



ENVIRONMENTAL  
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Noise

Monetisation  
of the health impact  
due to traffic noise



Swiss Agency for the Environment,  
Forests and Landscape SAEFL



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# Abstracts

- E** In an earlier study, the adverse effects on health from noise arising in specific road transport traffic situations were determined. The present study examines whether, and to what extent, these effects can be expressed in monetary terms using data from existing monetisation studies.
- The conclusions drawn in recent monetisation studies, in which the noise dependency of apartment rents and the monetary equivalents of avoidance of specified diseases were determined, are discussed. Data from these are used to estimate the costs of sleep disturbance and interference with communication arising from noise. The same quantities are also derived in other ways, i.e. from the marginal costs for hospital treatment, from monetary data for the value of a statistical life, and from the readiness of patients to bear the costs of therapeutic treatment. Results: the monetary equivalent of sleep disturbance over one year amounts to 2500–15'000 CHF, and that of interference with communication to 1500–9000 CHF. These values are compared with data from the National Research Programme, NFP 41.
- Keywords:  
noise,  
monetisation,  
health

- D** In einer vorausgegangenen Studie wurden die dem Lärm eines einzelnen Strassen-transportvorgangs zuzuordnenden Gesundheitsstörungen ermittelt. Hier wird nun untersucht, inwieweit verfügbare Ergebnisse von Monetarisierungsstudien dazu verwendet werden können, die ermittelten Gesundheitsschäden zusätzlich auch noch in Geldeinheiten auszudrücken.
- Die publizierten Ergebnisse neuerer Monetarisierungsstudien werden diskutiert, insoweit diese einen Bezug zu Lärmschäden haben. Es handelt sich hierbei um Studien über die Lärmabhängigkeit des Mietzinses, sowie um Studien, die Geldäquivalente für die Vermeidung bestimmter Krankheiten ermitteln. Daraus werden Schätzwerte für lärmbedingte Schlafstörung und Kommunikationsstörung entwickelt, wobei zusätzliche Schätzungen aus Kostengrenzwerten für Spitalbehandlung, Geldwerten für ein statistisches Leben und aus beobachteten Zahlungsbereitschaften für Therapien gewonnen werden. Ergebnis: Schlafstörung während eines Jahres entspricht einem Betrag von 2500–15'000 CHF, Kommunikationsstörung einem Betrag von 1500–9000 CHF. Es folgt ein Vergleich dieser Werte mit den Ergebnissen des Nationalen Forschungsprogramms NFP 41.
- Stichwörter:  
Lärm,  
Monetarisierung,  
Gesundheit

**F** Une précédente étude évaluait les troubles de la santé provoqués par le trafic routier. La présente publication examine dans quelle mesure les résultats des études de monétarisation peuvent être utilisés pour attribuer des valeurs monétaires à ces troubles de la santé.

Les résultats des études de monétarisation les plus récentes sont pris en compte dans la mesure où ces études ont un rapport avec les atteintes dues au bruit: études sur le lien entre bruit et loyers et études définissant les coûts de la prévention de certaines maladies. Ces études sont utilisées pour définir le coût approximatif des troubles du sommeil et de la communication dus au bruit. Des estimations complémentaires ont été développées en analysant les valeurs limites des frais de traitement hospitalier, les valeurs monétaires d'une vie statistique et les sommes que les personnes concernées sont prêtes à payer pour des thérapies. Conclusion: une année de troubles du sommeil correspond à une somme de 2500 à 15'000 francs, un an de troubles de la communication à un montant de 1500 à 9000 francs. Ces valeurs sont ensuite comparées avec les résultats du Programme national de recherche PNR 41.

Mots-clés:  
Bruit,  
monétarisation,  
santé

**I** In una ricerca precedente sono stati esaminati i disturbi alla salute causati dal rumore stradale provocato dal passaggio di un singolo veicolo di trasporto. Il presente studio esamina invece in che misura i risultati degli studi di monetizzazione possono essere utilizzati per quantificare in termini monetari i danni alla salute accertati.

I risultati emersi da recenti studi di monetizzazione vengono considerati nella misura in cui hanno un rapporto con i danni causati dall'inquinamento fonico. Si tratta di studi che esaminano il rapporto fra canone d'affitto e rumore, come pure di studi volti a stabilire l'equivalente in denaro necessario per prevenire determinate malattie. Questi studi consentono di stimare i costi causati dai disturbi del sonno e della comunicazione. Queste estimazioni sono complementate con i valori limite dei costi del trattamento ospedaliero, con i valori monetari relativi alla vita statistica e con i costi che le persone interessate sono disposte ad assumersi per le terapie. Conclusione: i costi di un anno di disturbi del sonno ammontano a 2500–15'000 franchi, mentre un anno di disturbi della comunicazione equivale a una somma di 1500–9000 franchi. I valori summenzionati vengono in seguito confrontati con i risultati scaturiti dal Programma nazionale di ricerca PNR 41.

Parole chiave:  
Rumore,  
monetarizzazione,  
salute

# Executive Summary

## **Road traffic noise: A cause of disease**

Traffic noise along roads can produce sound levels in nearby housing areas that not only represent a source of annoyance to residents in conventionally insulated buildings, but are also a known cause of health impairment. The most frequent effects on health are disturbance to sleep during the night, and to communication during the day. Disturbance (or interference) to communication caused by noise during the day can be interpreted as a health impairment in the wider sense because it is equivalent to physically damaged hearing organs. Long-term effects such as heart disease and mental disorders have also been mentioned in the literature. A significant proportion of the European population lives in buildings exposed to road traffic noise with an equivalent continuous sound pressure level of well above 55 decibel (dB(A)) during the day and 45 dB(A) at night. It is clear from this that road traffic noise has a significant impact on the health of the population.

## **Health impact in figures**

The state of health of a population can be expressed statistically as the number of disease cases and deaths per year. A more concise picture is obtained by summing the years of life lost due to premature death. Since, however, the years lived may be impaired by illness and invalidity, it has proved useful to express the impairment in terms of disability-weighted life years, using the disability weights per type of disease obtained from representative procedures. This method is used by the World Health Organisation (WHO) in its annual statistics, in which the burden of disease per country is expressed in DALY units (Disability Adjusted Life Years), i.e. in human life years lost entirely by premature death, or partly through disease. DALY units were also used to determine the marginal impairment to public health in Switzerland resulting from a 1000 kilometre long journey by car or truck (MÜLLER-WENK, 2002).

Frequently, impairment to health is also expressed in monetary terms. Monetisation methods, originally developed and applied in the USA, and later in other countries, are used to determine monetary equivalents of immaterial values such as avoidance of disease or premature death. They attempt to assign fractions of the price actually paid in real market transactions (property purchases, tenancy agreements, employment contracts, etc.) to components such as noise levels and health risk. Such methods are referred to as revealed preference methods. Alternatively, monetisation may be based on social surveys carried out on samples of the population in which the respondents are asked how much money they would be willing to pay for a hypothetical good assuming it to be available on the market (e.g. AIDS vaccination). These methods are referred to as willingness-to-pay methods.

## **Can noise abatement decisions be based on DALY or CHF?**

It is shown in Chapter 2 that either of these methods of measuring the impairment to health may play a part in selecting the most suitable noise abatement policy. Where the task involves making optimum use of a given budget in the interests of noise

abatement, the selection criterion should be the number of DALY won by each policy. If on the other hand a distance-dependent heavy vehicle tax is to be justified, it is appropriate to determine the health impairment caused by the vehicles in money units. As both units have their merits, there is widespread interest in exploring how to convert data on health impairment from one unit to another.

