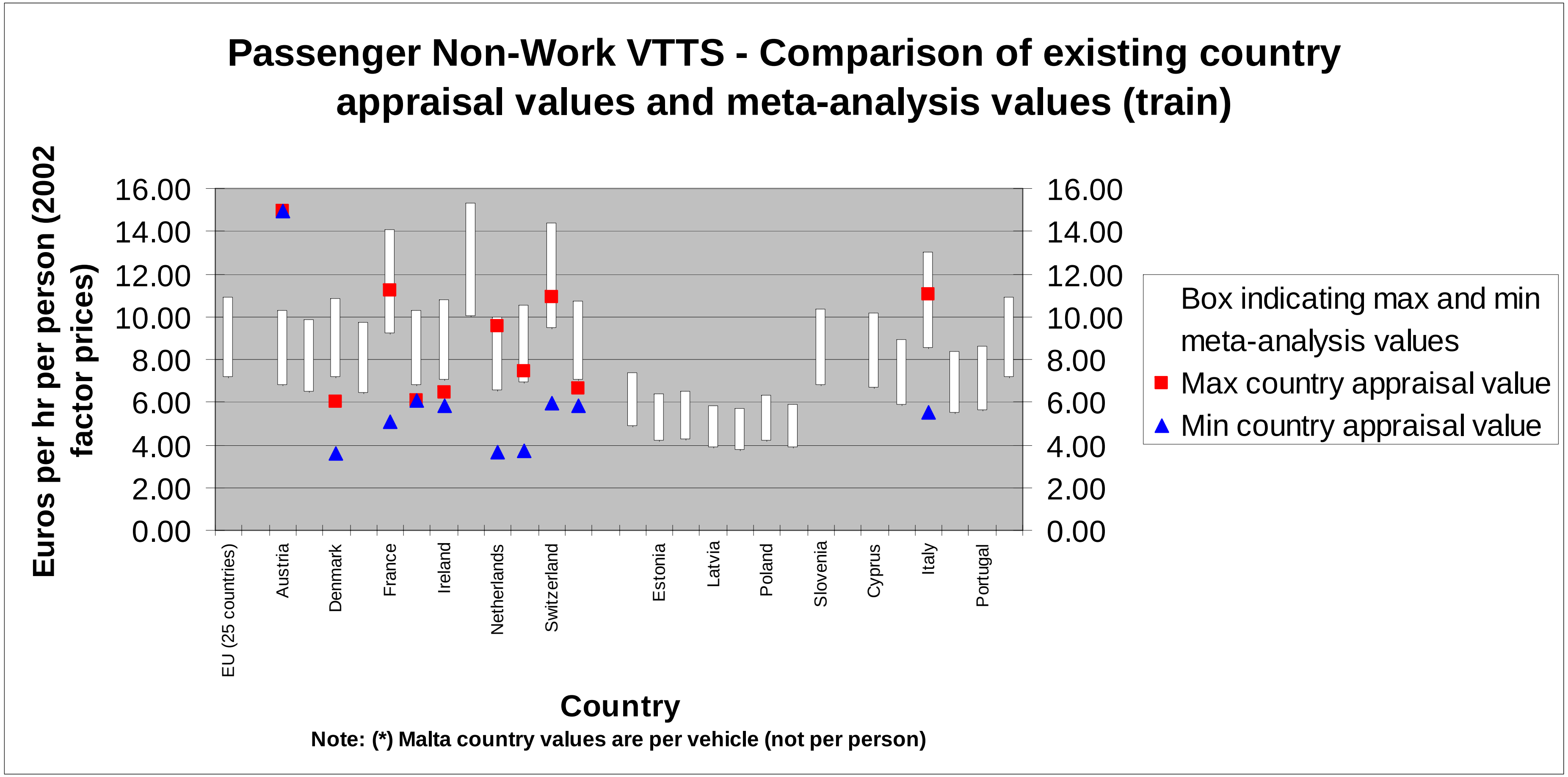
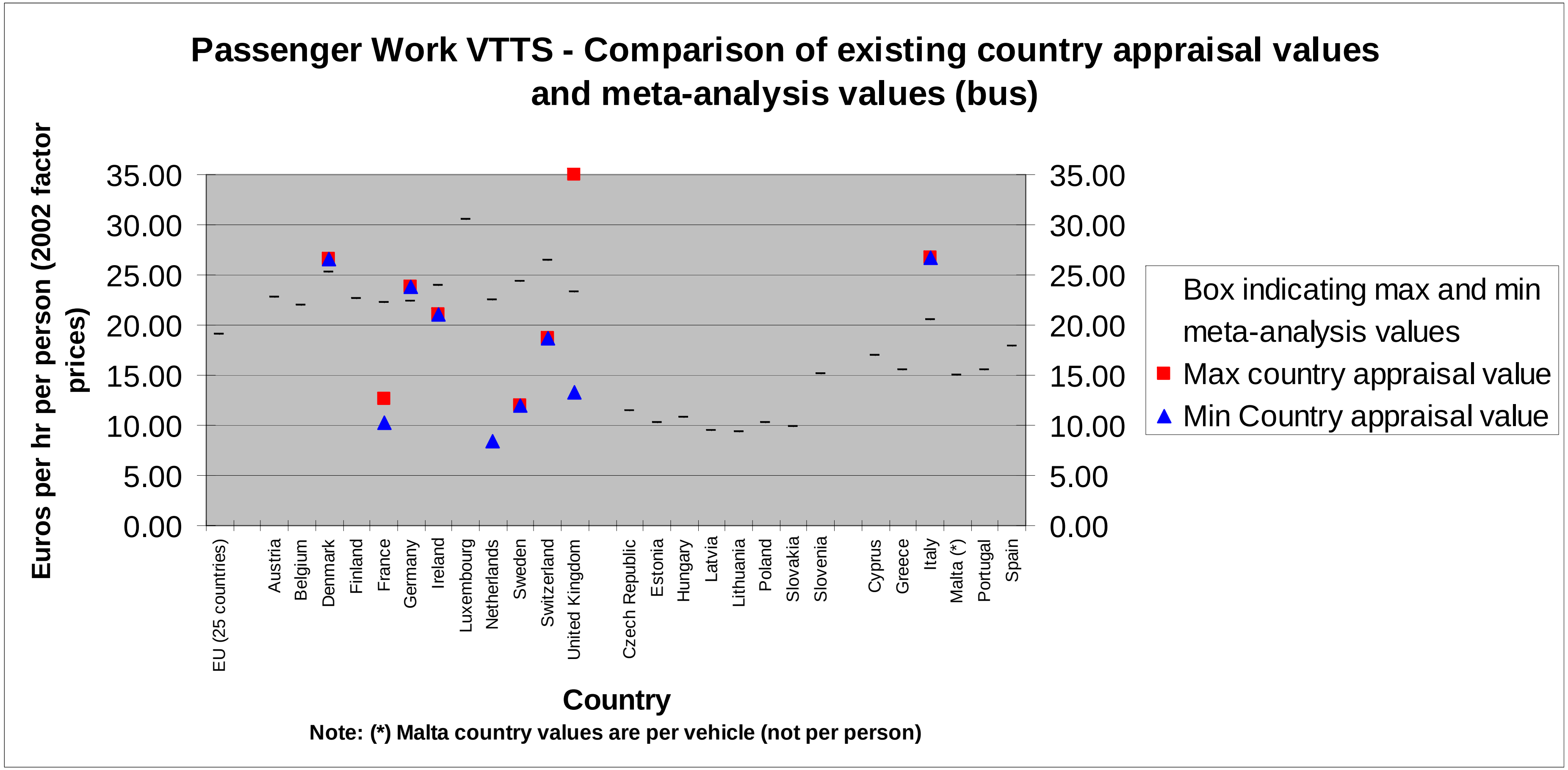

Passenger Non-Work VTTS - Comparison of existing country appraisal values and meta-analysis values (train)
Euros per hr per person (2002 factor prices)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
EU (25 countries)
Austria
Denmark
France
Ireland
Netherlands
Switzerland
Estonia
Latvia
Poland
Slovenia
Cyprus
Italy
Portugal
Country
Note: (*) Malta country values are per vehicle (not per person)
Box indicating max and min meta-analysis values
Max country appraisal value
Min country appraisal value

**Figure A-V-5**



Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-6**

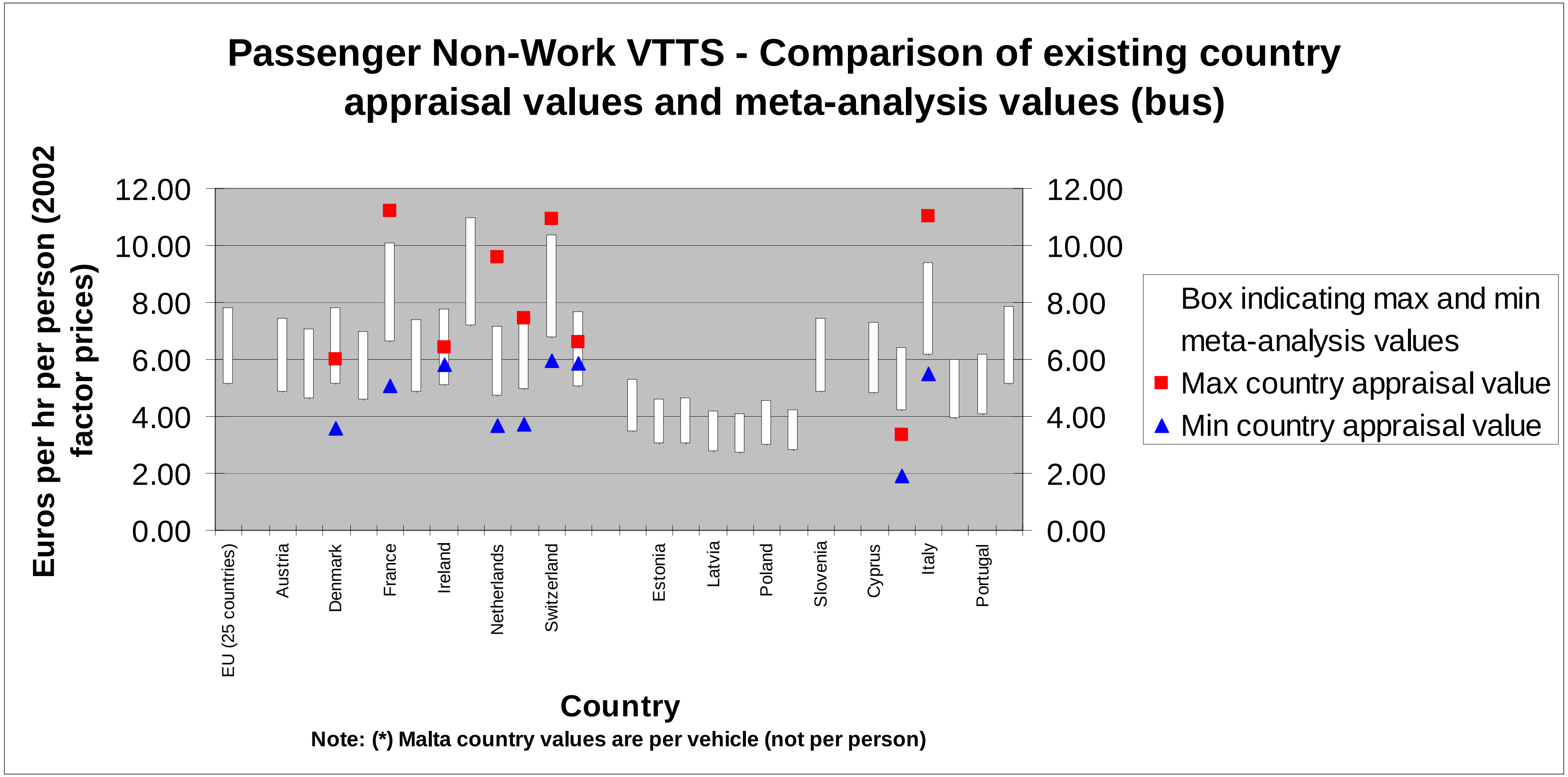

Passenger Non-Work VTTS - Comparison of existing country appraisal values and meta-analysis values (bus)
Euros per hr per person (2002 factor prices)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
EU (25 countries)
Austria
Denmark
France
Ireland
Netherlands
Switzerland
Estonia
Latvia
Poland
Slovenia
Cyprus
Italy
Portugal
Country
Box indicating max and min meta-analysis values
Max country appraisal value
Min country appraisal value
Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-7**

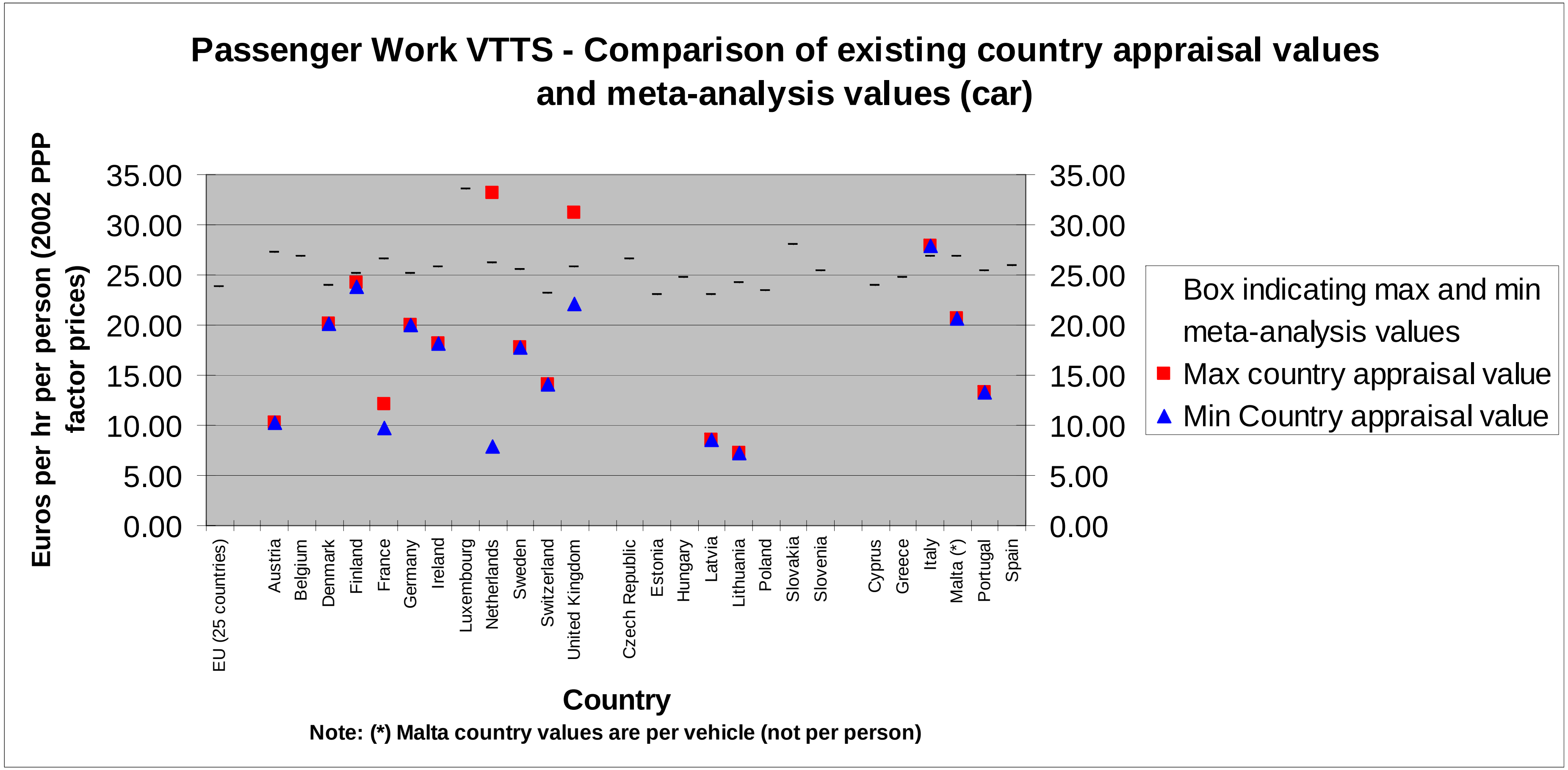
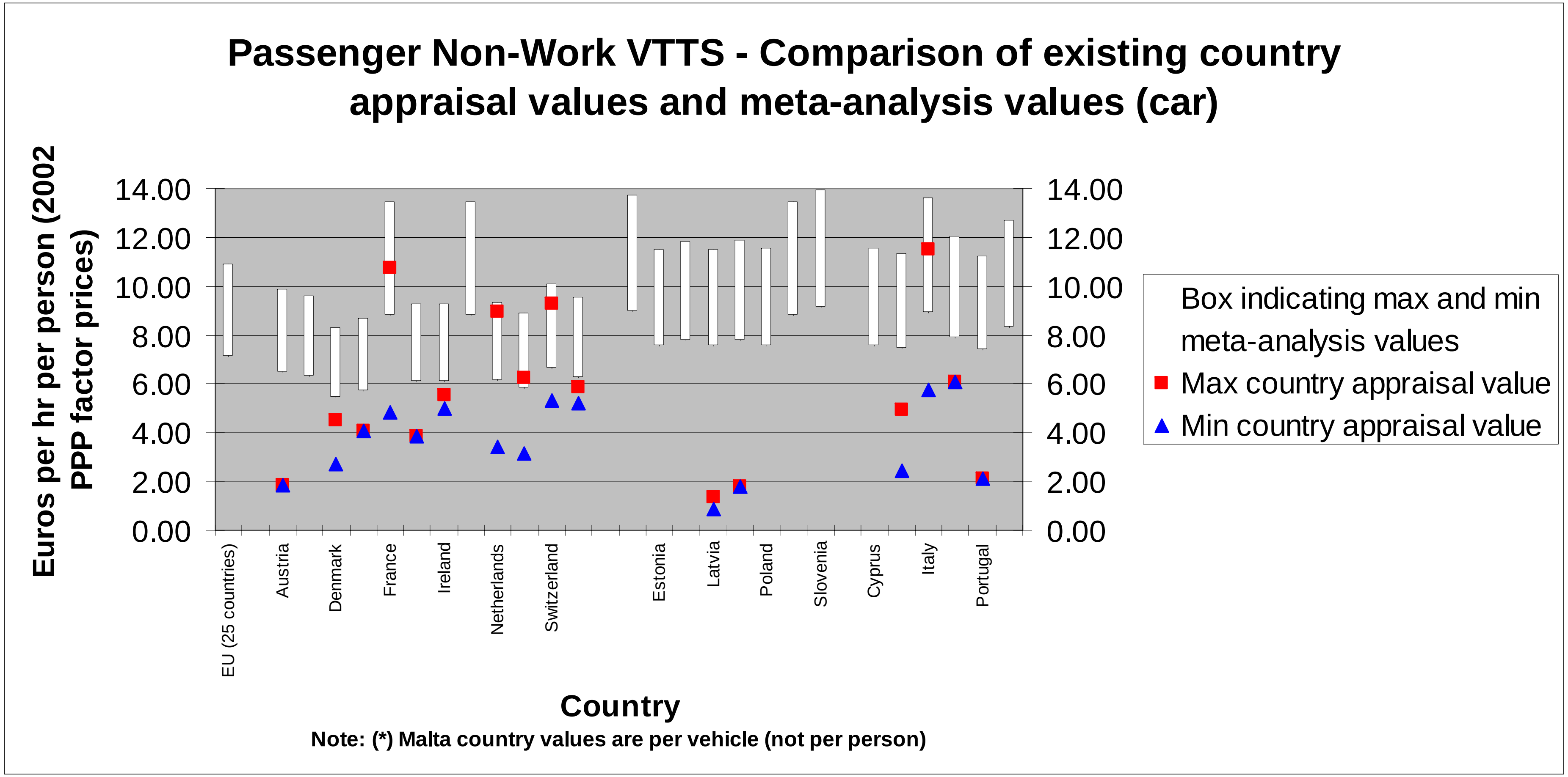

Passenger Work VTTS - Comparison of existing country appraisal values and meta-analysis values (car)
Euros per hr per person (2002 PPP factor prices)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
EU (25 countries)
Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Luxembourg
Netherlands
Sweden
Switzerland
United Kingdom
Czech Republic
Estonia
Hungary
Latvia
Lithuania
Poland
Slovakia
Slovenia
Cyprus
Greece
Italy
Malta (*)
Portugal
Spain
Country
Box indicating max and min meta-analysis values
■ Max country appraisal value
▲ Min Country appraisal value
Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-8**



Passenger Non-Work VTTS - Comparison of existing country appraisal values and meta-analysis values (car)

Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-9**

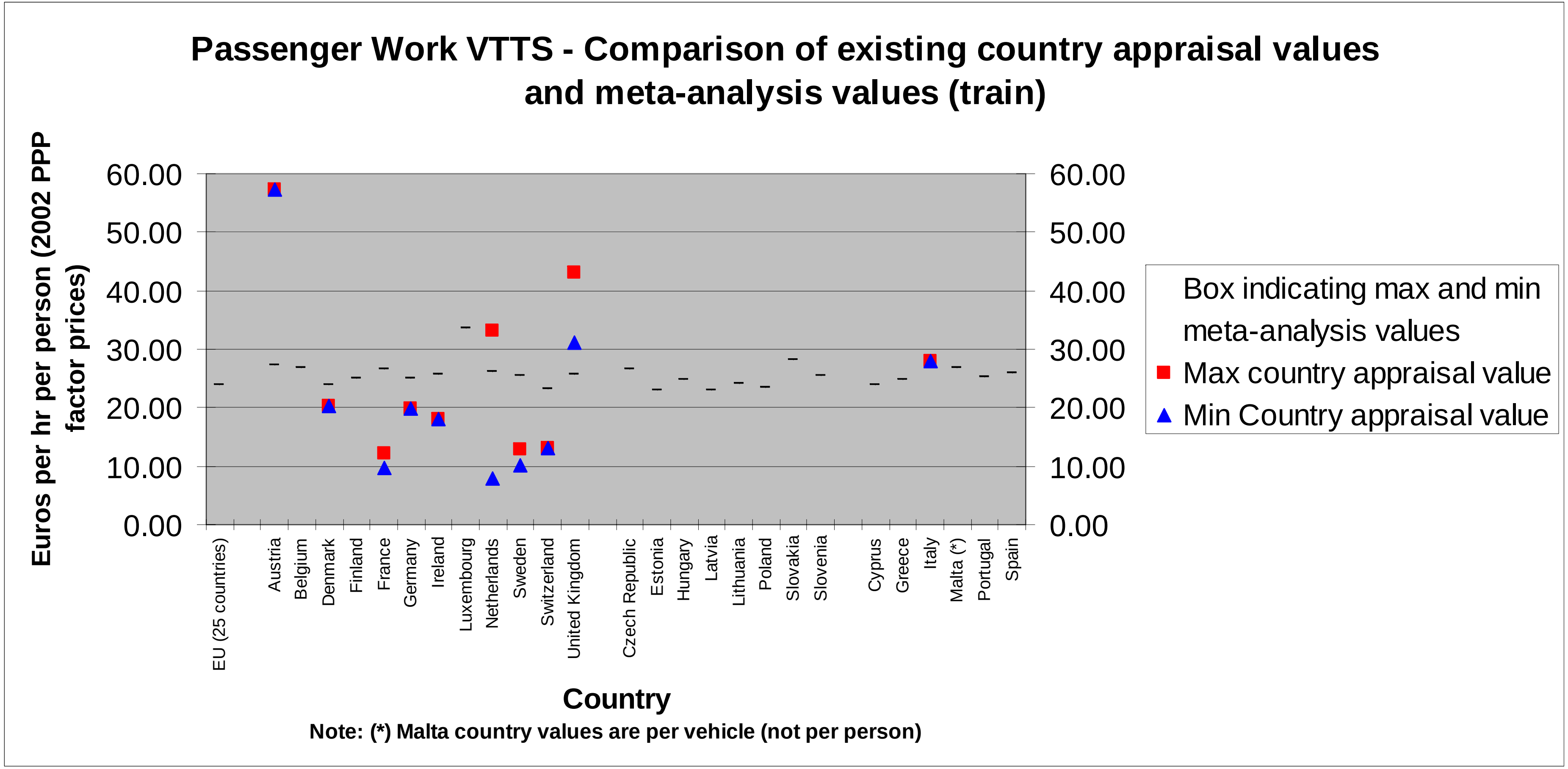
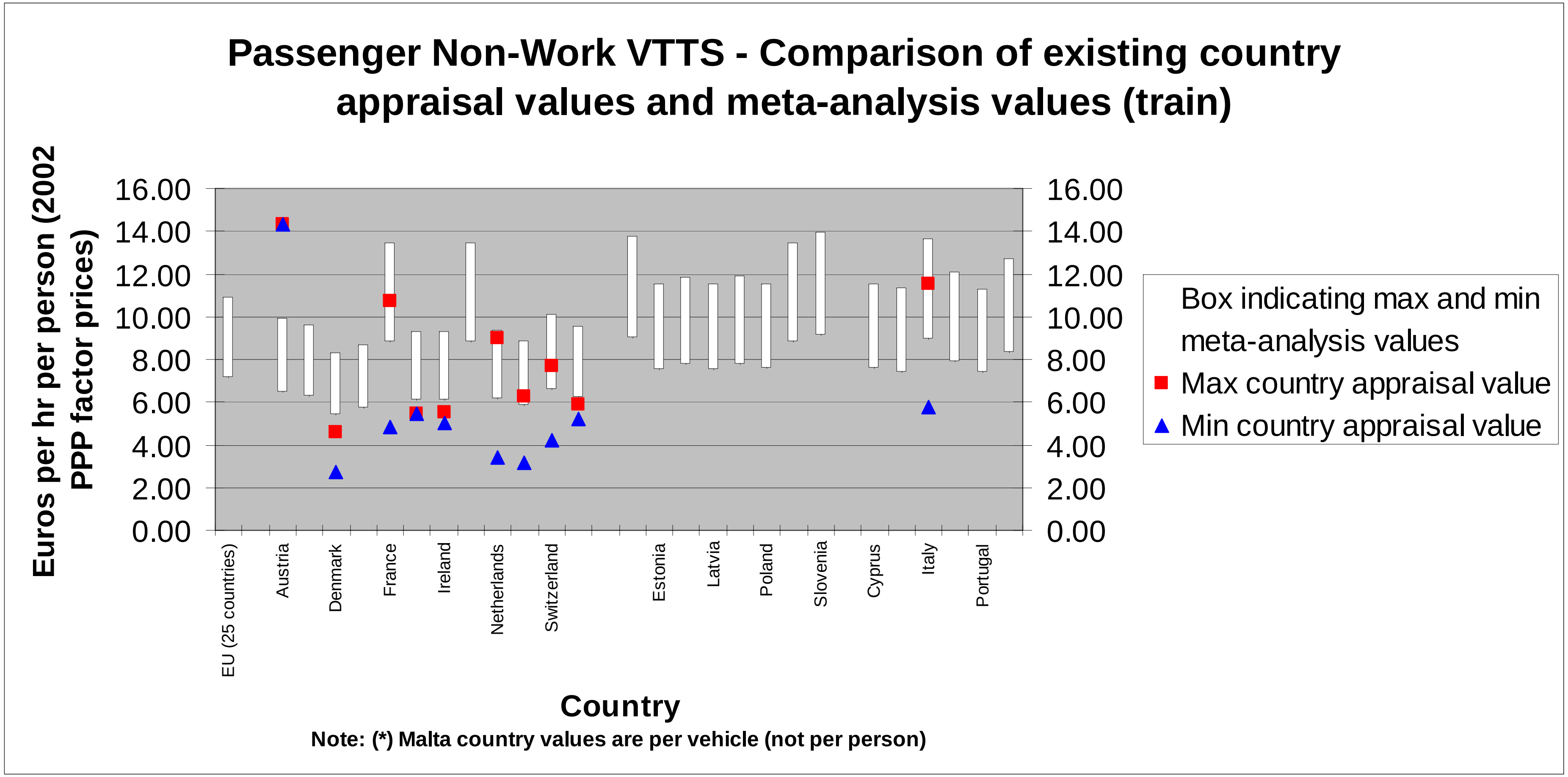

Passenger Work VTTS - Comparison of existing country appraisal values and meta-analysis values (train)
Euros per hr per person (2002 PPP factor prices)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
EU (25 countries)
Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Luxembourg
Netherlands
Sweden
Switzerland
United Kingdom
Czech Republic
Estonia
Hungary
Latvia
Lithuania
Poland
Slovakia
Slovenia
Cyprus
Greece
Italy
Malta (*)
Portugal
Spain
Country
Box indicating max and min meta-analysis values
Max country appraisal value
Min Country appraisal value
Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-10**



Passenger Non-Work VTTS - Comparison of existing country appraisal values and meta-analysis values (train)

Note: (*) Malta country values are per vehicle (not per person)

**Figure A-V-11**

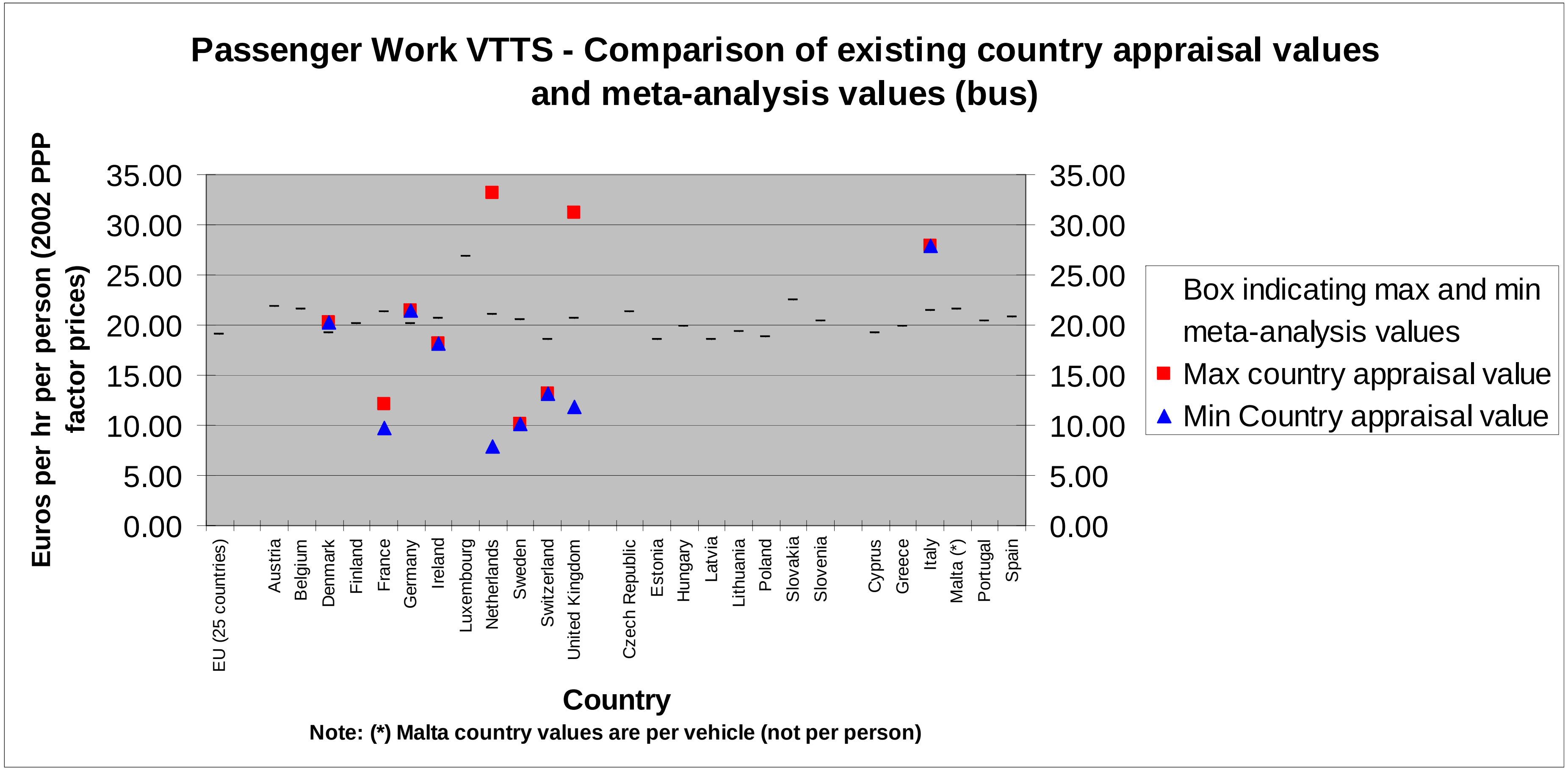
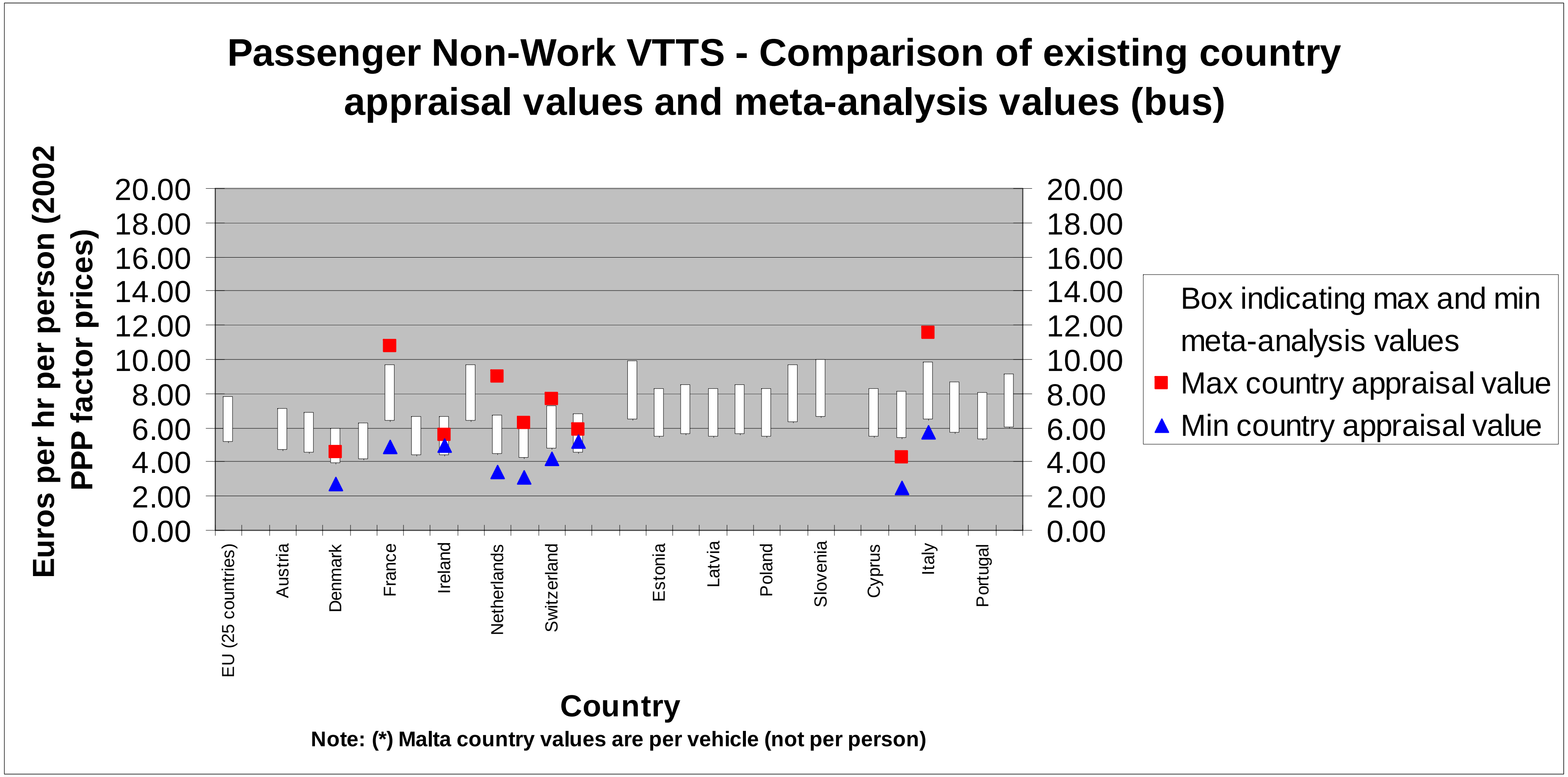

Passenger Work VTTS - Comparison of existing country appraisal values and meta-analysis values (bus)
Euros per hr per person (2002 PPP factor prices)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
EU (25 countries)
Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Luxembourg
Netherlands
Sweden
Switzerland
United Kingdom
Czech Republic
Estonia
Hungary
Latvia
Lithuania
Poland
Slovakia
Slovenia
Cyprus
Greece
Italy
Malta (*)
Portugal
Spain
Country
Note: (*) Malta country values are per vehicle (not per person)
Box indicating max and min meta-analysis values
Max country appraisal value
Min Country appraisal value

**Figure A-V-12**



Passenger Non-Work VTTS - Comparison of existing country appraisal values and meta-analysis values (bus)

Note: (*) Malta country values are per vehicle (not per person)

# General Issues in Costing Analysis: Units of account, Base years, and Currency conversion

## Annex B to HEATCO Deliverable 5

Alistair Hunt, University of Bath

## 1 Introduction

TEN-T – and indeed wider transport - project appraisal needs to ensure that all monetary inputs into the appraisal process are expressed in consistent forms with each other. There are three principal ways in which consistency is brought about. These include the expression of all monetary data:

- in a common unit of account (to account for taxes and subsidies)
- in a common base year for prices and values
- in a common currency

This guideline is designed to illustrate how monetary data can be expressed in i) a common unit of account in ii) a common currency, using iii) current prices. It draws on and updates the guideline developed for UNITE (Nellthorp et al, 2001). Each of the three issues is addressed individually, below.

## 2 A common unit of account

### 2.1 Context

The purpose of social appraisal of transport projects is to assess the net effect on human welfare of undertaking the project concerned. In order to allow the money values used in such an appraisal to best reflect economic welfare changes, we need to ensure that the values used are derived using the same unit of account.

The principle of adopting a common unit of account is likely to be particularly important in the context of a transport project appraisal where the cost and revenue data is a mix of data, some of which incorporates taxes (e.g. fuel duty, vehicle ownership taxes etc.) and subsidies, and some which do not. Consequently, this means that if both forms of data were used in a cost-benefit appraisal, this inconsistency would be likely to distort the outcome of the appraisal.

Since taxes and subsidies are generally treated as being transfers of funds rather than representing true resource costs or willingness to pay preferences, monetary values in project appraisals are often adjusted to exclude the impacts of taxes and subsidies. This is known as the *factor cost* unit of account: items are valued as if no indirect taxation or subsidy were applied.

However, since we are ultimately interested in measuring the (marginal) changes from the existing situation, it is equally appropriate to undertake the project appraisal using the *market price* unit of account, where items are valued as if they were being traded in consumer markets with all indirect taxes and subsidies in place. The important principle to establish is that a common approach is used i.e. either all values are expressed in factor cost terms or they are all expressed in market price terms.

### 2.2 Recommendations

We recommend that for TEN-T project appraisals factor costs should be the adopted unit of account. We make this recommendation based on what we think will be easiest for the practitioner. In this context we judge that cost elements are likely to be greater in number. Since these items are more often measured and reported at factor cost it is likely to be a less time-consuming exercise to convert (mainly revenue) values from market prices to factor costs. Additionally, the international aspect of TEN-T projects argues for the use of factor costs since the alternative of using the market price unit of account would require the analyst to choose a country in whose market prices it would be expressed, given that rates of indirect tax differ between countries, and therefore make for a more complicated exercise. We recommend that – for reasons of consistency - the data published by Eurostat and presented in Table 4 should be used rather than that in the country pro-formas.

## 2.3 Essential Mechanics

**Step 1**
The appraisal practitioner should first sort the monetary values to be used in the appraisal, according to whether they are expressed in terms of factor costs and market prices. The 2nd column of Table 4 in the Appendix shows the typical unit of account to be found in the cost/revenue data for each main impact category likely to be considered in such an appraisal. This does not mean that data will be in this unit of account in every country. Data will often be from business accounts or national accounts, and may therefore also be in any one of the alternative units of account (bases) listed in Table 5.

**Step 2**
The practitioner should next estimate the size of adjustment necessary to convert values expressed in market prices to factor costs. The numerical difference between factor cost and market price is the average rate of indirect taxation (net of subsidy) on consumer expenditure. In numerical terms, the difference varies from country to country. In the UK in 1998 the average rate of indirect taxation on consumer expenditure (henceforth $\tau$) was 21.9%. Transport costs expressed in the market price unit of account were therefore 1.219 times those expressed at factor cost. For ease of application, Table 6 gives average values of $\tau$ for EU countries available from 1995 to 2002. These values should be up-dated regularly by the practitioner by referring to the Eurostat/OECD's datasets on "Taxes linked to production and imports minus subsidies" and "Actual individual consumption"[1] for specific countries, as appropriate.

A more accurate analysis would entail deriving data directly from relevant company accounts. In these accounts, taxes will always be shown separately, as a transfer from the particular group (Users; Service Operators or Infrastructure Providers) to Government[2]. Subsidies will appear as transfers in the opposite direction. Therefore all costs should be shown net of all taxes and subsidies. Revenue will include all taxes. In order to compare costs and revenues:

- revenues obtained from other firms will generally be in the factor cost unit of account, so will require no adjustment;
- revenues obtained from final consumers will general be in the market prices unit of account, so the factor cost adjustment will need to be applied (divide by $1+\tau$).

**Step 3**
The adjustment from market price to factor cost should be made by dividing the market price by $(1 + \tau)$. Thus in Table 4 the adjustment required for each type of cost/revenue data identified is outlined in the 3rd column. The more detailed description of data types given in Table 5 also gives appropriate adjustments to be made.

---

[1] eg. see OECD (2000), *National Accounts of OECD Countries*; EUROSTAT Basic Statistics (annual to 1996).

[2] Note that when the economy is in a situation of rapid change and adjustment or where there are impediments to markets clearing so that factor or product markets are in disequilibrium market prices do not necessarily reflect the true value of the resource by all economic agents. Therefore, it is preferable to show explicitly all monetary transfers in order to be able to account for these potential distortions.

### 2.4 Numerical Example

**Step 1**. Suppose that a rail track cost is judged to be an input into a TEN-T multi-modal TEN-T project in Greece. The rail track cost is found to be available in market prices. The price given is €600 per tonne of track in 1998. We are using factor cost as our unit of account so this unit value needs to be converted from market prices.