It is shown in Chapter 4 that owing to methodical divergences there is no generally valid conversion factor for this. It nevertheless appears feasible to perform DALY-to-money conversions in limited areas. Thus practical suggestions based on several approaches are made in Chapter 5 for converting one year's sleep disturbance (0.055 DALY), or one year's interference with communication (0.033 DALY), to Swiss francs.

### **Results of monetisation studies**

The performance of a monetisation study is resource intensive and lies outside the scope of this work. In Chapter 3, with a view to expressing the impairment to health caused by road traffic noise in money units, a literature survey is first performed to identify recent monetisation studies on noise-related health effects applicable under Swiss conditions. The criteria 'recent' and 'Swiss' are significant insofar as current knowledge on 'benefit transfer' indicates that the admissibility of using monetisation data from remote periods or countries is very restricted. Furthermore, monetisation data on health impairment should not be used from other studies unless it is fully clear what cost elements are included (or not included). In addition to the intrinsic value of a reduction in health, there are other cost elements, such as the cost of medical treatment and care of the sick, and also that of lost working hours and loss in property values due to existing (or feared) disturbance to the inhabitants from noise. This study focuses mainly on the intrinsic value of health, firstly because this usually represents the largest damage component, and secondly because the assignment of a money sum to changes in health is a key problem still calling for more satisfactory solutions.

No monetisation study could be found in the literature that *directly* attaches a money value to the avoidance of sleep disturbance or interference with communication due to road traffic noise. In Chapter 3, however, some recent monetisation studies are discussed giving changes in property prices or apartment rents per dB(A) of traffic noise. The price changes roughly amount to 1% per dB(A). If it is assumed as a first approximation that the change in property prices is due solely to sleep disturbance of the occupants at night and interference with communication during the day, it is possible to derive their monetary equivalents. This is done in Chapter 5.1. In addition to monetisation studies on rents and property prices, a large number of studies exist on specific diseases. Of particular interest in the present context is the recent Swiss study covering tobacco related diseases discussed in Chapter 3. This attaches money amounts to cardiovascular diseases caused by tobacco abuse. The same type of disease may also be caused by long-term exposure to high noise levels. Within certain limits it is admissible to assign the same monetary value to a heart attack irrespectively of its origin, so that the monetisation performed in the tobacco study may be used to attach a money equivalent to a

noise-related heart attack. However, this approach was not pursued further for the reasons given in Chapter 4.2.

### **Determination of the monetary equivalents of sleep disturbance and interference with communication**

Since the available monetisation studies on apartment rents and various types of disease offer only a scant basis for determining the monetary equivalents of noise-related health impairments, Chapter 5 explores other possible approaches to obtaining the required data.

In medical practice, more-or-less explicit cost limits exist as guides to decision making on medical treatment directed toward a given improvement in a person's health. Where such treatments are mainly paid for by the government or by the social security system, it is often believed that their application should be restricted to cases where the cost per life year saved remains within defined and socially accepted limits. Whereas cost limits of this kind can be found in the Anglo-American literature, doctors in Switzerland apparently take decisions in this area without the benefit of an agreed social consensus on cost limits. In Chapter 5, starting from generally accepted cost limits for health improvement in Anglo-American practice, the attempt is made to derive monetary equivalents of sleep disturbance and interference with communication. As an alternative, the required monetary equivalents are derived from the value of a statistical life (VSL) or the value of a life year (VOLY), since these values are determined in a large number of monetisation studies. In view of the inadequacies apparent in current monetisation methods such as *hedonic pricing*, *contingent valuation* and *wage risk*, the attempt is also made to obtain the desired monetary equivalents by analysing people's actual buying decisions in cases where they have to pay for improvements (or avoidance of deterioration) in health themselves. Of particular interest in this connection are cosmetic surgery and preventive vaccination. From the prices paid for medical treatment of this kind, it is possible to determine the minimum value that patients would attach to an improvement in their state of health.

### **The results in figures**

The conclusion drawn in Chapter 5 from the various approaches to the problem of monetising noise related health impairment is that a monetary equivalent of 2500 to 15000 CHF per person (inflation adjusted to year 2000) may be attached to the avoidance of noise-related sleep disturbance for one year. The monetary equivalent of avoidance of interference with communication lies between 1500 and 9000 CHF. Whilst the lower estimates in each range are taken from studies on apartment rents, the upper estimates are from monetisation studies on the value of a statistical life (VSL) and from analyses of actual payments for cosmetic surgery. The large span between the lower and upper estimates arises from the fact that although four of the approaches discussed in Chapter 5 (i.e. apartment rents, cosmetic surgery, value of a statistical life, socially accepted limits for medical treatment costs) were selected as being relatively appropriate, they nevertheless resulted in diverging monetary equivalents. While each of the four preferred approaches has its merits, no valid reasons could be found for giving priority to any one method in order to narrow the

gap between the low and high estimates. Moreover, it has not yet proved possible to assess the influence of existing deficiencies in quantitative monetary terms.

### **Noise cost per vehicle kilometre**

In Chapter 6, the monetary equivalents obtained for health impairment due to road traffic noise are converted to noise costs per car or truck kilometre. Based on the lower estimates, and using statistical average ratios for daytime to night-time journeys, the resulting costs of noise are 1.44 Swiss centimes (ct.) per car kilometre and 10.3 ct. per truck kilometre. These amounts are very close to those determined in the national research programme *Traffic and the Environment* (NFP 41), which were also based on apartment rents. This may be seen to some extent as confirming the results of both studies. However, it must be mentioned that the money amounts determined here for sleep disturbance and interference with communication per vehicle kilometre would increase by up to a factor of six if the widely used VSL results alone had been taken as a basis. Further studies on money equivalents of noise related health impairments are therefore called for. A suitable proposal is made in the final Chapter of the report.

# 1 Objectives of the study

From a present-day standpoint, noise appears to represent an environmental problem inasmuch as noise emission from current transport systems affect the well-being of individuals. The causal relationship between the noise emission from a specific road traffic situation and the impairment to human health was quantified by MÜLLER-WENK (2002). The study expresses the extent of the health impairment in units corresponding to the state of health (DALY, disability adjusted life years), as used currently by the WHO for measuring public health (WHO 2002, Annex, Table 3).

In many cases, however, the extent of health impairment is also expressed in money units, e.g. where the costs of public health attributable to traffic are concerned (SWISS FEDERAL STATISTICAL OFFICE, 2002:67). The problem therefore arises of converting the units for the state of health to money units and vice versa. An additional question is the suitability of money or DALY units for the quantitative determination of a health status. The objective of the present study is to provide answers to these questions.

## 2 Monetisation – to what end?

In addition to the economic goods traded in markets (such as bread, insurance, shares), whose value is normally expressed in monetary terms, there are many other aspects of human society to which a positive value is attached, such as justice, affection, belief, natural diversity, cultural heritage and well-being. The values of the latter group can normally not be expressed adequately in money terms, unless one holds the view that the economic system is a superior regime to which all other manifestations of human life and interchange are subject. The authors of the present study do not share this view, which would imply that the representation of immaterial values in the form of money (monetisation) is unquestioned and requires no further justification. They thus find it understandable that some people reject monetisation on the grounds that «health cannot be expressed in monetary terms» or «there are things in life that cannot be expressed in money».

Situations can, however, arise in which it is justifiable to use monetisation techniques to attach a monetary value to entities that implicitly lie outside the economic system. This is particularly true of the impairment to health caused by environmental factors, which forms the subject of the present study. This chapter therefore discusses not only how the information on health impairment may be introduced into modern decision-making processes in questions involving the public interest, but also whether or not this information should be monetised.

### 2.1 Quantification of health impairment in the context of various decision methods

While the economic expenditure for noise abatement measures is naturally expressed in monetary units, there are three basic alternatives for the quantification of the health impairment resulting from noise:

- E** The measurable effects or symptoms are given directly. These may for example be the number of premature deaths – or as given here – the number of persons affected by heart attacks, sleep disturbance and interference with communication.
- U** The impairment to health is represented on a health scale graduated in direct proportion to the utility of the state of health. A whole range of proposals have been made for such scales, among them quality adjusted life years (QALY), and disability adjusted life years (DALY), as used in this study. These scales allow to sum up premature deaths and diseases of varying intensity using weighting factors (see Chapter 4.1 for a detailed discussion). It is pointed out here that the term utility represents the value of a material or immaterial good in the widest sense, and must on no account be confined to the economic *usefulness* of the good. In the stricter sense, units such as DALY and QALY do not express the economic value of a person as a production factor – rather, they are related to the *intrinsic* value of human health.

**B** Instead of using a utility scale aimed at health as such, the benefit can be monetised, that is to say, quantified in terms of money units. The above remarks on the term *utility* also apply to the term *benefit*. Especially where the value of a good is to be represented on a monetary plane, special care must be taken to ensure that the benefit does not dwindle to mere usefulness.

On the basis of these different units, three in practice widely used analytical methods for assessing the suitability of measures for avoiding health impairment can be distinguished:

**Cost effectiveness analysis (CEA):**

This is a characteristic procedure for assessing the efficiency of an avoidance measure. It expresses the ratio of the avoidance costs to the total of avoided cases of a particular health impairment, e.g. the operational costs of soot filters per case of lung cancer avoided. Where several different methods are available to reduce the number of cases of a particular impairment to health, CEA indicates the most economic of these methods. Where, however, competing avoidance strategies lead to a reduction in several types of health impairment, CEA does not usually provide a conclusive answer. As this often arises, CEA is mainly applied in cases where one type or class of health impairment predominates. Therefore CEA is often used to express the cost per avoided death.

**Cost utility analysis (CUA):**

This variant of the cost benefit analysis provides an efficiency characteristic for an avoidance measure. It expresses the ratio of the avoidance costs to the total of avoided cases of different health impairments, expressed in units such as DALY. Since CUA enables different types of health impairment to be summed up, it is also suitable for the assessment of measures for avoiding different types of health impairment to varying extents, e.g. a programme of noise abatement measures designed to achieve a reduction in sleep disturbance *and* heart attacks. Both CUA and CEA supply characteristic parameters obtained by dividing the financial expenditure by the effect in non-monetary terms. Neither of these methods will determine whether the measure found to be most effective generates an acceptable financial return.

**Cost benefit analysis (CBA)<sup>1</sup>:**

Cost benefit analysis (or cost yield analysis) gives the ratio of the economic expenditure for an avoidance measure to its effects expressed in money units. The information provided by CBA enables the relative advantages of alternative measures to be assessed based on a profitability criterion. Thus CBA can determine which measure or combination of measures by virtue of its/their positive effects (expressed in monetary terms) is/are likely to produce the greatest surplus value over and above the costs of the measures. Alternatively, the measure with the lowest cost benefit ratio can be determined. As opposed to CUA and CEA, cost benefit analysis may still be used where measures are directed not solely to improvements in health, but also to other alterations to the status quo (expressed in money units). Thus in principle, CBA could be used to relate the expenditure for a reduction in waste

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<sup>1</sup> This is frequently also referred to as the benefit cost analysis (BCA).

water pollution to the monetary equivalent of improved public health *plus* increased biodiversity. However, the wider applicability of CBA is only obtained at a price, as shown later in Chapter 2.4.

## 2.2 Various situations demanding noise abatement decisions, and the adequate choice of analytical method

We assume here that a situation requiring decision-making in noise abatement practice demands a selection of possible solution approaches that differ in respect of the extent of health impairment or benefit, the financial expenditure necessary and further possible aspects. The choice of analytical method depends on the particular problem at hand and that choice determines what units must be used for health impairment.

In the following, we shall list five typical situations requiring a decision in connection with the impairment to health resulting from road traffic noise. The examples illustrate the way in which each specific situation requires a different analytical method, and thus different units for the damage or benefit involved:

**Cost effective noise reduction down to the impact threshold for all citizens disturbed by road traffic noise.**

It is a declared political objective to reduce – within a specific time frame - the impact of noise for all inhabitants in Switzerland below the impact threshold. To seek the most cost effective bundle of measures for this is a typical application of CEA, since the target objective is clearly defined at the physical level (reduction of the impact to the impact threshold level). A preliminary investigation is required to determine which of the possible alternative measures (or bundle of measures) can achieve the objective of reducing the exposure. To do so, the reduction potential of the measures and the existing exposure level must be known. Note that both the reduction potential and the costs of a particular measure are usually influenced by the other measures within the bundle<sup>2</sup>. The final choice among the promising measures (or bundles of measures) is made based on the lowest investment or operating costs. Since the changes to be realised at the physical level were clearly specified at the outset, the health impairment avoided need not be determined - neither in the form of number of cases, nor in utility units, nor in monetised form.

**Comparison based on costs and benefits.**

The objective here is to evaluate several noise abatement measures such as whisper asphalt, noise barriers and emission regulations for individual vehicles, with respect to costs and benefits. In principle, this can be achieved with each of the three methods. However, should the relevant measures lead to disproportionate reductions in different forms of health impairment, CEA does not permit the measures to be ranked clearly in order of priority. CUA, on the other hand, does permit the meas-

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<sup>2</sup> In cases of sleep disturbance, the efficiency of noise barriers diminishes if at the same time speed limits are enforced and noise damping windows are installed.

ures to be ordered by efficiency, i.e. by the ratio of the benefits in the form of reduced health impairment to the noise abatement costs. However, possible additional benefits outside the sphere of public health, such as the utilisation of noise barriers as support structures for photovoltaic power stations are ignored in this method. Furthermore, CUA requires that each of the forms of health impairment affected by noise abatement measures be placed on a health related scale, e.g. expressed in DALY, therefore requiring appropriate weighting information. Finally, CBA enables both health related and other benefits to be considered, hence permitting a ranking list taking into account the widest possible spectrum of objectives. CBA also shows for which measures the benefits (in monetary terms) are higher than the costs. Note, however, that the monetisation of all of the benefits requires additional procedures to convert them to money units, and these are often incomplete, or are only available in a inconsistent or very imprecise form. In this case, the apparently wider applicability of CBA as against CUA is relativised by the reduced viability of its results.

**Division of budget among noise abatement measures.**

Let us assumed here that a fixed sum – e.g. CHF 200 million per year – is available for noise abatement measures, the task being to use this sum to achieve the greatest benefit. Should the main effect of the noise abatement measures be to reduce health impairment, CUA may be applied. When several types of health impairment are involved, this method allows the bundle of measures to be optimised. If in addition to the health related benefits, other benefits are to be considered, CBA may be used.

**Policies to minimise total social cost.**

Where noise policies are to be developed to equate the marginal costs of measures to the marginal benefit of avoiding health impairment, this is typically the province of CBA. Since in this case the marginal costs and benefits of a measure are influenced by other measures realised at the same time, not only the individual measures (as explained above), but also the bundles of measures must be analysed.

**External costs of noise exposure.**

Where the details of a distance-dependent heavy vehicle tax are to be laid down, the external costs of noise exposure must be determined in order for these to be internalised in conjunction with other external costs. In this case, health impairment must always be expressed in monetary terms. Here, CBA is the chosen analytical method. Since only external costs are to be considered, a distinction must be made in each case as to which costs may be regarded as internal. To take the example of the distance-dependent heavy vehicle tax, the health impairment to lorry drivers that occurred during working hours would not be considered as external costs.