**Step 2**. The adjustment from market prices to factor costs is made by dividing the market price unit value by 1 plus the average rate of indirect taxation on consumer expenditure ($\tau$). We need to identify the value of $\tau$; in this case we can find this by referring to Table 6. It is 17.2% for Greece in 1998.

**Step 3**. The adjustment is therefore made in the equation:

600/(1+0.172) = €511.9

## 3 Price Base

### 3.1 Context

The **general price level**[3] and the **relative price**[4] of individual goods and services in the economy, change with time[5]. This implies that the cost of individual goods and services included as input in the TEN-T project appraisal will also change over time. This presents two potential issues for such appraisal processes that we must deal with.

- expressing cost/benefit data in the prices of a common base year; and
- the price basis for future costs/benefits.

These issues are dealt separately in the following sub-sections.

### 3.2 Expressing Cost/Benefit Data in the Prices of a Common Base Year

---

[3] The **general price level** is given by the weighted average price of a representative 'basket' of consumer goods and services traded in the economy, relative to the price of that 'basket' at some fixed date in the past. As such, the general price level shows what is happening to consumer prices on average, and not what is happening to the price of individual consumer goods and services. Consequently, increases in the price of a specific good or service over time do not necessarily imply that the general price level has changed. For example, subject to the weights assigned to two items in the 'basket' of consumer goods and services, increases in the price of one item may be offset by decreases in the price of another item, to the extent that the average price level remains unchanged. Therefore, for the general price level to move upward, the prices of a majority of items in the 'basket' must increase. In the EU, the **Harmonised Index of Consumer Prices** is the standardised measure of changes in the general price level.

[4] As the term implies, this defines the price of a particular good or service relative to other goods and services in general. If any good or service is expected to change relative to the **general price level**, then it is said to have changed in **real** terms.

[5] This section relates to the general price level and the relative values of different 'cost' items in the HEATCO framework, but not to the discounting of future costs and benefits due to the phenomenon of time preference – that is being dealt with in a separate guideline.

### *Context*

When making comparisons between, say, two unit values to be used in a TEN-T project appraisal it is important to ensure that all cost data are expressed on an equivalent price basis, i.e. in the prices of a 'base' year[6]. In the context of processing time-dependent data such as costs in some form of economic analysis, the **base year** is the year selected for assembly of the 'raw' input data. For example, one set of data may be measured at current prices[7] in 1997 whereas the other set of data may be measured at current prices in 2002. If the economy experienced **inflation**[8] in the intervening period, direct comparison of the two data sets would be misleading. Thus, if the base year is 2002, and data in 1997 prices are used, then the final results will be biased downward. In order to use a base year it is necessary to express unit values in **constant price** terms, where a constant price is a value from which the overall effect of general price inflation has been removed[9].

### *Recommendations*

It is recommended that all unit values should be expressed in a common price base. As of writing, the year 2002 is the most recent year for which data on all conversion variables are available. We therefore suggest that this year should operate as the price base year in this set of guidelines, (sometimes known as the present value year), but that this base year should be adjusted regularly, according to data availability in future years.

The conversion from the price year in which the data is expressed to the price base year is undertaken using a price index. Ideally, this price index should be sectoral specific. In practice this is not always available. We recommend that the construction price index for construction (PIC) is used for construction costs and that the consumer price index is used for user benefits and externalities. In the European Union this latter index is known as the Harmonised Index of Consumer Prices (HICP). These indices are presented in Table 7 and Table 8 in Appendix 1.

### *Essential Mechanics*

The following two-step procedure should be used to express all 'raw' cost data on an equivalent price basis - i.e. in the prices of a 'common' base year.

### Step 1

The first step is to calculate a multiplier, or price adjuster, to be used in the conversion from the original data form to that of the base year. Thus:

---

[6] Typically in transport modelling and appraisal the following terms are used. "Base year" is used to reflect the calibration base year of the traffic or transport model from which demand forecasts are made (this is typically a year several years in the past for which travel demand and cost data is available for). The outputs from the transport model then feed into the CBA.

[7] **Current** (or **nominal**) **price** variables refer to values at the prices ruling when the variable was measured. Such prices have not been adjusted for the effects of **inflation**. Nominal price is interchangeably used with current price.

[8] **Inflation** is the term economists use to refer to increases in the general price level over time. The **inflation rate** defines the rate at which the general price increases over a specified time period – e.g. monthly or yearly.

[9] **Real** or **constant** price variables adjust **current price** variables for changes in the general level of prices – that is, they are inflation-adjusted prices.

Price adjuster
*equals*
Price index corresponding to the base year
*divided by*
Price index corresponding to the reference year of the 'raw' cost data

**Step 2**
The second step is to apply the price adjuster to the raw data, in order to bring about the conversion. Thus:

Adjusted cost data (in prices of base year)
*equals*
Price adjuster
*times*
The 'raw' cost data

***Numerical Example***
Suppose we know the price of a value of statistical life (VSL) in 1996 prices in France is €950,000. Now suppose that it is necessary to express the price data in 2002 prices - because 2002 is the 'price base' for our study. The required adjustment is shown below – based on the HICP data given in Table 7, below.

**Step 1:**

price adjuster: 1.083
*equals*
HIPC index (2002): 100
*divided by*
HIPC index (1996): 92.3

**Step 2:**

VSL in 2002 (base year): €1.029 million
*equals*
VSL in 1996: € 950,000
*multiplied by*
price adjuster: 1.083

Applying this method to years 1996-2004 the summary data are shown in Table 1.

**Table 1: VSL Current price – Constant Price conversion: France**

| | **A** **Current Prices** (€m) | **B** **Harmonised Index of Consumer Prices** (2002=100) | **C** **Price adjuster** (€m) | **D** **Constant Prices** (€m) |
|---|---|---|---|---|
| 1996 | 950,000 | 92.3 | 1.083 | 1,029,252 |
| 1997 | 963,380 | 93.6 | 1.068 | 1,029,252 |
| 1998 | 969,555 | 94.2 | 1.062 | 1,029,252 |

| | | | | |
|---|---|---|---|---|
| 1999 | 974,702 | 94.7 | 1.056 | 1,029,252 |
| 2000 | 992,199 | 96.4 | 1.037 | 1,029,252 |
| 2001 | 1,010,725 | 98.2 | 1.018 | 1,029,252 |
| 2002 | 1,029,252 | 100 | 1.000 | 1,029,252 |
| 2003 | 1,051,895 | 102.2 | 0.978 | 1,029,252 |
| 2004 | 1,076,598 | 104.6 | 0.956 | 1,029,252 |

Note that index numbers, which have no units, are values expressed as a percentage of a single base figure. For example, if the VSL is 1.029 million and €1.076 million in 2002 and 2004 respectively, the price in 2004 is 104.6 percent of that in 2002. In index terms, the VSL in 2002 and 2004 is 100 and 104.6, respectively.

## 3.3 The Price Basis for Future Costs

***Context***

The price basis for future costs has to consider two separate issues:
- changes in relative prices and
- changes in real value.

We discuss these in turn.

***Changes in relative prices***

Changes in the price of various goods and services (e.g. water, energy, health care, plant, equipment, property, etc.) are not restricted to the intervening years between the historical 'raw' cost data you collect and the base year of the costing analysis. Prices are also likely to vary over the study's time horizon (e.g. 2005 to 2030) - not least as a result of general price **inflation**. However, as with the treatment of historic costs in the previous section, the effect of inflation on future prices can be removed if we work with **constant** (or **real**) **prices**. In this way, only relative price changes are reflected in the analysis – i.e. where the price of an impact is anticipated to increase or decrease more or less than the general price level.

In economic analysis, a change in the relative price of a good or service is expected to result in a change in the amount of resources that must be foregone, e.g. invested in transport infrastructure, instead of being used elsewhere in the economy. Hence, changes in relative prices reflect changes in real resource use, and therefore should be recorded in the project appraisal in the years when such changes are expected. There are often – for example – cyclical fluctuations in construction costs that should be taken in to account. Otherwise, it is implicitly assumed that all cost data remain constant in real terms and relative to each other. It is important to note that adjustments for relative prices also need to be made for historical data time series.

Recommendations

We recommend that account must also be taken account of changes in prices relative to changes in the general price level and that unit values expressed presently in nominal, or current, price terms for future years should be converted to constant price terms.

The general procedure for adjusting to prices such as those for construction that are prone to movements relative to each other is summarised in two steps.

**Step 1**
The first step is to ensure that the unit prices being used are those estimated using long run average patterns of the unit prices. This step will therefore entail estimation of the long run average unit price for the cost or benefit unit and adjustment of the observed unit price to that long run average.

**Step 2**
In order to identify the relative price movement, the trend in the unit price over the future period of interest for the project appraisal should be identified and compared with the trend in the general price level. The resulting annual percentage change in unit prices relative to the general price level should then be applied to the unit price over the appraisal period.

Numerical Example

**Step 1**
Suppose that the price for a rail-sleeper unit for 2006 is quoted at €150. The long run average trend would however suggest that the unit price for 2006 is €180. An adjustment should therefore be made by applying a multiplier – also known as the relative price factor – of 1.2 to the quoted price.

**Step 2**
Suppose that the current price of rail-sleepers is expected to increase at a rate of 2.5 percent per year over the first ten years of the rail project, when the annual rate of general inflation over the same period is placed at 4 percent. The annual change in the relative price of rail-sleepers is thus given by:

$$\frac{(1+0.025)}{(1+0.040)}-1=-0.014\,.$$

Therefore, the cost of rail-sleepers in the appraisal, expressed in constant prices, should be reduced by 1.4 percent per year - reflecting this relative price change over the period for which it will continue.

***Changes in real value***
As GDP and GDP per capita changes over time it is reasonable to expect that the absolute value of a resource also changes. For example, it is likely to be the case that as GDP increases so the value that society places on noise improvements brought about by a TEN-T project also increases. As a consequence it would be appropriate to adjust the unit values related to future noise improvements in the appraisal of the project.

Recommendations
We recommend that changes in the future value of a resource should be fully reflected in the unit value(s) related to that resource in a TEN-T project appraisal. Current transport appraisal guidance generally links directly the rate of growth in GDP to the rate of growth in unit values. For instance, the real value of non-working time in France is adjusted at 70% of the rate of change in domestic consumption, whilst the unit value of work time at 100%. These two adjustments are equivalent to adopting income elasticities of 0.7 and 1.0, respectively.

The income elasticities tend to differ between resources and between countries. We recommend that – where evidence exists – the income elasticity used should be specific to the cost or benefit being considered. In sections 4.4.8, 5.2.4, 6.3.2, 6.4.3 and 6.5.3 below, specific recommendations are made for travel time, accidents, air pollution, noise and climate change impacts respectively. Where there is no robust impact-specific evidence we recommend that a unit income elasticity be adopted. Country GDP growth rate forecasts are presented in Table 10 and can be used in conjunction with the appropriate income elasticity to derive unit values for future time periods. It should be noted that future GDP growth rates are not necessarily likely to be the same as these historical rates. Thus, appraisal that adopts these rates should also undertake sensitivity analysis using a range of alternative GDP growth assumptions.

<u>Numerical Example</u>

**Step 1**
Identify the relationship between unit value changes and changes in GDP for the resource unit of interest.

Suppose that Belgium is proposed to participate in a TEN-T project with a 10-year time-scale assumed in the appraisal. Assume that the project brings work time-savings and that the real value of a work time unit increases by the rate of GDP growth. The 2002 unit price for work time is €7.8 per person-hour

**Step 2**
Plot the annual projected rates of GDP growth in percentage terms and indexed - against the unit value growth rates according to the adjustment rates assumed for the countries concerned.

Some illustrative unit value growth rates are presented in Table 2. Current actual growth rate forecasts for EU countries are given in Table 10.

**Table 2: Illustrative unit value growth rates**

| Year | GDP Growth rate (annual %) | GDP (Index) | Unit value |
|---|---|---|---|
| 2002 | 2.1 | 100 | 8.0 |
| 2003 | 2.1 | 102 | 8.1 |
| 2004 | 2.1 | 104.0 | 8.3 |
| 2005 | 2.1 | 106.1 | 8.5 |
| 2006 | 2.1 | 108.2 | 8.7 |
| 2007 | 2.1 | 110.4 | 8.8 |
| 2008 | 2.1 | 112.6 | 9.0 |
| 2009 | 2.1 | 114.9 | 9.2 |
| 2010 | 2.1 | 117.2 | 9.4 |
| 2011 | 2.1 | 119.5 | 9.6 |

# 4 A common currency

## 4.1 Context

International comparison of unit values may necessitate conversion from one currency to another if all values are to be expressed in comparable terms. For countries in the Eurozone, exchange rates are now locked and all values are expressed in Euro. However, for other countries in the EU25, currency conversion remains necessary.

When comparing values between countries, it is not sufficient to use official (nominal) exchange rates only since these do not reflect differences in purchasing power. Instead it is useful to use the purchasing power parity (PPP) exchange rate since it provides a more accurate guide to real differences in resource costs and WTP values in different countries. The PPP exchange rate is calculated from the relative value of a currency based on the amount of a "basket" of goods the currency will buy in their nation of usage. Typically, the prices of many goods will be considered, and weighted according to their importance in the economy. It should be noted, however, that future PPP will certainly change, if –and this is what we assume – the different income levels in Europe will become increasingly harmonised over time, though currently no model is available for estimating these changes. Where use of nominal Euro and PPP-equivalent Euro give different recommendations using the CBA decision-rule, the choice of which exchange rate to use will be dependent on the preference of the decision-maker

## 4.2 Recommendations

We recommend that unit values should be expressed in base year (2002) Euro. The Euro is chosen as the common currency because of its dominance in the geographical area likely to be affected by TEN-T projects. We recommend that unit values should be expressed in purchasing power equivalents, as well as at market exchange rate levels, in order to accommodate differences between purchasing power in different countries.

## 4.3 Essential Mechanics of PPP exchange rate conversion

### Step 1

To convert unit values to PPP values expressed in Euro, we should identify the PPP exchange rate between the two currencies in the base year. For the full range of EU countries these can be obtained from Eurostat[10]. For convenience, these PPP exchange rate conversion factors for the EU countries for 2002 are presented in Table 9[11]. Since some unit values for countries currently in the Eurozone may be dated to prior to their Euro conversion, the Euro conversion rates are also given in the table. Note that because PPP exchange rates take into account

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[10] http://epp.eurostat.cec.eu.int/cache/ITY_PUBLIC/KS-NJ-04-053/EN/KS-NJ-04-053-EN.PDF

[11] Note that, strictly speaking, since the PPP exchange rates are calculated on the basis of market prices, they are not consistent with the use of factor costs, which we recommend. However, the resulting error is likely to be trivial in comparison with the size of other uncertainties typically accommodated within CBA of transport infrastructure projects.

relative purchasing power in different countries – which nominal short run exchange rates may not do – one Euro in Belgium does not necessarily equate to one Euro in Italy. In this table, the rates are expressed relative to the average of the EU25 countries equaling 1.

**Step 2**
The unit value is then divided by The PPP exchange rate in the specific country, (column 3 of Table 9), assuming that it is currently expressed in 2002 prices, to give the unit value in 2002 PPP Euro terms.

### 4.4 Numerical Example

Suppose that a unit value of €30 per decibel of noise was identified in Greece. We would like to express it in terms of the EU25 Euro.

**Step 1**
The PPP exchange rate for Greece is presented in Column 3 of Table 9 i.e. 0.784962.

**Step 2**
To get the PPP-adjusted value in terms of EU25 Euro we divide the original unit value by the PPP.

30 ÷ 0.784962 = €38.218

## 5 Guidance on the sequencing of unit value conversions

The three conversion processes described above may be used on their own or sequentially depending on the initial form of the data. For example, Italian cost data, expressed as factor cost in 2002 prices needs only to use the final conversion process described above – conversion by the PPP exchange rate to the appropriate country PPP. (Clearly, if this is Italy, no further conversion is needed). On the other hand, German data, expressed in 1999 market prices may need to use all three conversion processes if the final value is to be expressed in the PPP terms of another country. In order to retain consistency between project appraisals, it is recommended that in the case where there is more than one conversion process necessary, the analyst make the appropriate conversions in the sequence order consistent with the presentation in this guideline. That is:

1) to a common unit of account
2) to a common base year (2002)
3) to a common currency
4) to projections of future unit values

### Numerical example of sequencing of unit value conversions

Suppose that the unit value for an accident-based minor injury in the UK is available expressed as £100 in 1999 market prices. We would like to use this value in a TEN-T project appraisal in Euro at 2002 prices, projected for future years. The following stages are therefore required in order to make the full conversion:

## Stage 1: Unit of account

**Step 1**
As indicated in the paragraph above, the unit value is presently expressed in market prices. We therefore need to convert to factor cost terms.

**Step 2**
The practitioner should next estimate the size of adjustment necessary to convert values expressed in market prices to factor costs. As shown in Table 6, in the UK in 1999 the average rate of indirect taxation on consumer expenditure ( $\tau$) was 22.0%.

**Step 3**
The adjustment from market price to factor cost should be made by dividing the market price by $(1 + \tau)$. Thus, in this case we have:

£100/(1+0.22) = £81.96

## Stage 2: Price base

**Step 1**
The first step is to calculate a multiplier, or price adjuster, to be used in the conversion from the original data form to that of the base year. Thus:

Price adjuster
*equals*
Price index corresponding to the base year
*divided by*
Price index corresponding to the reference year of the 'raw' cost data

It is necessary to express the price data in 2002 prices - because 2002 is the 'price base' for our study. The required adjustment is shown below – based on the HICP data for UK given in Table 7, below.

price adjuster: 1.033
*equals*
HIPC index (2002): 100
*divided by*
HIPC index (1999): 96.8

**Step 2**
The second step is to apply the price adjuster to the raw data, in order to bring about the conversion. Thus:

Adjusted cost data (in prices of base year)
*equals*
Price adjuster

*times*
The ‘raw’ cost data

In this example:

VSL in 2002 (base year): €84.67
*equals*
VSL in 1999: € 81.96
*multiplied by*
price adjuster: 1.033

## Stage 3: Currency Conversion

**Step 1**
To convert unit values to PPP values expressed in Euro, we should identify the PPP exchange rate between UK Sterling and EU25 Euro in the base year i.e. 2002.

The PPP exchange rate for UK to EU25 Euro in 2002 is presented in Column 4 of Table 9 i.e. 0.706638.

**Step 2**
To get the PPP-adjusted value in terms of EU25 Euro we divide the original unit value by the PPP.

€84.67 ÷ 0.784962 = €107.87

Note that since results are also usefully presented at their market exchange rates, non-Euro unit values should be converted to Euro at 2002 rates, given in Column 3 of Table 9.

## Stage 4: Projection of future unit values

Stage 3 shows that the accident-based minor injury value for the UK, adjusted to 2002 PPP Euro prices, is 107.87. Suppose that the CBA on the TEN-T project requires application of accident-based minor injury values over a 40-year appraisal period, to 2042. The following steps are therefore required to be made.

**Step 1**
To account for possible changes in relative price changes for the impact, the trend in the unit price over the future period of interest for the project appraisal should be identified and compared with the trend in the general price level. The resulting annual percentage change in unit prices relative to the general price level should then be applied to the unit price over the appraisal period

In the case of accident-based minor injuries, since the unit value has been derived from a relatively small number of non-market valuation studies, no trend in unit prices is presently discernible. No adjustment for changes in relative prices is therefore made in this example.

**Step 2**

To account for changes in real unit value over time we first identify any existing relationship between unit value changes and changes in GDP. The evidence is found to be insufficient to make robust estimates of the income elasticity of accident-based minor injuries in the EU. We therefore adopt the default assumption of a unit income elasticity.

We must then plot the annual projected rates of GDP growth in percentage terms – in this case the rate of 2.8% per annum for the UK - against the growth of the unit value, over the 40-year period. The resulting unit values for each year across the project appraisal period are presented in

**Table 3. Unit value projections for accident-based minor injuries in the UK**

| | | | |
|---|---|---|---|
| **Growth rate (annual %)** | | 2.80% | |
| **(annual multiplicative factor)** | | 1.028 | |
| **Year** | **Unit value** | **Year** | **Unit value** |
| 2002 | 107.87 | 2023 | 187.40 |
| 2003 | 110.89 | 2024 | 192.65 |
| 2004 | 114.00 | 2025 | 198.04 |
| 2005 | 117.19 | 2026 | 203.59 |
| 2006 | 120.47 | 2027 | 209.29 |
| 2007 | 123.84 | 2028 | 215.15 |
| 2008 | 127.31 | 2029 | 221.17 |
| 2009 | 130.87 | 2030 | 227.36 |
| 2010 | 134.54 | 2031 | 233.73 |
| 2011 | 138.31 | 2032 | 240.27 |
| 2012 | 142.18 | 2033 | 247.00 |
| 2013 | 146.16 | 2034 | 253.92 |
| 2014 | 150.25 | 2035 | 261.03 |
| 2015 | 154.46 | 2036 | 268.34 |
| 2016 | 158.78 | 2037 | 275.85 |
| 2017 | 163.23 | 2038 | 283.57 |
| 2018 | 167.80 | 2039 | 291.51 |
| 2019 | 172.50 | 2040 | 299.68 |
| 2020 | 177.33 | 2041 | 308.07 |
| 2021 | 182.29 | 2042 | 316.69 |
| 2022 | 187.40 | | |

## 6 References

CEC, IMF, OECD, UN & World Bank (1993), *System of National Accounts (SNA).* Brussels/Luxembourg, New York, Paris, Washington D.C.

Eurostat web-site: http://europa.eu.int/comm/eurostat/

Nellthorp J, Sansom T, Bickel P, Doll C and Lindberg G (2001), *Valuation Conventions for UNITE*, Institute for Transport Studies, University of Leeds. http://www.its.leeds.ac.uk/projects/unite/downloads/D5_Annex3.pdf

OECD (2000), *National Accounts of OECD Countries: Main Aggregates Volume 1 1988-1998*. OECD: Paris.

Pearce, DW and Nash, CA (1981), *The Social Appraisal of Projects: A Text in Cost-Benefit Analysis.* Macmillan: London. (p110/111)

## APPENDIX Tables referenced in Guideline

**Table 4**: **Adjustment to convert values to the Factor Cost Unit of Account**

| **Cost/revenue category** | **Typical unit of account of data** | **Adjustments needed** |
|---|---|---|
| Infrastructure Costs | Factor Cost | None |
| Supplier Operating Costs | Factor Cost | None |
| External User Costs | Factor Cost (working time & VOCs) | None |
| | Market Prices (non-working time & VOCs) | Divide by 1+τ |
| Accident Costs | Factor cost (healthcare costs) | None |
| | Market Prices (WTP for risk reductions) | Divide by 1+τ |
| Environmental Costs | Market Prices (for WTP data) | Divide by 1+τ |
| Taxes, Charges and Subsidies | Factor Cost (for payments made by firms) | None |
| | Market Prices (for payments made by final consumers) | Divide by 1+τ |

## Table 5. Alternatives for the Inclusion or Exclusion of Taxes in Prices

| | Includes | Difference | Example cost item: fuel for nonEB travel | Example cost item: materials for a new bridge |
|---|---|---|---|---|
| Market price | Price paid by purchaser including any VAT, other taxes, less subsidies to consumers[a], and including any delivery charges | - | Pump price | Inc-VAT price charged by supplier |
| Purchaser's price | Price paid by purchaser including **non-deductible** VAT and other taxes, less subsidies to consumers, and including any delivery charges | Market price **minus** deductible VAT | Pump price | Ex-VAT price charged by supplier |
| Producer's price | Amount received by the producer minus any VAT[b], with subsidies still excluded and excluding delivery charges | Purchaser's price **minus** any non-deductible VAT | Pump price minus VAT | Ex-VAT price charged by supplier |
| Basic price | Amount received by the producer minus any tax levied *per unit of output*[c], with subsidies per unit of output added back, and excluding delivery charges | Producer's price **minus** other taxes *per unit of output* **plus** subsidies per unit of output | Pump price minus VAT and fuel duty | Ex-VAT price charged by supplier |
| Factor cost | Amount received by the producer minus any taxes paid plus any subsidies | Basic price **minus** 'other taxes on production' | Pump price minus VAT and fuel duty, minus the element of business rates and any VED in production costs | Ex-VAT price charged by supplier, minus the element of business rates and VED in production costs |

Notes to the table:[a] eg. concessionary fares; [b] or similar *deductible* tax; [c] 'taxes on a product' in SNA terminology'

Source: Nellthorp et al (2001) based on CEC, IMF, OECD, UN & World Bank (1993), *System of National Accounts (SNA)*. Brussels/Luxembourg, New York, Paris, Washington D.C.

**Table 6. Average Rate of Indirect Taxation on Consumer Expenditure ($\tau$) in EU in 2002 Source: Eurostat[12]**

| per cent | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| Eurozone12 | 18.6 | 18.5 | 18.5 | 18.6 | 19.0 | 18.8 | 18.4 | 18.5 |
| Belgium | 21.2 | 21.7 | 22.0 | 21.7 | 22.5 | 22.2 | 21.4 | 21.9 |
| Denmark | 31.3 | 32.2 | 32.4 | 33.2 | 33.7 | 33.9 | 33.8 | 33.7 |
| Germany | 18.8 | 18.1 | 17.9 | 18.0 | 18.7 | 18.6 | 18.3 | 18.3 |
| Greece | 17.5 | 17.5 | 17.0 | 17.2 | 17.7 | 18.1 | 18.7 | 18.1 |
| Spain | 14.3 | 14.5 | 14.8 | 15.6 | 16.3 | 16.3 | 15.9 | 16.3 |
| France | 18.3 | 18.7 | 18.7 | 18.4 | 18.4 | 17.6 | 17.2 | 17.4 |
| Ireland | 25.2 | 25.2 | 25.8 | 26.0 | 26.2 | 26.8 | 25.0 | 25.8 |
| Italy | 17.6 | 17.2 | 17.5 | 17.9 | 18.1 | 18.0 | 17.3 | 17.1 |
| Luxembourg | 21.7 | 21.2 | 22.0 | 21.6 | 23.2 | 24.4 | 23.3 | 23.7 |
| Netherlands | 22.6 | 22.9 | 23.1 | 23.1 | 23.3 | 23.7 | 24.6 | 24.2 |
| Austria | 20.6 | 22.2 | 22.1 | 21.9 | 22.3 | 21.7 | 21.5 | 22.0 |
| Portugal | 19.5 | 19.7 | 19.5 | 19.8 | 19.8 | 19.7 | 19.4 | 20.1 |
| Finland | 28.2 | 27.8 | 29.7 | 29.6 | 29.8 | 29.0 | 27.6 | 28.0 |
| Sweden | 28.4 | 27.9 | 28.2 | 28.9 | 28.9 | 28.6 | 29.5 | 30.6 |
| Switzerland | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 7.6 |
| Latvia | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 18 |
| Lithuania | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 18 |
| Slovak Rep | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 19 |
| Malta | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 18 |
| UK | 21.8 | 21.7 | 21.9 | 21.6 | 22.0 | 21.7 | 21.3 | 21.3 |

Note: It is suggested that where indirect tax rates are needed for earlier or later years the rate that exists in the closest year is used. Thus, if rates are needed for 1991, the 1995 rate should be used, whilst if 2003 rates are needed, then 2002 rates should be used as proxies.

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[12] http://europa.eu.int/comm/eurostat/newcronos/reference/display.do?screen=welcomeref&open=/economy/gov/taxes&language=en&product=EU_economy_finance&root=EU_economy_finance&scrollto=197

## Table 7: Annual HICP (2002=100)

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU25 | - | 74.7 | 77.7 | 80.3 | 82.6 | 85.0 | 87.7 | 89.9 | 91.7 | 93.3 | 95.5 | 97.9 | 100.0 | 101.9 | 104.1 |
| EU15 | 73.7 | 77.5 | 80.5 | 83.4 | 85.7 | 88.2 | 90.2 | 91.7 | 93.0 | 94.1 | 95.8 | 98.0 | 100.0 | 101.9 | 103.9 |
| Belgium | *79.1* | 81.6 | 83.6 | 85.6 | 87.6 | 88.7 | 90.3 | 91.7 | 92.5 | 93.6 | 96.0 | 98.5 | 100.0 | 101.4 | 103.3 |
| Czech Republic | - | - | - | - | - | 68.9 | 75.1 | 81.2 | 89.1 | 90.6 | 94.3 | 98.5 | 100.0 | 99.9 | 102.5 |
| Denmark | 79.1 | 80.8 | 82.4 | 83.2 | 84.6 | 86.4 | 88.2 | 89.8 | 91.1 | 93.0 | 95.5 | 97.7 | 100.0 | 101.9 | 103.0 |
| Germany | *78.6* | *81.5* | *84.7* | *87.8* | *90.2* | 91.8 | 92.9 | 94.3 | 94.8 | 95.6 | 96.9 | 98.7 | 100.0 | 101.1 | 102.8 |
| Estonia | - | - | - | - | - | 59.9 | 71.7 | 78.4 | 85.3 | 87.9 | 91.4 | 96.6 | 100.0 | 101.4 | 104.5 |
| Greece | *38.7* | *46.2* | *53.6* | *61.3* | *68.0* | 74.4 | 80.1 | 84.5 | 88.3 | 90.3 | 92.9 | 96.3 | 100.0 | 103.4 | 106.6 |
| Spain | *64.3* | *68.1* | *72.1* | 75.5 | 79.1 | 82.8 | 85.7 | 87.3 | 88.9 | 90.8 | 93.9 | 96.6 | 100.0 | 103.2 | 106.3 |
| France | 80.8 | 83.5 | 85.5 | 87.4 | 88.9 | 90.5 | 92.3 | 93.6 | 94.2 | 94.7 | 96.4 | 98.2 | 100.0 | 102.2 | 104.6 |
| Ireland | *71.2* | *73.4* | *75.7* | *76.8* | *78.6* | 80.6 | 82.3 | 83.3 | 85.1 | 87.2 | 91.8 | 95.4 | 100.0 | 104.0 | 106.3 |
| Italy | 66.1 | 70.2 | 73.6 | 77.0 | 80.2 | 84.5 | 87.9 | 89.5 | 91.3 | 92.8 | 95.2 | 97.4 | 100.0 | 102.8 | 105.1 |
| Cyprus | - | - | - | - | - | - | 85.0 | 87.8 | 89.9 | 91.0 | 95.3 | 97.2 | 100.0 | 104.0 | 105.9 |
| Latvia | - | - | - | - | - | - | 81.0 | 87.6 | 91.3 | 93.2 | 95.7 | 98.0 | 100.0 | 102.9 | 109.3 |
| Lithuania | - | - | - | - | - | 67.9 | 84.7 | 92.2 | 96.8 | 97.4 | 98.3 | 99.6 | 100.0 | 99.0 | 100.1 |
| Luxembourg | *76.8* | *79.2* | *81.6* | *84.6* | *86.5* | 88.1 | 89.2 | 90.5 | 91.3 | 92.2 | 95.7 | 98.1 | 100.0 | 102.6 | 105.8 |
| Hungary | - | - | - | - | - | 43.1 | 53.3 | 63.1 | 72.0 | 79.3 | 87.1 | 95.1 | 100.0 | 104.7 | 111.8 |
| Malta | - | - | - | - | - | - | 83.7 | 87.0 | 90.2 | 92.3 | 95.1 | 97.5 | 100.0 | 101.9 | 104.7 |
| Netherlands | 74.7 | 77.1 | 79.3 | 80.6 | 82.3 | 83.4 | 84.7 | 86.3 | 87.7 | 89.6 | 91.6 | 96.3 | 100.0 | 102.2 | 103.7 |
| Austria | 78.6 | 81.1 | 83.9 | 86.5 | 88.9 | 90.4 | 91.9 | 93.0 | 93.8 | 94.2 | 96.0 | 98.3 | 100.0 | 101.3 | 103.2 |
| Poland | - | - | - | - | - | - | 61.4 | 70.6 | 79.0 | 84.6 | 93.2 | 98.1 | 100.0 | 100.7 | 104.3 |
| Portugal | 58.6 | 65.2 | 71.0 | 75.2 | 78.9 | 82.1 | 84.5 | 86.1 | 88.0 | 89.9 | 92.5 | 96.5 | 100.0 | 103.3 | 105.9 |
| Slovenia | - | - | - | - | - | 57.7 | 63.4 | 68.7 | 74.1 | 78.6 | 85.7 | 93.1 | 100.0 | 105.7 | 109.6 |
| Slovak Republic | - | - | - | - | - | 60.7 | 64.3 | 68.2 | 72.8 | 80.4 | 90.1 | 96.6 | 100.0 | 108.5 | 116.5 |
| Switzerland | 81.4 | | 89.6 | 92.5 | 93.4 | 95.1 | 95.8 | 96.3 | 96.3 | 97.1 | 98.3 | 99.6 | 100.0 | 100.9 | 101.6 |
| Finland | 77.7 | 81.2 | 83.8 | 86.6 | 87.9 | 88.2 | 89.3 | 90.4 | 91.6 | 92.7 | 95.5 | 98.0 | 100.0 | 101.3 | 101.5 |
| Sweden | 74.1 | 80.6 | 81.7 | 85.6 | 88.0 | 90.4 | 91.1 | 92.8 | 93.8 | 94.3 | 95.5 | 98.1 | 100.0 | 102.4 | 103.4 |
| UK | 74.8 | 80.5 | 83.9 | 86.0 | 87.7 | 90.2 | 92.4 | 94.0 | 95.5 | 96.8 | 97.6 | 98.8 | 100.0 | 101.4 | 102.7 |
| Iceland | *66.4* | *71.0* | *73.8* | *76.8* | *78.0* | 79.3 | 81.0 | 82.5 | 83.6 | 85.4 | 89.1 | 95.0 | 100.0 | 101.4 | 103.8 |
| Norway | *77.6* | *80.2* | *82.0* | *84.0* | *85.1* | 87.2 | 87.9 | 90.0 | 91.8 | 93.8 | 96.6 | 99.2 | 100.0 | 102.0 | 102.7 |
| Bulgaria | - | - | - | - | - | - | - | 65.6 | 77.8 | 79.8 | 88.0 | 94.5 | 100.0 | 102.3 | 108.7 |
| Romania | - | - | - | - | - | 5.1 | 7.0 | 18.0 | 28.6 | 41.6 | 60.7 | 81.6 | 100.0 | 115.2 | 128.9 |

Table 8: Annual PIC[13] (2002=100)

| | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
|---|---|---|---|---|---|---|---|---|---|---|
| EU25 | | 85.4 | 88.1 | 90.9 | 92.8 | 94.4 | 97.4 | 100.0 | 102.3 | 105.5 |
| EU15 | 84.7 | 87.0 | 89.3 | 91.6 | 93.2 | 94.5 | 97.3 | 100.0 | 102.4 | 105.0 |
| Belgium | 83.2 | 85.6 | 86.0 | 86.9 | 89.5 | 91.6 | 96.4 | 100.0 | 102.3 | 104.0 |
| Czech rep. | | | | | | 96.5 | 98.7 | 100.0 | 101.4 | 106.9 |
| Denmark | 83.6 | 87.5 | 89.5 | 92.1 | 94.2 | 94.9 | 97.7 | 100.0 | 101.5 | 102.6 |
| Germany | 95.4 | 96.4 | 96.9 | 97.8 | 98.6 | 98.9 | 99.5 | 100.0 | 100.8 | 101.9 |
| Estonia | 69.9 | 84.0 | 89.3 | 94.5 | 95.5 | 96.3 | 98.2 | 100.0 | 100.9 | 102.4 |
| Greece | 68.2 | 73.2 | 81.3 | 87.3 | 91.5 | 93.9 | 96.6 | 100.0 | 103.4 | 107.5 |
| Spain | 78.0 | 80.6 | 82.8 | 85.2 | 87.4 | 91.1 | 95.2 | 100.0 | 104.3 | 108.7 |
| France | | 93.7 | 95.5 | 97.1 | 96.5 | 93.2 | 96.3 | 100.0 | 103.1 | 106.7 |
| Ireland | 84.3 | 86.1 | 85.9 | 85.8 | 88.5 | 91.5 | 95.0 | 100.0 | 104.8 | 108.9 |
| Italy | 83.4 | 86.4 | 88.8 | 91.3 | 93.4 | 95.1 | 97.4 | 100.0 | 102.7 | 105.4 |
| Cyprus | | 80.1 | 84.9 | 87.7 | 90.5 | 92.9 | 97.4 | 100.0 | 104.4 | 109.6 |
| Latvia | | 78.9 | 88.6 | 92.5 | 94.9 | 96.5 | 98.7 | 100.0 | 103.0 | 110.0 |
| Lithuania | | | | | | | 100.2 | 100.0 | 99.6 | 102.1 |
| Lux. | 88.5 | 90.6 | 92.5 | 93.7 | 94.1 | 96.4 | 98.2 | 100.0 | 102.7 | 104.7 |
| Hungary | | | | | | | 93.0 | 100.0 | 105.9 | 113.9 |
| Malta | | 89.8 | 94.6 | 94.0 | 96.2 | 95.7 | 98.4 | 100.0 | 102.8 | 106.5 |
| Netherlands | 81.1 | 82.6 | 84.0 | 86.4 | 87.8 | 90.2 | 95.9 | 100.0 | 103.2 | 105.7 |
| Austria | 89.0 | 91.9 | 92.9 | 94.4 | 95.7 | 96.6 | 99.0 | 100.0 | 99.7 | 102.3 |
| Poland | | 66.6 | 75.6 | 83.8 | 89.9 | 95.2 | 98.9 | 100.0 | 100.4 | 108.5 |
| Portugal | 73.7 | 75.7 | 79.2 | 82.7 | 86.2 | 89.9 | 94.4 | 100.0 | 104.5 | 107.8 |
| Slovenia | | | | | | 88.1 | 94.9 | 100.0 | 104.5 | 109.5 |
| Slovakia | | 68.1 | 71.3 | 76.7 | 83.3 | 89.3 | 95.2 | 100.0 | 103.8 | 105.5 |
| Switz. | | | | | | 100.1 | 103.1 | 100 | 99.3 | |
| Finland | 85.3 | 86.3 | 88.4 | 90.4 | 92.4 | 94.7 | 98.1 | 100.0 | 102.7 | 104.1 |
| Sweden | 79.9 | 83.9 | 83.3 | 86.7 | 87.9 | 92.4 | 97.1 | 100.0 | 101.8 | 105.7 |
| UK | | 80.4 | 85.1 | 89.1 | 91.7 | 94.5 | 97.3 | 100.0 | 102.5 | 104.8 |
| Iceland | 76.9 | 79.5 | 81.2 | 82.8 | 84.2 | 86.1 | 92.5 | 100.0 | 102.3 | 105.4 |
| Norway | 80.4 | 81.8 | 84.0 | 86.2 | 90.5 | 93.5 | 97.0 | 100.0 | 103.1 | 106.8 |
| Bulgaria | | | 67.2 | 79.6 | 86.1 | 89.3 | 96.1 | 100.0 | 101.0 | 102.2 |
| Romania | | | | | | | 83.2 | 100.0 | 113.6 | 124.1 |

Source: Eurostat

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[13] Based on building construction costs.

**Table 9 Pre-Euro Exchange Rates and PPP Exchange rates (2002) - (EU25 = 1)**

| Country | **Eurozone Exchange Rates at time of joining Euro**[14] | **nominal exchange rate (currency:euro) 2002** | **PPP adjustment factor** | **PPP Exchange rates (2002)** |
|---|---|---|---|---|
| Austria | 13.760 | 1.000 | 1.043 | 1.043 |
| Belgium | 40.340 | 1.000 | 1.023 | 1.023 |
| Cyprus | N/A | 0.580 | 0.882 | 0.512 |
| Czech Rep | N/A | 30.804 | 0.537 | 16.531 |
| Denmark | N/A | 7.431 | 1.314 | 9.764 |
| Estonia | N/A | 15.647 | 0.556 | 8.700 |
| Finland | 5.946 | 1.000 | 1.120 | 1.120 |
| France | 6.560 | 1.000 | 1.043 | 1.043 |
| Germany | 1.956 | 1.000 | 1.111 | 1.111 |
| Greece | 340.750 | 1.000 | 0.785 | 0.785 |
| Hungary | N/A | 242.960 | 0.547 | 132.899 |
| Ireland | 0.788 | 1.000 | 1.161 | 1.161 |
| Italy | 1936.270 | 1.000 | 0.956 | 0.956 |
| Latvia | N/A | 0.581 | 0.508 | 0.295 |
| Lithuania | N/A | 3.459 | 0.479 | 1.658 |
| Luxembourg | 40.340 | 1.000 | 1.135 | 1.135 |
| Malta | N/A | 0.409 | 0.694 | 0.284 |
| Netherlands | 2.204 | 1.000 | 1.067 | 1.067 |
| Norway | N/A | 7.509 | 1.410 | 10.589 |
| Poland | N/A | 3.857 | 0.548 | 2.114 |
| Portugal | 200.482 | 1.000 | 0.763 | 0.763 |
| Slovak Rep | N/A | 42.694 | 0.440 | 18.770 |
| Slovenia | N/A | 225.977 | 0.740 | 167.223 |
| Spain | 166.386 | 1.000 | 0.861 | 0.861 |
| Sweden | N/A | 9.161 | 1.184 | 10.847 |
| Switzerland | N/A | 1.467 | 1.425 | 2.090 |
| UK | N/A | 0.629 | 1.124 | 0.707 |

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[14] At January 1st 2002

**Table 10** Forecast of average annual growth rates of GDP in EU countries (provisional figures)

| Country | Growth rate | | |
|---|---|---|---|
| | **2000-2010** | **2000-2020** | **2010-2020** |
| AU | 1.9% | 1.9% | 2.0% |
| BE | 2.0% | 2.0% | 2.0% |
| DK | 1.7% | 1.6% | 1.5% |
| FI | 2.3% | 2.1% | 1.9% |
| FR | 2.0% | 2.0% | 2.1% |
| GE | 1.2% | 1.5% | 1.7% |
| GR | 3.8% | 3.4% | 3.0% |
| IR | 5.0% | 4.3% | 3.5% |
| IT | 1.2% | 1.6% | 2.0% |
| LX | 4.1% | 4.4% | 4.8% |
| NL | 1.4% | 1.6% | 1.8% |
| PO | 1.3% | 2.0% | 2.8% |
| SP | 2.8% | 2.7% | 2.6% |
| SV | 2.4% | 2.4% | 2.3% |
| UK | 2.7% | 2.5% | 2.4% |
| CY | 3.7% | 3.6% | 3.5% |
| CZ | 3.4% | 3.4% | 3.3% |
| ES | 5.6% | 4.9% | 4.2% |
| HU | 3.7% | 3.5% | 3.2% |
| LA | 7.4% | 6.2% | 5.1% |
| LI | 6.5% | 5.7% | 4.9% |
| PD | 3.9% | 4.1% | 4.4% |
| SK | 4.6% | 4.5% | 4.3% |
| SN | 3.6% | 3.0% | 2.4% |
| EU25 | 2.0% | 2.1% | 2.2% |

Source: European Commission

# HEATCO – Deliverable 5, Annex C: Unreported accidents

## 1.1 Introduction

It is well known that not all road accidents are reported to the police. However, the usual data source for accidents is the police statistics. But if one takes the data on the injuries and fatalities from insurance companies and hospitals, the number of involved persons is much larger. Therefore the official (police) figures for accidents underestimate the true number of accidents, so that the official figures have to be corrected for unreported accidents.