The above examples demonstrate that not all situations in which decisions have to be taken on noise abatement measures demand the same analytical method, and that some decisions call for a monetary evaluation of health impairment. Here, therefore, in extension of the work of MÜLLER-WENK (2002), in which health impairment was determined in DALY, health impairment will now be determined additionally in monetary units.

### 2.3 Trends in USA, especially in the public health sector

CBA is an established analytical method that had been used earlier in project evaluation (DASGUPTA et al. 1972, SQUIRE & VAN DER TAK 1975), and that owing to its economically well-founded role as a welfare instrument, is currently the preferred tool among economists. The method gained further impetus when it was decided in the USA to introduce CBA in preparing laws and ordinances with high cost implications to demonstrate that the benefit to the national economy was greater than the cost (OMB, 1996). Following the US trend, other governments and very recently the EU have started to use CBA for the analysis of legislative proposals (e.g. EUROPEAN COMMISSION, 1999).

In the environmental and health sectors, the quantification of the benefits presents a difficulty. Not only is it difficult to express health impairment in monetary terms, but public acceptance of monetisation is often at a low ebb, i.e. many people are not prepared to assign a finite monetary value to human life.

This is the reason why in the USA efforts are being intensified to introduce CEA or CUA for all laws and ordinances<sup>3</sup>. The objective is to ensure that all legislation is based on the same recommended levels of expenditure for regaining lost life years (TENGS et al. 1995), or for health adjusted life years (such as quality adjusted life years (QALY), or disability adjusted life years (DALY))<sup>4</sup>. This would mean that for a given budget the expected health improvement is maximised. The Office of Management and Budget (OMB) reserves the right to introduce cost effective measures in a summary procedure, and either to postpone expensive measures or return them for further consideration. The enforcement authorities are now faced with the problem of how these requirements can be fulfilled and which units should be chosen. Among the economists who had till now been responsible for preparing CBAs, there are those who are considering how QALY, DALY and monetary units can be mutually converted (e.g. HUBBELL, 2002). Also see Chapter 5.7.

State and other highly regimented public health systems such as those in England and Canada also use CUA when deciding whether to include pharmaceuticals or treatment techniques in their approved lists. For this, the costs of pharmaceuticals or treatment are set in relationship to the expected health improvements (measured in QALY), and compared to existing pharmaceuticals and treatments. In addition, acceptability values have been established, mostly on an informal basis, and these are used by the pharmaceuticals industry to justify new medicines, and by the social

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<sup>3</sup> We are not suggesting here that these instruments are mutually convertible. In a response to articles in the technical press that had implied this, Dolan & Edlin (2002) argue that there is no direct connection between CBA and CEA, that CEA (as opposed to CBA) does not fulfil the scientific requirements in the welfare field, and that conversion is only justifiable from a non-welfare perspective and where interest centres on health maximisation.

<sup>4</sup> John D. Graham, Harvard Center of Risk Analysis, Boston, among others, has demanded this now for several decades (Graham et al. 1981, Graham 1982). Prof. John D. Graham was recently summoned to the OMB by President G.W. Bush, where he is now introducing these instruments.

insurance companies as a basis for identifying excessively expensive treatments and pharmaceuticals for which the health insurance is not prepared to pay (also see Chapter 5.3).

The above information demonstrates that CEA, CUA and CBA are in use at an international level in various applications in the field of public health, and that CUA in particular is gaining in importance. To permit the data available in the field of health impairment to be used in as many different ways as possible, it is in the public interest to be able to express these in both DALY or QALY and money units.

## **2.4 What is the best method of quantification and when should it be used?**

Assuming that a particular decision-making situation does not dictate the form of quantification or the analytical method from the outset, the following aspects should be considered when choosing the form of quantification (either E, U or B as explained in Chapter 2.1) and the possible analytical tool (i.e. CEA, CUA or CBA as explained in Chapter 2.1):

- To achieve comparability among different types of disease and premature death, either on the basis of units such as QALY or DALY, or of monetary units, additional valuation information over and above the usual identification and case number is required. The acquisition of the additional information is very time consuming, because valuation must be justified not on an arbitrary but on a representative basis. Moreover the additional information introduces further uncertainties into the method. Where the aggregation of different health impairments is not indispensable for providing a sufficient basis for decision, it is advisable to limit quantification to the determination of case numbers per case type (alternative E in Chapter 2.1).
- The existence of the same units is a necessary, but by no means a sufficient condition for the aggregation of quantities. Where money units are used in the aggregation, the risk of error is particularly great if the required values are taken from several different monetisation studies carried out under different conditions. Thus, for example, CHF equivalents of a lost year of life taken from an analysis of working wages (wage risk analysis) and CHF equivalents of a non-fatal heart attack from a contingent valuation (CV) study must be assumed to be non-additive unless they can be demonstrated to be compatible. The results in Chapter 5.7 illustrate the error that can occur when money amounts are added in an undiscerning manner. The danger of inconsistency is significantly reduced where the values of health impairment to be added are expressed (for example) in DALY, and where the necessary weighting factors are established at the outset by a co-ordinated procedure under suitably defined conditions. If, therefore, the aggregation of health impairment values cannot be circumnavigated, data consistency is easier to achieve in practice by the use of health scales (alternative U in Chapter 2.1) than by using monetised values (alternative B in Chapter 2.1).

- Decision makers should understand the relevant studies and be able to interpret the results, thereby enhancing credibility and improving the chances of political acceptance of measures proposed. This implies the need to maximise transparency and minimise complexity, and favours CEA or CUA, as opposed to CBA with its accompanying monetisation.
- Where benefits or impacts outside the sphere of public health are to be included, care should be taken to ensure that the unit chosen is capable of representing them (with monetary units often possible). Where it is not possible to use a single indicator for all quantities, the number of indicators<sup>5</sup> should be kept within reasonable bounds.
- From a pragmatic standpoint, it is essential to enquire whether the necessary data are available in sufficient quality to apply a given analytical method.

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<sup>5</sup> Where one or more indicators are used for health alone, and these are to be combined with other indicators for social effects, interventions in the ecosystem, etc., their interpretation can soon overtax a person's mental capacity.

### 3 Monetisation of health impairment: methods, components and previous studies

The concept of monetising impairments caused by noise, i.e. of expressing these in monetary units, is by no means new. A large number of monetisation studies have been performed, but only those concerning *traffic noise* (particularly road traffic noise) are of interest here, and the present study concerns the impacts on human well-being that occur within the *living space* only, so that a hearing impairment (for example) caused by high sound levels at the workplaces, or by exposure to loud music, have not been considered.

Numerous monetisation studies have investigated the influence of sound level on house prices and apartment rents based on the presumption that the well-being of the occupants is diminished at locations heavily exposed to noise, and that therefore the demand for these houses and apartments, and therefore their market prices, are lower. Other studies have investigated the relationship between the quality and quantity of work performed and the intensity of sound at the workplace, resulting in reduced economic value of the work performed at high noise levels. In yet another category of studies, the monetary equivalents of certain impairments to human health are calculated. In cases where noise exposure could also be a risk factor for these impairments (e.g. heart attack), such studies can be seen in the wider sense as monetisations of health impairment caused by noise. Since there is no 'market' for buying or selling impairment from noise, the above mentioned studies determine the necessary monetary equivalents for such impairments, either by isolating the price relevant noise component from real market transactions (revealed preference methods), or by enquiring into people's willingness to pay in a hypothetical market (stated preference methods).

Because the existing monetisation studies use a variety of methods to determine the various components of the impairment caused by traffic noise, their results are not comparable. In this chapter, we shall take a look at the components of noise impairment and their relationship to the transport activities causing them. This is followed by an overview of monetisation methods. Finally, the monetisation studies of relevance to the present study will be discussed.

#### 3.1 Components of external impairment due to non-avoided road traffic noise

The total damage due to noise is defined as the total of economic costs of implementing noise abatement measures and of impairment to humans, non-human life and inanimate objects resulting from non-avoided noise. Impairment can affect the perpetrators of the noise themselves (internal impact) or others (external impact). The present study is, however, restricted to the monetisation of the external impairment to the well-being of humans (i.e. health impairment), plus any consequential impairment, from non-avoided road traffic noise. Therefore, the following aspects of the total impairment have been *excluded* from the present study:

- Impairment due to *noise from sources other* than road vehicles. The preliminary focus on road traffic within the total spectrum of traffic noise should be understood as an assignment of priority to the most important noise source.
- The costs of realised *noise prevention measures* inclusive of noise attenuation measures such as noise barriers, noise protection windows and encapsulation of noise sources. In general, the economic costs of such measures are known, and, since they are already expressed in money units, do not call for monetisation.
- Noise impairment to *animals, plants and inanimate objects*. As yet, little is known on noise impairment to animals, whilst that to plants and other inanimate objects is unlikely. Noise related reductions in value can, however, occur with buildings (inanimate objects) and these *are* treated in the study. Here, however, the impairment in question does not concern the building fabric, since the decrease of the value of the building results from a diminution of the well-being of the occupants.
- *Internal noise impairment* to the perpetrator of the noise and his/her employees, particularly to drivers and other users of vehicles causing the noise.

According to the WHO (BERGLUND et al. 2000: 20–30) the following impairments to human health may result from noise:

- impairment of hearing organs
- interference with communication
- sleep disturbance
- cardiovascular and physiological effects
- psychical impairment

Hearing and psychical impairment are not to be expected at the sound levels characteristic of road traffic noise. They could, however, occur at the higher sound levels associated with the workplace and with 'acoustic' recreation (BERGLUND et al. 2000: 23, 29). The remaining three forms of health impairment due to noise are treated in MÜLLER-WENK (2002). These are also treated in the present study.

The economic consequences resulting from the above health impairments may be summarised as follows: value loss of property in areas subject to noise, lower work performance of those affected by noise (BERGLUND et al. 2000:30), and medical costs of improving the state of health of those affected by noise. These financial costs cannot simply be added to the 'intrinsic' cost of the health impairment 'as such', but a check has to be made to avoid double counts.

A breakdown of the various impairment components will prove of value. Based on the method of HOFSTETTER & HAMMITT (2002), the external health impairment resulting from road traffic noise may be classified as follows (table 1):

Table 1: Breakdown of the external components of impairment to human health resulting from road traffic noise (direct impairment and accompanying effects). This breakdown basically applies to all of the above mentioned cases of health impairment (i.e. impairment to the hearing organs, interference with communication, etc.).

Impairment component	1) Costs borne by noise-affected individuals or their living partners	2) Costs borne by third parties (state, risk sharing pool, employer)
A) Loss of bodily integrity (intrinsic)	A1) Monetary equivalents of loss of integrity, where not covered by compensation	A2) Payment of compensation for loss of integrity
B) Medical expenditure to limit (acute treatment) and stabilise loss of integrity	B1) Payments by patients affected by noise for doctors, medicine, laboratory tests, hospital treatment, equipment, prostheses	B2) Corresponding payments by health insurances, insurances, state
C) Non-medical expenditure to limit or stabilise loss of integrity	C1) Payments by patients for ear plugs, noise reduction in living and work spaces, and for temporary dislocation	C2) Corresponding payments by health insurances, insurances, state
D) Private expenditure on measures to compensate failing bodily integrity	D1) Payments by patients for care and house help, and unpaid assistance from living partners	D2) Corresponding payments by health insurances, insurances, state
E) Loss of performance in the case of employed persons	E1) Full or partial loss of wages minus any compensation for loss of employment	E2) Payment of compensation for loss of employment, costs to employers in the case of reduced work performance without salary reduction
F) Loss in the value of property affected by noise	F1) Lower rent as compensation for health impairment of patients. Reduction in selling price	F2) Reduced rents granted to transfer the burden to the owner of the property. Reduction in selling price

#### Discussion of table 1:

- Table 1 shows only the costs of impairment due to *non-avoided* noise. This is defined here as noise that is audible in the living or work space of the person affected by noise. Where the *total* external costs resulting from noise (i.e. those not arising with the perpetrator), in addition to those shown in table 1, are required, the costs of noise abatement measures along the propagation path between the perpetrator and the person affected by noise (e.g. noise barriers, noise protection windows and regulations to increase the distance between buildings) would have to be included.
- The intrinsic impairment A expresses the loss of bodily integrity 'as such', thereby expressing the health impairment due to noise. The important question here is to what extent the level of bodily functions still disposed of by the person affected are reduced below that of full health. An extreme loss of bodily functions can lead to loss of employment and the need for care. Accompanying impairment of this kind is *not included* in the loss of integrity, but is subsumed under E and D. The impairment A may be expressed at the physical level in DALY (disability adjusted life years), comprising both the duration of the impairment and its intensity (disability weight, DW) (MÜLLER-WENK, 2002, p. 47 ff.). It is a

central objective of this study to express the monetary equivalent of the impairment in DALY by means of suitable monetisation methods, thereby expressing the loss of integrity caused by noise in money units.

- In the present context, it is important to determine who must bear the costs of noise impairment. Table 1 shows this either to be the noise-affected individuals and/or those living in their households who constitute an economic unit, or third parties, for example the state, the employer or a risk sharing pool in the case of social and private insurance companies. The integrity impairment A occurs first with the person affected (A1). If, however, the person affected is granted compensation for the loss of integrity at the expense of the state or insurer (A2), this would be equivalent to a reduction in the net remaining impairment A1 to the person affected. Where, however, road traffic noise is the cause of the loss of integrity, the loss of integrity has till now been borne in full measure by the person affected, that is included in impairment A1. It would be conceivable to compensate the impairment to the integrity of a person by payments by the perpetrator of the noise, but this has not yet arisen in practice.
- Where a person affected by noise suffers a loss of bodily integrity, medical treatment to avoid a more serious loss of integrity may be necessary: Persons with sleep disturbance resulting from noise may require a periodical medical examination and may need to take medicines to avoid more serious consequences arising (these are *not* contained in the disability weight for sleep disturbance). The consumption of resources for medical treatment B is a financial burden that must either be carried by the person affected by noise (B1) or by the social insurance (B2). It is important to note that medical treatment under this heading is a measure for the stabilisation of the state of health expressed in A and not for regaining full bodily integrity. In addition to medical measures, measures C external to the medical area may be required. Thus a person affected by noise may decide either to fit his/her bedroom with materials having a substantial noise damping effect, or to escape from the noise each weekend by driving to a holiday cottage in a quieter area. In this case, the impairment A will be smaller than with those who do not take these measures.
- Where the loss of integrity A is extreme, a disabled person with specific bodily deficiencies may require nursing and care (D). This could, for example, be the case where a person has a heart attack as a result of traffic noise, thereby suffering invalidity. However, the health impairment resulting from road traffic noise is generally so low that the impairment D is practically negligible. Important to note is the fact that the cost of any necessary care is not included in the loss of integrity determined in DALY.
- Following from the loss of integrity A, the productivity of the person affected may decline quantitatively or qualitatively. Though this applies to all persons, it is of particular relevance to the employed. Should the productivity of a person subject to traffic noise at home decline at the workplace, this will not generally be noticed by the employer, and will therefore have no effect on wages. Thus any financial loss arising from loss of productivity is borne by the employer (E2). The opposite would be the case for invalidity resulting from a heart attack caused by noise, where a loss of wages must in fact be expected (E1), thereby

causing a burden to the person affected in addition to the loss of integrity A1, provided that no wage compensation is paid by the insurance company. Note that loss of productivity can also result from the noise level at the workplace, whereby in this case the principal cause of noise is internal, so that this does not generally constitute an external noise impairment as treated here.