When we speak of "unreported accidents" we mean unreported damage only accidents as well as unreported casualties from accidents.

According to the performas (see deliverable 1 of HEATCO) the vast majority of countries ignore non-reported accidents in evaluations of projects. Only three countries (Denmark, Sweden and Switzerland) correct for non-reported accidents. But while Germany does not correct for unreported accidents, a clear conclusion from the German study on unreported accidents is that official accident figures have to be corrected for unreported accidents.[1] We believe that unreported accidents should be included in careful evaluations because the number of injury accidents can easily be double as high as the police statistics show us.

While there is considerable literature on unreported road accidents, to our knowledge there is no – or almost no – literature on unreported accidents for other transport modes. For rail accidents it is sometimes stated that there are no unreported accidents or that only petty accidents – which can be neglected – are not reported:[2] In rail traffic accidents are hard to hide because they are often accompanied by (severe) delays of the concerned train and of other trains and because even single accidents are not only observed by only one (car or train) driver but by several people (passengers or rail company workers). Thus it is believed that unreported accidents in rail traffic can be neglected.[3]

For air and water traffic we could not find any literature at all. It can be expected that for air traffic there are also no unreported accidents (unless perhaps petty accidents) because of the mostly fatal consequences of an accident (even near misses are reported). For water accidents the lack of literature seems to indicate that unreported accidents are not relevant. Therefore we conclude that **underreporting of accidents is a road specific problem**. Thus in what follows we will only consider road accidents. Even if we tried to estimate the amount of underreporting for other transport modes (rail, air, water), this would not be possible, because there are no data which would allow such an estimation.

Most – but not all – road accidents have to be reported to the police. For example, in Switzerland, accidents with casualties or damages above 500 CHF (≈ 265 €) have to be reported.[4] In Norway, in contrast, damage only accidents do not have to be reported, only accidents with

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[1] Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden, p. 12.

[2] Suter et al. (2001), The Pilote Accounts of Switzerland – Appendix Report UNITE, p. 24.

[3] Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 32.

[4] Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 18-21.

an injury that is not inconsequential must be reported.[5] However, not all accidents are actually reported by the police. This is due to the following reasons:[6]

- people do not know or forget that they should report the accident to the police[7]
- the injury is not immediately detected (for example whiplash)
- minor injury (or assumed minor injury) (especially for single bicycle accidents)
- avoidance of inquiry by the police because of fear of prosecution (too high velocity, driving after drinking alcohol, etc.)
- accidents not occurring on a public road (in some countries as Norway)

Most of the unreported accidents are self-accidents (especially for bicyclists[8]).

Since all official accident figures are based on the number of accidents reported to the police, we must correct for the unreported accidents. In what follows we discuss how this can be done: We first examine the existing practice analysing how unreported accidents are estimated and showing the results which have been derived. Based on this we make some recommendations how unreported accidents should be treated in a European evaluation.

## 1.2 Existing Practice

### 1.2.1 Method of estimation

In several EU countries, mostly in the northern and western regions, clinical hospital data and sometimes also outpatient data on traffic injuries are linked with the police reported accident data on a national or regional level. This establishes the underreporting of registration of injury accidents by the police.[9] This is actually the case for the data for Denmark, Norway and Germany which will be discussed below. In Switzerland this estimation technique has only been used for senior citizens (above 65) and children (0-17). For the working age population another technique has been employed: All employed persons are insured against accidents. Therefore the number of injured people is taken form the insurance statistics and compared to the statistics from the police.[10]

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[5] If they involve at least one vehicle (bicycles count as vehicles) and occurs on a public road or an area open for public travel (Borger 1996, Problems in Traffic Accident Reporting).

[6] Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 18-21, Borger (1996), Problems in Traffic Accident Reporting, p. iv, Hvoslef et al. (1994), Under-Reporting of road traffic accidents recorded by the police, and Statistics Norway (2004), Road traffic accidents

[7] In Norway most road users are aware of the duty to report injury accidents to the police, but this duty is often forgotten (Borger 1996, Problems in Traffic Accident Reporting, p. iv).

[8] Hvoslef et al. (1994), Under-Reporting of road traffic accidents recorded by the police.

[9] European Transport Safety Council (2001), EU Transport accident, p. 12-13.

[10] Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 18-21.

The estimations in Switzerland are thought to be reliable, because about 80% of the accidents concern people in working age and the insurance statistics for this age group are very reliable.[11] In contrast, the data quality in Norway is limited. Thus although the sample size is rather large, several assumptions had to be applied for the estimations. Due to these assumptions it is believed that the actual factors in Norway should be higher than those estimated.[12]

Based on these data sources a **correction factor for unreported accidents** (= all accidents / reported accidents) can be calculated. However, not always are the results given in the form of the correction factor. Sometimes also the percentage of reported accidents is given (= reported accidents / all accidents) which is simply the inverse of the correction factor. The following table gives an overview of the results of different studies in different countries.

To calculate the cost of accidents we must multiply the number of accidents with the valuation of accidents. In order to consider unreported accidents the correction factor can either be applied to the number of accidents (or accident rate) or to the valuation. The first approach seems more natural, although the second approach is also used (for example in Denmark[13]).

All the countries in Table 1 are northern or western countries, because for the southern countries of the EU, no such studies on the completeness of the official registration of road accident injuries and fatalities are available.[14]

### 1.2.2 Discussion of Results

#### Fatalities

It is generally believed that all fatalities are registered. Nevertheless, some countries use a correction factor for unreported fatalities which is slightly above 1. Here the problem is not that fatalities are not reported, but that some people die after 30 days. But in the police statistics only the people dying within 30 days after the accident are reported as fatalities.

A French study (Laumon et al., 1997*)* for the region of Lyon established that as many as 12 per cent of fatalities were underreported in the official police based registration.[15] In Germany there is even a study which finds a correction factor for fatalities as high as 1.25.[16] However, based on a literature survey (including this study), another German study comes to the con

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[11] The factor for unreported accidents should deviate clearly less than 15% from the results of the study (Ecoplan 2002, Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 94).

[12] Borger (1996), Problems in Traffic Accident Reporting.

[13] Information by e-mail from COWI (Denmark) from 10.1.2005.

[14] European Transport Safety Council (2001), EU Transport accident, p. 12-13.

[15] European Transport Safety Council (2001), EU Transport accident, p. 12-13.

[16] Cited on p. 18 in Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden.

**Table 1: Overview of different correction factors for unreported accidents**

| country | differentiation | fatality | serious injury | slight injury | average injury | damage only | year | sample size |
|---|---|---|---|---|---|---|---|---|
| Sweden | National Road Administration | 1.00 | | | 2.4 | 7.0 | ? | ? |
| | average | | 3.19 | | | | 2004 | ? |
| | car | | 1.90 | | | | 2004 | ? |
| | motorbike/moped | | 3.68 | | | | 2004 | ? |
| | cyclist | | 7.20 | | | | 2004 | ? |
| | pedestrian | | 2.32 | | | | 2004 | ? |
| Denmark | | 1.00 | 2.23 | 10.38 | | | ? | 494 / 2532 |
| Norway | average | | X | 2.6 * X | ≥3.00 | | 1996 | 36'119 |
| | car | | | | ≥1.90 | | 1996 | 16'276 |
| | motorbike/moped | | | | ≥2.87 | | 1996 | 3'550 |
| | cyclist | | | | ≥13.49 | | 1996 | 12'801 |
| | pedestrian | | | | ≥2.44 | | 1996 | 2'903 |
| Switzerland | average | 1.02 | 1.89 | 4.11 | 3.64 | | 1998 | 80'460 |
| | average | | | | | 6.39 | 1991 | 493’178 |
| | car - all roads | 1.02 | | | 2.50 | | 1998 | 38'491 |
| | motorbike/moped - all roads | 1.02 | | | 4.61 | | 1998 | 23'763 |
| | cyclist - all roads | 1.02 | | | 8.00 | | 1998 | 26'412 |
| | pedestrian - all roads | 1.02 | | | 2.77 | | 1998 | 7'891 |
| | bus - all roads | 1.02 | | | 8.44 | | 1998 | 1'383 |
| | LGV/HGV - all roads | 1.02 | | | 3.78 | | 1998 | 2'436 |
| | car - not motorways | 1.02 | | | 2.81 | | 1998 | 38'491 |
| | motorbike/moped - not motorways | 1.02 | | | 4.66 | | 1998 | 23'763 |
| | cyclist - not motorways | 1.02 | | | 8.00 | | 1998 | 26'412 |
| | pedestrian - not motorways | 1.02 | | | 2.79 | | 1998 | 7'891 |
| | private bus - not motorways | 1.02 | | | 10.54 | | 1998 | 971 |
| | public bus - not motorways | 1.02 | | | 8.44 | | 1998 | 412 |
| | LGV/HGV - not motorways | 1.02 | | | 4.57 | | 1998 | 2'436 |
| Germany | average | ≤1.05 | 2.24 | 2.88 | 2.59 | | 1993 | ? |
| | car | | 1.75 | 2.05 | 1.92 | | 1993 | 1'629 |
| | motorbike/moped | | 2.00 | 2.50 | 2.29 | | 1993 | 1'210 |
| | cyclist | | 3.55 | 5.59 | 4.63 | | 1993 | 1'880 |
| | pedestrian | | 2.07 | 2.48 | 2.25 | | 1993 | 634 |
| | average | | | | | ≥2.00 | 1976 | ? |
| | damage 500-1000 € | | | | | 4.00 | 1985 | ? |
| | damage 1000-2500 € | | | | | 2.13 | 1985 | ? |
| | damage over 5000 € | | | | | 1.20 | 1985 | ? |
| UK | lower value | 1.00 | 1.10 | 1.22 | 1.16 | | ? | ? |
| | upper value | 1.00 | 1.18 | 1.43 | 1.33 | | ? | ? |

Shaded areas: These numbers are used in national evaluation frameworks. ? = Data not available.

Sources: *Sweden*: National Road Administration from performa, Larsson (2004), Bearbetning av patientstatistik för 1988-2001 avseende trafikskadade, p. 16 average for 1995-2001, *Denmark*: Source: Ulykkesgruppen - Odense universitetshospital, *Norway*: Borger (1996), Problems in Traffic Accident Reporting and own calculation, *Switzerland*: Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, for damage only figure: Ecoplan (1991), Soziale Kosten von Verkehrsunfällen in der Schweiz, p. 39, *Germany*: Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden, p. 3, 19 and own calculation from p.11 (weighted average for Bayern and other regions) and *UK*: Highway Agency (2001), Review of the Standards for the Provision of Nearside Safety Fences on Major Roads.

clusion that the correction factor for fatalities is less than 1.05.[17] In Switzerland a correction factor for unreported fatalities of 1.02 has been estimated from insurance statistics (of 597 fatalities). Thus due to deaths occurring after the first 30 days there are 2% more fatalities.[18]

### Injuries

As Table 1 shows the correction factor for unreported (average) injuries lies between 1.16 and 3.64. However, the differences between different vehicle types are large (factors up to 13.5 for cyclists). Moreover, some countries also differentiate between serious and slight injuries. As is to be expected the correction factor for unreported injuries falls with the severity of the accident. These factors will be analysed more closely below (see chapter 1.3.3).

There have also been attempts to analyse the correction factor for unreported injuries for different road types. In Switzerland it was assumed in the calculation of the results that the correction factor on motorways is 1.00 (for all vehicle categories) since it is hardly possible not to report an accident on a motorway (except perhaps petty accidents). In Norway accidents on national / county roads are 1.7 / 2.5 times less often reported than accidents on motorways.[19] In contrast, in Germany no difference between the correction factors for urban and non-urban accidents could be detected.[20] Overall, we must conclude that the evidence on correction factors for different road types is scarce and cannot be used to derive any recommendations for the EU. Thus **we must use the same factors for all road types**.

Another interesting piece of evidence comes from Norway where the correction factors is 2.1 for accidents involving motor vehicles (pedestrian – car, cyclist – motorcyclist, car alone etc.), but it is 65.8 for accidents not involving motor vehicles (cyclist – pedestrian, cyclist – cyclist, cyclist alone). Overall it is 3.0.[21]

### Damage only accidents

For damage only accidents the evidence on the correction factor for unreported accidents is rather scarce. For Germany there are two older studies (1976 and 1985) giving values of more than 2. A much higher correction factor of 7.0 is currently in use in Sweden. This correction factor is in line with an older study (1969) for Sweden giving a factor of 6.67.[22] In the new Swiss study there is no correction factor, but the costs of unreported accidents are in-

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[17] Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden, p. 3.

[18] Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 18-21.

[19] Borger (1996), Problems in Traffic Accident Reporting.

[20] Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden, p. 20.

[21] Borger (1996), Problems in Traffic Accident Reporting.

[22] Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden, p. 20.

cluded in the cost rate per reported accident.[23] In an older Swiss study a correction factor of 6.4 is estimated based on liability insurance statistics.[24]

## 1.3 Recommendations

After having given an overview of the existing practice in different countries in Europe, we are now going to derive some recommendations based on this evidence. Before doing so, however, we must discuss whether we should expect the correction factors for unreported accidents to be identical in all countries or whether they should differ. Then we discuss the correction factors for fatalities, injuries and damage only accidents in turn.

### 1.3.1 Differences between countries

In the literature the opinions on whether the correction factor is equal in all countries differ widely: Based on a literature overview a German study concludes that there are no fundamental differences between countries.[25] In contrast, another study concludes that the factor may vary widely between different Member States, so that it is obviously impossible to find a common European wide value.[26]

Looking at the underlying determinants of the level of reporting we should expect that the correction factor to differ between countries. The level of underreporting depends on a number of factors:[27]

- National factors connected to how accidents are defined, how serious the least reportable injury is etc. (see chapter 1.1).
- Differences in the local tradition for reporting accidents to the police.
- Organisation of the recording procedure.
- Bicycle accidents are often not reported and the amount of bicycle traffic varies between countries.

This is corroborated by the evidence in Table 1, which shows quite large differences between countries. Thus **each country has** a different reporting system and **different levels of underreporting**.[28] Therefore correction factors for unreported accidents ought to be developed by each individual country, because the rate of reporting can vary considerably from one

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[23] Ecoplan (2002), Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998, p. 108.

[24] Ecoplan (1991), Soziale Kosten von Verkehrsunfällen in der Schweiz, p. 39.

[25] Hautzinger et al. (1993), Dunkelziffer bei Unfällen mit Personenschaden, p. 22.

[26] Lindberg (1999), Calculating transport accident costs, p. 10.

[27] Hvoslef et al. (1994), Under-Reporting of road traffic accidents recorded by the police and own considerations.

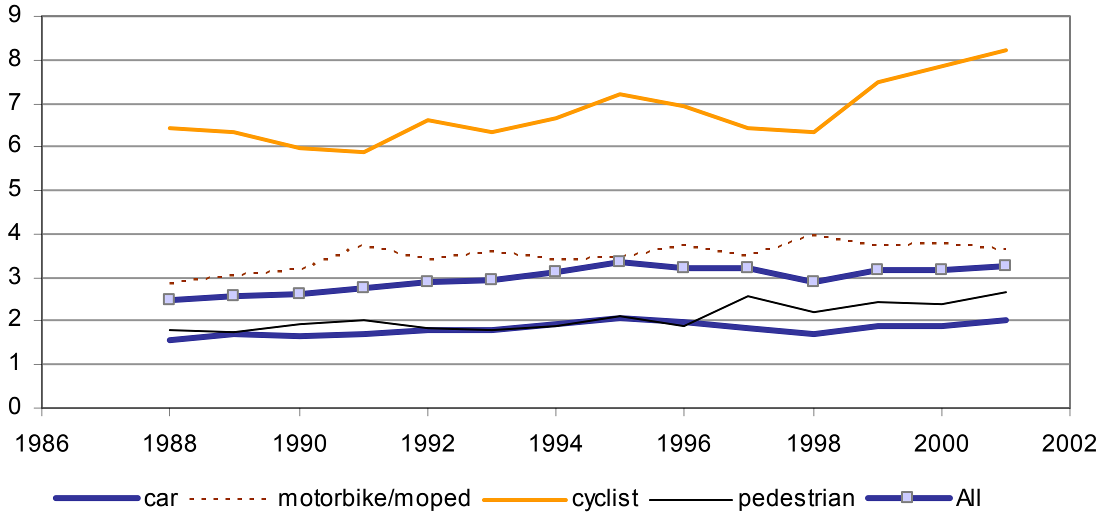
[28] European Transport Safety Council (2001), Assessing risk and setting targets in transport safety programmes, p. 13.

country to another.[29] However, the most important gaps in the existing EU accident data provision are in the areas of underreporting of single vehicle and injury accidents.[30]

Thus **whenever national values are available, these values should be used**. However, as we have seen in Table 1 only a few countries have national correction factors (Sweden, Denmark, Norway, Switzerland, Germany and the UK). For all the other countries there are no available data (to our knowledge). Therefore national studies should be started as soon as possible (especially in the southern part of Europe where numbers might be different and where no study exists to date). As long as no such studies are available, however, the assumption of a correction factor of 1 would be clearly misleading. Thus from the available evidence we must try to derive correction factors which can be applied in all EU countries without national studies. In deriving these numbers we are cautious in order not to overstate the problem of unreported accidents.

The problem of deriving a correction factor is further complicated by the fact that the correction factors do not have to be constant over time. The only analysis of the variation of the correction factor over time has been conducted in Sweden and shows that the correction factor for unreported accidents has increased by about 20% within 10 years (see following figure). Thus we should also use as actual figures as possible. In what follows we will nevertheless assume that the correction factor is constant over time because the evidence of one single study for one single country is not enough evidence for such an important adjustment.

**Figure 1: Development of the correction factor over time in Sweden**



Source: Own evaluation of data from Larsson (2004), Bearbetning av patientstatistik för 1988-2001 avseende trafikskadade, p. 16.

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[29] Hvoslef et al. (1994), Under-Reporting of road traffic accidents recorded by the police.

[30] European Transport Safety Council (2001), EU Transport accident, p. 10.

### 1.3.2 Fatalities

In Table 1 the correction factors of 1.00 mean that all fatalities dying within 30 days are reported. However, some casualties die only after these first 30 days. This has to be taken into account, since a fatality has much higher costs than a serious injury. Based on the available evidence we suspect the true correction factor lies between 1.00 and 1.05. Taking a cautious approach we choose a relatively small **correction factor for unreported fatalities** of **1.02** (see Table 2) – which is actually the correction factor derived in Switzerland. This value should be applied to **all countries** – even to those countries which explicitly state that the correction factor is 1.00. The reason for this is that here we are not dealing with the problem of underreporting which is different between countries, but with the problem of casualties dying after the first 30 days after the accident which we expect to be (about) equal in all countries.

### 1.3.3 Injuries

As mentioned we should use the actual corrections factor for the country under consideration if such correction factors exist. This is the case for Sweden, Denmark, Norway, Switzerland, Germany and the UK.

For all other countries we must derive European average corrections factors for unreported accidents. A fact which might complicate this task is that the available accident data might not be the same in all countries. Some countries might differentiate between serious and slight injuries while others do not. Therefore we have to provide factors for serious, slight and average injuries.

Looking at Table 1 we draw the following conclusions:

- When deriving a correction factor for an average injury we see that the correction factor varies between 1.25 in the UK, 2.4 in Sweden, 2.6 in Germany, ≥3 in Norway and 3.6 in Switzerland. Thus a cautious estimation for a European average is 2.25 (see Table 2).
- When we look at the correction factors for serious and average accidents we realize that the correction factor for average injuries is higher by a factor of 1.1 – 1.3 in Germany and the UK, but by a factor of 1.9 in Switzerland.[31] Thus we take 1.5 as a European average. Given the value of 2.25 for an average injury, this leads to a correction factor for serious injuries of 1.5.
- Finally, the correction factor for slight accidents is higher than for serious accidents by a factor of 1.1 – 1.6 in Germany and the UK, but by a much higher factor in Switzerland, Norway and Denmark (2.2, 2.6 or even 4.7). Based on these figures we assume that an European average is about 2.0, i.e. that the correction factor is double as high for slight injuries than for serious injuries. Thus the estimated correction factor for serious injuries is 3.0.

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[31] These figures cannot be seen directly from Table 1, but are derived from the figures in Table 1.

Compared with the values in Table 1 the estimates of the correction factor for serious injuries of 1.5 and for slight injuries of 3.0 are (well) below the estimation for Sweden, Denmark, Norway and Switzerland (up to a factor of 3.5 below the actual values) and thus they are below the values which are actually in use in Europe. They are broadly in line with the German estimates (too low for serious and average injuries, but to high for slight injuries). However, they are too high compared to the estimate for the UK which lies much below the numbers for the other countries. Finally, these factors are in line with earlier estimates of a European average which give factors of about 1.43 (1.25 – 1.67) for serious accidents and about 2.5 for slight accidents.[32]

**Table 2: Recommendation for European average correction factors for unreported 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 |

For some projects it might be important to differentiate between different vehicle types. To derive values for different vehicle types from Table 1 we have started with the average values derived above and have then taken the deviation from this average for different vehicle types averaging over the different country results for vehicle types.[33] The results are shown in Table 2: The deviation of the correction factor from 1 is half as large for cars than for an average accident (1.25 instead of 1.5). For pedestrians the deviation of the correction factor from 1 is 0.7 times that of the average. In contrast, the correction factor for motorbikes / mopeds and especially for bicycles is higher than the average. The result for bicycles of a correction factor for an average injury of 5.38 is in line with another conclusion for a European average (factor 5[34]).

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[32] Lindberg (1999), Calculating transport accident costs, p. 10 and European Transport Safety Council (2001), EU Transport accident, p. 12-13.

[33] We have first calculated for the different countries the deviation from a correction factor of 1 for a vehicle category relative to the average (for example car Sweden: (1.90-1) / (3.19-1) = 0.41). Then we have taken the average over the four countries with data (Sweden, Norway, Switzerland and Germany (first taking an average for the three result for Germany), for cars the average is 0.502) and have rounded this value (for cars 0.5). Then this rounded adjustment factor has been applied to the average values in Table 2.

[34] European Transport Safety Council (2001), EU Transport accident, p. 12-13.

### 1.3.4 Damage only accidents

There are only a few estimates for the corrections factor for unreported damage only accidents (see Table 1). One estimate is rather old (1976) and inconclusive (≥2), another estimate of 6.4 from Switzerland is also a bit old (1991), but the third estimate of 7.0 is currently used in Sweden. It must be expected that damage only accidents are less often reported than slight injury accidents. Therefore we would expect the correction factor to lie above the factor for slight injuries of 3.0. Since we are trying to select a cautious European average, we take a correction factor of 6.0.

It should be mentioned that it may not be possible to apply damage only correction factors in all countries since in certain countries there are no data on damage only accidents.

## 1.4 Conclusion

Underreporting is a road-specific problem which is not observed for other transport modes. In road traffic we must apply a correction factor for unreported accidents (= all accidents / reported accidents). The number of reported accidents must be increased by this factor.

These correction factors are likely to be different in different countries. Whenever national estimates for correction factors are available, we should therefore use these national factors. However, such factors are only existing for 6 countries (Sweden, Denmark, Norway, Switzerland, Germany and UK, see Table 1). For all other countries we are forced to use an average value derived from the results from these 6 countries. Our cautious estimates of the average correction factors for unreported accidents are given in Table 2. For average injuries the factor is 2.25, meaning that less than half of all injury accidents are actually reported to the police. For fatalities the correction factor is 1.02. The factor for fatalities should be applied in all countries alike, since here the problem is not underreporting, but that some accidents casualties die only after the first 30 days after the accident.

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# Derivation of fall-back values for impact and cost factors for airborne pollutants

## Annex D to HEATCO Deliverable 5

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# 1. Introduction

The following document describes the derivation of the country-specific impact factors and fall-back values for air pollution damages, which are recommended in HEATCO. The methodology is explained in chapter 1, the computer model used is described in chapter 2. Chapters 3 and 4 give the exposure-response functions and monetary values that were used to calculate the fall-back values, which are reported in chapter 5.

# 2. Methodology for the Estimation of Typical Damage Costs

## 2.1. General methodology

Environmental costs from transport activities cover a broad range of different impacts, including the various impacts of emissions of a large number of pollutants on human health, materials, ecosystems, flora and fauna. Impacts occur at the local, regional, European and global scale; damages caused by transport activities may be instantaneous, but also extend far into the future - up to several hundreds of years. The methods used to estimate environmental costs must be able to address these different scales, and it is furthermore necessary to select the most important among the large number of pollutants and damage categories for further analysis.

Most of the impacts of transport-related air pollutant emissions are highly site-specific; the most obvious example is the emission of fine particles: primary particles emitted in densely populated areas affect many people and thus causes much higher impacts than particles emitted in sparsely populated areas. Furthermore, damage costs vary considerably with the characteristics of the vehicles, trains, vessels or aircraft. A detailed bottom-up approach is required to be able to consider technology and site specific parameters, and variations of costs with time (in the case of noise: day time versus night time noise).

The so-called Impact Pathway Approach (IPA) was designed to meet these requirements. The general idea of monetising environmental (incl. health) costs resulting from building and use of transport infrastructure based on welfare economics is illustrated in Figure 2.1. A transport activity causes changes in environmental pressures (e.g. air pollutant emissions), which are dispersed, leading to changes in environmental burdens and associated impacts on various receptors, such as human beings, crops, building materials or ecosystems (e.g. emissions of air pollutants leading to respiratory diseases). This change in impacts leads either directly or indirectly (e.g. through health effects caused by air pollutants) to a change in the utility of the affected persons. Welfare changes resulting from these impacts are transferred into monetary values. Based on the concepts of welfare economics, monetary valuation follows the approach of 'willingness-to-pay' for improved environmental quality. It is obvious that not all impacts can be modelled for all pollutants in detail. For this reason the most important pollutants and damage categories (so-called "priority impact pathways") are selected for detailed analysis.

One of the strengths and main principles of the IPA is the valuation of damages (e.g. additional respiratory hospital admissions) and not pressures or effects (e.g. emissions of fine particles). The monetary valuation of concrete casualties (e.g. hospital admissions) is more reliable and transparent than deriving a general willingness-to-pay for reducing air pollution.

The IPA was developed, made operational by providing the models required on each stage and updated for air pollution impacts in the ExternE project series (see e.g. Friedrich and Bickel, 2001; European Commission, 1999 and 2005). Models for assessing impacts from noise were provided in the projects UNITE (see Bickel et al., 2003) and RECORDIT (see Schmid et al., 2001).

Many of the impact pathways include non-linearities, due to air chemistry for example, therefore impacts and costs from two scenarios are calculated: a reference scenario reflecting the base case concerning the amount of pollutants or noise emitted, and a modified scenario, which is based on the reference scenario, but with changes in emissions due to the activity considered. For the marginal analysis this may be an additional vehicle, for the sectoral analysis this may be the emissions from a whole transport sector in one country. The difference in physical impacts and resulting damage costs of both scenarios represents the effect of the activity considered.

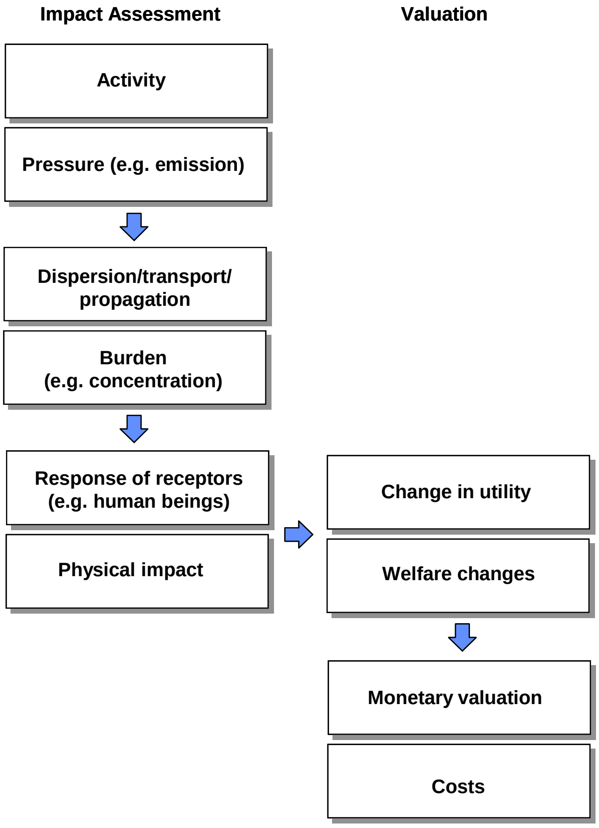

**Figure 2.1** The Impact Pathway Approach for the quantification of environmental costs.

This principle of modelling the pressure (e.g. emissions), resulting burden (e.g. pollutant concentration increase), response of receptors (e.g. health damages, annoyance caused by noise) and monetary valuation can and should be applied for all impact categories. The main bottleneck of this procedure is the availability of the models required for the different stages. For instance the assessment of impacts due to climate change is very challenging and damage cost estimates show a high uncertainty range. In this case it appears appropriate to apply a second best approach and to analyse preferences revealed in (political) decisions. The (avoidance) costs to reach a socially accepted target can be used as a proxy for society's willingness-to-pay to avoid the risks of climate change impacts.

It is important to note, that, although only changes of one specific road or route segment may be considered, the pollutant or noise emissions from all other sources and the background burden influence the change due to non-linearities and therefore have to be accounted for in the framework. If emissions of pollutants and noise that occur in the future (or the past) have to be assessed, scenarios of the emissions and concentrations of pollutants at that time have to be used.

The principle of the Impact Pathway Approach can be applied to all modes. The character of a burden may differ by mode, as e.g. for noise: roads usually cause a rather constant noise level, while noise from railway lines and airports is characterised by single events with high noise levels. Such differences have to be taken into account and the models used on the respective stage have to be adjusted accordingly. The application of the same approach for all modes ensures consistency of the resulting estimates.

Carrying out bottom-up calculations for every potential transport infrastructure project appears unrealistic due to the amount of data and time required. Hence, we suggest to use simplified relationships between environmental costs and the most relevant parameters (which are the amount of pollutants emitted, the height of the emission source, the geographical location within Europe and the character of the local environment around the emission source). These values should, however, be based on the Impact Pathway Approach with consistent sets of dose-response functions and monetary values as given e.g. in European Commission (2005). The following section explains the principle of deriving fall-back values.

## 2.2. Estimating typical damage costs from emission changes

Impacts and damages due to emissions of whole countries or economic sectors are calculated based on comparing two scenarios: a reference scenario including all emissions for one year and a scenario in which the emissions of the considered sector or country are subtracted from the reference scenario. The difference in the resulting damages between the two scenarios is interpreted as the damage costs caused by the emission of the respective country or economic sector. Figure 2.1. shows the emissions and damage costs estimated for the source sector 'Public Power, Commercial, and District Heating Plants' in Germany for illustration.

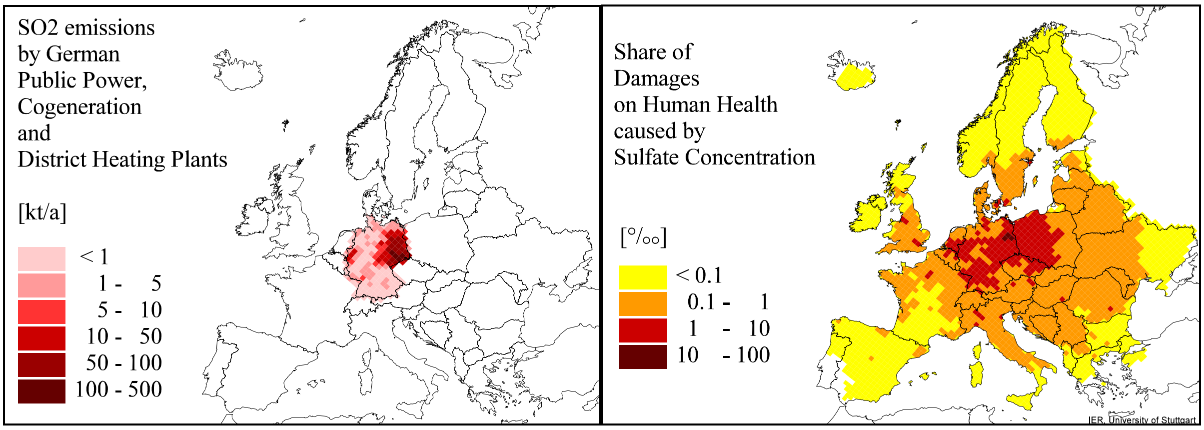

**Figure 2.2** $SO_2$ emissions of the German economic sector 'Public Power, Commercial, and District Heating Plants' distributed to the EMEP 50 grid and the shares of estimated physical impacts and damage costs on human health caused by sulphate concentration resulting from these emissions (Droste-Franke et al. 2004).

For the estimation of the damage factors in HEATCO the anthropogenic emissions in the respective countries in 1998 were increased by ten percent and compared to the unchanged scenario. Following this approach, the background concentrations caused by the remaining emissions are taken into account for each calculation. This is an important issue, as the considered chemical reactions are non-linear and depend on the available concentrations of reacting components in the atmosphere. In this way the average damage costs per tonne of emission for the next ten percent of emissions are estimated.

Impacts on human health due to primary particle emissions close to the emission sources and resulting costs were derived based on sector and population density specific estimates from a number of calculations and results within former EC projects (Droste-Franke and Friedrich 2003, Link et al. 2001, Preiss et al. 2004, Schmid et al. 2001).

# 3. The model system used

EcoSense is an integrated software tool developed for the assessment of environmental impacts and damage costs from electricity generation systems and other economic activities. EcoSense provides the main relevant data and models required for an integrated impact pathway assessment related to airborne pollutants.

The emission sources are distinguished by administrative region, economic activity and emission height (more or less than 100m above ground). By changing emission data in the inventory e.g. for a sector or country and comparing the results for the changed inventory with the unchanged, environmental damage cost caused by multiple sources can be assessed. The multi-source version was originally developed by IER in order to estimate environmental damages as contribution to environmental accounting (Droste-Franke et al. 2004). This version of EcoSense was applied to assess typical damage costs per tonne of emission. As mentioned above, effects due to primary particle emissions in the local environment around the sources were considered by using additionally site specific factors derived from a number of runs with local dispersion models.

## 3.1. Structure of the EcoSense System

Figure 3.1 shows the general structure of the EcoSense system. The main modules are

- a database system comprising several sub-modules,
- air transport models completely integrated into the system,
- impact assessment modules, and
- tools for the evaluation and presentation of results.

An important feature of the system design was the strict separation between the database module and the air transport modeling/impact assessment modules in order to be flexible with respect to further improvement and extension of EcoSense, e.g. in the area of the air quality models applied. Major advantages of the integration of the different models and data in one software tool is the provision of a comprehensive set of data and a consistent data management on all levels of the analysis (input data, intermediate results, final results).

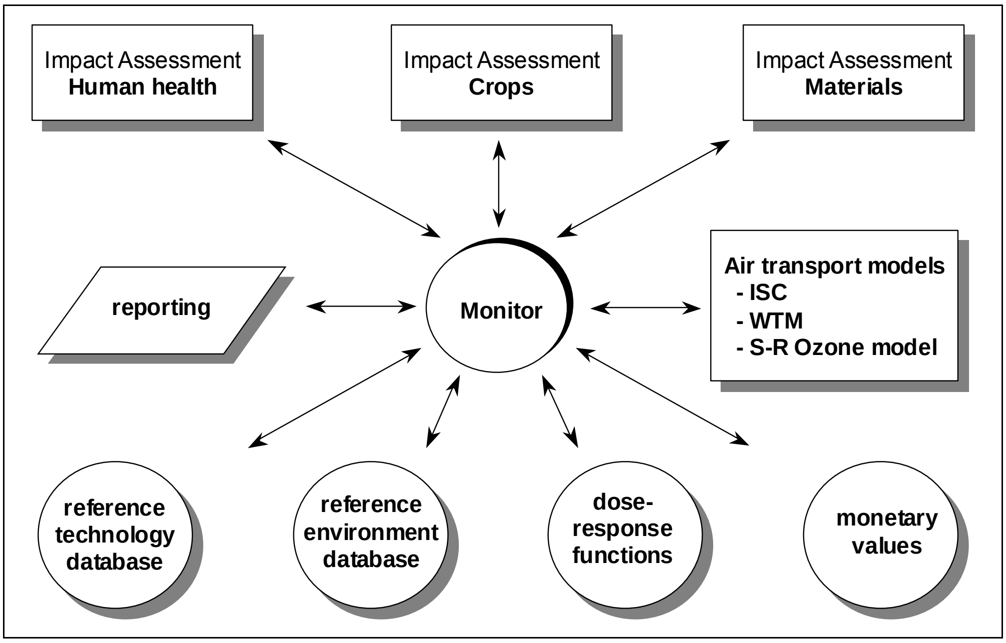

**Figure 3.1** Modular structure of the EcoSense model

### The Modelling Grid

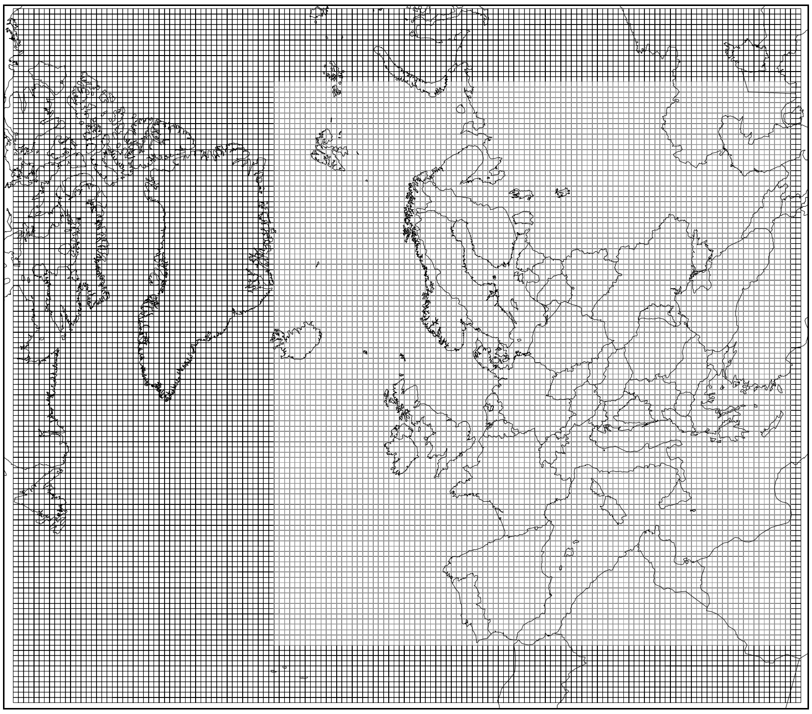

**Figure 3.2** Domains of the WTM-modelling grid for EcoSense Europe. Grey: Impact assessment modelling domain; black + grey: Air quality modelling domain

Air quality modelling and impact assessment are carried out on a regular grid, the EMEP 50 standard grid. It is defined as a 50 to 50 $km^2$ grid in its original polar stereographic projection. The grid extension is shown in Figure 3.2. Within the model it is distinguished between an air quality modelling domain (151*133 grid cells, dark shaded area) and a smaller impact assessment domain (99*108 grid cells, light shaded area). This approach avoids cut-off effects at the border of the air quality domain.

### Baseline Emission Data for EcoSense Multi-Source Version

The basic requirements for baseline emission data are a sufficient geographical resolution in terms of administrative units and at least a rough subdivision into source sectors. Furthermore, because of the non-linearity of the processes leading to the formation of secondary particles and ozone, the database should ideally contain all emissions of air pollutants in one year for the whole modelling domain.

In order to meet all the mentioned requirements, a detailed scenario including emissions of the pollutants in focus, $SO_2$, $NO_X$, $NH_3$, NMVOC, $PM_{10}$, and CO, was generated from published emission databases for the year 1998 and implemented into EcoSense. For a more detailed description see Droste-Franke and Friedrich (2003).

Starting point for deriving the emission inventory for 1998 was the CORINAIR 1990 emission database which shows a high resolution in both, economic source sectors and administrative units: Spatially and sectorally less detailed, but more current data sources like CORINAIR 1994 and EMEP 1998 were used to rescale the emissions of $SO_2$, $NO_X$, $NH_3$, and NMVOC at the resolution of country and main sector level (McInnes 1996, Richardson 1999, Vestreng 2001). Large structural changes in the German emissions between 1990 and 1998, were corrected on the level of main source sectors using data from (Wickert 2001). For emissions of primary particles ($PM_{10}$) the data situation is different. An applicable European emission database for $PM_{10}$ was only available for the year 1995. It was derived by TNO within the Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance (CEPMEIP) (TNO 2002). These published emission data on $PM_{10}$ are given only for whole countries and the main source sectors. In order to provide a database with more details in administrative and sector units, they were distributed in relation to emissions of substances which are supposed to have the most similar emission pattern in the respective source sector. For combustion related processes $SO_2$ emissions, for transport related processes $NO_X$ emissions and for production processes and solvent use NMVOC emission were taken (Pregger 2002).

**Table 3.1** The implemented main sectors of the 'Selected Nomenclature for Air Pollution' (SNAP)

| SNAP number | Name of Source Sector |
|---|---|
| 1 | Public power, cogeneration and district heating plants |
| 2 | Commercial, institutional, and residential combustion plants |
| 3 | Industrial combustion |
| 4 | Production processes |
| 5 | Extraction and distributions of fossil fuels |
| 6 | Solvent use |
| 7 | Road transport |
| 8 | Other mobile sources and machinery |
| 9 | Waste treatment and disposal |
| 10 | Agriculture |
| 11 | Nature |

The geographical resolution of the used inventory is as far as possible municipalities or level 3 expressed in the official 'NUTS' (Nomenclature of Territorial Units for Statistics). The source sectors considered in the emission database are the ten main source sectors of the widely-used 'Selected Nomenclature for Air Pollution' (SNAP) which are listed in Table 3.1.

### Meteorological and Receptor Data

Data sets on the meteorology across Europe are used as input especially for the Windrose Trajectory Model (WTM) (description see below). The data include wind speed, wind direction, and precipitation for the years 1990 and 1998 on the EMEP 50×50 $km^2$ grid.

The receptor data are originally given on administrative units (NUTS). Meteorological data was taken from EMEP for the year 1998.

**Table 3.2** Reference environment data included in the EcoSense database

| | Resolution | Source |
|---|---|---|
| **Receptor distribution** | | |
| Population | Admininistrative Units, EMEP 50×50 $km^2$ | EUROSTAT REGIO |
| Production of wheat, barley, sugar beat, potato, oats, rye, rice, tobacco, sunflower | Admininistrative Units, EMEP 50×50 $km^2$ | EUROSTAT REGIO |
| Inventory of natural stone, sandstone, zinc, galvanised steel, mortar, rendering, paint | Admininistrative Units, EMEP 50×50 $km^2$ | Extrapolation based on inventories of some European cities |
| **Meteorological data** | | |
| Wind speed | EMEP 50×50 $km^2$ | EMEP |
| Wind direction | EMEP 50×50 $km^2$ | EMEP |
| Precipitation | EMEP 50×50 $km^2$ | EMEP |
| **Emissions** | | |
| $SO_2$, $NO_x$, $NH_3$ , NMVOC in 1998 | EMEP 50×50 $km^2$ | EMEP, CORINAIR 1990/94 |

### Air Quality Modelling

The air quality models applied for the damage estimations are the Windrose Trajectory Model (WTM) and the Source Receptor Ozone Model (SROM). The WTM is a user-configurable trajectory model based on the Windrose approach of the Harwell Trajectory Model developed at Harwell Laboratory, UK (Derwent et al. 1988, Derwent and Nodop 1986). The implemented chemical mechanisms are shown in Figure 3.3.

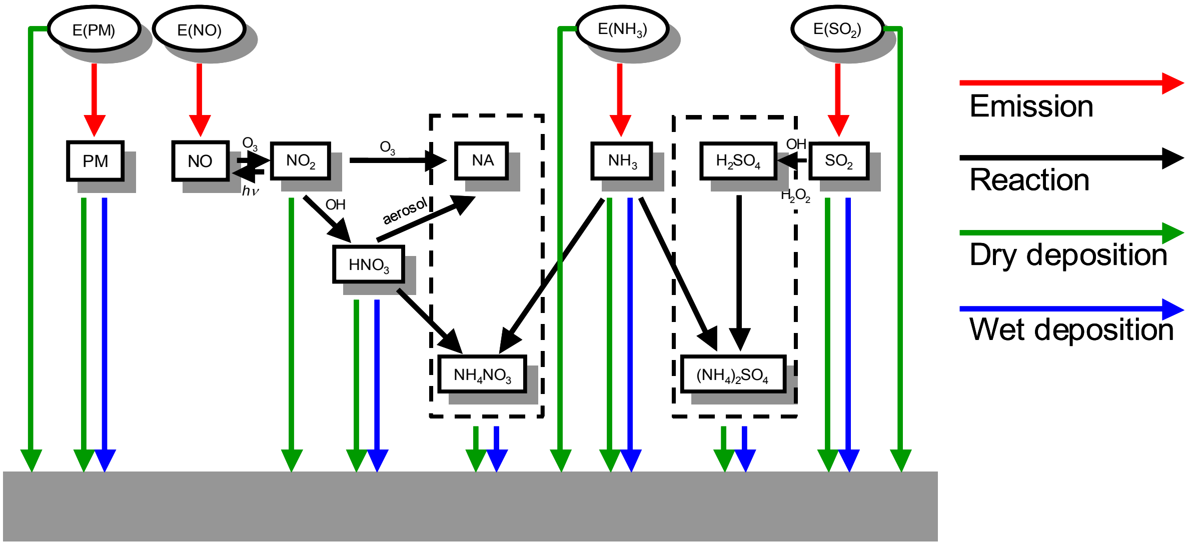

**Figure 3.3** Scheme of reactions implemented in the WTM model (Trukenmüller 2003)

The Source Receptor Ozone Model is a model which estimates ozone concentration by using source-receptor matrices. These were derived from results of the EMEP Ozone Model for different reduction scenarios (Simpson et al. 1997). The model is based on the EMEP iteration model developed by David Simpson (Simpson and Eliassen 1997).

More detailed information on the used models can be found in the publications to the ExternE projects (European Commission 1999a, European Commission 1999b, Friedrich and Bickel 2001).

# 4. Exposure-Response Functions

The exposure-response functions (ERF) used in the calculations are described in the following. More detailed descriptions can be found in the methodology descriptions of the ExternE project series in European Commission (1995, 1999a, 2005) and Friedrich and Bickel (2001).

## 4.1. Impact Assessment for Crops

**Effects from $SO_2$**

The function for effects from $SO_2$, recommended in ExternE is adapted from one derived by Baker et al. (1986). The function assumes that yield will increase with $SO_2$ from 0 to 6.8 ppb, and decline thereafter. The function is used to quantify changes in crop yield for wheat, barley, potato, sugar beet, and oats, and is defined as

$$y = 0.74 \cdot [SO_2] - 0.55 \cdot [SO_2]^2 \qquad \text{for } 0 < [SO_2] < 13.6 \text{ ppb}$$
$$y = -0.69 \cdot [SO_2] + 9.35 \qquad \text{for } [SO_2] > 13.6 \text{ ppb}$$

with $y$ = relative yield change
$[SO_2]$ = $SO_2$-concentration in ppb

**Effects from Ozone**

For the assessment of ozone impacts, a linear relation between yield loss and the AOT 40 value (Accumulated Ozone concentration above a Threshold of 40 ppbV) calculated for the growth period of crops (May to June) is assumed (Fuhrer 1996). The relative yield change is calculated using the following equation together with the sensitivity factors given in Table 4.1:

$$y = 99.7 - \alpha \cdot AOT40_{crops}$$

with $y$ = relative yield change
$\alpha$ = sensitivity factors

**Table 4.1** Sensitivity factors for different crop species

| **Sensitivity** | **$\alpha$** | **Crop species** |
|---|---|---|
| Slightly sensitive | 0.85 | rye, oats, rice |
| Sensitive | 1.7 | wheat, barley, potato, sunflower seed |
| Very sensitive | 3.4 | tobacco |

### Acidification of Agricultural Soils

An upper bound estimate of the amount of lime required to balance atmospheric acid inputs on agricultural soils across Europe is estimated. Ideally, the analysis of liming would be restricted to non-calcareous soils, but this refinement has not been introduced given that even the upper bound estimate of additional liming needs is small compared to other externalities. The additional lime required is calculated as:

$$\Delta L = 50 \text{ kg/meq} \cdot A \cdot \Delta D_A$$

with $\Delta L$ = additional lime requirement in kg/year
$A$ = agricultural area in ha
$\Delta D_A$ = annual acid deposition in meq/m$^2$/year

### Fertilisation Effects from Nitrogen Deposition

Nitrogen is an essential plant nutrient, applied by farmers in large quantity to their crops. The deposition of oxidised nitrogen to agricultural soils is thus beneficial (assuming that the dosage of any fertiliser applied by the farmer is not excessive). The reduction in fertiliser requirement is calculated as:

$$\Delta F = 14.0067 \text{ g/mol} \cdot A \cdot \Delta D_N$$

with $\Delta F$ = reduction in fertiliser requirement in kg/year
$A$ = agricultural area in km$^2$
$\Delta D_N$ = annual nitrogen deposition in meq/m$^2$/year

## 4.2. Impact Assessment for Building Material

The exposure-response functions used for impact assessment and recommended for ExternE (Friedrich and Bickel 2001) are listed below for different building materials. Apart from the exposure-response functions for carbonate paint (Haynie 1986), all are based on results from the UN-ECE ICP Materials (Kucera et al. 1997).

In a two-step approach, the exposure-response functions link the ambient concentration or deposition of pollutants to the rate of material corrosion, and the rate of corrosion to the exposure time of the material. Performance requirements determine the point at which replacement or maintenance is considered to become necessary. This point is given in terms of critical degradation. By entering the critical degradation into the formula and solving the equation for the reciprocal exposure time, the maintenance frequency is calculated.

**Limestone**

surface recession: $R = (2.7[SO_2]^{0.48}e^{-0.018T} + 0.019Rain[H^+]) \cdot t^{0.96}$

maintenance frequency: $1/t = [\,(2.7[SO_2]^{0.48}e^{-0.018T} + 0.019Rain[H^+])/R_{crit}\,]^{1/0.96}$

| | | |
|---|---|---|
| with | $R$ | surface recession in µm |
| | $1/t$ | maintenance frequency in 1/a |
| | $[SO_2]$ | $SO_2$ concentration in µg/m$^3$ |
| | $T$ | temperature in °C |
| | Rain | precipitation in mm/a |
| | $[H^+]$ | hydrogen ion concentration in precipitation in mg/l |
| | $R_{crit}$ | critical surface recession, European average value of 4000 µm |

**Sandstone, Natural Stone, Mortar, Rendering**

surface recession: $R = (2.0[SO_2]^{0.52}e^{f(T)} + 0.028Rain[H^+]) \cdot t^{0.91}$

maintenance frequency: $1/t = [\,(2.0[SO_2]^{0.52}e^{f(T)} + 0.028Rain[H^+])/R_{crit}\,]^{1/0.91}$

| | | |
|---|---|---|
| with | $R$ | surface recession in µm |
| | $1/t$ | maintenance frequency in 1/a |
| | $[SO_2]$ | $SO_2$ concentration in µg/m$^3$ |
| | $T$ | temperature in °C |
| | $f(T)$ | $f(T) = 0$ if $T < 10$ °C; $f(T) = -0.013(T-10)$ if $T > 10$ °C |
| | $t$ | time in years |
| | Rain | precipitation in mm/a |
| | $[H^+]$ | hydrogen ion concentration in precipitation in mg/l |
| | $R_{crit}$ | critical surface recession, European average value of 4000 µm |

**Zinc and Galvanised Steel**

mass loss: $ML = 1.4[SO_2]^{0.22}e^{0.018Rh}e^{f1(T)}t^{0.85} + 0.029Rain[H^+]t$

maintenance frequency: $1/t = 0.14[SO_2]^{0.26}e^{0.021Rh}e^{f2(T)}/R_{crit}^{1.18} + 0.0041Rain[H^+]/R_{crit}$

| | | |
|---|---|---|
| with | $ML$ | mass loss in g/m$^2$ |
| | $1/t$ | maintenance frequency in 1/a |
| | $[SO_2]$ | $SO_2$ concentration in µg/m$^3$ |
| | Rh | relative humidity in % |
| | $T$ | temperature in °C |
| | $f1(T)$ | $f1(T) = 0.062(T-10)$ if $T < 10$ °C; $f(T) = -0.021(T-10)$ if $T > 10$ °C |
| | $f2(T)$ | $f2(T) = 0.073(T-10)$ if $T < 10$ °C; $f(T) = -0.025(T-10)$ if $T > 10$ °C |
| | $t$ | time in years |
| | Rain | precipitation in mm/a |
| | $[H^+]$ | hydrogen ion concentration in precipitation in mg/l |
| | $R_{crit}$ | critical surface recession, country-specific values |

**Paint on Steel**

degradation rating: $A = (0.033[SO_2] + 0.013Rh + f(T) + 0.0013Rain[H^+])t^{0.41}$

maintenance frequency: $1/t = [\,(0.033[SO_2] + 0.013Rh + f(T) + 0.0013Rain[H^+])/A_{crit}\,]^{1/0.41}$

| | | |
|---|---|---|
| with | $A$ | degradation rating, originally A=(10-ASTM), with ASTM representing a rating between 1 and 10 (10 = unexposed) |
| | $1/t$ | maintenance frequency in 1/a |

| | |
|---|---|
| $[SO_2]$ | $SO_2$ concentration in µg/m$^3$ |
| Rh | relative humidity in % |
| T | temperature in °C |
| | f(T)f(T) = 0.015(T-11) if T < 11 °C; f(T) = -0.15(T-11) if T > 11 °C |
| Rain | precipitation in mm/a |
| $[H^+]$ | hydrogen ion concentration in precipitation in mg/l |
| $A_{crit}$ | the rating at which maintenance should occur, European value: 5 |

**Paint on Galvanised Steel**

degradation rating: $A = (0.0084[SO_2] + 0.015Rh + f(T) + 0.00082Rain[H^+])t^{0.43}$

maintenance frequency: $1/t = [ (0.0084[SO_2] + 0.015Rh + f(T) + 0.00082Rain[H^+])/A_{crit} ]^{1/0.43}$

| | | |
|---|---|---|
| with | A | degradation rating, originally A=(10-ASTM), with ASTM representing a rating between 1 and 10 (10 = unexposed) |
| | 1/t | maintenance frequency in 1/a |
| | $[SO_2]$ | $SO_2$ concentration in µg/m$^3$ |
| | Rh | relative humidity in % |
| | T | temperature in °C |
| | f(T) | f(T) = 0.04(T-10) if T < 10 °C; f(T) = -0.064(T-10) if T > 10 °C |
| | Rain | precipitation in mm/a |
| | $[H^+]$ | hydrogen ion concentration in precipitation in mg/l |
| | $A_{crit}$ | the rating at which maintenance should occur, European value: 5 |

**Carbonate Paint**

material loss: $R = 0.12 (1 - \exp(-0.121Rh/(100-Rh)))[SO_2] + 0.0174Rain[H^+]$

maintenance frequency: $1/t = (0.12 (1 - \exp(-0.121Rh/(100-Rh)))[SO_2] + 0.0174Rain[H^+])/R_{crit}$

| | | |
|---|---|---|
| with | R | annual surface recession in µm/a |
| | 1/t | maintenance frequency in 1/a |
| | $[SO_2]$ | $SO_2$ concentration in µg/m$^3$ |
| | Rh | relative humidity in % |
| | Rain | precipitation in mm/a |
| | $[H^+]$ | hydrogen ion concentration in precipitation in mg/l |
| | $R_{crit}$ | critical surface recession, country specific values |

## 4.3. Impact Assessment for Human Health

The assessed effects on human health and the applied concentration-response functions (CRF) are given in The terms ‘acute’ and ‘chronic’ relate to the time over which exposure to air pollution is relevant. ‘Acute’ relates to short-term exposures, hence ‘acute mortality’ relates to deaths that are brought forward as a result of pollution exposure over a period of days. ‘Chronic’ relates to problems of long-term exposure.

Table 3.2. The CRF were taken from European Commission (2005), where references to the underlying studies are given.

The terms ‘acute’ and ‘chronic’ relate to the time over which exposure to air pollution is relevant. ‘Acute’ relates to short-term exposures, hence ‘acute mortality’ relates to deaths that are brought forward as a result of pollution exposure over a period of days. ‘Chronic’ relates to problems of long-term exposure.

**Table 3.2** Concentration-Response functions for human health impacts due to air pollution according to the most current recommendations of the ExternE team (European Commission 2005). The exposure response slope, $f_{er}$, has units of [cases/(year · person · $\mu g/m^3$)] for morbidity and chronic mortality, and [%change in annual mortality rate/($\mu g/m^3$)] for acute mortality. PM10 given as annual mean concentrations, $O_3$ as seasonal 6-h-average concentration.

| **Health Effect** | **Pollutant**[a] | **Concentration Response Factor** | **Risk Group** |
|---|---|---|---|
| Acute mortality - Years of life lost due to acute exposure | $O_3$ | 0.03% | All |
| Chronic mortality - Years of life lost (YOLL) due to chronic exposure | PM10 | 4.00E-04 | All |
| New cases of chronic bronchitis | PM10 | 2.65E-05 | Age > 27 |
| Respiratory hospital admissions | $O_3$ | 1.25E-05 | Age > 65 |
|  | PM10 | 7.03E-06 | All |
| Attributable emergency cardiac hospital admissions | PM10 | 4.34E-06 | All |
| Restricted activity days | PM10 | 5.41E-02 | Age 15 to 64 |
| Minor restricted activity days | $O_3$ | 1.15E-02 | Age 18 to 64 |
| Cough days | $O_3$ | 9.30E-02 | Age 5 to 14 |
| Symptom days (Lower respiratory symptoms including cough) | $PM_{10}$ | 1.30E-01 | Age > 18 with chronic respiratory symptoms |
| Days of Lower respiratory symptoms (excluding cough) | $O_3$ | 1.60E-02 | Age 5 to 14 |
| Days of Lower respiratory symptoms, including cough, in children in the general population, i.e. extra symptoms days | PM10 | 1.86E-01 | Age 5 to 14 |
| Days of bronchodilator use | $O_3$ | 7.30E-02 | Age > 20 with asthma |
|  | PM10 | 9.12E-02 | Age > 20 with asthma |
|  | PM10 | 1.80E-02 | Age 5 to 14 with asthma |

[a] the PM10 values can be directly applied on secondary sulfate aerosols. Before they are applied to nitrates, the values have to be divided by a factor of two. For application to $PM_{2.5}$ from combustion processes the $PM_{10}$ values have to be multiplied by 2.5.

The functions given in The terms ‘acute’ and ‘chronic’ relate to the time over which exposure to air pollution is relevant. ‘Acute’ relates to short-term exposures, hence ‘acute mortality’ relates to deaths that are brought forward as a result of pollution exposure over a period of days. ‘Chronic’ relates to problems of long-term exposure.
Table 3.2 are applied to different risk groups of the population. The shares of population representing the different groups are given in Table 3.3.

**Table 3.3** Share of population representing the risk groups for the health effects

| **Risk Group** | **Share of EU population** |
|---|---|
| Age 5 to 14 | 11 % |
| Age 15 to 64 | 67 % |
| Age 18 to 64 | 64 % |
| Age > 27 | 70 % |
| Age > 65 | 14 % |
| Age > 18 with chronic respiratory symptoms | 25 % |
| Age 5 to 14 with asthma | 2 % |
| Age > 20 with asthma | 4 % |

# 5. Monetary Values used for Economic Valuation

Table 4.1. shows the monetary values used for the evaluation of the damage costs. The values are based on European Commission (2005), converted to €$_{2002}$ factor costs using the average rate of indirect taxation in the Eurozone and the harmonised index of consumer prices given in HEATCO Annex B to Deliverable 5 (Tables 6 and 7). In agreement with the practice of the UNITE project (see Nellthorp et al. 2001) damages in the country where the emission takes place are valued with the "local" value, damages in other countries were valued with the European average values given below. For deriving local values it was assumed that the willingness-to-pay varies according to the GDP per capita in the different countries, i.e. local value = European value / GDP per capita in EU25 * GDP per capita in study country.

**Table 4.1** Monetary values (European average) used for economic valuation (€$_{2002}$ factor costs)

| Impact | €$_{2002}$ per unit |
|---|---|
| **Human health, effects in respective units** | |
| Acute mortality - Years of life lost due to acute exposure | 60500 |
| Chronic mortality - Years of life lost (YOLL) due to chronic exposure | 40300 |
| New cases of chronic bronchitis | 153000 |
| Hospital admissions (respiratory and attributable emergency cardiac) | 1900 |
| Restricted activity days | 76 |
| Minor restricted activity days; cough days; symptom days (lower respiratory symptoms including cough); days of lower respiratory symptoms (excluding cough); days of lower respiratory symptoms, including cough, in children in the general population, i.e. extra symptoms days | 31 |
| Days of bronchodilator usage | 1.0 |
| **Crops, yield loss in decitonnes** | |
| Barley – yield loss | 6.3 |
| Oats – yield loss | 6.6 |
| Potato – yield loss | 9.6 |
| Rice – yield loss | 254.9 |
| Rye – yield loss | 18.3 |
| Sugar beet – yield loss | 6.6 |
| Sunflower seed – yield loss | 25.8 |
| Tobacco – yield loss | 3414 |
| Wheat – yield loss | 11.3 |
| Fertiliser | 53 |
| Lime | 1.8 |
| **Material, maintenance area in m$^2$** | |
| Galvanised steel | country specific (14 – 45) |
| Limestone | 299 |
| Mortar | 33 |
| Natural stone | 299 |
| Paint | 13 |
| Rendering | 33 |
| Sandstone | 299 |
| Zinc | 27 |

# 6. Results

Table 6.1 and Table 6.3 present cost factors in € per tonne of pollutant emitted by road and other ground level transport (e.g. diesel trains) and power plants (high stack emissions)[1]. The estimates are based on EcoSense calculations for ground level and high stack emissions respectively, using 1998 background emissions and meteorology as described in chapter 2. The values include estimates for local effects of $PM_{2.5}$ for transport and $PM_{10}$ for high stack emissions, the character of the local environment in terms of population density close to the emission source was assumed to be urban and outside urban areas. Table 6.5 and Table 6.6 show the corresponding impact factors in years of life lost per 1000 tonnes of pollutant emitted. Impacts (in years of life lost) and costs (in €) have to be calculated separately, applying the impact factors (Table 6.5 and Table 6.6) and the cost factors (Table 6.1 and Table 6.3) to the amount of pollutant emitted.

**Table 6.1** Cost factors for road transport emissions* per tonne of pollutant emitted in $€_{2002}$ (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **Effective pollutant** | **$O_3$, Nitrates, Crops** | **$O_3$** | **Sulphates, Acid deposition, Crops** | **$PM_{2.5}$** | |
| **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.

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[1] Table 6.2 and Table 6.4 give the corresponding values in PPP.

The PPP adjusted values in Table 6.2 differ from the values in Table 6.1 only for costs due to primary particle emissions. $NO_x$, NMVOC and $SO_2$ have virtually no local effects as most of their impact is caused after chemical transformation to other substances (ammoniumnitrates and –sulfates, 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 €. The same applies for Table 6.4 and Table 6.3 respectively. For the latter, differences are very small as the local share of impacts is much smaller for high level emission sources.

**Table 6.2** Cost factors for road transport emissions* per tonne of pollutant emitted in $€_{2002}$ PPP (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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.

The variation of the values presented in Table 6.1 to Table 6.6 illustrates the site specificity of the damage caused. Depending on meteorological conditions, background emissions and air chemistry processes, as well as population affected a unit of pollutant emitted may cause very different costs. Costs due to $NO_x$ emissions include damages caused by nitrates (secondary particles), ozone, nitrogen and acid deposition. NMVOC causes damages via ozone formation. For $SO_2$ damages arise from sulphates (secondary particles), acid deposition and directly on crops. Damages from primary particle emissions are given in the column “$PM_{2.5}$” and “$PM_{10}$” respectively.

The numbers provided 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 $SO_2$ between countries is mainly caused by air chemistry (incl. ozone formation) and the population affected. For primary particles no air chemistry is involved, therefore differences reflect the population affected, which is determined mainly by distance to the emission source and the prevailing wind direction.

**Table 6.3** Cost factors for electricity production emissions* per ton of pollutant emitted in €$_{2002}$ (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{2.5}$** | |
|---|---|---|---|---|---|
| **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 | 4,200 | 15,000 | 12,000 |
| Belgium | 2,700 | 1,100 | 5,700 | 17,000 | 14,000 |
| Cyprus** | 500 | 1,100 | 400 | 3,000 | 2,000 |
| Czech Republic | 2,900 | 1,100 | 4,200 | 9,000 | 8,000 |
| Denmark | 1,900 | 800 | 2,100 | 9,000 | 5,000 |
| Estonia | 1,400 | 500 | 1,200 | 3,000 | 2,000 |
| Finland | 900 | 200 | 800 | 6,000 | 3,000 |
| France | 4,800 | 800 | 4,400 | 14,000 | 11,000 |
| Germany | 2,800 | 1,100 | 4,300 | 12,000 | 9,000 |
| Greece | 2,300 | 600 | 1,200 | 4,000 | 3,000 |
| Hungary | 5,100 | 800 | 4,300 | 8,000 | 7,000 |
| Ireland | 1,800 | 400 | 1,600 | 8,000 | 4,000 |
| Italy | 3,000 | 1,600 | 1,700 | 9,000 | 7,000 |
| Latvia | 1,800 | 500 | 1,500 | 3,000 | 2,000 |
| Lithuania | 2,600 | 500 | 1,900 | 3,000 | 3,000 |
| Luxemburg | 4,700 | 1,400 | 5,200 | 17,000 | 12,000 |
| Malta ($O_3$ estimated) | 500 | 1,100 | 400 | 3,000 | 1,000 |
| Netherlands | 2,600 | 1,000 | 5,500 | 18,000 | 14,000 |
| Poland | 3,000 | 800 | 3,800 | 9,000 | 8,000 |
| Portugal | 2,500 | 1,000 | 1,700 | 6,000 | 5,000 |
| Slovakia | 4,600 | 1,100 | 4,000 | 7,000 | 6,000 |
| Slovenia | 4,400 | 700 | 4,200 | 7,000 | 6,000 |
| Spain | 2,400 | 500 | 1,900 | 6,000 | 4,000 |
| Sweden | 1,100 | 300 | 1,000 | 7,000 | 3,000 |
| Switzerland | 4,600 | 600 | 4,200 | 18,000 | 13,000 |
| United Kingdom | 1,400 | 700 | 3,000 | 13,000 | 10,000 |

Notes: Cost categories included are: human health, crop losses, material damages.
* Values are applicable to high stack emissions from power plants.
** Estimated values as Cyprus outside of modelling domain.

**Table 6.4** Cost factors for electricity production emissions* per ton of pollutant emitted in €$_{2002}$ PPP (factor prices).

| **Pollutant emitted** | **$NO_x$** | **NMVOC** | **$SO_2$** | **$PM_{10}$** | **$PM_{10}$** |
|---|---|---|---|---|---|
| Effective pollutant | $O_3$, Nitrates, Crops | $O_3$ | Sulphates, Acid deposition, Crops | $PM_{10}$ | $PM_{10}$ |
| Local environment | | | | urban | outside built-up areas |
| Austria | 4,300 | 600 | 4,200 | 15,000 | 12,000 |
| Belgium | 2,700 | 1,100 | 5,700 | 17,000 | 14,000 |
| Cyprus** | 500 | 1,100 | 400 | 4,000 | 2,000 |
| Czech Republic | 2,900 | 1,100 | 4,200 | 10,000 | 9,000 |
| Denmark | 1,900 | 800 | 2,100 | 8,000 | 5,000 |
| Estonia | 1,400 | 500 | 1,200 | 4,000 | 3,000 |
| Finland | 900 | 200 | 800 | 6,000 | 3,000 |
| France | 4,800 | 800 | 4,400 | 14,000 | 11,000 |
| Germany | 2,800 | 1,100 | 4,300 | 12,000 | 9,000 |
| Greece | 2,300 | 600 | 1,200 | 5,000 | 3,000 |
| Hungary | 5,100 | 800 | 4,300 | 9,000 | 7,000 |
| Ireland | 1,800 | 400 | 1,600 | 7,000 | 4,000 |
| Italy | 3,000 | 1,600 | 1,700 | 10,000 | 7,000 |
| Latvia | 1,800 | 500 | 1,500 | 3,000 | 2,000 |
| Lithuania | 2,600 | 500 | 1,900 | 4,000 | 3,000 |
| Luxemburg | 4,700 | 1,400 | 5,200 | 16,000 | 12,000 |
| Malta ($O_3$ estimated) | 500 | 1,100 | 400 | 4,000 | 2,000 |
| Netherlands | 2,600 | 1,000 | 5,500 | 17,000 | 14,000 |
| Poland | 3,000 | 800 | 3,800 | 9,000 | 8,000 |
| Portugal | 2,500 | 1,000 | 1,700 | 7,000 | 5,000 |
| Slovakia | 4,600 | 1,100 | 4,000 | 8,000 | 7,000 |
| Slovenia | 4,400 | 700 | 4,200 | 8,000 | 6,000 |
| Spain | 2,400 | 500 | 1,900 | 6,000 | 4,000 |
| Sweden | 1,100 | 300 | 1,000 | 6,000 | 3,000 |
| Switzerland | 4,600 | 600 | 4,200 | 16,000 | 12,000 |
| United Kingdom | 1,400 | 700 | 3,000 | 13,000 | 10,000 |

Notes: Cost categories included are: human health, crop losses, material damages.
* Values are applicable to high stack emissions from power plants.
** Estimated values as Cyprus outside of modelling domain.

**Table 6.5** 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** | **$SO_2$** | **$PM_{2.5}$** | **$PM_{2.5}$** |
|---|---|---|---|---|---|
| Effective pollutant | $O_3$, Nitrates | $O_3$ | Sulphates | $PM_{2.5}$ | $PM_{2.5}$ |
| 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.

**Table 6.6** Impact factors for electricity production emissions* (lost life expectancy in years of life lost per 1000 tonnes of pollutant emitted).

| **Pollutant emitted** | **NO$_x$** | **NMVOC** | **SO$_2$** | **PM$_{10}$** | **PM$_{10}$** |
|---|---|---|---|---|---|
| Effective pollutant | O$_3$, Nitrates | O$_3$ | Sulphates | PM$_{10}$ | PM$_{10}$ |
| Local environment | | | | urban | outside built-up areas |
| Austria | 62 | 0.6 | 62 | 210 | 180 |
| Belgium | 57 | 1.3 | 84 | 250 | 210 |
| Cyprus** | 9 | 0.5 | 7 | 60 | 30 |
| Czech Republic | 46 | 1.0 | 60 | 180 | 140 |
| Denmark | 31 | 0.9 | 31 | 100 | 70 |
| Estonia | 18 | 1.5 | 18 | 80 | 50 |
| Finland | 12 | 0.2 | 11 | 70 | 40 |
| France | 67 | 0.8 | 67 | 200 | 170 |
| Germany | 48 | 1.2 | 62 | 180 | 140 |
| Greece | 21 | 0.2 | 17 | 80 | 50 |
| Hungary | 63 | 0.6 | 62 | 160 | 120 |
| Ireland | 28 | 0.7 | 25 | 90 | 50 |
| Italy | 47 | 0.8 | 26 | 140 | 100 |
| Latvia | 22 | 0.9 | 22 | 80 | 50 |
| Lithuania | 29 | 0.9 | 28 | 90 | 60 |
| Luxemburg | 70 | 1.5 | 77 | 220 | 180 |
| Malta (O$_3$ estimated) | 9 | 0.5 | 7 | 60 | 30 |
| Netherlands | 55 | 1.1 | 81 | 250 | 220 |
| Poland | 45 | 0.8 | 53 | 170 | 140 |
| Portugal | 25 | 0.5 | 27 | 110 | 80 |
| Slovakia | 57 | 1.0 | 57 | 150 | 120 |
| Slovenia | 62 | 0.5 | 62 | 130 | 100 |
| Spain | 30 | 0.4 | 29 | 90 | 60 |
| Sweden | 14 | 0.4 | 14 | 70 | 40 |
| Switzerland | 70 | 0.7 | 64 | 220 | 190 |
| United Kingdom | 31 | 1.0 | 45 | 180 | 150 |

Notes: * Values are applicable to high stack emissions from power plants.
** Estimated values as Cyprus outside of modelling domain.

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# Derivation of fall-back values for impacts due to noise

## Annex E to HEATCO Deliverable 5

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# 1 Introduction

The following document describes the derivation of the impact factors and country-specific fall-back values for noise, which are recommended in HEATCO.

The perception of sound follows a logarithmic scale, which results in considerable non-linearities of the impacts and associated costs due to a change in noise levels (in the following we refer to the equivalent noise level $L_{Aeq}$). The background noise level plays an important role: whereas in a quiet neighbourhood (40 dB(A)) an additional 40 dB(A), i.e. a doubling of the noise, results in a total level of 43 dB(A), the same noise increment of 40 dB(A) only leads to a total noise level of 60.04 dB(A) in a noisy environment with a background noise level of 60 dB(A). Besides this peculiarity of energetic addition of noise levels the perception, in particular the disturbance caused by changes in the noise level have to be considered. This, together with the very local character of noise makes impact assessment a challenging task; and the models used to quantify noise exposure must be able to map the environment (receptors, buildings), the vehicle technology (PC, HGV etc.) and the traffic situation (e.g. speed and traffic volume) adequately.

The general procedure for taking into account the site and technology specific characteristics is the same as for air pollution: Two scenarios are calculated: a reference scenario reflecting the present situation with traffic volume, speed distribution, vehicle technologies etc., and the case scenario which is based on the reference scenario, but includes the changes due to the project alternative considered. The difference in damage costs between both scenarios represents the noise costs due to the project assessed. It is important to quantify total exposure levels and not only exposure increments, because for certain impacts thresholds have to be considered. For instance, some exposure-response functions for health impacts are applicable only above a threshold of 70 dB(A) (see De Kluizenaar et al., 2001).

Depending on the exposure-response relationships available different noise indicators are required for the quantification of impacts. Examples of indicators that are commonly used are equivalent noise levels for different times of day, e.g. $L_{Aeq}$(7.00-19.00), $L_{Aeq}$(19.00-23.00), $L_{Aeq}$(23.00-7.00) and the compound day-evening-night noise indicator $L_{DEN}$ (see European Commission, 2000 for details on noise indicators). Usually noise levels are calculated as incident sound at the façade of the buildings

## 2 Noise impacts

Two major impacts are usually considered when assessing noise impacts:

- Annoyance, reflecting the disturbance which individuals experience when exposed to (traffic) noise.
- Health impacts, related to the long term exposure to noise, mainly stress related health effects like hypertension and myocardial infarction.

It can be assumed that these two effects are independent, i.e. the potential long term health risk is not taken into account in people's perceived noise annoyance.

A large amount of scientific literature on health and psychosocial effects considering a variety of potential effects of transport noise is available. For instance, De Kluizenaar et al. (2001) reviewed the state of the art, reporting risks due to noise exposure in the living environment. They identified quantitative functions for relative and absolute risks for the effect categories presented in Table 2.1.

**Table 2.1** Categorisation of effects and related impact categories (source: De Kluizenaar et al., 2001).

| Category | Measure given | Impacts |
|---|---|---|
| Stress related health effects | RR | Hypertension and ischemic heart disease |
| Psychosocial effects | AR | Annoyance |
| Sleep disturbance | AR | Awakenings and subjective sleep quality |
| RR = relative risk; AR = absolute risk | | |

A more recent study undertaken in Switzerland (Bundesamt für Raumentwicklung, 2004) reviewed additional empirical studies and concluded that for impacts from road and rail noise only few evidence has emerged in addition to De Kluizenaar et al. (2001)[1], which was the basis for calculations in the UNITE project (see Bickel et al. 2003).

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[1] Bundesamt für Raumentwicklung (2004, p. 71)

To avoid double counting due to expected overlaps in annoyance and sleep disturbance, the latter was not considered for deriving fall-back values.

**Table 2.2** Exposure-response functions for health effects from noise considered.

| | Relative risk (de Kluizenaar et al. 2001) | Base risk | Survival probability | Specific endpoint | Impact per case |
|---|---|---|---|---|---|
| Myocard infarction Threshold: 70 dB(A) | $(0.5 + 0.008 * L_{den})$ | 0.005 | 0.7 | expected cases | |
| | | | | years of life lost | 7 years of life lost |
| | | | | days in hospital | 18 days in hospital |
| | | | | days absent from work | 70 days absent from work |
| Angina pectoris (hosp. admission) Threshold: 70 dB(A) | $(0.5 + 0.008 * L_{den})$ | 0.0015 | | expected cases | |
| | | | | days in hospital | 14 days in hospital |
| | | | | days absent from work | 58 days absent from work |
| Hypertension (hospital admission) Threshold: 70 dB(A) | $(0.5 + 0.007 * L_{den})$ | 0.0015 | | | 17 days in hospital |

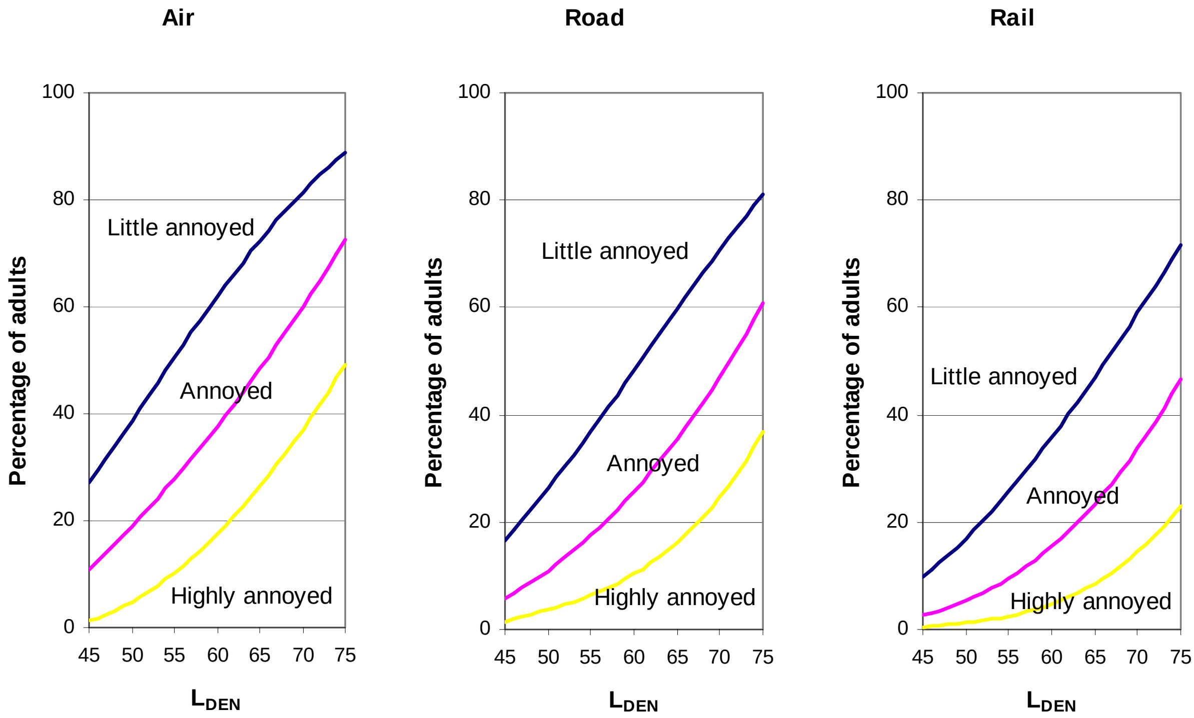

**Figure 2.1** Percentage of adult population feeling little annoyed, annoyed and highly annoyed as a function of noise levels (source: European Commission 2002).

Figure 2.1 shows the exposure-response functions predicting annoyance reactions on the population level as recommended by European Commission (2002). The impact indicator recommended is the number of persons highly annoyed, which can be calculated using the percentages given in Table 2.3.

**Table 2.3** Impact indicator for noise exposure: percentage of adult persons highly annoyed per person (all ages) exposed – based on functions in European Commission (2002), assuming 80% of population are adults.

| $L_{den}$<br>(dB(A)) | Road<br>% | Rail<br>% | Aircraft<br>% |
|---|---|---|---|
| ≥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 |

# 3 Monetary Valuation

## 3.1 Health effects

The monetary values applied for health effects are based on European Commission (2005), converted to €$_{2002}$ factor costs using the average rate of indirect taxation in the Eurozone and the harmonised index of consumer prices given in HEATCO Annex B to Deliverable 5 (Tables 6 and 7). For deriving country-specific values it was assumed that the willingness-to-pay varies according to the GDP per capita in the different countries, i.e. country value = European value / GDP per capita in EU25 * GDP per capita in study country.

**Table 3.1** Monetary values (European average) for valuing health effects (€$_{2002}$ factor costs)

| Impact | €$_{2002}$ per unit |
|---|---|
| Year of life lost (YOLL) due to long-term exposure | 40300 |
| Hospital day | 310 |
| Hospital day cardiology | 590 |
| Absentee costs per day | 84 |

## 3.2 Annoyance

Given its high importance for the results and the challenges in its measurement, the value of annoyance caused by noise requires particular consideration. The main cost component of annoyance is disutility experienced, for which no market exists. Stated preference (SP) and revealed preference (RP) methods have been employed to estimate the economic value of changes in noise levels. The noise valuation literature is dominated by Hedonic Price (HP) studies (most of them old) on road traffic and aircraft noise of varying quality. HP studies analyse the housing market to explore the extent to which differences in property prices reflect individuals´ willingness-to-pay (WTP) for lower noise levels. Resulting values seem to be problematic to transfer, however, both theoretically and in practice (Day 2001).

The number of SP studies on road traffic noise is increasing, but only a few present WTP in terms of "euro per annoyed person per year" for different annoyance levels (little annoyed, annoyed and highly annoyed), which correspond to the endpoints of exposure-response functions. Due to the low number of studies that can be used for this approach, a "second-best" alternative was to evaluate the SP studies available with regards to quality (e.g. avoid using studies with scenarios based on changes in exposure rather than annoyance and health impacts), choose the best ones, and calculate a value in terms of "euro per dB per person per year". This was done by Navrud (2002) to establish an EU-value.

The country-specific "central values" per person exposed to a certain noise level given in Table 3.3 (€$_{2002}$) and in Table 3.4 (€$_{2002}$ PPP) comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003) and quantifiable costs of health effects.