- Buildings and property affected by noise have demonstrably lower selling prices and rents. As already mentioned, this results not from physical damage to the property but from the lower amenity value due to the noise. The impairment (F) is therefore caused not directly by the noise but indirectly via a causal chain leading from noise emission through actual or expected impairment to the well-being of the occupants, and finally to price-setting in the apartment market. Where rents are reduced as a result of traffic noise, this effectively corresponds to a transfer of the financial burden from the occupant affected by noise to the owner of the property (F2). The transfer is complete if the rent reduction equals the sum  $A1 + B1 + C1 + D1 + E1$  of all types of impairment of human well-being caused by noise.
- It is important to understand that in determining the total external burden caused by noise, the reduction in the value of property F cannot simply be added to the burden  $A+B+C+D+E$ , since this would lead to double count as explained in the above argumentation. Double count would also arise if the impairments  $A+B+C+D+E$  were added to give the total external burden while it is not clear that in determining the loss of integrity A, the condition of non-inclusion of the impairments B, C, D and E was properly fulfilled. It is, however, safe to assume that where the loss of integrity is of comparatively small magnitude, which is usually the case for road traffic noise (MÜLLER-WENK, 2002), the effect of double count is negligible.
- Where cases of health impairment due to noise are monetised on the basis of personal assessment (stated preference) or market behaviour (revealed preference) of those affected by noise, the resulting monetised impairment only contains the components accruing at the person affected by noise or his/her living partners, and of which they are therefore to some extent aware. As a result, the monetisation figure does not contain any financial burden carried by others (A2 to F2).

### 3.2 Causal chains and monetisation of environmental impacts

It is characteristic of environmental impacts (and in particular the impairment to human health caused by road traffic noise) that the damage does not occur at the same time and place as the effect that caused it. Rather, a chain of cause and effect lies between the initial cause and the impact. In the case of road traffic noise, the following health related causal chain may be identified:

- Motor vehicles in motion produce noise from the engine, tyres and other sources.
- An average noise level results from the volume and constitution of traffic along transport routes.

- The propagation of noise results in a noise level at the outside of buildings.
- The resulting noise level inside the building depends on the building design.
- Persons within the buildings subject to noise suffer from impairment to health.
- Persons whose health is affected by noise suffer an economic burden since they are dependent on medical treatment and their productivity is reduced.
- Certain components of this burden are transferred from the person affected by noise to third parties (health insurance, employer, landlord) via social insurance or markets.

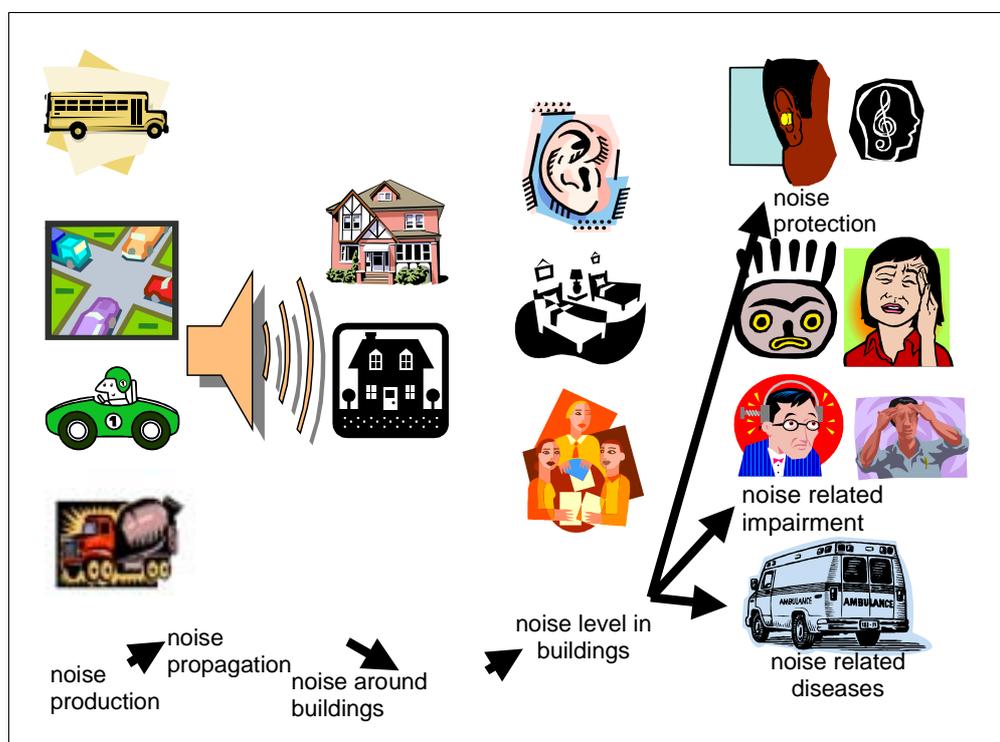


Fig. 1: Chain of health impairment effects due to road traffic noise.

The monetisation of environmental impact does not require the causal chain to be known. It is however, desirable to establish the path of causation before determining the impact and its monetary equivalent, for the following reasons:

- The identification of the causal chains reveals the causative mechanisms leading to the impact and provides an insight into the relationship between the types of impact involved. The causal chain is an instrument for avoiding double counts and gaps in the determination of impacts. Thus the causal chain represents an important supplement to the breakdown of impact components shown in table 1.
- The analysis of the causal chain simplifies the task of identifying and quantifying not only the observable but also the anticipated impact.
- At the same time, the causal chain pinpoints the stages at which the impacts could be defined, recorded and monetised, and proves helpful in choosing the most suitable stage.

- To ensure that the polluter-pays principle may be applied, environmental impact must not only be quantifiable, but also attributable to the perpetrator. Where this is not the case, the identification and monetisation of environmental impact is suited only for compensating those affected. The causal chain provides the basis for cost assignment to those responsible.
- Information on environmental impact has greater persuasive power in the political arena when it is based on clearly defined causal chains. The monetisation of environmental impact through the use of statistical methods alone, without an analysis of the causal mechanisms, is less convincing and may also be scientifically challengeable.

Thus as a first step, a quantified causal chain was established for the evaluation of the impairment to human health caused by road traffic noise. This chain commences with a single journey of a motor vehicle along the national road network and ends with the type, number and weighting of the seriousness of the impairment to health caused (MÜLLER-WENK, 2002). In a second step we treat here the question how these effects can also be expressed in money units. Using the causal chain established above, the monetised impairment can be allocated recursively to individual vehicles in relation to the distance travelled by them on the Swiss road network.