To enable the application of the exposure-response functions predicting annoyance reactions on the population level as recommended by European Commission (2002), HEATCO's Work

Package 5 carried out stated preference surveys in five European countries (see Navrud et al. 2006). Based on surveys in Germany, Hungary, Norway, Spain, Sweden and the UK, values for application in Europe were derived for the annoyance levels highly annoyed, annoyed and little annoyed. As these values are still subject to peer review, they are recommended for sensitivity analysis ("new approach" – see Table 3.5 and Table 3.6). The same is the case for the values based on hedonic pricing studies as applied in UNITE (see Bickel et al. 2003) – the "high values" given in Table 3.7. and Table 3.8

**Table 3.2** Annual willingness-to-pay for reducing annoyance per person per dB (€$_{2002}$ factor costs) applied for deriving central values, new approach and high values.

| | **Central values** | **New approach** | **High values** |
|---|---|---|---|
| All modes | 8.0[1] | | 18.4[1] |
| Road, aircraft – little annoyed | | 30 | |
| Road, aircraft – annoyed | | 68 | |
| Road, aircraft – highly annoyed | | 68 | |
| Rail – little annoyed | | 30 | |
| Rail – annoyed | | 48 | |
| Rail – highly annoyed | | 48 | |

[1] Threshold for road and aircraft: 50 dB(A), rail: 55 dB(A)

**Table 3.3** Cost factors (Central values) for noise exposure (€$_{2002}$, factor costs, per year per person exposed).

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 10 | 0 | 16 | 10 | 0 | 15 | 6 | 0 | 9 | 3 | 0 | 5 | 13 | 0 | 20 | 2 | 0 | 3 | 10 | 0 | 16 |
| ≥52 | 21 | 0 | 32 | 19 | 0 | 30 | 12 | 0 | 18 | 6 | 0 | 9 | 26 | 0 | 40 | 4 | 0 | 6 | 20 | 0 | 32 |
| ≥53 | 31 | 0 | 48 | 29 | 0 | 45 | 18 | 0 | 27 | 9 | 0 | 14 | 39 | 0 | 60 | 6 | 0 | 10 | 31 | 0 | 47 |
| ≥54 | 41 | 0 | 64 | 39 | 0 | 60 | 24 | 0 | 37 | 12 | 0 | 18 | 52 | 0 | 80 | 8 | 0 | 13 | 41 | 0 | 63 |
| ≥55 | 52 | 0 | 80 | 48 | 0 | 75 | 29 | 0 | 46 | 15 | 0 | 23 | 64 | 0 | 100 | 10 | 0 | 16 | 51 | 0 | 79 |
| ≥56 | 62 | 10 | 96 | 58 | 10 | 90 | 35 | 6 | 55 | 18 | 3 | 27 | 77 | 13 | 120 | 12 | 2 | 19 | 61 | 10 | 95 |
| ≥57 | 72 | 21 | 112 | 67 | 19 | 104 | 41 | 12 | 64 | 21 | 6 | 32 | 90 | 26 | 140 | 14 | 4 | 22 | 71 | 20 | 110 |
| ≥58 | 83 | 31 | 128 | 77 | 29 | 119 | 47 | 18 | 73 | 23 | 9 | 36 | 103 | 39 | 160 | 16 | 6 | 26 | 81 | 31 | 126 |
| ≥59 | 93 | 41 | 144 | 87 | 39 | 134 | 53 | 24 | 82 | 26 | 12 | 41 | 116 | 52 | 180 | 19 | 8 | 29 | 92 | 41 | 142 |
| ≥60 | 103 | 52 | 160 | 96 | 48 | 149 | 59 | 29 | 91 | 29 | 15 | 46 | 129 | 64 | 200 | 21 | 10 | 32 | 102 | 51 | 158 |
| ≥61 | 114 | 62 | 176 | 106 | 58 | 164 | 65 | 35 | 100 | 32 | 18 | 50 | 142 | 77 | 220 | 23 | 12 | 35 | 112 | 61 | 174 |
| ≥62 | 124 | 72 | 192 | 116 | 67 | 179 | 71 | 41 | 110 | 35 | 21 | 55 | 155 | 90 | 240 | 25 | 14 | 38 | 122 | 71 | 189 |
| ≥63 | 134 | 83 | 208 | 125 | 77 | 194 | 77 | 47 | 119 | 38 | 23 | 59 | 168 | 103 | 260 | 27 | 16 | 41 | 132 | 81 | 205 |
| ≥64 | 144 | 93 | 224 | 135 | 87 | 209 | 82 | 53 | 128 | 41 | 26 | 64 | 181 | 116 | 280 | 29 | 19 | 45 | 143 | 92 | 221 |
| ≥65 | 155 | 103 | 240 | 144 | 96 | 224 | 88 | 59 | 137 | 44 | 29 | 68 | 193 | 129 | 300 | 31 | 21 | 48 | 153 | 102 | 237 |
| ≥66 | 165 | 114 | 256 | 154 | 106 | 239 | 94 | 65 | 146 | 47 | 32 | 73 | 206 | 142 | 320 | 33 | 23 | 51 | 163 | 112 | 252 |
| ≥67 | 175 | 124 | 272 | 164 | 116 | 254 | 100 | 71 | 155 | 50 | 35 | 77 | 219 | 155 | 340 | 35 | 25 | 54 | 173 | 122 | 268 |
| ≥68 | 186 | 134 | 288 | 173 | 125 | 269 | 106 | 77 | 164 | 53 | 38 | 82 | 232 | 168 | 360 | 37 | 27 | 57 | 183 | 132 | 284 |
| ≥69 | 196 | 144 | 304 | 183 | 135 | 284 | 112 | 82 | 173 | 56 | 41 | 87 | 245 | 181 | 380 | 39 | 29 | 61 | 193 | 143 | 300 |
| ≥70 | 206 | 155 | 320 | 193 | 144 | 298 | 118 | 88 | 183 | 59 | 44 | 91 | 258 | 193 | 400 | 41 | 31 | 64 | 204 | 153 | 316 |
| ≥71 | 274 | 222 | 393 | 256 | 208 | 367 | 156 | 127 | 224 | 78 | 63 | 112 | 342 | 278 | 491 | 55 | 44 | 78 | 270 | 219 | 388 |
| ≥72 | 291 | 240 | 416 | 272 | 224 | 388 | 166 | 137 | 237 | 83 | 68 | 118 | 364 | 299 | 520 | 58 | 48 | 83 | 287 | 236 | 410 |
| ≥73 | 308 | 257 | 439 | 288 | 240 | 410 | 176 | 147 | 251 | 88 | 73 | 125 | 385 | 321 | 549 | 61 | 51 | 88 | 304 | 253 | 433 |
| ≥74 | 326 | 274 | 462 | 304 | 256 | 431 | 186 | 156 | 264 | 93 | 78 | 131 | 407 | 343 | 577 | 65 | 55 | 92 | 321 | 270 | 456 |
| ≥75 | 343 | 291 | 485 | 320 | 272 | 452 | 196 | 166 | 277 | 98 | 83 | 138 | 429 | 364 | 606 | 68 | 58 | 97 | 338 | 287 | 478 |
| ≥76 | 360 | 309 | 508 | 336 | 288 | 474 | 206 | 176 | 290 | 103 | 88 | 145 | 450 | 386 | 635 | 72 | 62 | 101 | 355 | 305 | 501 |
| ≥77 | 378 | 326 | 531 | 352 | 304 | 495 | 215 | 186 | 303 | 107 | 93 | 151 | 472 | 407 | 663 | 75 | 65 | 106 | 372 | 322 | 524 |
| ≥78 | 395 | 343 | 554 | 368 | 320 | 517 | 225 | 196 | 316 | 112 | 98 | 158 | 493 | 429 | 692 | 79 | 68 | 110 | 390 | 339 | 546 |
| ≥79 | 412 | 361 | 577 | 384 | 336 | 538 | 235 | 206 | 329 | 117 | 103 | 164 | 515 | 450 | 721 | 82 | 72 | 115 | 407 | 356 | 569 |
| ≥80 | 429 | 378 | 600 | 401 | 352 | 559 | 245 | 216 | 342 | 122 | 108 | 171 | 537 | 472 | 749 | 86 | 75 | 120 | 424 | 373 | 592 |
| ≥81 | 447 | 395 | 623 | 417 | 369 | 581 | 255 | 225 | 355 | 127 | 112 | 177 | 558 | 494 | 778 | 89 | 79 | 124 | 441 | 390 | 614 |

Table 3.3 continued (Central values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 9 | 0 | 15 | 10 | 0 | 15 | 5 | 0 | 8 | 3 | 0 | 4 | 13 | 0 | 19 | 8 | 0 | 13 | 2 | 0 | 2 |
| ≥52 | 19 | 0 | 29 | 19 | 0 | 30 | 10 | 0 | 15 | 5 | 0 | 8 | 25 | 0 | 39 | 17 | 0 | 26 | 3 | 0 | 5 |
| ≥53 | 28 | 0 | 44 | 29 | 0 | 45 | 15 | 0 | 23 | 8 | 0 | 12 | 38 | 0 | 58 | 25 | 0 | 39 | 5 | 0 | 7 |
| ≥54 | 38 | 0 | 59 | 39 | 0 | 60 | 20 | 0 | 31 | 10 | 0 | 16 | 50 | 0 | 78 | 34 | 0 | 52 | 6 | 0 | 10 |
| ≥55 | 47 | 0 | 73 | 49 | 0 | 75 | 25 | 0 | 38 | 13 | 0 | 20 | 63 | 0 | 97 | 42 | 0 | 65 | 8 | 0 | 12 |
| ≥56 | 57 | 9 | 88 | 58 | 10 | 91 | 30 | 5 | 46 | 16 | 3 | 24 | 75 | 13 | 116 | 50 | 8 | 78 | 10 | 2 | 15 |
| ≥57 | 66 | 19 | 103 | 68 | 19 | 106 | 34 | 10 | 53 | 18 | 5 | 28 | 88 | 25 | 136 | 59 | 17 | 91 | 11 | 3 | 17 |
| ≥58 | 76 | 28 | 118 | 78 | 29 | 121 | 39 | 15 | 61 | 21 | 8 | 32 | 100 | 38 | 155 | 67 | 25 | 104 | 13 | 5 | 20 |
| ≥59 | 85 | 38 | 132 | 88 | 39 | 136 | 44 | 20 | 69 | 23 | 10 | 36 | 113 | 50 | 175 | 75 | 34 | 117 | 14 | 6 | 22 |
| ≥60 | 95 | 47 | 147 | 97 | 49 | 151 | 49 | 25 | 76 | 26 | 13 | 40 | 125 | 63 | 194 | 84 | 42 | 130 | 16 | 8 | 25 |
| ≥61 | 104 | 57 | 162 | 107 | 58 | 166 | 54 | 30 | 84 | 29 | 16 | 44 | 138 | 75 | 213 | 92 | 50 | 143 | 18 | 10 | 27 |
| ≥62 | 114 | 66 | 176 | 117 | 68 | 181 | 59 | 34 | 92 | 31 | 18 | 48 | 150 | 88 | 233 | 101 | 59 | 156 | 19 | 11 | 30 |
| ≥63 | 123 | 76 | 191 | 127 | 78 | 196 | 64 | 39 | 99 | 34 | 21 | 52 | 163 | 100 | 252 | 109 | 67 | 169 | 21 | 13 | 32 |
| ≥64 | 133 | 85 | 206 | 136 | 88 | 211 | 69 | 44 | 107 | 36 | 23 | 56 | 175 | 113 | 272 | 117 | 75 | 182 | 22 | 14 | 35 |
| ≥65 | 142 | 95 | 220 | 146 | 97 | 226 | 74 | 49 | 115 | 39 | 26 | 60 | 188 | 125 | 291 | 126 | 84 | 195 | 24 | 16 | 37 |
| ≥66 | 152 | 104 | 235 | 156 | 107 | 242 | 79 | 54 | 122 | 42 | 29 | 64 | 200 | 138 | 310 | 134 | 92 | 208 | 25 | 18 | 40 |
| ≥67 | 161 | 114 | 250 | 166 | 117 | 257 | 84 | 59 | 130 | 44 | 31 | 68 | 213 | 150 | 330 | 143 | 101 | 221 | 27 | 19 | 42 |
| ≥68 | 171 | 123 | 265 | 175 | 127 | 272 | 89 | 64 | 137 | 47 | 34 | 72 | 225 | 163 | 349 | 151 | 109 | 234 | 29 | 21 | 44 |
| ≥69 | 180 | 133 | 279 | 185 | 136 | 287 | 94 | 69 | 145 | 49 | 36 | 76 | 238 | 175 | 369 | 159 | 117 | 247 | 30 | 22 | 47 |
| ≥70 | 190 | 142 | 294 | 195 | 146 | 302 | 99 | 74 | 153 | 52 | 39 | 80 | 250 | 188 | 388 | 168 | 126 | 260 | 32 | 24 | 49 |
| ≥71 | 252 | 204 | 361 | 259 | 210 | 371 | 131 | 106 | 188 | 69 | 56 | 99 | 332 | 270 | 477 | 223 | 181 | 319 | 42 | 34 | 61 |
| ≥72 | 268 | 220 | 382 | 275 | 226 | 393 | 139 | 114 | 199 | 73 | 60 | 105 | 353 | 291 | 505 | 237 | 195 | 338 | 45 | 37 | 64 |
| ≥73 | 283 | 236 | 403 | 291 | 242 | 414 | 147 | 123 | 210 | 78 | 65 | 110 | 374 | 312 | 532 | 251 | 209 | 357 | 48 | 40 | 68 |
| ≥74 | 299 | 252 | 424 | 307 | 259 | 436 | 155 | 131 | 220 | 82 | 69 | 116 | 395 | 332 | 560 | 265 | 223 | 375 | 50 | 42 | 71 |
| ≥75 | 315 | 268 | 445 | 324 | 275 | 458 | 164 | 139 | 231 | 86 | 73 | 122 | 416 | 353 | 588 | 279 | 237 | 394 | 53 | 45 | 75 |
| ≥76 | 331 | 284 | 467 | 340 | 291 | 479 | 172 | 147 | 242 | 91 | 78 | 128 | 437 | 374 | 616 | 293 | 251 | 413 | 56 | 48 | 78 |
| ≥77 | 347 | 299 | 488 | 356 | 308 | 501 | 180 | 156 | 253 | 95 | 82 | 134 | 458 | 395 | 644 | 307 | 265 | 431 | 58 | 50 | 82 |
| ≥78 | 363 | 315 | 509 | 373 | 324 | 523 | 188 | 164 | 264 | 99 | 86 | 139 | 479 | 416 | 672 | 321 | 279 | 450 | 61 | 53 | 86 |
| ≥79 | 379 | 331 | 530 | 389 | 340 | 544 | 197 | 172 | 275 | 104 | 91 | 145 | 500 | 437 | 699 | 335 | 293 | 468 | 64 | 56 | 89 |
| ≥80 | 394 | 347 | 551 | 405 | 357 | 566 | 205 | 180 | 286 | 108 | 95 | 151 | 521 | 458 | 727 | 349 | 307 | 487 | 66 | 58 | 93 |
| ≥81 | 410 | 363 | 572 | 422 | 373 | 588 | 213 | 189 | 297 | 112 | 99 | 157 | 542 | 479 | 755 | 363 | 321 | 506 | 69 | 61 | 96 |

Table 3.3 continued (Central values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 2 | 0 | 3 | 14 | 0 | 21 | 4 | 0 | 6 | 10 | 0 | 16 | 2 | 0 | 3 | 5 | 0 | 7 | 2 | 0 | 3 |
| ≥52 | 3 | 0 | 5 | 27 | 0 | 42 | 8 | 0 | 13 | 21 | 0 | 32 | 4 | 0 | 6 | 9 | 0 | 15 | 4 | 0 | 6 |
| ≥53 | 5 | 0 | 8 | 41 | 0 | 64 | 12 | 0 | 19 | 31 | 0 | 49 | 6 | 0 | 9 | 14 | 0 | 22 | 5 | 0 | 8 |
| ≥54 | 6 | 0 | 10 | 55 | 0 | 85 | 17 | 0 | 26 | 42 | 0 | 65 | 8 | 0 | 13 | 19 | 0 | 29 | 7 | 0 | 11 |
| ≥55 | 8 | 0 | 13 | 68 | 0 | 106 | 21 | 0 | 32 | 52 | 0 | 81 | 10 | 0 | 16 | 24 | 0 | 37 | 9 | 0 | 14 |
| ≥56 | 10 | 2 | 15 | 82 | 14 | 127 | 25 | 4 | 38 | 63 | 10 | 97 | 12 | 2 | 19 | 28 | 5 | 44 | 11 | 2 | 17 |
| ≥57 | 11 | 3 | 18 | 96 | 27 | 149 | 29 | 8 | 45 | 73 | 21 | 114 | 14 | 4 | 22 | 33 | 9 | 51 | 13 | 4 | 20 |
| ≥58 | 13 | 5 | 20 | 110 | 41 | 170 | 33 | 12 | 51 | 84 | 31 | 130 | 16 | 6 | 25 | 38 | 14 | 59 | 14 | 5 | 22 |
| ≥59 | 15 | 6 | 23 | 123 | 55 | 191 | 37 | 17 | 58 | 94 | 42 | 146 | 18 | 8 | 28 | 43 | 19 | 66 | 16 | 7 | 25 |
| ≥60 | 16 | 8 | 25 | 137 | 68 | 212 | 41 | 21 | 64 | 105 | 52 | 162 | 20 | 10 | 31 | 47 | 24 | 73 | 18 | 9 | 28 |
| ≥61 | 18 | 10 | 28 | 151 | 82 | 234 | 45 | 25 | 70 | 115 | 63 | 179 | 22 | 12 | 35 | 52 | 28 | 81 | 20 | 11 | 31 |
| ≥62 | 19 | 11 | 30 | 164 | 96 | 255 | 50 | 29 | 77 | 126 | 73 | 195 | 24 | 14 | 38 | 57 | 33 | 88 | 22 | 13 | 34 |
| ≥63 | 21 | 13 | 33 | 178 | 110 | 276 | 54 | 33 | 83 | 136 | 84 | 211 | 26 | 16 | 41 | 61 | 38 | 95 | 23 | 14 | 36 |
| ≥64 | 23 | 15 | 35 | 192 | 123 | 297 | 58 | 37 | 90 | 147 | 94 | 227 | 28 | 18 | 44 | 66 | 43 | 103 | 25 | 16 | 39 |
| ≥65 | 24 | 16 | 38 | 205 | 137 | 318 | 62 | 41 | 96 | 157 | 105 | 243 | 30 | 20 | 47 | 71 | 47 | 110 | 27 | 18 | 42 |
| ≥66 | 26 | 18 | 40 | 219 | 151 | 340 | 66 | 45 | 102 | 168 | 115 | 260 | 32 | 22 | 50 | 76 | 52 | 117 | 29 | 20 | 45 |
| ≥67 | 28 | 19 | 43 | 233 | 164 | 361 | 70 | 50 | 109 | 178 | 126 | 276 | 34 | 24 | 53 | 80 | 57 | 125 | 31 | 22 | 48 |
| ≥68 | 29 | 21 | 45 | 247 | 178 | 382 | 74 | 54 | 115 | 188 | 136 | 292 | 37 | 26 | 57 | 85 | 61 | 132 | 32 | 23 | 50 |
| ≥69 | 31 | 23 | 48 | 260 | 192 | 403 | 78 | 58 | 122 | 199 | 147 | 308 | 39 | 28 | 60 | 90 | 66 | 139 | 34 | 25 | 53 |
| ≥70 | 32 | 24 | 50 | 274 | 205 | 425 | 83 | 62 | 128 | 209 | 157 | 325 | 41 | 30 | 63 | 95 | 71 | 147 | 36 | 27 | 56 |
| ≥71 | 43 | 35 | 62 | 364 | 295 | 522 | 110 | 89 | 157 | 278 | 226 | 399 | 54 | 44 | 77 | 125 | 102 | 180 | 48 | 39 | 69 |
| ≥72 | 46 | 38 | 65 | 386 | 318 | 552 | 117 | 96 | 167 | 295 | 243 | 422 | 57 | 47 | 82 | 133 | 110 | 191 | 51 | 42 | 73 |
| ≥73 | 48 | 40 | 69 | 409 | 341 | 583 | 123 | 103 | 176 | 313 | 261 | 445 | 61 | 50 | 86 | 141 | 118 | 201 | 54 | 45 | 77 |
| ≥74 | 51 | 43 | 72 | 432 | 364 | 613 | 130 | 110 | 185 | 331 | 278 | 469 | 64 | 54 | 91 | 149 | 126 | 212 | 57 | 48 | 81 |
| ≥75 | 54 | 46 | 76 | 455 | 387 | 644 | 137 | 117 | 194 | 348 | 296 | 492 | 67 | 57 | 95 | 157 | 133 | 222 | 60 | 51 | 85 |
| ≥76 | 56 | 48 | 80 | 478 | 410 | 674 | 144 | 124 | 203 | 366 | 313 | 515 | 71 | 61 | 100 | 165 | 141 | 233 | 63 | 54 | 89 |
| ≥77 | 59 | 51 | 83 | 501 | 433 | 704 | 151 | 130 | 212 | 383 | 331 | 539 | 74 | 64 | 104 | 173 | 149 | 243 | 66 | 57 | 93 |
| ≥78 | 62 | 54 | 87 | 524 | 456 | 735 | 158 | 137 | 222 | 401 | 348 | 562 | 78 | 67 | 109 | 181 | 157 | 254 | 69 | 60 | 97 |
| ≥79 | 65 | 57 | 90 | 547 | 478 | 765 | 165 | 144 | 231 | 418 | 366 | 585 | 81 | 71 | 113 | 189 | 165 | 264 | 72 | 63 | 101 |
| ≥80 | 67 | 59 | 94 | 570 | 501 | 796 | 172 | 151 | 240 | 436 | 383 | 608 | 84 | 74 | 118 | 197 | 173 | 275 | 75 | 66 | 105 |
| ≥81 | 70 | 62 | 98 | 593 | 524 | 826 | 179 | 158 | 249 | 453 | 401 | 632 | 88 | 78 | 122 | 205 | 181 | 285 | 78 | 69 | 109 |

Table 3.3 continued (Central values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 4 | 0 | 7 | 7 | 0 | 10 | 11 | 0 | 17 | 15 | 0 | 23 | 11 | 0 | 17 |
| ≥52 | 9 | 0 | 14 | 13 | 0 | 20 | 22 | 0 | 34 | 30 | 0 | 47 | 21 | 0 | 33 |
| ≥53 | 13 | 0 | 21 | 20 | 0 | 31 | 33 | 0 | 51 | 45 | 0 | 70 | 32 | 0 | 50 |
| ≥54 | 18 | 0 | 28 | 26 | 0 | 41 | 44 | 0 | 68 | 61 | 0 | 94 | 43 | 0 | 66 |
| ≥55 | 22 | 0 | 35 | 33 | 0 | 51 | 55 | 0 | 85 | 76 | 0 | 117 | 53 | 0 | 83 |
| ≥56 | 27 | 4 | 42 | 39 | 7 | 61 | 66 | 11 | 102 | 91 | 15 | 141 | 64 | 11 | 99 |
| ≥57 | 31 | 9 | 48 | 46 | 13 | 71 | 77 | 22 | 119 | 106 | 30 | 164 | 75 | 21 | 116 |
| ≥58 | 36 | 13 | 55 | 53 | 20 | 82 | 88 | 33 | 136 | 121 | 45 | 188 | 85 | 32 | 132 |
| ≥59 | 40 | 18 | 62 | 59 | 26 | 92 | 99 | 44 | 153 | 136 | 61 | 211 | 96 | 43 | 149 |
| ≥60 | 45 | 22 | 69 | 66 | 33 | 102 | 110 | 55 | 170 | 151 | 76 | 235 | 107 | 53 | 165 |
| ≥61 | 49 | 27 | 76 | 72 | 39 | 112 | 120 | 66 | 187 | 166 | 91 | 258 | 117 | 64 | 182 |
| ≥62 | 54 | 31 | 83 | 79 | 46 | 122 | 131 | 77 | 204 | 182 | 106 | 281 | 128 | 75 | 198 |
| ≥63 | 58 | 36 | 90 | 86 | 53 | 133 | 142 | 88 | 221 | 197 | 121 | 305 | 139 | 85 | 215 |
| ≥64 | 63 | 40 | 97 | 92 | 59 | 143 | 153 | 99 | 238 | 212 | 136 | 328 | 149 | 96 | 232 |
| ≥65 | 67 | 45 | 104 | 99 | 66 | 153 | 164 | 110 | 255 | 227 | 151 | 352 | 160 | 107 | 248 |
| ≥66 | 71 | 49 | 111 | 105 | 72 | 163 | 175 | 120 | 272 | 242 | 166 | 375 | 171 | 117 | 265 |
| ≥67 | 76 | 54 | 118 | 112 | 79 | 173 | 186 | 131 | 289 | 257 | 182 | 399 | 181 | 128 | 281 |
| ≥68 | 80 | 58 | 125 | 118 | 86 | 184 | 197 | 142 | 306 | 272 | 197 | 422 | 192 | 139 | 298 |
| ≥69 | 85 | 63 | 131 | 125 | 92 | 194 | 208 | 153 | 323 | 287 | 212 | 446 | 203 | 149 | 314 |
| ≥70 | 89 | 67 | 138 | 132 | 99 | 204 | 219 | 164 | 340 | 303 | 227 | 469 | 213 | 160 | 331 |
| ≥71 | 119 | 96 | 170 | 175 | 142 | 251 | 291 | 236 | 417 | 402 | 326 | 577 | 283 | 230 | 407 |
| ≥72 | 126 | 104 | 180 | 186 | 153 | 265 | 309 | 254 | 442 | 427 | 351 | 610 | 301 | 248 | 430 |
| ≥73 | 133 | 111 | 190 | 197 | 164 | 280 | 327 | 273 | 466 | 452 | 377 | 644 | 319 | 266 | 454 |
| ≥74 | 141 | 119 | 200 | 208 | 175 | 295 | 346 | 291 | 490 | 478 | 402 | 677 | 337 | 283 | 478 |
| ≥75 | 148 | 126 | 210 | 219 | 186 | 309 | 364 | 309 | 515 | 503 | 427 | 711 | 355 | 301 | 501 |
| ≥76 | 156 | 134 | 220 | 230 | 197 | 324 | 382 | 328 | 539 | 528 | 453 | 745 | 372 | 319 | 525 |
| ≥77 | 163 | 141 | 230 | 241 | 208 | 338 | 401 | 346 | 563 | 554 | 478 | 778 | 390 | 337 | 549 |
| ≥78 | 171 | 148 | 240 | 252 | 219 | 353 | 419 | 364 | 588 | 579 | 503 | 812 | 408 | 355 | 573 |
| ≥79 | 178 | 156 | 249 | 263 | 230 | 368 | 437 | 383 | 612 | 604 | 529 | 846 | 426 | 373 | 596 |
| ≥80 | 186 | 163 | 259 | 274 | 241 | 382 | 456 | 401 | 636 | 630 | 554 | 879 | 444 | 391 | 620 |
| ≥81 | 193 | 171 | 269 | 285 | 252 | 397 | 474 | 419 | 661 | 655 | 579 | 913 | 462 | 408 | 644 |

Note: The central values comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003) and quantifiable costs of health effects.

**Table 3.4** Cost factors (Central values) for noise exposure (€$_{2002}$ PPP, factor costs, per year per person exposed).

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 10 | 0 | 15 | 9 | 0 | 15 | 7 | 0 | 10 | 5 | 0 | 8 | 10 | 0 | 15 | 4 | 0 | 6 | 9 | 0 | 14 |
| ≥52 | 20 | 0 | 31 | 19 | 0 | 29 | 13 | 0 | 21 | 11 | 0 | 17 | 20 | 0 | 30 | 7 | 0 | 11 | 18 | 0 | 28 |
| ≥53 | 30 | 0 | 46 | 28 | 0 | 44 | 20 | 0 | 31 | 16 | 0 | 25 | 29 | 0 | 46 | 11 | 0 | 17 | 27 | 0 | 42 |
| ≥54 | 40 | 0 | 61 | 38 | 0 | 58 | 27 | 0 | 41 | 22 | 0 | 34 | 39 | 0 | 61 | 15 | 0 | 23 | 36 | 0 | 56 |
| ≥55 | 49 | 0 | 77 | 47 | 0 | 73 | 33 | 0 | 52 | 27 | 0 | 42 | 49 | 0 | 76 | 19 | 0 | 29 | 45 | 0 | 70 |
| ≥56 | 59 | 10 | 92 | 56 | 9 | 88 | 40 | 7 | 62 | 33 | 5 | 51 | 59 | 10 | 91 | 22 | 4 | 34 | 55 | 9 | 85 |
| ≥57 | 69 | 20 | 107 | 66 | 19 | 102 | 47 | 13 | 72 | 38 | 11 | 59 | 69 | 20 | 106 | 26 | 7 | 40 | 64 | 18 | 99 |
| ≥58 | 79 | 30 | 123 | 75 | 28 | 117 | 53 | 20 | 83 | 44 | 16 | 68 | 79 | 29 | 122 | 30 | 11 | 46 | 73 | 27 | 113 |
| ≥59 | 89 | 40 | 138 | 85 | 38 | 131 | 60 | 27 | 93 | 49 | 22 | 76 | 88 | 39 | 137 | 33 | 15 | 52 | 82 | 36 | 127 |
| ≥60 | 99 | 49 | 153 | 94 | 47 | 146 | 67 | 33 | 103 | 55 | 27 | 85 | 98 | 49 | 152 | 37 | 19 | 57 | 91 | 45 | 141 |
| ≥61 | 109 | 59 | 169 | 104 | 56 | 160 | 73 | 40 | 114 | 60 | 33 | 93 | 108 | 59 | 167 | 41 | 22 | 63 | 100 | 55 | 155 |
| ≥62 | 119 | 69 | 184 | 113 | 66 | 175 | 80 | 47 | 124 | 66 | 38 | 102 | 118 | 69 | 183 | 44 | 26 | 69 | 109 | 64 | 169 |
| ≥63 | 129 | 79 | 199 | 122 | 75 | 190 | 87 | 53 | 135 | 71 | 44 | 110 | 128 | 79 | 198 | 48 | 30 | 75 | 118 | 73 | 183 |
| ≥64 | 139 | 89 | 215 | 132 | 85 | 204 | 93 | 60 | 145 | 77 | 49 | 119 | 137 | 88 | 213 | 52 | 33 | 80 | 127 | 82 | 197 |
| ≥65 | 148 | 99 | 230 | 141 | 94 | 219 | 100 | 67 | 155 | 82 | 55 | 127 | 147 | 98 | 228 | 56 | 37 | 86 | 136 | 91 | 211 |
| ≥66 | 158 | 109 | 245 | 151 | 104 | 233 | 107 | 73 | 166 | 88 | 60 | 136 | 157 | 108 | 243 | 59 | 41 | 92 | 145 | 100 | 225 |
| ≥67 | 168 | 119 | 261 | 160 | 113 | 248 | 114 | 80 | 176 | 93 | 66 | 144 | 167 | 118 | 259 | 63 | 44 | 98 | 155 | 109 | 240 |
| ≥68 | 178 | 129 | 276 | 169 | 122 | 263 | 120 | 87 | 186 | 98 | 71 | 153 | 177 | 128 | 274 | 67 | 48 | 103 | 164 | 118 | 254 |
| ≥69 | 188 | 139 | 291 | 179 | 132 | 277 | 127 | 93 | 197 | 104 | 77 | 161 | 186 | 137 | 289 | 70 | 52 | 109 | 173 | 127 | 268 |
| ≥70 | 198 | 148 | 307 | 188 | 141 | 292 | 134 | 100 | 207 | 109 | 82 | 170 | 196 | 147 | 304 | 74 | 56 | 115 | 182 | 136 | 282 |
| ≥71 | 263 | 213 | 377 | 250 | 203 | 359 | 177 | 144 | 254 | 145 | 118 | 208 | 261 | 212 | 374 | 98 | 80 | 141 | 241 | 196 | 346 |
| ≥72 | 279 | 230 | 399 | 266 | 219 | 379 | 188 | 155 | 269 | 154 | 127 | 221 | 277 | 228 | 396 | 104 | 86 | 149 | 256 | 211 | 366 |
| ≥73 | 296 | 246 | 421 | 281 | 234 | 400 | 200 | 166 | 284 | 164 | 136 | 233 | 293 | 244 | 417 | 111 | 92 | 157 | 272 | 226 | 387 |
| ≥74 | 312 | 263 | 443 | 297 | 250 | 421 | 211 | 177 | 299 | 173 | 145 | 245 | 310 | 261 | 439 | 117 | 98 | 166 | 287 | 241 | 407 |
| ≥75 | 329 | 279 | 465 | 313 | 266 | 442 | 222 | 189 | 314 | 182 | 154 | 257 | 326 | 277 | 461 | 123 | 104 | 174 | 302 | 257 | 427 |
| ≥76 | 345 | 296 | 487 | 329 | 282 | 463 | 233 | 200 | 329 | 191 | 164 | 269 | 343 | 294 | 483 | 129 | 111 | 182 | 317 | 272 | 447 |
| ≥77 | 362 | 313 | 509 | 344 | 297 | 484 | 244 | 211 | 343 | 200 | 173 | 281 | 359 | 310 | 505 | 135 | 117 | 190 | 333 | 287 | 468 |
| ≥78 | 379 | 329 | 531 | 360 | 313 | 505 | 255 | 222 | 358 | 209 | 182 | 294 | 375 | 326 | 527 | 142 | 123 | 199 | 348 | 302 | 488 |
| ≥79 | 395 | 346 | 553 | 376 | 329 | 526 | 267 | 233 | 373 | 218 | 191 | 306 | 392 | 343 | 548 | 148 | 129 | 207 | 363 | 318 | 508 |
| ≥80 | 412 | 362 | 575 | 392 | 345 | 547 | 278 | 244 | 388 | 228 | 200 | 318 | 408 | 359 | 570 | 154 | 135 | 215 | 378 | 333 | 528 |
| ≥81 | 428 | 379 | 597 | 407 | 360 | 568 | 289 | 256 | 403 | 237 | 209 | 330 | 425 | 376 | 592 | 160 | 142 | 223 | 393 | 348 | 548 |

Table 3.4 continued (Central values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 9 | 0 | 14 | 9 | 0 | 14 | 6 | 0 | 10 | 5 | 0 | 7 | 11 | 0 | 17 | 9 | 0 | 14 | 3 | 0 | 5 |
| ≥52 | 18 | 0 | 28 | 18 | 0 | 27 | 13 | 0 | 19 | 9 | 0 | 15 | 22 | 0 | 33 | 18 | 0 | 27 | 6 | 0 | 10 |
| ≥53 | 27 | 0 | 42 | 26 | 0 | 41 | 19 | 0 | 29 | 14 | 0 | 22 | 32 | 0 | 50 | 26 | 0 | 41 | 9 | 0 | 15 |
| ≥54 | 36 | 0 | 56 | 35 | 0 | 54 | 25 | 0 | 39 | 19 | 0 | 29 | 43 | 0 | 67 | 35 | 0 | 54 | 13 | 0 | 19 |
| ≥55 | 45 | 0 | 70 | 44 | 0 | 68 | 31 | 0 | 49 | 24 | 0 | 37 | 54 | 0 | 84 | 44 | 0 | 68 | 16 | 0 | 24 |
| ≥56 | 55 | 9 | 85 | 53 | 9 | 82 | 38 | 6 | 58 | 28 | 5 | 44 | 65 | 11 | 100 | 53 | 9 | 82 | 19 | 3 | 29 |
| ≥57 | 64 | 18 | 99 | 61 | 18 | 95 | 44 | 13 | 68 | 33 | 9 | 51 | 75 | 22 | 117 | 61 | 18 | 95 | 22 | 6 | 34 |
| ≥58 | 73 | 27 | 113 | 70 | 26 | 109 | 50 | 19 | 78 | 38 | 14 | 59 | 86 | 32 | 134 | 70 | 26 | 109 | 25 | 9 | 39 |
| ≥59 | 82 | 36 | 127 | 79 | 35 | 122 | 56 | 25 | 88 | 43 | 19 | 66 | 97 | 43 | 150 | 79 | 35 | 122 | 28 | 13 | 44 |
| ≥60 | 91 | 45 | 141 | 88 | 44 | 136 | 63 | 31 | 97 | 47 | 24 | 74 | 108 | 54 | 167 | 88 | 44 | 136 | 31 | 16 | 49 |
| ≥61 | 100 | 55 | 155 | 96 | 53 | 149 | 69 | 38 | 107 | 52 | 28 | 81 | 119 | 65 | 184 | 96 | 53 | 149 | 35 | 19 | 53 |
| ≥62 | 109 | 64 | 169 | 105 | 61 | 163 | 75 | 44 | 117 | 57 | 33 | 88 | 129 | 75 | 200 | 105 | 61 | 163 | 38 | 22 | 58 |
| ≥63 | 118 | 73 | 183 | 114 | 70 | 177 | 82 | 50 | 126 | 62 | 38 | 96 | 140 | 86 | 217 | 114 | 70 | 177 | 41 | 25 | 63 |
| ≥64 | 127 | 82 | 197 | 123 | 79 | 190 | 88 | 56 | 136 | 66 | 43 | 103 | 151 | 97 | 234 | 123 | 79 | 190 | 44 | 28 | 68 |
| ≥65 | 136 | 91 | 211 | 132 | 88 | 204 | 94 | 63 | 146 | 71 | 47 | 110 | 162 | 108 | 251 | 132 | 88 | 204 | 47 | 31 | 73 |
| ≥66 | 145 | 100 | 225 | 140 | 96 | 217 | 100 | 69 | 156 | 76 | 52 | 118 | 172 | 119 | 267 | 140 | 96 | 217 | 50 | 35 | 78 |
| ≥67 | 155 | 109 | 240 | 149 | 105 | 231 | 107 | 75 | 165 | 81 | 57 | 125 | 183 | 129 | 284 | 149 | 105 | 231 | 53 | 38 | 83 |
| ≥68 | 164 | 118 | 254 | 158 | 114 | 245 | 113 | 82 | 175 | 85 | 62 | 132 | 194 | 140 | 301 | 158 | 114 | 245 | 56 | 41 | 88 |
| ≥69 | 173 | 127 | 268 | 167 | 123 | 258 | 119 | 88 | 185 | 90 | 66 | 140 | 205 | 151 | 317 | 167 | 123 | 258 | 60 | 44 | 92 |
| ≥70 | 182 | 136 | 282 | 175 | 132 | 272 | 125 | 94 | 195 | 95 | 71 | 147 | 216 | 162 | 334 | 175 | 132 | 272 | 63 | 47 | 97 |
| ≥71 | 241 | 196 | 346 | 233 | 189 | 334 | 167 | 135 | 239 | 126 | 102 | 181 | 286 | 232 | 411 | 233 | 189 | 334 | 83 | 68 | 120 |
| ≥72 | 256 | 211 | 366 | 247 | 204 | 354 | 177 | 146 | 253 | 134 | 110 | 191 | 304 | 250 | 435 | 247 | 204 | 354 | 89 | 73 | 126 |
| ≥73 | 272 | 226 | 387 | 262 | 218 | 373 | 188 | 156 | 267 | 142 | 118 | 202 | 322 | 268 | 459 | 262 | 218 | 373 | 94 | 78 | 133 |
| ≥74 | 287 | 241 | 407 | 277 | 233 | 393 | 198 | 167 | 281 | 150 | 126 | 212 | 340 | 286 | 483 | 277 | 233 | 393 | 99 | 83 | 140 |
| ≥75 | 302 | 257 | 427 | 291 | 248 | 412 | 209 | 177 | 295 | 158 | 134 | 223 | 358 | 304 | 507 | 291 | 248 | 412 | 104 | 89 | 147 |
| ≥76 | 317 | 272 | 447 | 306 | 262 | 432 | 219 | 188 | 309 | 166 | 142 | 234 | 376 | 322 | 530 | 306 | 262 | 432 | 110 | 94 | 154 |
| ≥77 | 333 | 287 | 468 | 321 | 277 | 451 | 230 | 198 | 323 | 174 | 150 | 244 | 394 | 340 | 554 | 321 | 277 | 451 | 115 | 99 | 161 |
| ≥78 | 348 | 302 | 488 | 335 | 292 | 471 | 240 | 209 | 337 | 182 | 158 | 255 | 412 | 359 | 578 | 335 | 292 | 471 | 120 | 104 | 168 |
| ≥79 | 363 | 318 | 508 | 350 | 306 | 490 | 251 | 219 | 351 | 190 | 166 | 265 | 430 | 377 | 602 | 350 | 306 | 490 | 125 | 110 | 175 |
| ≥80 | 378 | 333 | 528 | 365 | 321 | 509 | 261 | 230 | 365 | 197 | 174 | 276 | 448 | 395 | 626 | 365 | 321 | 509 | 131 | 115 | 182 |
| ≥81 | 393 | 348 | 548 | 379 | 336 | 529 | 272 | 240 | 379 | 205 | 182 | 286 | 467 | 413 | 650 | 379 | 336 | 529 | 136 | 120 | 189 |

Table 3.4 continued (Central values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| L$_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 3 | 0 | 5 | 12 | 0 | 19 | 6 | 0 | 9 | 10 | 0 | 15 | 4 | 0 | 6 | 6 | 0 | 10 | 4 | 0 | 6 |
| ≥52 | 7 | 0 | 10 | 24 | 0 | 37 | 12 | 0 | 18 | 20 | 0 | 30 | 7 | 0 | 11 | 12 | 0 | 19 | 8 | 0 | 13 |
| ≥53 | 10 | 0 | 16 | 36 | 0 | 56 | 18 | 0 | 28 | 29 | 0 | 46 | 11 | 0 | 17 | 19 | 0 | 29 | 12 | 0 | 19 |
| ≥54 | 14 | 0 | 21 | 48 | 0 | 75 | 24 | 0 | 37 | 39 | 0 | 61 | 15 | 0 | 23 | 25 | 0 | 38 | 16 | 0 | 25 |
| ≥55 | 17 | 0 | 26 | 60 | 0 | 94 | 30 | 0 | 46 | 49 | 0 | 76 | 19 | 0 | 29 | 31 | 0 | 48 | 21 | 0 | 32 |
| ≥56 | 20 | 3 | 31 | 72 | 12 | 112 | 36 | 6 | 55 | 59 | 10 | 91 | 22 | 4 | 34 | 37 | 6 | 58 | 25 | 4 | 38 |
| ≥57 | 24 | 7 | 37 | 84 | 24 | 131 | 42 | 12 | 65 | 69 | 20 | 106 | 26 | 7 | 40 | 43 | 12 | 67 | 29 | 8 | 45 |
| ≥58 | 27 | 10 | 42 | 97 | 36 | 150 | 48 | 18 | 74 | 79 | 29 | 122 | 30 | 11 | 46 | 50 | 19 | 77 | 33 | 12 | 51 |
| ≥59 | 30 | 14 | 47 | 109 | 48 | 168 | 54 | 24 | 83 | 88 | 39 | 137 | 33 | 15 | 52 | 56 | 25 | 86 | 37 | 16 | 57 |
| ≥60 | 34 | 17 | 52 | 121 | 60 | 187 | 60 | 30 | 92 | 98 | 49 | 152 | 37 | 19 | 57 | 62 | 31 | 96 | 41 | 21 | 64 |
| ≥61 | 37 | 20 | 58 | 133 | 72 | 206 | 65 | 36 | 101 | 108 | 59 | 167 | 41 | 22 | 63 | 68 | 37 | 106 | 45 | 25 | 70 |
| ≥62 | 41 | 24 | 63 | 145 | 84 | 224 | 71 | 42 | 111 | 118 | 69 | 183 | 44 | 26 | 69 | 74 | 43 | 115 | 49 | 29 | 76 |
| ≥63 | 44 | 27 | 68 | 157 | 97 | 243 | 77 | 48 | 120 | 128 | 79 | 198 | 48 | 30 | 75 | 81 | 50 | 125 | 53 | 33 | 83 |
| ≥64 | 47 | 30 | 73 | 169 | 109 | 262 | 83 | 54 | 129 | 137 | 88 | 213 | 52 | 33 | 80 | 87 | 56 | 134 | 57 | 37 | 89 |
| ≥65 | 51 | 34 | 79 | 181 | 121 | 281 | 89 | 60 | 138 | 147 | 98 | 228 | 56 | 37 | 86 | 93 | 62 | 144 | 62 | 41 | 95 |
| ≥66 | 54 | 37 | 84 | 193 | 133 | 299 | 95 | 65 | 148 | 157 | 108 | 243 | 59 | 41 | 92 | 99 | 68 | 154 | 66 | 45 | 102 |
| ≥67 | 57 | 41 | 89 | 205 | 145 | 318 | 101 | 71 | 157 | 167 | 118 | 259 | 63 | 44 | 98 | 105 | 74 | 163 | 70 | 49 | 108 |
| ≥68 | 61 | 44 | 94 | 217 | 157 | 337 | 107 | 77 | 166 | 177 | 128 | 274 | 67 | 48 | 103 | 111 | 81 | 173 | 74 | 53 | 114 |
| ≥69 | 64 | 47 | 99 | 229 | 169 | 355 | 113 | 83 | 175 | 186 | 137 | 289 | 70 | 52 | 109 | 118 | 87 | 182 | 78 | 57 | 121 |
| ≥70 | 68 | 51 | 105 | 241 | 181 | 374 | 119 | 89 | 185 | 196 | 147 | 304 | 74 | 56 | 115 | 124 | 93 | 192 | 82 | 62 | 127 |
| ≥71 | 90 | 73 | 129 | 320 | 260 | 460 | 158 | 128 | 227 | 261 | 212 | 374 | 98 | 80 | 141 | 164 | 133 | 236 | 109 | 88 | 156 |
| ≥72 | 95 | 78 | 136 | 340 | 280 | 486 | 168 | 138 | 240 | 277 | 228 | 396 | 104 | 86 | 149 | 175 | 144 | 250 | 116 | 95 | 165 |
| ≥73 | 101 | 84 | 144 | 361 | 300 | 513 | 178 | 148 | 253 | 293 | 244 | 417 | 111 | 92 | 157 | 185 | 154 | 264 | 123 | 102 | 175 |
| ≥74 | 107 | 90 | 151 | 381 | 321 | 540 | 188 | 158 | 266 | 310 | 261 | 439 | 117 | 98 | 166 | 196 | 165 | 277 | 129 | 109 | 184 |
| ≥75 | 112 | 95 | 159 | 401 | 341 | 567 | 198 | 168 | 280 | 326 | 277 | 461 | 123 | 104 | 174 | 206 | 175 | 291 | 136 | 116 | 193 |
| ≥76 | 118 | 101 | 166 | 421 | 361 | 594 | 208 | 178 | 293 | 343 | 294 | 483 | 129 | 111 | 182 | 216 | 185 | 305 | 143 | 123 | 202 |
| ≥77 | 124 | 107 | 174 | 441 | 381 | 621 | 218 | 188 | 306 | 359 | 310 | 505 | 135 | 117 | 190 | 227 | 196 | 319 | 150 | 130 | 211 |
| ≥78 | 129 | 112 | 181 | 462 | 401 | 647 | 228 | 198 | 319 | 375 | 326 | 527 | 142 | 123 | 199 | 237 | 206 | 332 | 157 | 136 | 220 |
| ≥79 | 135 | 118 | 189 | 482 | 422 | 674 | 238 | 208 | 333 | 392 | 343 | 548 | 148 | 129 | 207 | 247 | 216 | 346 | 164 | 143 | 229 |
| ≥80 | 141 | 124 | 196 | 502 | 442 | 701 | 248 | 218 | 346 | 408 | 359 | 570 | 154 | 135 | 215 | 258 | 227 | 360 | 171 | 150 | 238 |
| ≥81 | 146 | 129 | 204 | 522 | 462 | 728 | 258 | 228 | 359 | 425 | 376 | 592 | 160 | 142 | 223 | 268 | 237 | 374 | 178 | 157 | 248 |

Table 3.4 continued (Central values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 6 | 0 | 9 | 8 | 0 | 12 | 9 | 0 | 14 | 11 | 0 | 16 | 9 | 0 | 15 |
| ≥52 | 12 | 0 | 19 | 15 | 0 | 24 | 19 | 0 | 29 | 21 | 0 | 33 | 19 | 0 | 29 |
| ≥53 | 18 | 0 | 28 | 23 | 0 | 36 | 28 | 0 | 43 | 32 | 0 | 49 | 28 | 0 | 44 |
| ≥54 | 24 | 0 | 37 | 31 | 0 | 47 | 37 | 0 | 57 | 42 | 0 | 66 | 38 | 0 | 59 |
| ≥55 | 30 | 0 | 47 | 38 | 0 | 59 | 46 | 0 | 72 | 53 | 0 | 82 | 47 | 0 | 74 |
| ≥56 | 36 | 6 | 56 | 46 | 8 | 71 | 56 | 9 | 86 | 64 | 11 | 99 | 57 | 9 | 88 |
| ≥57 | 42 | 12 | 65 | 53 | 15 | 83 | 65 | 19 | 100 | 74 | 21 | 115 | 66 | 19 | 103 |
| ≥58 | 48 | 18 | 75 | 61 | 23 | 95 | 74 | 28 | 115 | 85 | 32 | 132 | 76 | 28 | 118 |
| ≥59 | 54 | 24 | 84 | 69 | 31 | 107 | 83 | 37 | 129 | 96 | 42 | 148 | 85 | 38 | 132 |
| ≥60 | 60 | 30 | 94 | 76 | 38 | 118 | 93 | 46 | 143 | 106 | 53 | 165 | 95 | 47 | 147 |
| ≥61 | 66 | 36 | 103 | 84 | 46 | 130 | 102 | 56 | 158 | 117 | 64 | 181 | 104 | 57 | 162 |
| ≥62 | 72 | 42 | 112 | 92 | 53 | 142 | 111 | 65 | 172 | 127 | 74 | 198 | 114 | 66 | 177 |
| ≥63 | 78 | 48 | 122 | 99 | 61 | 154 | 120 | 74 | 186 | 138 | 85 | 214 | 123 | 76 | 191 |
| ≥64 | 84 | 54 | 131 | 107 | 69 | 166 | 130 | 83 | 201 | 149 | 96 | 230 | 133 | 85 | 206 |
| ≥65 | 90 | 60 | 140 | 115 | 76 | 178 | 139 | 93 | 215 | 159 | 106 | 247 | 142 | 95 | 221 |
| ≥66 | 97 | 66 | 150 | 122 | 84 | 190 | 148 | 102 | 229 | 170 | 117 | 263 | 152 | 104 | 235 |
| ≥67 | 103 | 72 | 159 | 130 | 92 | 201 | 157 | 111 | 244 | 181 | 127 | 280 | 161 | 114 | 250 |
| ≥68 | 109 | 78 | 168 | 138 | 99 | 213 | 167 | 120 | 258 | 191 | 138 | 296 | 171 | 123 | 265 |
| ≥69 | 115 | 84 | 178 | 145 | 107 | 225 | 176 | 130 | 272 | 202 | 149 | 313 | 180 | 133 | 280 |
| ≥70 | 121 | 90 | 187 | 153 | 115 | 237 | 185 | 139 | 287 | 212 | 159 | 329 | 190 | 142 | 294 |
| ≥71 | 160 | 130 | 230 | 203 | 165 | 291 | 246 | 199 | 352 | 282 | 229 | 405 | 252 | 205 | 362 |
| ≥72 | 170 | 140 | 243 | 216 | 177 | 308 | 261 | 215 | 373 | 300 | 247 | 428 | 268 | 220 | 383 |
| ≥73 | 180 | 150 | 257 | 228 | 190 | 325 | 277 | 230 | 394 | 317 | 264 | 452 | 284 | 236 | 404 |
| ≥74 | 190 | 160 | 270 | 241 | 203 | 342 | 292 | 246 | 414 | 335 | 282 | 475 | 300 | 252 | 425 |
| ≥75 | 201 | 170 | 283 | 254 | 216 | 359 | 307 | 261 | 435 | 353 | 300 | 499 | 316 | 268 | 446 |
| ≥76 | 211 | 180 | 297 | 267 | 229 | 376 | 323 | 277 | 455 | 371 | 318 | 523 | 331 | 284 | 467 |
| ≥77 | 221 | 191 | 310 | 280 | 241 | 393 | 338 | 292 | 476 | 388 | 335 | 546 | 347 | 300 | 488 |
| ≥78 | 231 | 201 | 324 | 292 | 254 | 410 | 354 | 308 | 496 | 406 | 353 | 570 | 363 | 316 | 509 |
| ≥79 | 241 | 211 | 337 | 305 | 267 | 427 | 369 | 323 | 517 | 424 | 371 | 593 | 379 | 332 | 530 |
| ≥80 | 251 | 221 | 351 | 318 | 280 | 444 | 385 | 339 | 538 | 442 | 389 | 617 | 395 | 347 | 552 |
| ≥81 | 261 | 231 | 364 | 331 | 293 | 461 | 400 | 354 | 558 | 460 | 406 | 641 | 411 | 363 | 573 |

Note: The Central values comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003) and quantifiable costs of health effects.

**Table 3.5** Cost factors (New approach) for noise exposure (€$_{2002}$, factor costs, per year per person exposed).

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 6 | 3 | 10 | 5 | 2 | 9 | 3 | 1 | 6 | 2 | 1 | 3 | 7 | 3 | 12 | 1 | 1 | 2 | 6 | 3 | 10 |
| ≥44 | 6 | 3 | 11 | 6 | 3 | 10 | 4 | 2 | 6 | 2 | 1 | 3 | 8 | 4 | 14 | 1 | 1 | 2 | 6 | 3 | 11 |
| ≥45 | 7 | 3 | 12 | 7 | 3 | 12 | 4 | 2 | 7 | 2 | 1 | 4 | 9 | 4 | 16 | 1 | 1 | 2 | 7 | 3 | 12 |
| ≥46 | 8 | 4 | 14 | 8 | 4 | 13 | 5 | 2 | 8 | 2 | 1 | 4 | 10 | 5 | 17 | 2 | 1 | 3 | 8 | 4 | 14 |
| ≥47 | 9 | 4 | 15 | 9 | 4 | 14 | 5 | 3 | 9 | 3 | 1 | 4 | 11 | 6 | 19 | 2 | 1 | 3 | 9 | 4 | 15 |
| ≥48 | 10 | 5 | 16 | 9 | 5 | 15 | 6 | 3 | 9 | 3 | 1 | 5 | 13 | 6 | 21 | 2 | 1 | 3 | 10 | 5 | 16 |
| ≥49 | 11 | 6 | 18 | 10 | 5 | 17 | 6 | 3 | 10 | 3 | 2 | 5 | 14 | 7 | 22 | 2 | 1 | 4 | 11 | 6 | 18 |
| ≥50 | 12 | 6 | 19 | 11 | 6 | 18 | 7 | 4 | 11 | 3 | 2 | 5 | 15 | 8 | 24 | 2 | 1 | 4 | 12 | 6 | 19 |
| ≥51 | 13 | 7 | 21 | 12 | 6 | 19 | 8 | 4 | 12 | 4 | 2 | 6 | 17 | 9 | 26 | 3 | 1 | 4 | 13 | 7 | 20 |
| ≥52 | 15 | 8 | 22 | 14 | 7 | 21 | 8 | 4 | 13 | 4 | 2 | 6 | 18 | 9 | 27 | 3 | 2 | 4 | 14 | 7 | 22 |
| ≥53 | 16 | 8 | 23 | 15 | 8 | 22 | 9 | 5 | 13 | 4 | 2 | 7 | 20 | 10 | 29 | 3 | 2 | 5 | 15 | 8 | 23 |
| ≥54 | 17 | 9 | 25 | 16 | 8 | 23 | 10 | 5 | 14 | 5 | 3 | 7 | 21 | 11 | 31 | 3 | 2 | 5 | 17 | 9 | 25 |
| ≥55 | 18 | 10 | 26 | 17 | 9 | 25 | 10 | 6 | 15 | 5 | 3 | 7 | 23 | 12 | 33 | 4 | 2 | 5 | 18 | 10 | 26 |
| ≥56 | 19 | 11 | 28 | 18 | 10 | 26 | 11 | 6 | 16 | 6 | 3 | 8 | 24 | 13 | 35 | 4 | 2 | 6 | 19 | 10 | 27 |
| ≥57 | 21 | 11 | 29 | 19 | 11 | 27 | 12 | 6 | 17 | 6 | 3 | 8 | 26 | 14 | 36 | 4 | 2 | 6 | 20 | 11 | 29 |
| ≥58 | 22 | 12 | 31 | 21 | 11 | 29 | 13 | 7 | 17 | 6 | 3 | 9 | 28 | 15 | 38 | 4 | 2 | 6 | 22 | 12 | 30 |
| ≥59 | 23 | 13 | 32 | 22 | 12 | 30 | 13 | 7 | 18 | 7 | 4 | 9 | 29 | 16 | 40 | 5 | 3 | 6 | 23 | 13 | 32 |
| ≥60 | 25 | 14 | 34 | 23 | 13 | 31 | 14 | 8 | 19 | 7 | 4 | 10 | 31 | 17 | 42 | 5 | 3 | 7 | 24 | 14 | 33 |
| ≥61 | 26 | 15 | 35 | 24 | 14 | 33 | 15 | 8 | 20 | 7 | 4 | 10 | 33 | 19 | 44 | 5 | 3 | 7 | 26 | 15 | 35 |
| ≥62 | 28 | 16 | 37 | 26 | 15 | 34 | 16 | 9 | 21 | 8 | 5 | 10 | 35 | 20 | 46 | 6 | 3 | 7 | 27 | 16 | 36 |
| ≥63 | 29 | 17 | 38 | 27 | 16 | 35 | 17 | 10 | 22 | 8 | 5 | 11 | 36 | 21 | 48 | 6 | 3 | 8 | 29 | 17 | 38 |
| ≥64 | 31 | 18 | 40 | 29 | 17 | 37 | 17 | 10 | 23 | 9 | 5 | 11 | 38 | 22 | 49 | 6 | 4 | 8 | 30 | 18 | 39 |
| ≥65 | 32 | 19 | 41 | 30 | 18 | 38 | 18 | 11 | 23 | 9 | 5 | 12 | 40 | 24 | 51 | 6 | 4 | 8 | 32 | 19 | 40 |
| ≥66 | 34 | 20 | 42 | 31 | 19 | 40 | 19 | 11 | 24 | 10 | 6 | 12 | 42 | 25 | 53 | 7 | 4 | 8 | 33 | 20 | 42 |
| ≥67 | 35 | 21 | 44 | 33 | 20 | 41 | 20 | 12 | 25 | 10 | 6 | 13 | 44 | 26 | 55 | 7 | 4 | 9 | 35 | 21 | 43 |
| ≥68 | 37 | 22 | 45 | 34 | 21 | 42 | 21 | 13 | 26 | 10 | 6 | 13 | 46 | 28 | 57 | 7 | 4 | 9 | 36 | 22 | 45 |
| ≥69 | 38 | 23 | 47 | 36 | 22 | 44 | 22 | 13 | 27 | 11 | 7 | 13 | 48 | 29 | 59 | 8 | 5 | 9 | 38 | 23 | 46 |
| ≥70 | 40 | 24 | 48 | 37 | 23 | 45 | 23 | 14 | 28 | 11 | 7 | 14 | 50 | 31 | 60 | 8 | 5 | 10 | 40 | 24 | 48 |
| ≥71 | 99 | 83 | 107 | 92 | 77 | 100 | 56 | 47 | 61 | 28 | 24 | 30 | 124 | 104 | 134 | 20 | 17 | 21 | 98 | 82 | 106 |
| ≥72 | 108 | 91 | 115 | 100 | 85 | 108 | 61 | 52 | 66 | 31 | 26 | 33 | 134 | 114 | 144 | 21 | 18 | 23 | 106 | 90 | 114 |
| ≥73 | 116 | 99 | 124 | 108 | 93 | 116 | 66 | 57 | 71 | 33 | 28 | 35 | 145 | 124 | 155 | 23 | 20 | 25 | 115 | 98 | 122 |
| ≥74 | 125 | 108 | 132 | 116 | 100 | 123 | 71 | 61 | 75 | 36 | 31 | 38 | 156 | 134 | 165 | 25 | 21 | 26 | 123 | 106 | 130 |
| ≥75 | 134 | 116 | 141 | 125 | 108 | 131 | 76 | 66 | 80 | 38 | 33 | 40 | 167 | 145 | 176 | 27 | 23 | 28 | 132 | 114 | 139 |
| ≥76 | 142 | 124 | 149 | 133 | 116 | 139 | 81 | 71 | 85 | 40 | 35 | 42 | 178 | 155 | 186 | 28 | 25 | 30 | 140 | 122 | 147 |
| ≥77 | 151 | 132 | 157 | 141 | 124 | 147 | 86 | 76 | 90 | 43 | 38 | 45 | 189 | 165 | 197 | 30 | 26 | 31 | 149 | 131 | 155 |
| ≥78 | 160 | 141 | 166 | 149 | 131 | 154 | 91 | 80 | 94 | 45 | 40 | 47 | 200 | 176 | 207 | 32 | 28 | 33 | 158 | 139 | 163 |
| ≥79 | 168 | 149 | 174 | 157 | 139 | 162 | 96 | 85 | 99 | 48 | 42 | 49 | 210 | 186 | 217 | 34 | 30 | 35 | 166 | 147 | 172 |
| ≥80 | 177 | 157 | 182 | 165 | 147 | 170 | 101 | 90 | 104 | 50 | 45 | 52 | 221 | 197 | 228 | 35 | 31 | 36 | 175 | 155 | 180 |
| ≥81 | 186 | 166 | 190 | 174 | 155 | 178 | 106 | 95 | 109 | 53 | 47 | 54 | 232 | 207 | 238 | 37 | 33 | 38 | 183 | 164 | 188 |

Table 3.5 continued (New approach values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 5 | 2 | 9 | 5 | 2 | 9 | 3 | 1 | 5 | 1 | 1 | 3 | 7 | 3 | 12 | 5 | 2 | 8 | 1 | 0 | 2 |
| ≥44 | 6 | 3 | 10 | 6 | 3 | 11 | 3 | 1 | 5 | 2 | 1 | 3 | 8 | 4 | 14 | 5 | 2 | 9 | 1 | 0 | 2 |
| ≥45 | 7 | 3 | 11 | 7 | 3 | 12 | 3 | 2 | 6 | 2 | 1 | 3 | 9 | 4 | 15 | 6 | 3 | 10 | 1 | 1 | 2 |
| ≥46 | 8 | 4 | 13 | 8 | 4 | 13 | 4 | 2 | 7 | 2 | 1 | 3 | 10 | 5 | 17 | 7 | 3 | 11 | 1 | 1 | 2 |
| ≥47 | 8 | 4 | 14 | 9 | 4 | 14 | 4 | 2 | 7 | 2 | 1 | 4 | 11 | 5 | 18 | 7 | 4 | 12 | 1 | 1 | 2 |
| ≥48 | 9 | 5 | 15 | 10 | 5 | 16 | 5 | 2 | 8 | 3 | 1 | 4 | 12 | 6 | 20 | 8 | 4 | 13 | 2 | 1 | 3 |
| ≥49 | 10 | 5 | 16 | 11 | 5 | 17 | 5 | 3 | 9 | 3 | 1 | 4 | 14 | 7 | 22 | 9 | 5 | 14 | 2 | 1 | 3 |
| ≥50 | 11 | 6 | 18 | 12 | 6 | 18 | 6 | 3 | 9 | 3 | 2 | 5 | 15 | 8 | 23 | 10 | 5 | 16 | 2 | 1 | 3 |
| ≥51 | 12 | 6 | 19 | 13 | 6 | 19 | 6 | 3 | 10 | 3 | 2 | 5 | 16 | 8 | 25 | 11 | 6 | 17 | 2 | 1 | 3 |
| ≥52 | 13 | 7 | 20 | 14 | 7 | 21 | 7 | 4 | 11 | 4 | 2 | 6 | 18 | 9 | 27 | 12 | 6 | 18 | 2 | 1 | 3 |
| ≥53 | 14 | 8 | 22 | 15 | 8 | 22 | 7 | 4 | 11 | 4 | 2 | 6 | 19 | 10 | 28 | 13 | 7 | 19 | 2 | 1 | 4 |
| ≥54 | 16 | 8 | 23 | 16 | 8 | 23 | 8 | 4 | 12 | 4 | 2 | 6 | 20 | 11 | 30 | 14 | 7 | 20 | 3 | 1 | 4 |
| ≥55 | 17 | 9 | 24 | 17 | 9 | 25 | 9 | 5 | 13 | 5 | 2 | 7 | 22 | 12 | 32 | 15 | 8 | 21 | 3 | 2 | 4 |
| ≥56 | 18 | 10 | 25 | 18 | 10 | 26 | 9 | 5 | 13 | 5 | 3 | 7 | 24 | 13 | 34 | 16 | 9 | 23 | 3 | 2 | 4 |
| ≥57 | 19 | 10 | 27 | 20 | 11 | 28 | 10 | 5 | 14 | 5 | 3 | 7 | 25 | 14 | 35 | 17 | 9 | 24 | 3 | 2 | 5 |
| ≥58 | 20 | 11 | 28 | 21 | 11 | 29 | 11 | 6 | 15 | 6 | 3 | 8 | 27 | 15 | 37 | 18 | 10 | 25 | 3 | 2 | 5 |
| ≥59 | 21 | 12 | 30 | 22 | 12 | 30 | 11 | 6 | 15 | 6 | 3 | 8 | 28 | 16 | 39 | 19 | 11 | 26 | 4 | 2 | 5 |
| ≥60 | 23 | 13 | 31 | 23 | 13 | 32 | 12 | 7 | 16 | 6 | 4 | 8 | 30 | 17 | 41 | 20 | 11 | 27 | 4 | 2 | 5 |
| ≥61 | 24 | 14 | 32 | 25 | 14 | 33 | 12 | 7 | 17 | 7 | 4 | 9 | 32 | 18 | 43 | 21 | 12 | 28 | 4 | 2 | 5 |
| ≥62 | 25 | 15 | 34 | 26 | 15 | 35 | 13 | 8 | 17 | 7 | 4 | 9 | 33 | 19 | 44 | 22 | 13 | 30 | 4 | 2 | 6 |
| ≥63 | 27 | 15 | 35 | 27 | 16 | 36 | 14 | 8 | 18 | 7 | 4 | 10 | 35 | 20 | 46 | 24 | 14 | 31 | 4 | 3 | 6 |
| ≥64 | 28 | 16 | 36 | 29 | 17 | 37 | 15 | 9 | 19 | 8 | 4 | 10 | 37 | 22 | 48 | 25 | 14 | 32 | 5 | 3 | 6 |
| ≥65 | 29 | 17 | 38 | 30 | 18 | 39 | 15 | 9 | 20 | 8 | 5 | 10 | 39 | 23 | 50 | 26 | 15 | 33 | 5 | 3 | 6 |
| ≥66 | 31 | 18 | 39 | 32 | 19 | 40 | 16 | 10 | 20 | 8 | 5 | 11 | 41 | 24 | 52 | 27 | 16 | 35 | 5 | 3 | 7 |
| ≥67 | 32 | 19 | 40 | 33 | 20 | 41 | 17 | 10 | 21 | 9 | 5 | 11 | 43 | 25 | 53 | 29 | 17 | 36 | 5 | 3 | 7 |
| ≥68 | 34 | 20 | 42 | 35 | 21 | 43 | 18 | 11 | 22 | 9 | 6 | 11 | 45 | 27 | 55 | 30 | 18 | 37 | 6 | 3 | 7 |
| ≥69 | 35 | 21 | 43 | 36 | 22 | 44 | 18 | 11 | 22 | 10 | 6 | 12 | 47 | 28 | 57 | 31 | 19 | 38 | 6 | 4 | 7 |
| ≥70 | 37 | 22 | 44 | 38 | 23 | 46 | 19 | 12 | 23 | 10 | 6 | 12 | 49 | 30 | 59 | 33 | 20 | 39 | 6 | 4 | 7 |
| ≥71 | 91 | 76 | 98 | 93 | 78 | 101 | 47 | 40 | 51 | 25 | 21 | 27 | 120 | 101 | 130 | 80 | 67 | 87 | 15 | 13 | 17 |
| ≥72 | 99 | 84 | 106 | 102 | 86 | 109 | 51 | 43 | 55 | 27 | 23 | 29 | 130 | 110 | 140 | 87 | 74 | 94 | 17 | 14 | 18 |
| ≥73 | 107 | 91 | 114 | 110 | 94 | 117 | 55 | 47 | 59 | 29 | 25 | 31 | 141 | 120 | 150 | 94 | 81 | 101 | 18 | 15 | 19 |
| ≥74 | 115 | 99 | 121 | 118 | 101 | 125 | 60 | 51 | 63 | 31 | 27 | 33 | 151 | 130 | 160 | 101 | 87 | 107 | 19 | 17 | 20 |
| ≥75 | 123 | 106 | 129 | 126 | 109 | 133 | 64 | 55 | 67 | 34 | 29 | 35 | 162 | 140 | 170 | 108 | 94 | 114 | 21 | 18 | 22 |
| ≥76 | 131 | 114 | 137 | 134 | 117 | 141 | 68 | 59 | 71 | 36 | 31 | 37 | 172 | 150 | 181 | 116 | 101 | 121 | 22 | 19 | 23 |
| ≥77 | 139 | 122 | 144 | 142 | 125 | 148 | 72 | 63 | 75 | 38 | 33 | 40 | 183 | 161 | 191 | 123 | 108 | 128 | 23 | 20 | 24 |
| ≥78 | 147 | 129 | 152 | 151 | 133 | 156 | 76 | 67 | 79 | 40 | 35 | 42 | 194 | 171 | 201 | 130 | 114 | 135 | 25 | 22 | 26 |
| ≥79 | 155 | 137 | 160 | 159 | 141 | 164 | 80 | 71 | 83 | 42 | 38 | 44 | 204 | 181 | 211 | 137 | 121 | 141 | 26 | 23 | 27 |
| ≥80 | 163 | 145 | 167 | 167 | 149 | 172 | 85 | 75 | 87 | 45 | 40 | 46 | 215 | 191 | 221 | 144 | 128 | 148 | 27 | 24 | 28 |
| ≥81 | 171 | 152 | 175 | 176 | 157 | 180 | 89 | 79 | 91 | 47 | 42 | 48 | 226 | 201 | 231 | 151 | 135 | 155 | 29 | 26 | 29 |

Table 3.5 continued (New approach values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 1 | 0 | 2 | 7 | 3 | 13 | 2 | 1 | 4 | 6 | 3 | 10 | 1 | 1 | 2 | 3 | 1 | 5 | 1 | 0 | 2 |
| ≥44 | 1 | 0 | 2 | 9 | 4 | 15 | 3 | 1 | 4 | 7 | 3 | 11 | 1 | 1 | 2 | 3 | 1 | 5 | 1 | 1 | 2 |
| ≥45 | 1 | 1 | 2 | 10 | 5 | 17 | 3 | 1 | 5 | 7 | 4 | 13 | 1 | 1 | 2 | 3 | 2 | 6 | 1 | 1 | 2 |
| ≥46 | 1 | 1 | 2 | 11 | 5 | 18 | 3 | 2 | 6 | 8 | 4 | 14 | 2 | 1 | 3 | 4 | 2 | 6 | 1 | 1 | 2 |
| ≥47 | 1 | 1 | 2 | 12 | 6 | 20 | 4 | 2 | 6 | 9 | 5 | 15 | 2 | 1 | 3 | 4 | 2 | 7 | 2 | 1 | 3 |
| ≥48 | 2 | 1 | 3 | 14 | 7 | 22 | 4 | 2 | 7 | 10 | 5 | 17 | 2 | 1 | 3 | 5 | 2 | 8 | 2 | 1 | 3 |
| ≥49 | 2 | 1 | 3 | 15 | 7 | 24 | 4 | 2 | 7 | 11 | 6 | 18 | 2 | 1 | 4 | 5 | 3 | 8 | 2 | 1 | 3 |
| ≥50 | 2 | 1 | 3 | 16 | 8 | 25 | 5 | 2 | 8 | 12 | 6 | 19 | 2 | 1 | 4 | 6 | 3 | 9 | 2 | 1 | 3 |
| ≥51 | 2 | 1 | 3 | 18 | 9 | 27 | 5 | 3 | 8 | 14 | 7 | 21 | 3 | 1 | 4 | 6 | 3 | 9 | 2 | 1 | 4 |
| ≥52 | 2 | 1 | 3 | 19 | 10 | 29 | 6 | 3 | 9 | 15 | 8 | 22 | 3 | 1 | 4 | 7 | 3 | 10 | 3 | 1 | 4 |
| ≥53 | 2 | 1 | 4 | 21 | 11 | 31 | 6 | 3 | 9 | 16 | 8 | 24 | 3 | 2 | 5 | 7 | 4 | 11 | 3 | 1 | 4 |
| ≥54 | 3 | 1 | 4 | 22 | 12 | 33 | 7 | 4 | 10 | 17 | 9 | 25 | 3 | 2 | 5 | 8 | 4 | 11 | 3 | 2 | 4 |
| ≥55 | 3 | 2 | 4 | 24 | 13 | 35 | 7 | 4 | 11 | 18 | 10 | 27 | 4 | 2 | 5 | 8 | 4 | 12 | 3 | 2 | 5 |
| ≥56 | 3 | 2 | 4 | 26 | 14 | 37 | 8 | 4 | 11 | 20 | 11 | 28 | 4 | 2 | 5 | 9 | 5 | 13 | 3 | 2 | 5 |
| ≥57 | 3 | 2 | 5 | 27 | 15 | 39 | 8 | 5 | 12 | 21 | 12 | 30 | 4 | 2 | 6 | 9 | 5 | 13 | 4 | 2 | 5 |
| ≥58 | 3 | 2 | 5 | 29 | 16 | 41 | 9 | 5 | 12 | 22 | 12 | 31 | 4 | 2 | 6 | 10 | 6 | 14 | 4 | 2 | 5 |
| ≥59 | 4 | 2 | 5 | 31 | 17 | 43 | 9 | 5 | 13 | 24 | 13 | 33 | 5 | 3 | 6 | 11 | 6 | 15 | 4 | 2 | 6 |
| ≥60 | 4 | 2 | 5 | 33 | 19 | 45 | 10 | 6 | 13 | 25 | 14 | 34 | 5 | 3 | 7 | 11 | 6 | 15 | 4 | 2 | 6 |
| ≥61 | 4 | 2 | 6 | 35 | 20 | 47 | 10 | 6 | 14 | 27 | 15 | 36 | 5 | 3 | 7 | 12 | 7 | 16 | 5 | 3 | 6 |
| ≥62 | 4 | 2 | 6 | 37 | 21 | 49 | 11 | 6 | 15 | 28 | 16 | 37 | 5 | 3 | 7 | 13 | 7 | 17 | 5 | 3 | 6 |
| ≥63 | 5 | 3 | 6 | 39 | 22 | 50 | 12 | 7 | 15 | 30 | 17 | 39 | 6 | 3 | 7 | 13 | 8 | 17 | 5 | 3 | 7 |
| ≥64 | 5 | 3 | 6 | 41 | 24 | 52 | 12 | 7 | 16 | 31 | 18 | 40 | 6 | 4 | 8 | 14 | 8 | 18 | 5 | 3 | 7 |
| ≥65 | 5 | 3 | 6 | 43 | 25 | 54 | 13 | 8 | 16 | 33 | 19 | 42 | 6 | 4 | 8 | 15 | 9 | 19 | 6 | 3 | 7 |
| ≥66 | 5 | 3 | 7 | 45 | 26 | 56 | 13 | 8 | 17 | 34 | 20 | 43 | 7 | 4 | 8 | 15 | 9 | 19 | 6 | 3 | 7 |
| ≥67 | 6 | 3 | 7 | 47 | 28 | 58 | 14 | 8 | 18 | 36 | 21 | 45 | 7 | 4 | 9 | 16 | 10 | 20 | 6 | 4 | 8 |
| ≥68 | 6 | 3 | 7 | 49 | 29 | 60 | 15 | 9 | 18 | 37 | 22 | 46 | 7 | 4 | 9 | 17 | 10 | 21 | 6 | 4 | 8 |
| ≥69 | 6 | 4 | 7 | 51 | 31 | 62 | 15 | 9 | 19 | 39 | 24 | 48 | 8 | 5 | 9 | 18 | 11 | 21 | 7 | 4 | 8 |
| ≥70 | 6 | 4 | 8 | 53 | 32 | 64 | 16 | 10 | 19 | 41 | 25 | 49 | 8 | 5 | 10 | 18 | 11 | 22 | 7 | 4 | 8 |
| ≥71 | 16 | 13 | 17 | 131 | 110 | 142 | 40 | 33 | 43 | 100 | 84 | 109 | 19 | 16 | 21 | 45 | 38 | 49 | 17 | 15 | 19 |
| ≥72 | 17 | 14 | 18 | 143 | 121 | 153 | 43 | 36 | 46 | 109 | 92 | 117 | 21 | 18 | 23 | 49 | 42 | 53 | 19 | 16 | 20 |
| ≥73 | 18 | 16 | 19 | 154 | 132 | 164 | 47 | 40 | 50 | 118 | 101 | 126 | 23 | 20 | 24 | 53 | 45 | 57 | 20 | 17 | 22 |
| ≥74 | 20 | 17 | 21 | 166 | 143 | 175 | 50 | 43 | 53 | 127 | 109 | 134 | 25 | 21 | 26 | 57 | 49 | 61 | 22 | 19 | 23 |
| ≥75 | 21 | 18 | 22 | 177 | 154 | 187 | 53 | 46 | 56 | 135 | 117 | 143 | 26 | 23 | 28 | 61 | 53 | 64 | 23 | 20 | 25 |
| ≥76 | 22 | 19 | 23 | 189 | 165 | 198 | 57 | 50 | 60 | 144 | 126 | 151 | 28 | 24 | 29 | 65 | 57 | 68 | 25 | 22 | 26 |
| ≥77 | 24 | 21 | 25 | 200 | 176 | 209 | 60 | 53 | 63 | 153 | 134 | 160 | 30 | 26 | 31 | 69 | 61 | 72 | 26 | 23 | 28 |
| ≥78 | 25 | 22 | 26 | 212 | 187 | 220 | 64 | 56 | 66 | 162 | 143 | 168 | 31 | 28 | 33 | 73 | 64 | 76 | 28 | 25 | 29 |
| ≥79 | 26 | 23 | 27 | 224 | 198 | 231 | 67 | 60 | 70 | 171 | 151 | 176 | 33 | 29 | 34 | 77 | 68 | 80 | 29 | 26 | 30 |
| ≥80 | 28 | 25 | 29 | 235 | 209 | 242 | 71 | 63 | 73 | 180 | 160 | 185 | 35 | 31 | 36 | 81 | 72 | 83 | 31 | 28 | 32 |
| ≥81 | 29 | 26 | 30 | 247 | 220 | 253 | 74 | 66 | 76 | 189 | 168 | 193 | 37 | 33 | 37 | 85 | 76 | 87 | 33 | 29 | 33 |

Table 3.5 continued (New approach values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 2 | 1 | 4 | 4 | 2 | 6 | 6 | 3 | 11 | 8 | 4 | 15 | 6 | 3 | 10 |
| ≥44 | 3 | 1 | 5 | 4 | 2 | 7 | 7 | 3 | 12 | 9 | 4 | 16 | 7 | 3 | 12 |
| ≥45 | 3 | 2 | 5 | 5 | 2 | 8 | 8 | 4 | 13 | 11 | 5 | 18 | 8 | 4 | 13 |
| ≥46 | 4 | 2 | 6 | 5 | 3 | 9 | 9 | 4 | 15 | 12 | 6 | 20 | 9 | 4 | 14 |
| ≥47 | 4 | 2 | 7 | 6 | 3 | 10 | 10 | 5 | 16 | 13 | 7 | 22 | 9 | 5 | 16 |
| ≥48 | 4 | 2 | 7 | 6 | 3 | 11 | 11 | 5 | 17 | 15 | 7 | 24 | 11 | 5 | 17 |
| ≥49 | 5 | 2 | 8 | 7 | 4 | 11 | 12 | 6 | 19 | 16 | 8 | 26 | 12 | 6 | 18 |
| ≥50 | 5 | 3 | 8 | 8 | 4 | 12 | 13 | 7 | 20 | 18 | 9 | 28 | 13 | 6 | 20 |
| ≥51 | 6 | 3 | 9 | 9 | 4 | 13 | 14 | 7 | 22 | 20 | 10 | 30 | 14 | 7 | 21 |
| ≥52 | 6 | 3 | 10 | 9 | 5 | 14 | 15 | 8 | 23 | 21 | 11 | 32 | 15 | 8 | 23 |
| ≥53 | 7 | 4 | 10 | 10 | 5 | 15 | 17 | 9 | 25 | 23 | 12 | 34 | 16 | 9 | 24 |
| ≥54 | 7 | 4 | 11 | 11 | 6 | 16 | 18 | 10 | 26 | 25 | 13 | 36 | 17 | 9 | 26 |
| ≥55 | 8 | 4 | 11 | 12 | 6 | 17 | 19 | 10 | 28 | 27 | 14 | 39 | 19 | 10 | 27 |
| ≥56 | 8 | 5 | 12 | 12 | 7 | 18 | 21 | 11 | 29 | 28 | 15 | 41 | 20 | 11 | 29 |
| ≥57 | 9 | 5 | 13 | 13 | 7 | 19 | 22 | 12 | 31 | 30 | 17 | 43 | 21 | 12 | 30 |
| ≥58 | 10 | 5 | 13 | 14 | 8 | 20 | 23 | 13 | 33 | 32 | 18 | 45 | 23 | 13 | 32 |
| ≥59 | 10 | 6 | 14 | 15 | 8 | 20 | 25 | 14 | 34 | 34 | 19 | 47 | 24 | 13 | 33 |
| ≥60 | 11 | 6 | 15 | 16 | 9 | 21 | 26 | 15 | 36 | 36 | 20 | 49 | 26 | 14 | 35 |
| ≥61 | 11 | 6 | 15 | 17 | 9 | 22 | 28 | 16 | 37 | 38 | 22 | 51 | 27 | 15 | 36 |
| ≥62 | 12 | 7 | 16 | 18 | 10 | 23 | 29 | 17 | 39 | 40 | 23 | 54 | 29 | 16 | 38 |
| ≥63 | 13 | 7 | 16 | 19 | 11 | 24 | 31 | 18 | 40 | 43 | 25 | 56 | 30 | 17 | 39 |
| ≥64 | 13 | 8 | 17 | 19 | 11 | 25 | 32 | 19 | 42 | 45 | 26 | 58 | 32 | 18 | 41 |
| ≥65 | 14 | 8 | 18 | 20 | 12 | 26 | 34 | 20 | 44 | 47 | 28 | 60 | 33 | 20 | 42 |
| ≥66 | 15 | 9 | 18 | 21 | 13 | 27 | 36 | 21 | 45 | 49 | 29 | 62 | 35 | 21 | 44 |
| ≥67 | 15 | 9 | 19 | 22 | 13 | 28 | 37 | 22 | 47 | 52 | 31 | 64 | 36 | 22 | 45 |
| ≥68 | 16 | 10 | 20 | 23 | 14 | 29 | 39 | 24 | 48 | 54 | 32 | 67 | 38 | 23 | 47 |
| ≥69 | 17 | 10 | 20 | 24 | 15 | 30 | 41 | 25 | 50 | 56 | 34 | 69 | 40 | 24 | 48 |
| ≥70 | 17 | 11 | 21 | 26 | 16 | 31 | 42 | 26 | 51 | 59 | 36 | 71 | 41 | 25 | 50 |
| ≥71 | 43 | 36 | 46 | 63 | 53 | 68 | 105 | 88 | 114 | 145 | 122 | 157 | 102 | 86 | 111 |
| ≥72 | 47 | 39 | 50 | 69 | 58 | 74 | 114 | 97 | 123 | 158 | 134 | 169 | 111 | 94 | 119 |
| ≥73 | 50 | 43 | 54 | 74 | 63 | 79 | 123 | 105 | 131 | 170 | 146 | 182 | 120 | 103 | 128 |
| ≥74 | 54 | 47 | 57 | 80 | 69 | 84 | 133 | 114 | 140 | 183 | 158 | 194 | 129 | 111 | 137 |
| ≥75 | 58 | 50 | 61 | 85 | 74 | 90 | 142 | 123 | 149 | 196 | 170 | 206 | 138 | 120 | 145 |
| ≥76 | 62 | 54 | 64 | 91 | 79 | 95 | 151 | 132 | 158 | 209 | 182 | 218 | 147 | 128 | 154 |
| ≥77 | 65 | 57 | 68 | 96 | 84 | 100 | 160 | 141 | 167 | 221 | 194 | 231 | 156 | 137 | 163 |
| ≥78 | 69 | 61 | 72 | 102 | 90 | 106 | 169 | 149 | 176 | 234 | 206 | 243 | 165 | 145 | 171 |
| ≥79 | 73 | 64 | 75 | 107 | 95 | 111 | 179 | 158 | 185 | 247 | 219 | 255 | 174 | 154 | 180 |
| ≥80 | 77 | 68 | 79 | 113 | 100 | 116 | 188 | 167 | 193 | 260 | 231 | 267 | 183 | 163 | 188 |
| ≥81 | 80 | 72 | 82 | 119 | 106 | 121 | 197 | 176 | 202 | 273 | 243 | 279 | 192 | 172 | 197 |

Note: The New approach values are based on the expected annoyance level of exposed population, valued with the WTP for reducing annoyance based on the HEATCO stated preference studies (see Navrud et al. 2006), and quantifiable costs of health effects.

**Table 3.6** Cost factors (New approach) for noise exposure (€$_{2002}$ PPP, factor costs, per year per person exposed).