Where the impairment to human well-being through road traffic noise is concerned, at what stage of the causal chain should the attempt be made to express the environmental impact in monetary terms? On the basis of the causal chain, the following observations regarding the point of attack of monetisation are made:

- Of course it is advantageous to directly monetise the values in the causal chain whose monetary equivalent is required at a precise moment. If, for example, a country total of the intrinsic value of sleep disturbance caused by road traffic noise (A in table 1) is required, the monetary equivalent of one sleep disturbance case is determined and afterwards multiplied with the number of cases shown by the causal chain. This procedure can, however, fail where the existing monetisation methods (cf. fig. 2) are inappropriate at this stage, either due to a lack of data for the analysis of market transactions that have taken place, or because no hypothetical market can be formulated that would be understood by survey participants.
- If, consequently, a value is chosen for monetisation that lies on the causal chain either *before* or *after* the desired point, the problem arises of converting the monetary equivalent determined to the monetary equivalent desired. Once – for example – it has been established what amount a person concerned would be prepared to pay for a certain reduction in the number of vehicles per hour on a certain road, or how much more rent he/she would be prepared to pay for a quieter apartment, the monetary equivalent of sleep disturbance can be determined. This money amount could then be converted along the causal chain, taking into account, however, the particular components of impairment in table 1 that are affected.

- In practice, in view of the very large effort needed to prepare additional monetisation studies, the results of existing studies are often used. In this case, it is essential to ensure that the above conversions are correctly performed.

### 3.3 Classification and definitions of monetisation methods

As the names for monetisation methods and their classifications vary in the literature, figure 2 shows the classification used here based on Pearce & Howarth (2000). The methods shown are suitable for determining the so-called damage costs. In other category of methods, the costs of avoiding such damage are assessed. Thus in the latter, the costs of anti-emission and anti-exposure measures for avoiding impairment are determined. As discussed in Chapter 2.2, the impairment costs may be used to establish the level of economically acceptable expenditure for the avoidance of impairment. Thus the avoidance costs will not be further treated here.

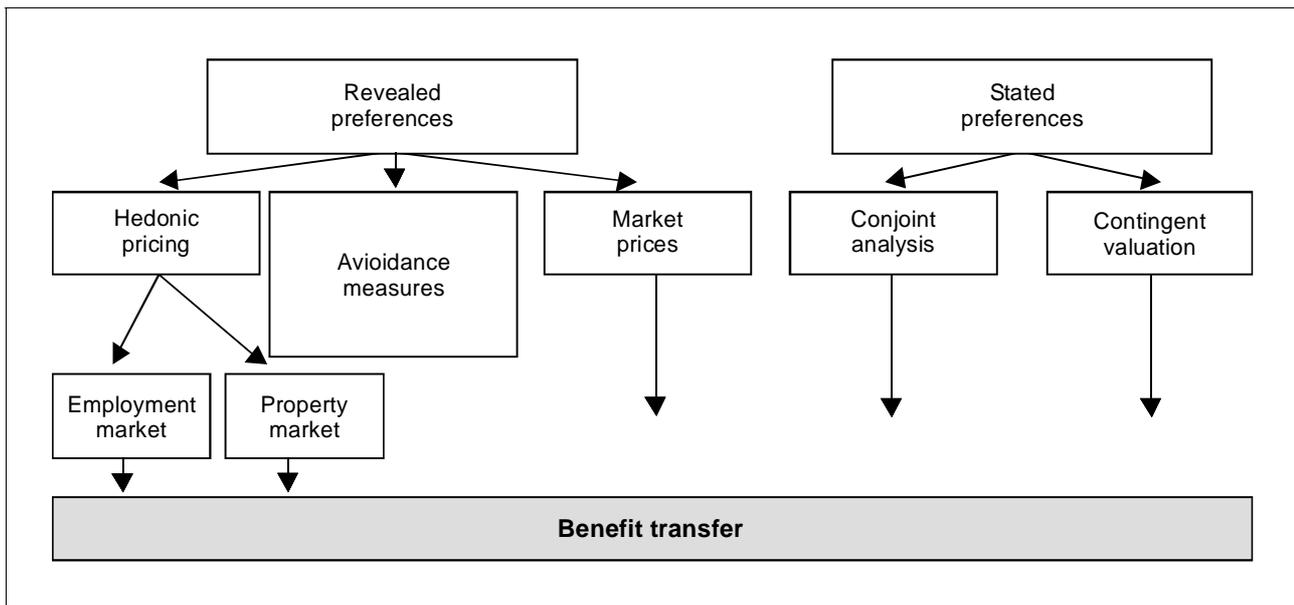


Fig. 2: Classification of monetisation methods for damage costs based on PEARCE & HOWARTH (2000).

In this work, three of the methods shown in figure 2 are significant: hedonic pricing, contingent valuation and conjoint analysis. With hedonic pricing, real market transactions are analysed to determine what proportion of the market price can be assigned to a single feature of the traded good, for example the noise exposure of a property, or the willingness of an employee to accept the higher health risk associated with his/her particular workplace. In contingent valuation, people are asked to imagine a hypothetical market for a good (e.g. protection against disease) and then to say what they would be willing to pay for it, assuming it were to be offered for

sale. Conjoint analysis differs from contingent valuation in that the participants, instead of being asked how much they would be prepared to pay for a particular good, are presented with different hypothetical goods having different property profiles (e.g. apartments with different characteristics), and then asked to state their preferences in descending order. This information is used to obtain the money value the participants implicitly attach to a specific property of the goods.

A further distinction is made in monetisation methods between the willingness to pay (WTP) and the willingness to accept (WTA), for which table 2 gives four different types. PEARCE & HOWARTH (2000) assume that the methods 'property market', 'market prices' and 'avoidance measures' typically involve WTP procedures, whereas the 'employment market' method typically involves WTA procedures. The other two methods shown on figure 2 ('conjoint analysis' and 'contingent valuation') are either WTP or WTA procedures, depending on the way questions are formulated. As shown in Chapter 4.4, the values found for the four cases cited differ considerably. It is therefore important to take this classification into account in discussing the results (see Chapter 5.7).

Table 2: Four ways of formulating questions.

	Improved conditions	Deterioration in conditions
Willingness to pay WTP	1) Maximum willingness to pay for the improvement	2) Maximum willingness to pay to prevent the deterioration
Willingness to accept compensation (WTA)	3) Minimum compensation to do without the improvement	4) Minimum compensation to accept the deterioration

### 3.4 Results of monetisation studies

Before discussing the available monetisation studies in detail, we single out those which concern items of interest to us.

#### 3.4.1 Summary of possible approaches

Several monetisation studies are available for the determination of the monetary equivalents of health impairment caused by noise and accompanying impairment, as required in the present study. These may be divided into the following groups:

- Determination of the drop in price of one-family houses or apartment rents as a function of the noise level outside of the building resulting from road traffic. The results are normally expressed in % of price reduction per additional dB(A) above a threshold value. This is calculated by multiple regression based on a sufficient number of real market transactions (hedonic pricing). Some studies obtain the same information by questioning a sample of individuals (contingent valuation). Using the data for the noise-related rent reduction of apartments, the

monetary equivalents of the corresponding impairment to health of the occupants may be derived.

- Determination of the monetary equivalent of non-occurrence of individual forms of noise-related health impairment, namely sleep disturbance, interference with communication and cardiovascular effects (cf. Chapter 3.1). Even if the actual cause of the impairment in a existing monetisation study was of another type than noise, the results pertaining to such health impairment may still be useful to the present study. This is the case for heart attacks: these are recognised to be a possible consequence of high noise exposure, whilst available monetisation studies have determined the willingness to pay for the avoidance of heart attacks caused by other factors than noise. The results of monetisation are expressed in money units per avoided case of health impairment of a particular intensity and duration. The money value is typically derived from questioning individuals (contingent valuation), and them stating the value in money units that they would attach either to avoiding the occurrence of the health impairment, or to reducing the probability of its occurrence. Unfortunately, monetisation studies are available neither for sleep disturbance nor for interference with communication, the most common forms of health impairment due to road traffic noise. In these cases, the results of monetisation studies for similarly serious health impairments of other kinds can be used, adjusting – however - the stated willingness to pay according to the ratio of seriousness of the types of impairment involved.