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 5 | 2 | 10 | 5 | 2 | 9 | 4 | 2 | 6 | 3 | 1 | 5 | 5 | 2 | 9 | 2 | 1 | 4 | 5 | 2 | 9 |
| ≥44 | 6 | 3 | 11 | 6 | 3 | 10 | 4 | 2 | 7 | 3 | 2 | 6 | 6 | 3 | 11 | 2 | 1 | 4 | 6 | 3 | 10 |
| ≥45 | 7 | 3 | 12 | 7 | 3 | 11 | 5 | 2 | 8 | 4 | 2 | 7 | 7 | 3 | 12 | 3 | 1 | 4 | 6 | 3 | 11 |
| ≥46 | 8 | 4 | 13 | 8 | 4 | 13 | 5 | 3 | 9 | 4 | 2 | 7 | 8 | 4 | 13 | 3 | 1 | 5 | 7 | 4 | 12 |
| ≥47 | 9 | 4 | 15 | 8 | 4 | 14 | 6 | 3 | 10 | 5 | 2 | 8 | 9 | 4 | 14 | 3 | 2 | 5 | 8 | 4 | 13 |
| ≥48 | 10 | 5 | 16 | 9 | 5 | 15 | 7 | 3 | 11 | 5 | 3 | 9 | 10 | 5 | 16 | 4 | 2 | 6 | 9 | 4 | 15 |
| ≥49 | 11 | 5 | 17 | 10 | 5 | 16 | 7 | 4 | 12 | 6 | 3 | 9 | 11 | 5 | 17 | 4 | 2 | 6 | 10 | 5 | 16 |
| ≥50 | 12 | 6 | 18 | 11 | 6 | 18 | 8 | 4 | 12 | 7 | 3 | 10 | 12 | 6 | 18 | 4 | 2 | 7 | 11 | 5 | 17 |
| ≥51 | 13 | 7 | 20 | 12 | 6 | 19 | 9 | 4 | 13 | 7 | 4 | 11 | 13 | 7 | 20 | 5 | 2 | 7 | 12 | 6 | 18 |
| ≥52 | 14 | 7 | 21 | 13 | 7 | 20 | 9 | 5 | 14 | 8 | 4 | 12 | 14 | 7 | 21 | 5 | 3 | 8 | 13 | 7 | 19 |
| ≥53 | 15 | 8 | 22 | 14 | 8 | 21 | 10 | 5 | 15 | 8 | 4 | 12 | 15 | 8 | 22 | 6 | 3 | 8 | 14 | 7 | 21 |
| ≥54 | 16 | 9 | 24 | 15 | 8 | 23 | 11 | 6 | 16 | 9 | 5 | 13 | 16 | 9 | 24 | 6 | 3 | 9 | 15 | 8 | 22 |
| ≥55 | 17 | 9 | 25 | 17 | 9 | 24 | 12 | 6 | 17 | 10 | 5 | 14 | 17 | 9 | 25 | 6 | 3 | 9 | 16 | 9 | 23 |
| ≥56 | 19 | 10 | 27 | 18 | 10 | 25 | 13 | 7 | 18 | 10 | 6 | 15 | 18 | 10 | 26 | 7 | 4 | 10 | 17 | 9 | 24 |
| ≥57 | 20 | 11 | 28 | 19 | 10 | 27 | 13 | 7 | 19 | 11 | 6 | 15 | 20 | 11 | 28 | 7 | 4 | 10 | 18 | 10 | 26 |
| ≥58 | 21 | 12 | 29 | 20 | 11 | 28 | 14 | 8 | 20 | 12 | 6 | 16 | 21 | 12 | 29 | 8 | 4 | 11 | 19 | 11 | 27 |
| ≥59 | 22 | 13 | 31 | 21 | 12 | 29 | 15 | 8 | 21 | 12 | 7 | 17 | 22 | 12 | 31 | 8 | 5 | 12 | 21 | 11 | 28 |
| ≥60 | 24 | 13 | 32 | 23 | 13 | 31 | 16 | 9 | 22 | 13 | 7 | 18 | 24 | 13 | 32 | 9 | 5 | 12 | 22 | 12 | 30 |
| ≥61 | 25 | 14 | 34 | 24 | 14 | 32 | 17 | 10 | 23 | 14 | 8 | 19 | 25 | 14 | 33 | 9 | 5 | 13 | 23 | 13 | 31 |
| ≥62 | 26 | 15 | 35 | 25 | 14 | 33 | 18 | 10 | 24 | 15 | 8 | 19 | 26 | 15 | 35 | 10 | 6 | 13 | 24 | 14 | 32 |
| ≥63 | 28 | 16 | 36 | 27 | 15 | 35 | 19 | 11 | 25 | 15 | 9 | 20 | 28 | 16 | 36 | 10 | 6 | 14 | 26 | 15 | 34 |
| ≥64 | 29 | 17 | 38 | 28 | 16 | 36 | 20 | 12 | 26 | 16 | 9 | 21 | 29 | 17 | 38 | 11 | 6 | 14 | 27 | 16 | 35 |
| ≥65 | 31 | 18 | 39 | 29 | 17 | 37 | 21 | 12 | 27 | 17 | 10 | 22 | 31 | 18 | 39 | 12 | 7 | 15 | 28 | 17 | 36 |
| ≥66 | 32 | 19 | 41 | 31 | 18 | 39 | 22 | 13 | 27 | 18 | 11 | 23 | 32 | 19 | 40 | 12 | 7 | 15 | 30 | 18 | 37 |
| ≥67 | 34 | 20 | 42 | 32 | 19 | 40 | 23 | 14 | 28 | 19 | 11 | 23 | 33 | 20 | 42 | 13 | 8 | 16 | 31 | 19 | 39 |
| ≥68 | 35 | 21 | 44 | 34 | 20 | 41 | 24 | 14 | 29 | 20 | 12 | 24 | 35 | 21 | 43 | 13 | 8 | 16 | 32 | 20 | 40 |
| ≥69 | 37 | 22 | 45 | 35 | 21 | 43 | 25 | 15 | 30 | 20 | 12 | 25 | 37 | 22 | 45 | 14 | 8 | 17 | 34 | 21 | 41 |
| ≥70 | 38 | 23 | 46 | 37 | 22 | 44 | 26 | 16 | 31 | 21 | 13 | 26 | 38 | 23 | 46 | 14 | 9 | 17 | 35 | 22 | 43 |
| ≥71 | 95 | 80 | 103 | 90 | 76 | 98 | 64 | 54 | 69 | 52 | 44 | 57 | 94 | 79 | 102 | 35 | 30 | 38 | 87 | 73 | 94 |
| ≥72 | 103 | 87 | 111 | 98 | 83 | 105 | 70 | 59 | 75 | 57 | 48 | 61 | 102 | 87 | 110 | 39 | 33 | 41 | 95 | 80 | 102 |
| ≥73 | 111 | 95 | 119 | 106 | 91 | 113 | 75 | 64 | 80 | 62 | 53 | 66 | 110 | 94 | 118 | 42 | 36 | 44 | 102 | 87 | 109 |
| ≥74 | 120 | 103 | 127 | 114 | 98 | 121 | 81 | 70 | 86 | 66 | 57 | 70 | 119 | 102 | 126 | 45 | 39 | 47 | 110 | 95 | 116 |
| ≥75 | 128 | 111 | 135 | 122 | 106 | 128 | 86 | 75 | 91 | 71 | 61 | 75 | 127 | 110 | 134 | 48 | 42 | 50 | 118 | 102 | 124 |
| ≥76 | 136 | 119 | 143 | 130 | 113 | 136 | 92 | 80 | 96 | 75 | 66 | 79 | 135 | 118 | 142 | 51 | 44 | 53 | 125 | 109 | 131 |
| ≥77 | 145 | 127 | 151 | 138 | 121 | 143 | 98 | 86 | 102 | 80 | 70 | 83 | 144 | 126 | 150 | 54 | 47 | 56 | 133 | 117 | 139 |
| ≥78 | 153 | 135 | 159 | 146 | 128 | 151 | 103 | 91 | 107 | 85 | 75 | 88 | 152 | 134 | 157 | 57 | 50 | 59 | 141 | 124 | 146 |
| ≥79 | 161 | 143 | 167 | 154 | 136 | 159 | 109 | 96 | 113 | 89 | 79 | 92 | 160 | 142 | 165 | 60 | 53 | 62 | 148 | 131 | 153 |
| ≥80 | 170 | 151 | 175 | 162 | 144 | 166 | 115 | 102 | 118 | 94 | 83 | 97 | 169 | 150 | 173 | 64 | 56 | 65 | 156 | 139 | 160 |
| ≥81 | 178 | 159 | 183 | 170 | 151 | 174 | 120 | 107 | 123 | 99 | 88 | 101 | 177 | 158 | 181 | 67 | 59 | 68 | 164 | 146 | 168 |

Table 3.6 continued (New approach values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 5 | 2 | 9 | 5 | 2 | 8 | 3 | 2 | 6 | 3 | 1 | 5 | 6 | 3 | 10 | 5 | 2 | 8 | 2 | 1 | 3 |
| ≥44 | 6 | 3 | 10 | 5 | 3 | 10 | 4 | 2 | 7 | 3 | 1 | 5 | 7 | 3 | 12 | 5 | 3 | 10 | 2 | 1 | 3 |
| ≥45 | 6 | 3 | 11 | 6 | 3 | 11 | 4 | 2 | 8 | 3 | 2 | 6 | 8 | 4 | 13 | 6 | 3 | 11 | 2 | 1 | 4 |
| ≥46 | 7 | 4 | 12 | 7 | 3 | 12 | 5 | 2 | 8 | 4 | 2 | 6 | 9 | 4 | 14 | 7 | 3 | 12 | 3 | 1 | 4 |
| ≥47 | 8 | 4 | 13 | 8 | 4 | 13 | 6 | 3 | 9 | 4 | 2 | 7 | 10 | 5 | 16 | 8 | 4 | 13 | 3 | 1 | 5 |
| ≥48 | 9 | 4 | 15 | 9 | 4 | 14 | 6 | 3 | 10 | 5 | 2 | 8 | 11 | 5 | 17 | 9 | 4 | 14 | 3 | 2 | 5 |
| ≥49 | 10 | 5 | 16 | 10 | 5 | 15 | 7 | 3 | 11 | 5 | 3 | 8 | 12 | 6 | 19 | 10 | 5 | 15 | 3 | 2 | 5 |
| ≥50 | 11 | 5 | 17 | 10 | 5 | 16 | 7 | 4 | 12 | 6 | 3 | 9 | 13 | 7 | 20 | 10 | 5 | 16 | 4 | 2 | 6 |
| ≥51 | 12 | 6 | 18 | 11 | 6 | 18 | 8 | 4 | 13 | 6 | 3 | 9 | 14 | 7 | 22 | 11 | 6 | 18 | 4 | 2 | 6 |
| ≥52 | 13 | 7 | 19 | 12 | 6 | 19 | 9 | 5 | 13 | 7 | 3 | 10 | 15 | 8 | 23 | 12 | 6 | 19 | 4 | 2 | 7 |
| ≥53 | 14 | 7 | 21 | 13 | 7 | 20 | 10 | 5 | 14 | 7 | 4 | 11 | 16 | 9 | 24 | 13 | 7 | 20 | 5 | 3 | 7 |
| ≥54 | 15 | 8 | 22 | 14 | 8 | 21 | 10 | 5 | 15 | 8 | 4 | 11 | 18 | 9 | 26 | 14 | 8 | 21 | 5 | 3 | 8 |
| ≥55 | 16 | 9 | 23 | 15 | 8 | 22 | 11 | 6 | 16 | 8 | 4 | 12 | 19 | 10 | 27 | 15 | 8 | 22 | 6 | 3 | 8 |
| ≥56 | 17 | 9 | 24 | 16 | 9 | 24 | 12 | 6 | 17 | 9 | 5 | 13 | 20 | 11 | 29 | 16 | 9 | 24 | 6 | 3 | 8 |
| ≥57 | 18 | 10 | 26 | 18 | 10 | 25 | 13 | 7 | 18 | 10 | 5 | 13 | 22 | 12 | 30 | 18 | 10 | 25 | 6 | 3 | 9 |
| ≥58 | 19 | 11 | 27 | 19 | 10 | 26 | 13 | 7 | 19 | 10 | 6 | 14 | 23 | 13 | 32 | 19 | 10 | 26 | 7 | 4 | 9 |
| ≥59 | 21 | 11 | 28 | 20 | 11 | 27 | 14 | 8 | 20 | 11 | 6 | 15 | 24 | 14 | 34 | 20 | 11 | 27 | 7 | 4 | 10 |
| ≥60 | 22 | 12 | 30 | 21 | 12 | 29 | 15 | 8 | 20 | 11 | 6 | 15 | 26 | 15 | 35 | 21 | 12 | 29 | 8 | 4 | 10 |
| ≥61 | 23 | 13 | 31 | 22 | 13 | 30 | 16 | 9 | 21 | 12 | 7 | 16 | 27 | 16 | 37 | 22 | 13 | 30 | 8 | 5 | 11 |
| ≥62 | 24 | 14 | 32 | 23 | 13 | 31 | 17 | 10 | 22 | 13 | 7 | 17 | 29 | 17 | 38 | 23 | 13 | 31 | 8 | 5 | 11 |
| ≥63 | 26 | 15 | 34 | 25 | 14 | 32 | 18 | 10 | 23 | 13 | 8 | 17 | 30 | 18 | 40 | 25 | 14 | 32 | 9 | 5 | 12 |
| ≥64 | 27 | 16 | 35 | 26 | 15 | 34 | 19 | 11 | 24 | 14 | 8 | 18 | 32 | 19 | 41 | 26 | 15 | 34 | 9 | 5 | 12 |
| ≥65 | 28 | 17 | 36 | 27 | 16 | 35 | 20 | 11 | 25 | 15 | 9 | 19 | 34 | 20 | 43 | 27 | 16 | 35 | 10 | 6 | 12 |
| ≥66 | 30 | 18 | 37 | 29 | 17 | 36 | 20 | 12 | 26 | 15 | 9 | 20 | 35 | 21 | 44 | 29 | 17 | 36 | 10 | 6 | 13 |
| ≥67 | 31 | 19 | 39 | 30 | 18 | 37 | 21 | 13 | 27 | 16 | 10 | 20 | 37 | 22 | 46 | 30 | 18 | 37 | 11 | 6 | 13 |
| ≥68 | 32 | 20 | 40 | 31 | 19 | 39 | 22 | 13 | 28 | 17 | 10 | 21 | 38 | 23 | 47 | 31 | 19 | 39 | 11 | 7 | 14 |
| ≥69 | 34 | 21 | 41 | 33 | 20 | 40 | 23 | 14 | 29 | 18 | 11 | 22 | 40 | 24 | 49 | 33 | 20 | 40 | 12 | 7 | 14 |
| ≥70 | 35 | 22 | 43 | 34 | 21 | 41 | 24 | 15 | 29 | 18 | 11 | 22 | 42 | 26 | 51 | 34 | 21 | 41 | 12 | 7 | 15 |
| ≥71 | 87 | 73 | 94 | 84 | 70 | 91 | 60 | 50 | 65 | 46 | 38 | 49 | 103 | 87 | 112 | 84 | 70 | 91 | 30 | 25 | 33 |
| ≥72 | 95 | 80 | 102 | 91 | 77 | 98 | 65 | 55 | 70 | 49 | 42 | 53 | 112 | 95 | 121 | 91 | 77 | 98 | 33 | 28 | 35 |
| ≥73 | 102 | 87 | 109 | 99 | 84 | 105 | 71 | 60 | 75 | 53 | 46 | 57 | 121 | 104 | 129 | 99 | 84 | 105 | 35 | 30 | 38 |
| ≥74 | 110 | 95 | 116 | 106 | 91 | 112 | 76 | 65 | 80 | 57 | 49 | 61 | 130 | 112 | 138 | 106 | 91 | 112 | 38 | 33 | 40 |
| ≥75 | 118 | 102 | 124 | 113 | 98 | 119 | 81 | 70 | 85 | 61 | 53 | 65 | 139 | 121 | 147 | 113 | 98 | 119 | 41 | 35 | 43 |
| ≥76 | 125 | 109 | 131 | 121 | 105 | 127 | 86 | 75 | 91 | 65 | 57 | 68 | 149 | 130 | 156 | 121 | 105 | 127 | 43 | 38 | 45 |
| ≥77 | 133 | 117 | 139 | 128 | 112 | 134 | 92 | 80 | 96 | 69 | 61 | 72 | 158 | 138 | 164 | 128 | 112 | 134 | 46 | 40 | 48 |
| ≥78 | 141 | 124 | 146 | 136 | 120 | 141 | 97 | 86 | 101 | 73 | 65 | 76 | 167 | 147 | 173 | 136 | 120 | 141 | 49 | 43 | 50 |
| ≥79 | 148 | 131 | 153 | 143 | 127 | 148 | 102 | 91 | 106 | 77 | 69 | 80 | 176 | 156 | 182 | 143 | 127 | 148 | 51 | 45 | 53 |
| ≥80 | 156 | 139 | 160 | 151 | 134 | 155 | 108 | 96 | 111 | 81 | 72 | 84 | 185 | 164 | 190 | 151 | 134 | 155 | 54 | 48 | 55 |
| ≥81 | 164 | 146 | 168 | 158 | 141 | 162 | 113 | 101 | 116 | 86 | 76 | 88 | 194 | 173 | 199 | 158 | 141 | 162 | 57 | 50 | 58 |

Table 3.6 continued (New approach values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 2 | 1 | 3 | 7 | 3 | 12 | 3 | 1 | 6 | 5 | 2 | 9 | 2 | 1 | 4 | 3 | 2 | 6 | 2 | 1 | 4 |
| ≥44 | 2 | 1 | 4 | 8 | 4 | 13 | 4 | 2 | 6 | 6 | 3 | 11 | 2 | 1 | 4 | 4 | 2 | 7 | 3 | 1 | 4 |
| ≥45 | 2 | 1 | 4 | 9 | 4 | 15 | 4 | 2 | 7 | 7 | 3 | 12 | 3 | 1 | 4 | 4 | 2 | 8 | 3 | 1 | 5 |
| ≥46 | 3 | 1 | 5 | 10 | 5 | 16 | 5 | 2 | 8 | 8 | 4 | 13 | 3 | 1 | 5 | 5 | 2 | 8 | 3 | 2 | 5 |
| ≥47 | 3 | 1 | 5 | 11 | 5 | 18 | 5 | 3 | 9 | 9 | 4 | 14 | 3 | 2 | 5 | 6 | 3 | 9 | 4 | 2 | 6 |
| ≥48 | 3 | 2 | 5 | 12 | 6 | 19 | 6 | 3 | 10 | 10 | 5 | 16 | 4 | 2 | 6 | 6 | 3 | 10 | 4 | 2 | 7 |
| ≥49 | 4 | 2 | 6 | 13 | 7 | 21 | 6 | 3 | 10 | 11 | 5 | 17 | 4 | 2 | 6 | 7 | 3 | 11 | 4 | 2 | 7 |
| ≥50 | 4 | 2 | 6 | 14 | 7 | 22 | 7 | 4 | 11 | 12 | 6 | 18 | 4 | 2 | 7 | 7 | 4 | 12 | 5 | 2 | 8 |
| ≥51 | 4 | 2 | 7 | 16 | 8 | 24 | 8 | 4 | 12 | 13 | 7 | 20 | 5 | 2 | 7 | 8 | 4 | 12 | 5 | 3 | 8 |
| ≥52 | 5 | 2 | 7 | 17 | 9 | 26 | 8 | 4 | 13 | 14 | 7 | 21 | 5 | 3 | 8 | 9 | 5 | 13 | 6 | 3 | 9 |
| ≥53 | 5 | 3 | 8 | 18 | 10 | 27 | 9 | 5 | 14 | 15 | 8 | 22 | 6 | 3 | 8 | 9 | 5 | 14 | 6 | 3 | 9 |
| ≥54 | 6 | 3 | 8 | 20 | 10 | 29 | 10 | 5 | 14 | 16 | 9 | 24 | 6 | 3 | 9 | 10 | 5 | 15 | 7 | 4 | 10 |
| ≥55 | 6 | 3 | 9 | 21 | 11 | 31 | 10 | 6 | 15 | 17 | 9 | 25 | 6 | 3 | 9 | 11 | 6 | 16 | 7 | 4 | 10 |
| ≥56 | 6 | 3 | 9 | 23 | 12 | 32 | 11 | 6 | 16 | 18 | 10 | 26 | 7 | 4 | 10 | 12 | 6 | 17 | 8 | 4 | 11 |
| ≥57 | 7 | 4 | 10 | 24 | 13 | 34 | 12 | 7 | 17 | 20 | 11 | 28 | 7 | 4 | 10 | 12 | 7 | 18 | 8 | 5 | 12 |
| ≥58 | 7 | 4 | 10 | 26 | 14 | 36 | 13 | 7 | 18 | 21 | 12 | 29 | 8 | 4 | 11 | 13 | 7 | 18 | 9 | 5 | 12 |
| ≥59 | 8 | 4 | 11 | 27 | 15 | 38 | 13 | 8 | 19 | 22 | 12 | 31 | 8 | 5 | 12 | 14 | 8 | 19 | 9 | 5 | 13 |
| ≥60 | 8 | 5 | 11 | 29 | 16 | 39 | 14 | 8 | 19 | 24 | 13 | 32 | 9 | 5 | 12 | 15 | 8 | 20 | 10 | 6 | 13 |
| ≥61 | 9 | 5 | 11 | 31 | 17 | 41 | 15 | 9 | 20 | 25 | 14 | 33 | 9 | 5 | 13 | 16 | 9 | 21 | 10 | 6 | 14 |
| ≥62 | 9 | 5 | 12 | 32 | 19 | 43 | 16 | 9 | 21 | 26 | 15 | 35 | 10 | 6 | 13 | 17 | 10 | 22 | 11 | 6 | 15 |
| ≥63 | 10 | 6 | 12 | 34 | 20 | 44 | 17 | 10 | 22 | 28 | 16 | 36 | 10 | 6 | 14 | 17 | 10 | 23 | 12 | 7 | 15 |
| ≥64 | 10 | 6 | 13 | 36 | 21 | 46 | 18 | 10 | 23 | 29 | 17 | 38 | 11 | 6 | 14 | 18 | 11 | 24 | 12 | 7 | 16 |
| ≥65 | 11 | 6 | 13 | 38 | 22 | 48 | 19 | 11 | 24 | 31 | 18 | 39 | 12 | 7 | 15 | 19 | 11 | 25 | 13 | 7 | 16 |
| ≥66 | 11 | 7 | 14 | 39 | 23 | 50 | 19 | 11 | 25 | 32 | 19 | 40 | 12 | 7 | 15 | 20 | 12 | 25 | 13 | 8 | 17 |
| ≥67 | 12 | 7 | 14 | 41 | 25 | 51 | 20 | 12 | 25 | 33 | 20 | 42 | 13 | 8 | 16 | 21 | 13 | 26 | 14 | 8 | 17 |
| ≥68 | 12 | 7 | 15 | 43 | 26 | 53 | 21 | 13 | 26 | 35 | 21 | 43 | 13 | 8 | 16 | 22 | 13 | 27 | 15 | 9 | 18 |
| ≥69 | 13 | 8 | 15 | 45 | 27 | 55 | 22 | 13 | 27 | 37 | 22 | 45 | 14 | 8 | 17 | 23 | 14 | 28 | 15 | 9 | 19 |
| ≥70 | 13 | 8 | 16 | 47 | 29 | 57 | 23 | 14 | 28 | 38 | 23 | 46 | 14 | 9 | 17 | 24 | 15 | 29 | 16 | 10 | 19 |
| ≥71 | 32 | 27 | 35 | 116 | 97 | 125 | 57 | 48 | 62 | 94 | 79 | 102 | 35 | 30 | 38 | 59 | 50 | 64 | 39 | 33 | 43 |
| ≥72 | 35 | 30 | 38 | 126 | 106 | 135 | 62 | 53 | 67 | 102 | 87 | 110 | 39 | 33 | 41 | 65 | 55 | 69 | 43 | 36 | 46 |
| ≥73 | 38 | 33 | 41 | 136 | 116 | 145 | 67 | 57 | 71 | 110 | 94 | 118 | 42 | 36 | 44 | 70 | 60 | 74 | 46 | 39 | 49 |
| ≥74 | 41 | 35 | 43 | 146 | 126 | 155 | 72 | 62 | 76 | 119 | 102 | 126 | 45 | 39 | 47 | 75 | 65 | 79 | 50 | 43 | 53 |
| ≥75 | 44 | 38 | 46 | 156 | 135 | 164 | 77 | 67 | 81 | 127 | 110 | 134 | 48 | 42 | 50 | 80 | 69 | 84 | 53 | 46 | 56 |
| ≥76 | 47 | 41 | 49 | 166 | 145 | 174 | 82 | 72 | 86 | 135 | 118 | 142 | 51 | 44 | 53 | 85 | 74 | 89 | 57 | 49 | 59 |
| ≥77 | 49 | 43 | 51 | 177 | 155 | 184 | 87 | 76 | 91 | 144 | 126 | 150 | 54 | 47 | 56 | 91 | 79 | 94 | 60 | 53 | 63 |
| ≥78 | 52 | 46 | 54 | 187 | 165 | 194 | 92 | 81 | 96 | 152 | 134 | 157 | 57 | 50 | 59 | 96 | 84 | 99 | 63 | 56 | 66 |
| ≥79 | 55 | 49 | 57 | 197 | 174 | 203 | 97 | 86 | 100 | 160 | 142 | 165 | 60 | 53 | 62 | 101 | 89 | 104 | 67 | 59 | 69 |
| ≥80 | 58 | 52 | 60 | 207 | 184 | 213 | 102 | 91 | 105 | 169 | 150 | 173 | 64 | 56 | 65 | 106 | 95 | 109 | 70 | 63 | 72 |
| ≥81 | 61 | 54 | 62 | 217 | 194 | 223 | 107 | 96 | 110 | 177 | 158 | 181 | 67 | 59 | 68 | 112 | 100 | 114 | 74 | 66 | 76 |

Table 3.6 continued (New approach values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥43 | 3 | 2 | 6 | 4 | 2 | 7 | 5 | 2 | 9 | 6 | 3 | 10 | 5 | 2 | 9 |
| ≥44 | 4 | 2 | 7 | 5 | 2 | 8 | 6 | 3 | 10 | 7 | 3 | 12 | 6 | 3 | 10 |
| ≥45 | 4 | 2 | 7 | 5 | 3 | 9 | 7 | 3 | 11 | 8 | 4 | 13 | 7 | 3 | 11 |
| ≥46 | 5 | 2 | 8 | 6 | 3 | 10 | 7 | 4 | 12 | 8 | 4 | 14 | 8 | 4 | 13 |
| ≥47 | 5 | 3 | 9 | 7 | 3 | 11 | 8 | 4 | 14 | 9 | 5 | 16 | 8 | 4 | 14 |
| ≥48 | 6 | 3 | 10 | 8 | 4 | 12 | 9 | 5 | 15 | 10 | 5 | 17 | 9 | 5 | 15 |
| ≥49 | 7 | 3 | 10 | 8 | 4 | 13 | 10 | 5 | 16 | 12 | 6 | 18 | 10 | 5 | 16 |
| ≥50 | 7 | 4 | 11 | 9 | 5 | 14 | 11 | 6 | 17 | 13 | 6 | 20 | 11 | 6 | 18 |
| ≥51 | 8 | 4 | 12 | 10 | 5 | 15 | 12 | 6 | 18 | 14 | 7 | 21 | 12 | 6 | 19 |
| ≥52 | 8 | 4 | 13 | 11 | 6 | 16 | 13 | 7 | 20 | 15 | 8 | 23 | 13 | 7 | 20 |
| ≥53 | 9 | 5 | 14 | 12 | 6 | 17 | 14 | 7 | 21 | 16 | 8 | 24 | 14 | 8 | 22 |
| ≥54 | 10 | 5 | 15 | 13 | 7 | 18 | 15 | 8 | 22 | 17 | 9 | 26 | 16 | 8 | 23 |
| ≥55 | 11 | 6 | 15 | 13 | 7 | 19 | 16 | 9 | 24 | 19 | 10 | 27 | 17 | 9 | 24 |
| ≥56 | 11 | 6 | 16 | 14 | 8 | 21 | 17 | 9 | 25 | 20 | 11 | 29 | 18 | 10 | 26 |
| ≥57 | 12 | 7 | 17 | 15 | 8 | 22 | 19 | 10 | 26 | 21 | 12 | 30 | 19 | 10 | 27 |
| ≥58 | 13 | 7 | 18 | 16 | 9 | 23 | 20 | 11 | 27 | 23 | 13 | 32 | 20 | 11 | 28 |
| ≥59 | 14 | 8 | 19 | 17 | 10 | 24 | 21 | 12 | 29 | 24 | 13 | 33 | 21 | 12 | 30 |
| ≥60 | 14 | 8 | 20 | 18 | 10 | 25 | 22 | 13 | 30 | 25 | 14 | 35 | 23 | 13 | 31 |
| ≥61 | 15 | 9 | 21 | 19 | 11 | 26 | 23 | 13 | 31 | 27 | 15 | 36 | 24 | 14 | 32 |
| ≥62 | 16 | 9 | 21 | 20 | 12 | 27 | 25 | 14 | 33 | 28 | 16 | 38 | 25 | 15 | 34 |
| ≥63 | 17 | 10 | 22 | 22 | 12 | 28 | 26 | 15 | 34 | 30 | 17 | 39 | 27 | 15 | 35 |
| ≥64 | 18 | 10 | 23 | 23 | 13 | 29 | 27 | 16 | 35 | 31 | 18 | 41 | 28 | 16 | 36 |
| ≥65 | 19 | 11 | 24 | 24 | 14 | 30 | 29 | 17 | 37 | 33 | 19 | 42 | 30 | 17 | 38 |
| ≥66 | 20 | 12 | 25 | 25 | 15 | 31 | 30 | 18 | 38 | 35 | 21 | 44 | 31 | 18 | 39 |
| ≥67 | 21 | 12 | 26 | 26 | 16 | 33 | 32 | 19 | 39 | 36 | 22 | 45 | 32 | 19 | 40 |
| ≥68 | 22 | 13 | 27 | 27 | 16 | 34 | 33 | 20 | 41 | 38 | 23 | 47 | 34 | 20 | 42 |
| ≥69 | 22 | 14 | 27 | 28 | 17 | 35 | 34 | 21 | 42 | 40 | 24 | 48 | 35 | 21 | 43 |
| ≥70 | 23 | 14 | 28 | 30 | 18 | 36 | 36 | 22 | 43 | 41 | 25 | 50 | 37 | 23 | 44 |
| ≥71 | 58 | 49 | 63 | 73 | 61 | 79 | 89 | 74 | 96 | 102 | 85 | 110 | 91 | 76 | 99 |
| ≥72 | 63 | 53 | 67 | 80 | 67 | 85 | 96 | 82 | 103 | 111 | 94 | 119 | 99 | 84 | 106 |
| ≥73 | 68 | 58 | 72 | 86 | 74 | 92 | 104 | 89 | 111 | 120 | 102 | 127 | 107 | 91 | 114 |
| ≥74 | 73 | 63 | 77 | 92 | 80 | 98 | 112 | 96 | 119 | 128 | 111 | 136 | 115 | 99 | 122 |
| ≥75 | 78 | 68 | 82 | 99 | 86 | 104 | 120 | 104 | 126 | 137 | 119 | 145 | 123 | 106 | 129 |
| ≥76 | 83 | 73 | 87 | 105 | 92 | 110 | 128 | 111 | 133 | 146 | 128 | 153 | 131 | 114 | 137 |
| ≥77 | 88 | 77 | 92 | 112 | 98 | 116 | 135 | 119 | 141 | 155 | 136 | 162 | 139 | 122 | 145 |
| ≥78 | 93 | 82 | 97 | 118 | 104 | 123 | 143 | 126 | 148 | 164 | 145 | 170 | 147 | 129 | 152 |
| ≥79 | 98 | 87 | 102 | 125 | 110 | 129 | 151 | 134 | 156 | 173 | 153 | 179 | 155 | 137 | 160 |
| ≥80 | 104 | 92 | 107 | 131 | 117 | 135 | 159 | 141 | 163 | 182 | 162 | 187 | 163 | 145 | 168 |
| ≥81 | 109 | 97 | 111 | 138 | 123 | 141 | 167 | 149 | 171 | 191 | 171 | 196 | 171 | 153 | 175 |

Note: The New approach values are based on the expected annoyance level of exposed population, valued with the WTP for reducing annoyance based on the HEATCO stated preference studies (see Navrud et al. 2006), and quantifiable costs of health effects.

**Table 3.7** Cost factors (High values) for noise exposure (€$_{2002}$, factor costs, per year per person exposed).

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 24 | 0 | 37 | 22 | 0 | 34 | 13 | 0 | 21 | 7 | 0 | 10 | 29 | 0 | 46 | 5 | 0 | 7 | 23 | 0 | 36 |
| ≥52 | 47 | 0 | 73 | 44 | 0 | 68 | 27 | 0 | 42 | 13 | 0 | 21 | 59 | 0 | 91 | 9 | 0 | 15 | 47 | 0 | 72 |
| ≥53 | 71 | 0 | 110 | 66 | 0 | 102 | 40 | 0 | 63 | 20 | 0 | 31 | 88 | 0 | 137 | 14 | 0 | 22 | 70 | 0 | 108 |
| ≥54 | 94 | 0 | 146 | 88 | 0 | 136 | 54 | 0 | 83 | 27 | 0 | 42 | 118 | 0 | 183 | 19 | 0 | 29 | 93 | 0 | 144 |
| ≥55 | 118 | 0 | 183 | 110 | 0 | 170 | 67 | 0 | 104 | 34 | 0 | 52 | 147 | 0 | 228 | 23 | 0 | 36 | 116 | 0 | 180 |
| ≥56 | 141 | 24 | 219 | 132 | 22 | 205 | 81 | 13 | 125 | 40 | 7 | 62 | 177 | 29 | 274 | 28 | 5 | 44 | 140 | 23 | 216 |
| ≥57 | 165 | 47 | 256 | 154 | 44 | 239 | 94 | 27 | 146 | 47 | 13 | 73 | 206 | 59 | 320 | 33 | 9 | 51 | 163 | 47 | 252 |
| ≥58 | 189 | 71 | 292 | 176 | 66 | 273 | 108 | 40 | 167 | 54 | 20 | 83 | 236 | 88 | 365 | 38 | 14 | 58 | 186 | 70 | 288 |
| ≥59 | 212 | 94 | 329 | 198 | 88 | 307 | 121 | 54 | 188 | 60 | 27 | 94 | 265 | 118 | 411 | 42 | 19 | 66 | 209 | 93 | 324 |
| ≥60 | 236 | 118 | 365 | 220 | 110 | 341 | 135 | 67 | 209 | 67 | 34 | 104 | 295 | 147 | 457 | 47 | 23 | 73 | 233 | 116 | 360 |
| ≥61 | 259 | 141 | 402 | 242 | 132 | 375 | 148 | 81 | 229 | 74 | 40 | 114 | 324 | 177 | 502 | 52 | 28 | 80 | 256 | 140 | 397 |
| ≥62 | 283 | 165 | 438 | 264 | 154 | 409 | 161 | 94 | 250 | 81 | 47 | 125 | 353 | 206 | 548 | 56 | 33 | 87 | 279 | 163 | 433 |
| ≥63 | 306 | 189 | 475 | 286 | 176 | 443 | 175 | 108 | 271 | 87 | 54 | 135 | 383 | 236 | 594 | 61 | 38 | 95 | 302 | 186 | 469 |
| ≥64 | 330 | 212 | 512 | 308 | 198 | 477 | 188 | 121 | 292 | 94 | 60 | 146 | 412 | 265 | 639 | 66 | 42 | 102 | 326 | 209 | 505 |
| ≥65 | 354 | 236 | 548 | 330 | 220 | 511 | 202 | 135 | 313 | 101 | 67 | 156 | 442 | 295 | 685 | 70 | 47 | 109 | 349 | 233 | 541 |
| ≥66 | 377 | 259 | 585 | 352 | 242 | 545 | 215 | 148 | 334 | 107 | 74 | 166 | 471 | 324 | 731 | 75 | 52 | 117 | 372 | 256 | 577 |
| ≥67 | 401 | 283 | 621 | 374 | 264 | 580 | 229 | 161 | 354 | 114 | 81 | 177 | 501 | 353 | 776 | 80 | 56 | 124 | 395 | 279 | 613 |
| ≥68 | 424 | 306 | 658 | 396 | 286 | 614 | 242 | 175 | 375 | 121 | 87 | 187 | 530 | 383 | 822 | 85 | 61 | 131 | 419 | 302 | 649 |
| ≥69 | 448 | 330 | 694 | 418 | 308 | 648 | 256 | 188 | 396 | 127 | 94 | 198 | 560 | 412 | 868 | 89 | 66 | 138 | 442 | 326 | 685 |
| ≥70 | 471 | 354 | 731 | 440 | 330 | 682 | 269 | 202 | 417 | 134 | 101 | 208 | 589 | 442 | 913 | 94 | 70 | 146 | 465 | 349 | 721 |
| ≥71 | 552 | 434 | 825 | 515 | 405 | 769 | 315 | 248 | 471 | 157 | 124 | 235 | 690 | 543 | 1030 | 110 | 87 | 164 | 545 | 429 | 814 |
| ≥72 | 583 | 465 | 868 | 544 | 434 | 810 | 333 | 265 | 495 | 166 | 132 | 247 | 728 | 581 | 1085 | 116 | 93 | 173 | 575 | 459 | 856 |
| ≥73 | 613 | 495 | 912 | 572 | 462 | 850 | 350 | 283 | 520 | 175 | 141 | 259 | 766 | 619 | 1139 | 122 | 99 | 182 | 605 | 489 | 899 |
| ≥74 | 644 | 526 | 955 | 601 | 491 | 891 | 367 | 300 | 545 | 183 | 150 | 272 | 805 | 657 | 1193 | 128 | 105 | 190 | 635 | 519 | 942 |
| ≥75 | 674 | 556 | 998 | 629 | 519 | 932 | 385 | 318 | 570 | 192 | 158 | 284 | 843 | 695 | 1248 | 134 | 111 | 199 | 665 | 549 | 985 |
| ≥76 | 705 | 587 | 1042 | 658 | 548 | 972 | 402 | 335 | 595 | 201 | 167 | 297 | 881 | 734 | 1302 | 141 | 117 | 208 | 695 | 579 | 1028 |
| ≥77 | 735 | 618 | 1085 | 686 | 576 | 1013 | 420 | 352 | 619 | 209 | 176 | 309 | 919 | 772 | 1356 | 147 | 123 | 216 | 725 | 609 | 1071 |
| ≥78 | 766 | 648 | 1129 | 715 | 605 | 1053 | 437 | 370 | 644 | 218 | 184 | 321 | 957 | 810 | 1411 | 153 | 129 | 225 | 756 | 639 | 1114 |
| ≥79 | 796 | 679 | 1172 | 743 | 633 | 1094 | 454 | 387 | 669 | 227 | 193 | 334 | 995 | 848 | 1465 | 159 | 135 | 234 | 786 | 669 | 1157 |
| ≥80 | 827 | 709 | 1216 | 772 | 662 | 1134 | 472 | 405 | 694 | 235 | 202 | 346 | 1033 | 886 | 1519 | 165 | 141 | 242 | 816 | 700 | 1200 |
| ≥81 | 858 | 740 | 1259 | 800 | 690 | 1175 | 489 | 422 | 719 | 244 | 211 | 358 | 1072 | 924 | 1574 | 171 | 147 | 251 | 846 | 730 | 1242 |

Table 3.7 continued (High values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 22 | 0 | 34 | 22 | 0 | 34 | 11 | 0 | 17 | 6 | 0 | 9 | 29 | 0 | 44 | 19 | 0 | 30 | 4 | 0 | 6 |
| ≥52 | 43 | 0 | 67 | 45 | 0 | 69 | 23 | 0 | 35 | 12 | 0 | 18 | 57 | 0 | 89 | 38 | 0 | 59 | 7 | 0 | 11 |
| ≥53 | 65 | 0 | 101 | 67 | 0 | 103 | 34 | 0 | 52 | 18 | 0 | 28 | 86 | 0 | 133 | 57 | 0 | 89 | 11 | 0 | 17 |
| ≥54 | 87 | 0 | 134 | 89 | 0 | 138 | 45 | 0 | 70 | 24 | 0 | 37 | 114 | 0 | 177 | 77 | 0 | 119 | 15 | 0 | 23 |
| ≥55 | 108 | 0 | 168 | 111 | 0 | 172 | 56 | 0 | 87 | 30 | 0 | 46 | 143 | 0 | 222 | 96 | 0 | 148 | 18 | 0 | 28 |
| ≥56 | 130 | 22 | 201 | 134 | 22 | 207 | 68 | 11 | 105 | 36 | 6 | 55 | 172 | 29 | 266 | 115 | 19 | 178 | 22 | 4 | 34 |
| ≥57 | 152 | 43 | 235 | 156 | 45 | 241 | 79 | 23 | 122 | 42 | 12 | 64 | 200 | 57 | 310 | 134 | 38 | 208 | 25 | 7 | 39 |
| ≥58 | 173 | 65 | 269 | 178 | 67 | 276 | 90 | 34 | 140 | 47 | 18 | 74 | 229 | 86 | 354 | 153 | 57 | 237 | 29 | 11 | 45 |
| ≥59 | 195 | 87 | 302 | 200 | 89 | 310 | 101 | 45 | 157 | 53 | 24 | 83 | 257 | 114 | 399 | 172 | 77 | 267 | 33 | 15 | 51 |
| ≥60 | 217 | 108 | 336 | 223 | 111 | 345 | 113 | 56 | 174 | 59 | 30 | 92 | 286 | 143 | 443 | 191 | 96 | 297 | 36 | 18 | 56 |
| ≥61 | 238 | 130 | 369 | 245 | 134 | 379 | 124 | 68 | 192 | 65 | 36 | 101 | 314 | 172 | 487 | 211 | 115 | 326 | 40 | 22 | 62 |
| ≥62 | 260 | 152 | 403 | 267 | 156 | 414 | 135 | 79 | 209 | 71 | 42 | 110 | 343 | 200 | 532 | 230 | 134 | 356 | 44 | 25 | 68 |
| ≥63 | 282 | 173 | 436 | 289 | 178 | 448 | 146 | 90 | 227 | 77 | 47 | 119 | 372 | 229 | 576 | 249 | 153 | 386 | 47 | 29 | 73 |
| ≥64 | 303 | 195 | 470 | 312 | 200 | 483 | 158 | 101 | 244 | 83 | 53 | 129 | 400 | 257 | 620 | 268 | 172 | 416 | 51 | 33 | 79 |
| ≥65 | 325 | 217 | 504 | 334 | 223 | 517 | 169 | 113 | 262 | 89 | 59 | 138 | 429 | 286 | 665 | 287 | 191 | 445 | 55 | 36 | 85 |
| ≥66 | 347 | 238 | 537 | 356 | 245 | 552 | 180 | 124 | 279 | 95 | 65 | 147 | 457 | 314 | 709 | 306 | 211 | 475 | 58 | 40 | 90 |
| ≥67 | 368 | 260 | 571 | 378 | 267 | 586 | 191 | 135 | 296 | 101 | 71 | 156 | 486 | 343 | 753 | 326 | 230 | 505 | 62 | 44 | 96 |
| ≥68 | 390 | 282 | 604 | 401 | 289 | 621 | 203 | 146 | 314 | 107 | 77 | 165 | 515 | 372 | 798 | 345 | 249 | 534 | 66 | 47 | 102 |
| ≥69 | 411 | 303 | 638 | 423 | 312 | 655 | 214 | 158 | 331 | 113 | 83 | 175 | 543 | 400 | 842 | 364 | 268 | 564 | 69 | 51 | 107 |
| ≥70 | 433 | 325 | 671 | 445 | 334 | 690 | 225 | 169 | 349 | 119 | 89 | 184 | 572 | 429 | 886 | 383 | 287 | 594 | 73 | 55 | 113 |
| ≥71 | 507 | 399 | 758 | 521 | 410 | 778 | 264 | 207 | 394 | 139 | 109 | 207 | 670 | 527 | 1000 | 449 | 353 | 670 | 85 | 67 | 127 |
| ≥72 | 535 | 427 | 797 | 550 | 439 | 819 | 278 | 222 | 414 | 147 | 117 | 218 | 707 | 564 | 1053 | 473 | 378 | 705 | 90 | 72 | 134 |
| ≥73 | 563 | 455 | 837 | 579 | 468 | 860 | 293 | 236 | 435 | 154 | 125 | 229 | 744 | 601 | 1105 | 498 | 402 | 740 | 95 | 77 | 141 |
| ≥74 | 591 | 483 | 877 | 608 | 496 | 901 | 307 | 251 | 456 | 162 | 132 | 240 | 781 | 638 | 1158 | 523 | 427 | 776 | 99 | 81 | 147 |
| ≥75 | 620 | 511 | 917 | 637 | 525 | 943 | 322 | 266 | 477 | 170 | 140 | 251 | 818 | 675 | 1211 | 548 | 452 | 811 | 104 | 86 | 154 |
| ≥76 | 648 | 539 | 957 | 665 | 554 | 984 | 336 | 280 | 497 | 177 | 148 | 262 | 855 | 712 | 1264 | 573 | 477 | 846 | 109 | 91 | 161 |
| ≥77 | 676 | 567 | 997 | 694 | 583 | 1025 | 351 | 295 | 518 | 185 | 155 | 273 | 892 | 749 | 1316 | 597 | 502 | 882 | 114 | 95 | 168 |
| ≥78 | 704 | 595 | 1037 | 723 | 612 | 1066 | 366 | 309 | 539 | 193 | 163 | 284 | 929 | 786 | 1369 | 622 | 526 | 917 | 118 | 100 | 174 |
| ≥79 | 732 | 623 | 1077 | 752 | 641 | 1107 | 380 | 324 | 560 | 200 | 171 | 295 | 966 | 823 | 1422 | 647 | 551 | 952 | 123 | 105 | 181 |
| ≥80 | 760 | 651 | 1117 | 781 | 669 | 1148 | 395 | 338 | 580 | 208 | 178 | 306 | 1003 | 860 | 1475 | 672 | 576 | 988 | 128 | 110 | 188 |
| ≥81 | 788 | 680 | 1157 | 809 | 698 | 1189 | 409 | 353 | 601 | 216 | 186 | 317 | 1040 | 897 | 1527 | 697 | 601 | 1023 | 132 | 114 | 194 |

Table 3.7 continued (High values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 4 | 0 | 6 | 31 | 0 | 48 | 9 | 0 | 15 | 24 | 0 | 37 | 5 | 0 | 7 | 11 | 0 | 17 | 4 | 0 | 6 |
| ≥52 | 7 | 0 | 11 | 63 | 0 | 97 | 19 | 0 | 29 | 48 | 0 | 74 | 9 | 0 | 14 | 22 | 0 | 33 | 8 | 0 | 13 |
| ≥53 | 11 | 0 | 17 | 94 | 0 | 145 | 28 | 0 | 44 | 72 | 0 | 111 | 14 | 0 | 22 | 32 | 0 | 50 | 12 | 0 | 19 |
| ≥54 | 15 | 0 | 23 | 125 | 0 | 194 | 38 | 0 | 59 | 96 | 0 | 148 | 19 | 0 | 29 | 43 | 0 | 67 | 16 | 0 | 26 |
| ≥55 | 18 | 0 | 29 | 156 | 0 | 242 | 47 | 0 | 73 | 120 | 0 | 185 | 23 | 0 | 36 | 54 | 0 | 84 | 21 | 0 | 32 |
| ≥56 | 22 | 4 | 34 | 188 | 31 | 291 | 57 | 9 | 88 | 144 | 24 | 222 | 28 | 5 | 43 | 65 | 11 | 100 | 25 | 4 | 38 |
| ≥57 | 26 | 7 | 40 | 219 | 63 | 339 | 66 | 19 | 102 | 167 | 48 | 260 | 32 | 9 | 50 | 76 | 22 | 117 | 29 | 8 | 45 |
| ≥58 | 30 | 11 | 46 | 250 | 94 | 388 | 75 | 28 | 117 | 191 | 72 | 297 | 37 | 14 | 57 | 86 | 32 | 134 | 33 | 12 | 51 |
| ≥59 | 33 | 15 | 52 | 282 | 125 | 436 | 85 | 38 | 132 | 215 | 96 | 334 | 42 | 19 | 65 | 97 | 43 | 151 | 37 | 16 | 58 |
| ≥60 | 37 | 18 | 57 | 313 | 156 | 485 | 94 | 47 | 146 | 239 | 120 | 371 | 46 | 23 | 72 | 108 | 54 | 167 | 41 | 21 | 64 |
| ≥61 | 41 | 22 | 63 | 344 | 188 | 533 | 104 | 57 | 161 | 263 | 144 | 408 | 51 | 28 | 79 | 119 | 65 | 184 | 45 | 25 | 70 |
| ≥62 | 44 | 26 | 69 | 375 | 219 | 582 | 113 | 66 | 176 | 287 | 167 | 445 | 56 | 32 | 86 | 130 | 76 | 201 | 49 | 29 | 77 |
| ≥63 | 48 | 30 | 74 | 407 | 250 | 630 | 123 | 75 | 190 | 311 | 191 | 482 | 60 | 37 | 93 | 140 | 86 | 218 | 54 | 33 | 83 |
| ≥64 | 52 | 33 | 80 | 438 | 282 | 679 | 132 | 85 | 205 | 335 | 215 | 519 | 65 | 42 | 101 | 151 | 97 | 234 | 58 | 37 | 89 |
| ≥65 | 55 | 37 | 86 | 469 | 313 | 727 | 142 | 94 | 219 | 359 | 239 | 556 | 69 | 46 | 108 | 162 | 108 | 251 | 62 | 41 | 96 |
| ≥66 | 59 | 41 | 92 | 501 | 344 | 776 | 151 | 104 | 234 | 383 | 263 | 593 | 74 | 51 | 115 | 173 | 119 | 268 | 66 | 45 | 102 |
| ≥67 | 63 | 44 | 97 | 532 | 375 | 824 | 160 | 113 | 249 | 407 | 287 | 630 | 79 | 56 | 122 | 184 | 130 | 284 | 70 | 49 | 109 |
| ≥68 | 67 | 48 | 103 | 563 | 407 | 873 | 170 | 123 | 263 | 431 | 311 | 667 | 83 | 60 | 129 | 194 | 140 | 301 | 74 | 54 | 115 |
| ≥69 | 70 | 52 | 109 | 594 | 438 | 921 | 179 | 132 | 278 | 454 | 335 | 704 | 88 | 65 | 136 | 205 | 151 | 318 | 78 | 58 | 121 |
| ≥70 | 74 | 55 | 115 | 626 | 469 | 970 | 189 | 142 | 293 | 478 | 359 | 742 | 93 | 69 | 144 | 216 | 162 | 335 | 82 | 62 | 128 |
| ≥71 | 87 | 68 | 129 | 733 | 577 | 1094 | 221 | 174 | 330 | 560 | 441 | 837 | 109 | 85 | 162 | 253 | 199 | 378 | 97 | 76 | 144 |
| ≥72 | 91 | 73 | 136 | 773 | 617 | 1152 | 233 | 186 | 347 | 591 | 472 | 881 | 115 | 91 | 171 | 267 | 213 | 398 | 102 | 81 | 152 |
| ≥73 | 96 | 78 | 143 | 814 | 657 | 1210 | 246 | 198 | 365 | 622 | 503 | 925 | 121 | 97 | 179 | 281 | 227 | 417 | 107 | 87 | 159 |
| ≥74 | 101 | 82 | 150 | 854 | 698 | 1267 | 258 | 211 | 382 | 653 | 534 | 969 | 127 | 103 | 188 | 295 | 241 | 437 | 113 | 92 | 167 |
| ≥75 | 106 | 87 | 157 | 895 | 739 | 1325 | 270 | 223 | 400 | 684 | 565 | 1013 | 133 | 109 | 196 | 309 | 255 | 457 | 118 | 97 | 175 |
| ≥76 | 111 | 92 | 163 | 935 | 779 | 1383 | 282 | 235 | 417 | 715 | 596 | 1057 | 139 | 115 | 205 | 323 | 269 | 477 | 123 | 103 | 182 |
| ≥77 | 115 | 97 | 170 | 976 | 820 | 1441 | 294 | 247 | 435 | 746 | 627 | 1101 | 145 | 121 | 213 | 337 | 283 | 497 | 129 | 108 | 190 |
| ≥78 | 120 | 102 | 177 | 1016 | 860 | 1498 | 307 | 259 | 452 | 777 | 658 | 1146 | 151 | 127 | 222 | 351 | 297 | 517 | 134 | 113 | 197 |
| ≥79 | 125 | 106 | 184 | 1057 | 901 | 1556 | 319 | 272 | 469 | 808 | 689 | 1190 | 157 | 133 | 230 | 365 | 311 | 537 | 139 | 119 | 205 |
| ≥80 | 130 | 111 | 191 | 1097 | 941 | 1614 | 331 | 284 | 487 | 839 | 720 | 1234 | 162 | 139 | 239 | 379 | 325 | 557 | 145 | 124 | 213 |
| ≥81 | 134 | 116 | 198 | 1138 | 982 | 1671 | 343 | 296 | 504 | 870 | 751 | 1278 | 168 | 145 | 247 | 393 | 339 | 577 | 150 | 129 | 220 |

Table 3.7 continued (High values for noise exposure in €$_{2002}$ factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 10 | 0 | 16 | 15 | 0 | 23 | 25 | 0 | 39 | 35 | 0 | 54 | 24 | 0 | 38 |
| ≥52 | 20 | 0 | 32 | 30 | 0 | 47 | 50 | 0 | 78 | 69 | 0 | 107 | 49 | 0 | 76 |
| ≥53 | 31 | 0 | 47 | 45 | 0 | 70 | 75 | 0 | 116 | 104 | 0 | 161 | 73 | 0 | 113 |
| ≥54 | 41 | 0 | 63 | 60 | 0 | 93 | 100 | 0 | 155 | 138 | 0 | 214 | 97 | 0 | 151 |
| ≥55 | 51 | 0 | 79 | 75 | 0 | 116 | 125 | 0 | 194 | 173 | 0 | 268 | 122 | 0 | 189 |
| ≥56 | 61 | 10 | 95 | 90 | 15 | 140 | 150 | 25 | 233 | 207 | 35 | 321 | 146 | 24 | 227 |
| ≥57 | 71 | 20 | 111 | 105 | 30 | 163 | 175 | 50 | 271 | 242 | 69 | 375 | 171 | 49 | 264 |
| ≥58 | 82 | 31 | 126 | 120 | 45 | 186 | 200 | 75 | 310 | 277 | 104 | 429 | 195 | 73 | 302 |
| ≥59 | 92 | 41 | 142 | 135 | 60 | 210 | 225 | 100 | 349 | 311 | 138 | 482 | 219 | 97 | 340 |
| ≥60 | 102 | 51 | 158 | 150 | 75 | 233 | 250 | 125 | 388 | 346 | 173 | 536 | 244 | 122 | 378 |
| ≥61 | 112 | 61 | 174 | 165 | 90 | 256 | 275 | 150 | 427 | 380 | 207 | 589 | 268 | 146 | 416 |
| ≥62 | 122 | 71 | 190 | 180 | 105 | 280 | 300 | 175 | 465 | 415 | 242 | 643 | 292 | 171 | 453 |
| ≥63 | 133 | 82 | 205 | 195 | 120 | 303 | 325 | 200 | 504 | 449 | 277 | 696 | 317 | 195 | 491 |
| ≥64 | 143 | 92 | 221 | 210 | 135 | 326 | 350 | 225 | 543 | 484 | 311 | 750 | 341 | 219 | 529 |
| ≥65 | 153 | 102 | 237 | 225 | 150 | 349 | 375 | 250 | 582 | 518 | 346 | 804 | 366 | 244 | 567 |
| ≥66 | 163 | 112 | 253 | 240 | 165 | 373 | 400 | 275 | 620 | 553 | 380 | 857 | 390 | 268 | 604 |
| ≥67 | 173 | 122 | 269 | 256 | 180 | 396 | 425 | 300 | 659 | 588 | 415 | 911 | 414 | 292 | 642 |
| ≥68 | 184 | 133 | 285 | 271 | 195 | 419 | 450 | 325 | 698 | 622 | 449 | 964 | 439 | 317 | 680 |
| ≥69 | 194 | 143 | 300 | 286 | 210 | 443 | 475 | 350 | 737 | 657 | 484 | 1018 | 463 | 341 | 718 |
| ≥70 | 204 | 153 | 316 | 301 | 225 | 466 | 500 | 375 | 776 | 691 | 518 | 1071 | 487 | 366 | 756 |
| ≥71 | 239 | 188 | 357 | 352 | 277 | 526 | 586 | 461 | 875 | 810 | 637 | 1209 | 571 | 449 | 853 |
| ≥72 | 252 | 201 | 376 | 372 | 296 | 553 | 619 | 493 | 921 | 854 | 682 | 1273 | 603 | 481 | 897 |
| ≥73 | 265 | 214 | 394 | 391 | 316 | 581 | 651 | 526 | 967 | 899 | 726 | 1336 | 634 | 512 | 942 |
| ≥74 | 279 | 228 | 413 | 410 | 335 | 609 | 683 | 558 | 1014 | 944 | 771 | 1400 | 666 | 544 | 987 |
| ≥75 | 292 | 241 | 432 | 430 | 355 | 637 | 716 | 591 | 1060 | 989 | 816 | 1464 | 697 | 575 | 1032 |
| ≥76 | 305 | 254 | 451 | 449 | 374 | 664 | 748 | 623 | 1106 | 1034 | 861 | 1528 | 729 | 607 | 1077 |
| ≥77 | 318 | 267 | 470 | 469 | 394 | 692 | 781 | 655 | 1152 | 1078 | 905 | 1592 | 760 | 638 | 1122 |
| ≥78 | 331 | 280 | 488 | 488 | 413 | 720 | 813 | 688 | 1198 | 1123 | 950 | 1655 | 792 | 670 | 1167 |
| ≥79 | 345 | 294 | 507 | 508 | 433 | 748 | 845 | 720 | 1244 | 1168 | 995 | 1719 | 823 | 702 | 1212 |
| ≥80 | 358 | 307 | 526 | 527 | 452 | 775 | 878 | 753 | 1291 | 1213 | 1040 | 1783 | 855 | 733 | 1257 |
| ≥81 | 371 | 320 | 545 | 547 | 472 | 803 | 910 | 785 | 1337 | 1257 | 1084 | 1847 | 887 | 765 | 1302 |

Note: The High values comprise the WTP for reducing annoyance based on hedonic pricing studies (see Bickel et al., 2003) and quantifiable costs of health effects.

**Table 3.8** Cost factors (High values) for noise exposure (€$_{2002}$ PPP, factor costs, per year per person exposed).

| $L_{den}$ | **Austria** | | | **Belgium** | | | **Cyprus** | | | **Czech Republic** | | | **Denmark** | | | **Estonia** | | | **Finland** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 23 | 0 | 35 | 21 | 0 | 33 | 15 | 0 | 24 | 12 | 0 | 19 | 22 | 0 | 35 | 8 | 0 | 13 | 21 | 0 | 32 |
| ≥52 | 45 | 0 | 70 | 43 | 0 | 67 | 31 | 0 | 47 | 25 | 0 | 39 | 45 | 0 | 69 | 17 | 0 | 26 | 42 | 0 | 64 |
| ≥53 | 68 | 0 | 105 | 64 | 0 | 100 | 46 | 0 | 71 | 37 | 0 | 58 | 67 | 0 | 104 | 25 | 0 | 39 | 62 | 0 | 97 |
| ≥54 | 90 | 0 | 140 | 86 | 0 | 133 | 61 | 0 | 95 | 50 | 0 | 77 | 90 | 0 | 139 | 34 | 0 | 52 | 83 | 0 | 129 |
| ≥55 | 113 | 0 | 175 | 107 | 0 | 167 | 76 | 0 | 118 | 62 | 0 | 97 | 112 | 0 | 174 | 42 | 0 | 66 | 104 | 0 | 161 |
| ≥56 | 136 | 23 | 210 | 129 | 21 | 200 | 92 | 15 | 142 | 75 | 12 | 116 | 135 | 22 | 208 | 51 | 8 | 79 | 125 | 21 | 193 |
| ≥57 | 158 | 45 | 245 | 150 | 43 | 233 | 107 | 31 | 165 | 87 | 25 | 136 | 157 | 45 | 243 | 59 | 17 | 92 | 145 | 42 | 225 |
| ≥58 | 181 | 68 | 280 | 172 | 64 | 267 | 122 | 46 | 189 | 100 | 37 | 155 | 179 | 67 | 278 | 68 | 25 | 105 | 166 | 62 | 257 |
| ≥59 | 203 | 90 | 315 | 193 | 86 | 300 | 137 | 61 | 213 | 112 | 50 | 174 | 202 | 90 | 313 | 76 | 34 | 118 | 187 | 83 | 290 |
| ≥60 | 226 | 113 | 350 | 215 | 107 | 333 | 153 | 76 | 236 | 125 | 62 | 194 | 224 | 112 | 347 | 85 | 42 | 131 | 208 | 104 | 322 |
| ≥61 | 249 | 136 | 385 | 236 | 129 | 367 | 168 | 92 | 260 | 137 | 75 | 213 | 247 | 135 | 382 | 93 | 51 | 144 | 228 | 125 | 354 |
| ≥62 | 271 | 158 | 420 | 258 | 150 | 400 | 183 | 107 | 284 | 150 | 87 | 232 | 269 | 157 | 417 | 101 | 59 | 157 | 249 | 145 | 386 |
| ≥63 | 294 | 181 | 455 | 279 | 172 | 433 | 198 | 122 | 307 | 162 | 100 | 252 | 291 | 179 | 452 | 110 | 68 | 170 | 270 | 166 | 418 |
| ≥64 | 316 | 203 | 490 | 301 | 193 | 467 | 214 | 137 | 331 | 175 | 112 | 271 | 314 | 202 | 486 | 118 | 76 | 183 | 291 | 187 | 451 |
| ≥65 | 339 | 226 | 525 | 322 | 215 | 500 | 229 | 153 | 355 | 187 | 125 | 291 | 336 | 224 | 521 | 127 | 85 | 197 | 311 | 208 | 483 |
| ≥66 | 362 | 249 | 561 | 344 | 236 | 533 | 244 | 168 | 378 | 200 | 137 | 310 | 359 | 247 | 556 | 135 | 93 | 210 | 332 | 228 | 515 |
| ≥67 | 384 | 271 | 596 | 365 | 258 | 567 | 259 | 183 | 402 | 212 | 150 | 329 | 381 | 269 | 591 | 144 | 101 | 223 | 353 | 249 | 547 |
| ≥68 | 407 | 294 | 631 | 387 | 279 | 600 | 275 | 198 | 426 | 225 | 162 | 349 | 404 | 291 | 625 | 152 | 110 | 236 | 374 | 270 | 579 |
| ≥69 | 429 | 316 | 666 | 408 | 301 | 633 | 290 | 214 | 449 | 237 | 175 | 368 | 426 | 314 | 660 | 161 | 118 | 249 | 395 | 291 | 612 |
| ≥70 | 452 | 339 | 701 | 430 | 322 | 666 | 305 | 229 | 473 | 250 | 187 | 387 | 448 | 336 | 695 | 169 | 127 | 262 | 415 | 311 | 644 |
| ≥71 | 530 | 417 | 791 | 504 | 396 | 752 | 357 | 281 | 534 | 293 | 230 | 437 | 525 | 413 | 784 | 198 | 156 | 296 | 487 | 383 | 726 |
| ≥72 | 559 | 446 | 832 | 531 | 424 | 792 | 377 | 301 | 562 | 309 | 246 | 460 | 554 | 442 | 825 | 209 | 167 | 311 | 513 | 410 | 765 |
| ≥73 | 588 | 475 | 874 | 559 | 452 | 831 | 397 | 321 | 590 | 325 | 263 | 483 | 583 | 471 | 867 | 220 | 178 | 327 | 540 | 436 | 803 |
| ≥74 | 617 | 504 | 916 | 587 | 480 | 871 | 417 | 340 | 618 | 341 | 279 | 506 | 612 | 500 | 908 | 231 | 189 | 342 | 567 | 463 | 841 |
| ≥75 | 647 | 534 | 957 | 615 | 508 | 911 | 436 | 360 | 646 | 357 | 295 | 529 | 641 | 529 | 950 | 242 | 200 | 358 | 594 | 490 | 879 |
| ≥76 | 676 | 563 | 999 | 643 | 535 | 950 | 456 | 380 | 674 | 374 | 311 | 552 | 670 | 558 | 991 | 253 | 210 | 374 | 621 | 517 | 918 |
| ≥77 | 705 | 592 | 1041 | 671 | 563 | 990 | 476 | 400 | 702 | 390 | 327 | 575 | 699 | 587 | 1032 | 264 | 221 | 389 | 648 | 544 | 956 |
| ≥78 | 734 | 621 | 1082 | 699 | 591 | 1030 | 496 | 419 | 730 | 406 | 344 | 598 | 728 | 616 | 1074 | 275 | 232 | 405 | 675 | 571 | 994 |
| ≥79 | 764 | 651 | 1124 | 726 | 619 | 1069 | 515 | 439 | 759 | 422 | 360 | 621 | 757 | 645 | 1115 | 286 | 243 | 420 | 702 | 598 | 1033 |
| ≥80 | 793 | 680 | 1166 | 754 | 647 | 1109 | 535 | 459 | 787 | 438 | 376 | 645 | 786 | 674 | 1156 | 297 | 254 | 436 | 728 | 625 | 1071 |
| ≥81 | 822 | 709 | 1208 | 782 | 675 | 1149 | 555 | 479 | 815 | 455 | 392 | 668 | 815 | 703 | 1198 | 307 | 265 | 452 | 755 | 652 | 1109 |

Table 3.8 continued (High values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **France** | | | **Germany** | | | **Greece** | | | **Hungary** | | | **Ireland** | | | **Italy** | | | **Latvia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 21 | 0 | 32 | 20 | 0 | 31 | 14 | 0 | 22 | 11 | 0 | 17 | 25 | 0 | 38 | 20 | 0 | 31 | 7 | 0 | 11 |
| ≥52 | 42 | 0 | 64 | 40 | 0 | 62 | 29 | 0 | 44 | 22 | 0 | 34 | 49 | 0 | 76 | 40 | 0 | 62 | 14 | 0 | 22 |
| ≥53 | 62 | 0 | 97 | 60 | 0 | 93 | 43 | 0 | 67 | 33 | 0 | 50 | 74 | 0 | 114 | 60 | 0 | 93 | 21 | 0 | 33 |
| ≥54 | 83 | 0 | 129 | 80 | 0 | 124 | 57 | 0 | 89 | 43 | 0 | 67 | 98 | 0 | 153 | 80 | 0 | 124 | 29 | 0 | 44 |
| ≥55 | 104 | 0 | 161 | 100 | 0 | 155 | 72 | 0 | 111 | 54 | 0 | 84 | 123 | 0 | 191 | 100 | 0 | 155 | 36 | 0 | 56 |
| ≥56 | 125 | 21 | 193 | 120 | 20 | 186 | 86 | 14 | 133 | 65 | 11 | 101 | 148 | 25 | 229 | 120 | 20 | 186 | 43 | 7 | 67 |
| ≥57 | 145 | 42 | 225 | 140 | 40 | 217 | 100 | 29 | 156 | 76 | 22 | 118 | 172 | 49 | 267 | 140 | 40 | 217 | 50 | 14 | 78 |
| ≥58 | 166 | 62 | 257 | 160 | 60 | 248 | 115 | 43 | 178 | 87 | 33 | 134 | 197 | 74 | 305 | 160 | 60 | 248 | 57 | 21 | 89 |
| ≥59 | 187 | 83 | 290 | 180 | 80 | 279 | 129 | 57 | 200 | 98 | 43 | 151 | 222 | 98 | 343 | 180 | 80 | 279 | 64 | 29 | 100 |
| ≥60 | 208 | 104 | 322 | 200 | 100 | 310 | 143 | 72 | 222 | 108 | 54 | 168 | 246 | 123 | 382 | 200 | 100 | 310 | 72 | 36 | 111 |
| ≥61 | 228 | 125 | 354 | 220 | 120 | 341 | 158 | 86 | 244 | 119 | 65 | 185 | 271 | 148 | 420 | 220 | 120 | 341 | 79 | 43 | 122 |
| ≥62 | 249 | 145 | 386 | 240 | 140 | 373 | 172 | 100 | 267 | 130 | 76 | 202 | 295 | 172 | 458 | 240 | 140 | 373 | 86 | 50 | 133 |
| ≥63 | 270 | 166 | 418 | 260 | 160 | 404 | 186 | 115 | 289 | 141 | 87 | 218 | 320 | 197 | 496 | 260 | 160 | 404 | 93 | 57 | 144 |
| ≥64 | 291 | 187 | 451 | 280 | 180 | 435 | 201 | 129 | 311 | 152 | 98 | 235 | 345 | 222 | 534 | 280 | 180 | 435 | 100 | 64 | 156 |
| ≥65 | 311 | 208 | 483 | 300 | 200 | 466 | 215 | 143 | 333 | 163 | 108 | 252 | 369 | 246 | 572 | 300 | 200 | 466 | 107 | 72 | 167 |
| ≥66 | 332 | 228 | 515 | 320 | 220 | 497 | 229 | 158 | 355 | 173 | 119 | 269 | 394 | 271 | 611 | 320 | 220 | 497 | 115 | 79 | 178 |
| ≥67 | 353 | 249 | 547 | 340 | 240 | 528 | 244 | 172 | 378 | 184 | 130 | 286 | 419 | 295 | 649 | 340 | 240 | 528 | 122 | 86 | 189 |
| ≥68 | 374 | 270 | 579 | 361 | 260 | 559 | 258 | 186 | 400 | 195 | 141 | 302 | 443 | 320 | 687 | 361 | 260 | 559 | 129 | 93 | 200 |
| ≥69 | 395 | 291 | 612 | 381 | 280 | 590 | 272 | 201 | 422 | 206 | 152 | 319 | 468 | 345 | 725 | 381 | 280 | 590 | 136 | 100 | 211 |
| ≥70 | 415 | 311 | 644 | 401 | 300 | 621 | 287 | 215 | 444 | 217 | 163 | 336 | 492 | 369 | 763 | 401 | 300 | 621 | 143 | 107 | 222 |
| ≥71 | 487 | 383 | 726 | 469 | 369 | 701 | 336 | 264 | 501 | 254 | 200 | 379 | 577 | 454 | 861 | 469 | 369 | 701 | 168 | 132 | 251 |
| ≥72 | 513 | 410 | 765 | 495 | 395 | 738 | 354 | 283 | 528 | 268 | 214 | 399 | 609 | 486 | 907 | 495 | 395 | 738 | 177 | 141 | 264 |
| ≥73 | 540 | 436 | 803 | 521 | 421 | 774 | 373 | 301 | 554 | 282 | 228 | 419 | 641 | 517 | 952 | 521 | 421 | 774 | 186 | 151 | 277 |
| ≥74 | 567 | 463 | 841 | 547 | 447 | 811 | 391 | 320 | 581 | 296 | 242 | 439 | 672 | 549 | 998 | 547 | 447 | 811 | 196 | 160 | 290 |
| ≥75 | 594 | 490 | 879 | 573 | 473 | 848 | 410 | 338 | 607 | 310 | 256 | 459 | 704 | 581 | 1043 | 573 | 473 | 848 | 205 | 169 | 304 |
| ≥76 | 621 | 517 | 918 | 599 | 499 | 885 | 429 | 357 | 634 | 324 | 270 | 479 | 736 | 613 | 1088 | 599 | 499 | 885 | 214 | 178 | 317 |
| ≥77 | 648 | 544 | 956 | 625 | 525 | 922 | 447 | 375 | 660 | 338 | 284 | 499 | 768 | 645 | 1134 | 625 | 525 | 922 | 224 | 188 | 330 |
| ≥78 | 675 | 571 | 994 | 651 | 551 | 959 | 466 | 394 | 686 | 352 | 298 | 519 | 800 | 677 | 1179 | 651 | 551 | 959 | 233 | 197 | 343 |
| ≥79 | 702 | 598 | 1033 | 677 | 577 | 996 | 484 | 413 | 713 | 366 | 312 | 539 | 832 | 709 | 1225 | 677 | 577 | 996 | 242 | 206 | 356 |
| ≥80 | 728 | 625 | 1071 | 703 | 603 | 1033 | 503 | 431 | 739 | 380 | 326 | 559 | 864 | 741 | 1270 | 703 | 603 | 1033 | 251 | 216 | 370 |
| ≥81 | 755 | 652 | 1109 | 729 | 628 | 1070 | 521 | 450 | 766 | 394 | 340 | 579 | 896 | 773 | 1316 | 729 | 628 | 1070 | 261 | 225 | 383 |

Table 3.8 continued (High values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **Lithouania** | | | **Luxemburg** | | | **Malta** | | | **Netherlands** | | | **Poland** | | | **Portugal** | | | **Slovakia** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 8 | 0 | 12 | 28 | 0 | 43 | 14 | 0 | 21 | 22 | 0 | 35 | 8 | 0 | 13 | 14 | 0 | 22 | 9 | 0 | 15 |
| ≥52 | 15 | 0 | 24 | 55 | 0 | 85 | 27 | 0 | 42 | 45 | 0 | 69 | 17 | 0 | 26 | 28 | 0 | 44 | 19 | 0 | 29 |
| ≥53 | 23 | 0 | 36 | 83 | 0 | 128 | 41 | 0 | 63 | 67 | 0 | 104 | 25 | 0 | 39 | 42 | 0 | 66 | 28 | 0 | 44 |
| ≥54 | 31 | 0 | 48 | 110 | 0 | 171 | 54 | 0 | 84 | 90 | 0 | 139 | 34 | 0 | 52 | 57 | 0 | 88 | 37 | 0 | 58 |
| ≥55 | 39 | 0 | 60 | 138 | 0 | 214 | 68 | 0 | 105 | 112 | 0 | 174 | 42 | 0 | 66 | 71 | 0 | 110 | 47 | 0 | 73 |
| ≥56 | 46 | 8 | 72 | 165 | 28 | 256 | 82 | 14 | 126 | 135 | 22 | 208 | 51 | 8 | 79 | 85 | 14 | 132 | 56 | 9 | 87 |
| ≥57 | 54 | 15 | 84 | 193 | 55 | 299 | 95 | 27 | 148 | 157 | 45 | 243 | 59 | 17 | 92 | 99 | 28 | 154 | 66 | 19 | 102 |
| ≥58 | 62 | 23 | 96 | 221 | 83 | 342 | 109 | 41 | 169 | 179 | 67 | 278 | 68 | 25 | 105 | 113 | 42 | 175 | 75 | 28 | 116 |
| ≥59 | 69 | 31 | 108 | 248 | 110 | 385 | 122 | 54 | 190 | 202 | 90 | 313 | 76 | 34 | 118 | 127 | 57 | 197 | 84 | 37 | 131 |
| ≥60 | 77 | 39 | 120 | 276 | 138 | 427 | 136 | 68 | 211 | 224 | 112 | 347 | 85 | 42 | 131 | 141 | 71 | 219 | 94 | 47 | 145 |
| ≥61 | 85 | 46 | 132 | 303 | 165 | 470 | 150 | 82 | 232 | 247 | 135 | 382 | 93 | 51 | 144 | 156 | 85 | 241 | 103 | 56 | 160 |
| ≥62 | 93 | 54 | 144 | 331 | 193 | 513 | 163 | 95 | 253 | 269 | 157 | 417 | 101 | 59 | 157 | 170 | 99 | 263 | 112 | 66 | 174 |
| ≥63 | 100 | 62 | 156 | 358 | 221 | 555 | 177 | 109 | 274 | 291 | 179 | 452 | 110 | 68 | 170 | 184 | 113 | 285 | 122 | 75 | 189 |
| ≥64 | 108 | 69 | 167 | 386 | 248 | 598 | 190 | 122 | 295 | 314 | 202 | 486 | 118 | 76 | 183 | 198 | 127 | 307 | 131 | 84 | 203 |
| ≥65 | 116 | 77 | 179 | 413 | 276 | 641 | 204 | 136 | 316 | 336 | 224 | 521 | 127 | 85 | 197 | 212 | 141 | 329 | 141 | 94 | 218 |
| ≥66 | 123 | 85 | 191 | 441 | 303 | 684 | 218 | 150 | 337 | 359 | 247 | 556 | 135 | 93 | 210 | 226 | 156 | 351 | 150 | 103 | 232 |
| ≥67 | 131 | 93 | 203 | 469 | 331 | 726 | 231 | 163 | 358 | 381 | 269 | 591 | 144 | 101 | 223 | 241 | 170 | 373 | 159 | 112 | 247 |
| ≥68 | 139 | 100 | 215 | 496 | 358 | 769 | 245 | 177 | 379 | 404 | 291 | 625 | 152 | 110 | 236 | 255 | 184 | 395 | 169 | 122 | 261 |
| ≥69 | 147 | 108 | 227 | 524 | 386 | 812 | 258 | 190 | 400 | 426 | 314 | 660 | 161 | 118 | 249 | 269 | 198 | 417 | 178 | 131 | 276 |
| ≥70 | 154 | 116 | 239 | 551 | 413 | 854 | 272 | 204 | 422 | 448 | 336 | 695 | 169 | 127 | 262 | 283 | 212 | 439 | 187 | 141 | 291 |
| ≥71 | 181 | 142 | 270 | 646 | 508 | 964 | 319 | 251 | 476 | 525 | 413 | 784 | 198 | 156 | 296 | 332 | 261 | 495 | 220 | 173 | 328 |
| ≥72 | 191 | 152 | 284 | 681 | 544 | 1015 | 336 | 268 | 501 | 554 | 442 | 825 | 209 | 167 | 311 | 350 | 279 | 521 | 232 | 185 | 345 |
| ≥73 | 201 | 162 | 298 | 717 | 579 | 1066 | 354 | 286 | 526 | 583 | 471 | 867 | 220 | 178 | 327 | 368 | 297 | 547 | 244 | 197 | 362 |
| ≥74 | 211 | 172 | 313 | 753 | 615 | 1117 | 371 | 303 | 551 | 612 | 500 | 908 | 231 | 189 | 342 | 386 | 316 | 573 | 256 | 209 | 380 |
| ≥75 | 221 | 182 | 327 | 788 | 651 | 1167 | 389 | 321 | 576 | 641 | 529 | 950 | 242 | 200 | 358 | 405 | 334 | 599 | 268 | 221 | 397 |
| ≥76 | 231 | 192 | 341 | 824 | 686 | 1218 | 407 | 339 | 601 | 670 | 558 | 991 | 253 | 210 | 374 | 423 | 352 | 625 | 280 | 233 | 414 |
| ≥77 | 241 | 202 | 355 | 860 | 722 | 1269 | 424 | 356 | 626 | 699 | 587 | 1032 | 264 | 221 | 389 | 441 | 371 | 652 | 292 | 245 | 432 |
| ≥78 | 251 | 212 | 370 | 896 | 758 | 1320 | 442 | 374 | 651 | 728 | 616 | 1074 | 275 | 232 | 405 | 460 | 389 | 678 | 304 | 258 | 449 |
| ≥79 | 261 | 222 | 384 | 931 | 793 | 1371 | 459 | 391 | 676 | 757 | 645 | 1115 | 286 | 243 | 420 | 478 | 407 | 704 | 317 | 270 | 466 |
| ≥80 | 271 | 232 | 398 | 967 | 829 | 1422 | 477 | 409 | 701 | 786 | 674 | 1156 | 297 | 254 | 436 | 496 | 426 | 730 | 329 | 282 | 483 |
| ≥81 | 281 | 242 | 412 | 1003 | 865 | 1473 | 495 | 427 | 726 | 815 | 703 | 1198 | 307 | 265 | 452 | 515 | 444 | 756 | 341 | 294 | 501 |

Table 3.8 continued (High values for noise exposure in €$_{2002}$ PPP factor costs per year per person exposed).

| $L_{den}$ | **Slovenia** | | | **Spain** | | | **Sweden** | | | **Switzerland** | | | **United Kingdom** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dB(A) | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft | Road | Rail | Aircraft |
| ≥51 | 14 | 0 | 21 | 17 | 0 | 27 | 21 | 0 | 33 | 24 | 0 | 38 | 22 | 0 | 34 |
| ≥52 | 28 | 0 | 43 | 35 | 0 | 54 | 42 | 0 | 66 | 49 | 0 | 75 | 43 | 0 | 67 |
| ≥53 | 41 | 0 | 64 | 52 | 0 | 81 | 63 | 0 | 98 | 73 | 0 | 113 | 65 | 0 | 101 |
| ≥54 | 55 | 0 | 85 | 70 | 0 | 108 | 85 | 0 | 131 | 97 | 0 | 150 | 87 | 0 | 134 |
| ≥55 | 69 | 0 | 107 | 87 | 0 | 135 | 106 | 0 | 164 | 121 | 0 | 188 | 108 | 0 | 168 |
| ≥56 | 83 | 14 | 128 | 105 | 17 | 162 | 127 | 21 | 197 | 146 | 24 | 226 | 130 | 22 | 202 |
| ≥57 | 96 | 28 | 150 | 122 | 35 | 189 | 148 | 42 | 229 | 170 | 49 | 263 | 152 | 43 | 235 |
| ≥58 | 110 | 41 | 171 | 140 | 52 | 216 | 169 | 63 | 262 | 194 | 73 | 301 | 173 | 65 | 269 |
| ≥59 | 124 | 55 | 192 | 157 | 70 | 244 | 190 | 85 | 295 | 218 | 97 | 338 | 195 | 87 | 302 |
| ≥60 | 138 | 69 | 214 | 175 | 87 | 271 | 211 | 106 | 328 | 243 | 121 | 376 | 217 | 108 | 336 |
| ≥61 | 152 | 83 | 235 | 192 | 105 | 298 | 232 | 127 | 360 | 267 | 146 | 414 | 239 | 130 | 370 |
| ≥62 | 165 | 96 | 256 | 209 | 122 | 325 | 254 | 148 | 393 | 291 | 170 | 451 | 260 | 152 | 403 |
| ≥63 | 179 | 110 | 278 | 227 | 140 | 352 | 275 | 169 | 426 | 315 | 194 | 489 | 282 | 173 | 437 |
| ≥64 | 193 | 124 | 299 | 244 | 157 | 379 | 296 | 190 | 459 | 340 | 218 | 526 | 304 | 195 | 471 |
| ≥65 | 207 | 138 | 320 | 262 | 175 | 406 | 317 | 211 | 491 | 364 | 243 | 564 | 325 | 217 | 504 |
| ≥66 | 221 | 152 | 342 | 279 | 192 | 433 | 338 | 232 | 524 | 388 | 267 | 602 | 347 | 239 | 538 |
| ≥67 | 234 | 165 | 363 | 297 | 209 | 460 | 359 | 254 | 557 | 412 | 291 | 639 | 369 | 260 | 571 |
| ≥68 | 248 | 179 | 385 | 314 | 227 | 487 | 380 | 275 | 590 | 437 | 315 | 677 | 390 | 282 | 605 |
| ≥69 | 262 | 193 | 406 | 332 | 244 | 514 | 402 | 296 | 622 | 461 | 340 | 714 | 412 | 304 | 639 |
| ≥70 | 276 | 207 | 427 | 349 | 262 | 541 | 423 | 317 | 655 | 485 | 364 | 752 | 434 | 325 | 672 |
| ≥71 | 323 | 254 | 482 | 409 | 322 | 611 | 495 | 389 | 739 | 568 | 447 | 848 | 508 | 400 | 758 |
| ≥72 | 341 | 272 | 507 | 432 | 344 | 643 | 522 | 417 | 778 | 600 | 478 | 893 | 536 | 428 | 798 |
| ≥73 | 359 | 290 | 533 | 454 | 367 | 675 | 550 | 444 | 817 | 631 | 510 | 938 | 564 | 456 | 838 |
| ≥74 | 376 | 307 | 558 | 477 | 389 | 707 | 577 | 471 | 856 | 662 | 541 | 983 | 592 | 484 | 878 |
| ≥75 | 394 | 325 | 584 | 499 | 412 | 739 | 605 | 499 | 895 | 694 | 573 | 1027 | 620 | 512 | 918 |
| ≥76 | 412 | 343 | 609 | 522 | 435 | 772 | 632 | 526 | 934 | 725 | 604 | 1072 | 648 | 540 | 958 |
| ≥77 | 430 | 361 | 635 | 545 | 457 | 804 | 659 | 554 | 973 | 757 | 635 | 1117 | 676 | 568 | 998 |
| ≥78 | 448 | 379 | 660 | 567 | 480 | 836 | 687 | 581 | 1012 | 788 | 667 | 1162 | 705 | 596 | 1038 |
| ≥79 | 466 | 397 | 685 | 590 | 503 | 868 | 714 | 608 | 1051 | 820 | 698 | 1206 | 733 | 624 | 1078 |
| ≥80 | 483 | 415 | 711 | 612 | 525 | 900 | 741 | 636 | 1090 | 851 | 730 | 1251 | 761 | 652 | 1118 |
| ≥81 | 501 | 432 | 736 | 635 | 548 | 933 | 769 | 663 | 1129 | 882 | 761 | 1296 | 789 | 680 | 1158 |

Note: The High values comprise the WTP for reducing annoyance based on hedonic pricing studies (see Bickel et al., 2003) and quantifiable costs of health effects.

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