The conclusions in Chapters 5.3 to 5.6 indicate that there are other possible, and practically applicable, approaches to the solution of the problem of determining monetary equivalents of health impairments due to road traffic noise. In the following, the available monetisation studies that may be utilised in adopting the two above mentioned approaches will be discussed.

### **3.4.2 Reduction in property prices and apartment rents caused by noise**

A large number of empirical studies are now available on the reduction in property prices and apartment rents in relation to the noise level of road traffic. A list of these can be found in WEINBERGER (1991:114) and SOMMER et al. (2000:53). As transposing the results of social studies from other cultural milieus and from past epochs is problematic, we will concentrate here on more recent studies performed in Switzerland and Germany.

- SOMMER et al. (2000) analysed the actual selling prices of a subset of 380 single family houses among the totality of those sold in the Canton of Zurich between 1995 and 1999 (hedonic pricing method, cf. fig. 2) with regard to the importance of road traffic noise as an influence factor. The result: the selling price declined linearly by 0.66% for an increase in road traffic noise of 1 dB(A) during the day, whereby the 95%-confidence interval had a lower limit of 0.23% and an upper limit of 1.03%. This linear dependency of the selling price on road traffic noise level outside of the building does not apply to sound levels below 45–50 dB(A)

during the day, because such intensity of noise is barely audible, due to the general background noise. It is not entirely clear from the study whether the regression analysis was programmed to reduce the calculated noise level for each object by a constant value, with the objective of achieving a more-or-less linear dependency between noise and price. SOMMER et al. (2000: 51–53) compare the noise dependency of prices for single family houses in Zurich with the price dependency of properties and rents found in other Swiss and international studies. Based on this analysis, the authors recommend an average value for the dependency of property prices and apartment rents of 0.91% per dB(A) of daytime road noise in Switzerland (SOMMER et al. 2000:55). In addition, the authors analysed the dependency of apartment rents on noise in the City of Zurich (SOMMER et al. 2000:30ff) where they were unable to find a significant correlation between the level of apartment rents and the level of noise exposure. The authors did not, however, conclude from this that rents are independent of noise exposure, but rather that their data on rents, and the means of determining them, were of insufficient quality.

- Likewise, ITEN (1990) studied current apartment rents of a subset of 195 apartments in the City of Zurich by means of multiple regression (hedonic pricing), with particular reference to the effect on prices of the noise level arising from road traffic noise. The published data show that apartment rents decrease by 0.8–0.9% for an increase of 1 dB(A) during the day, whereby this factor varies with the noise level, as given in more detail in ITEN (1990:101). This result, which was taken into account in the above mentioned recommendation by SOMMER, is comparable to that of SOMMER'S et al. (2000) regression analysis, although the two studies differ greatly in their choice of descriptive variables and in the form of the regression equations (SOMMER et al., 2000:20; ITEN, 1990:97). In Iten's study, the noise dependency of apartment rents was carried out not only with hedonic pricing but also based on structured oral questioning of tenants (conjoint analysis, stated preference). In this, the central question to the tenants of the 195 apartments was in what order of priorities they would place apartments of the same type at different hypothetical locations. Noise exposure was one of the five attributes attached to the locations, and was expressed in three classes: quiet, fairly loud, loud. This classification was very rough and did not allow the interviewees to interpret it clearly. Statistical methods were used to determine the 'implicit price function' and the individual willingness to pay for less noise as a function of noise level and income. It is noteworthy that the individual willingness to pay for a reduction of noise of 20dB (A) is roughly the same in both study methods (conjoint analysis, hedonic regression) (ITEN, 1990:120).
- BARANZINI & RAMIREZ (2002) also studied real apartment rents, with prices averaged over the period 1993–2000, of 11'661 apartments in the Canton of Geneva by means of multiple regression, in which - among other things - the influence on pricing of the rating sound level L<sub>r</sub> (outside of the building) from all sources of noise was determined, whereby despite the proximity of the airport, road traffic noise was clearly the dominating factor. However, in contrast to the above mentioned studies, the average of the noise levels during the day and at night was used, and this led to a noise level of some 5 dB(A) below that of the

more commonly used day method. Nevertheless, the average noise level outside the Geneva apartments determined in the study of  $L_r = 60.6$  dB(A) is unusually high. One would therefore expect the percentage of rent reduction per additional dB(A) of noise of the Geneva study to be higher than in comparable studies. Thus it is astonishing that the multiple regression on the Geneva data shows a rent reduction of only 0.1% per additional dB(A), i.e. significantly lower than in the other studies. Baranzini's explanation that «... results are not directly comparable, since in particular the measure of noise differs» is not entirely convincing in view of the above results. It is also surprising that the separate analysis of apartments with non-controlled rents and apartments with government-controlled rents, the price reduction per additional dB(A) for the former was only 0.087%, whereas for the latter it was much higher at 0.44%. One would have expected the controlled rents to show a less pronounced dependency on the noise level, because government-controlled apartments are usually so cheap that the market forces do not enforce a further price reduction at noisy locations. Thus the results of Baranzini must be regarded for the moment as questionable.

- Further analyses of rents in Switzerland using multiple regression by Pommerehne for the City of Basle, and by Soguel for the City of Neuchâtel, are cited in SOMMER et al. (2000). We shall not discuss this work here in detail. These two studies, which are often cited and used, show rent reductions per additional dB(A) of 1.26% and 0.91% respectively.
- In 1989, WEINBERGER et al (1991) determined the Federal German population's willingness to pay for a quieter apartment. Using a carefully designed written questionnaire (contingent valuation) distributed among a sample of 6057 households in West Germany, 3281 valid responses were returned. Using noise registers, the data on the equivalent continuous sound level for each participant's actual apartment was entered in the database used in the study. Care was taken to ensure that the variation of noise exposure within the stratified sample was the same as that in the totality of Federal German households. The willingness to pay was assessed based on the leading question: «Please imagine that you have the opportunity to live in a quieter road in the same area, but that no other changes are made in your living conditions. How much more rent would you be prepared to pay for the quieter apartment, (a) assuming that hardly any noise is heard there; (b) little noise is heard there». In analysing the responses, «hardly any noise» was assumed equal to an equivalent continuous sound level during the day of 40 dB(A) outside of the building, and «little noise» to 55 dB(A). This assumption was subsequently shown to be justified based on a detailed evaluation of the questionnaires. The study was carefully planned to enable controls to be applied to estimate the range of possible error resulting from misinterpretation of answer refusals, of incorrectly interpreted questions and of intentionally untrue answers, and to correct these where necessary. The central result of the study was the determination of the average individual's willingness to pay in DM (as of 1989) per month per person in a household for 'almost no' road traffic noise (i.e. 40 dB(A) during the day). The resulting willingness to pay, averaged over all income groups, clearly correlated with the yearly average of the daytime noise level  $L$  of the building currently inhabited by those questioned. This will-

ingness to pay for 'hardly any noise', depending on the noise level  $L$  of the actual apartment, is expressed by the equation  $1.97 \cdot L - 82.56$  DM at 1989 prices (WEINBERGER et al., 1991:182/183). In other words, the participants declared themselves ready to pay about 2 DM more rent per person and month for an apartment having 1 dB(A) less daytime noise (outside the building) than their present apartment. This average value conceals a moderate dependency of the willingness to pay on the total income of the household after taxes and social insurance, whereby the study shows that the willingness to pay rises much less sharply than the income (WEINBERGER et al., 1991:172). As opposed to the studies mentioned above, the Weinberger study shows the maximum amount in DM people are prepared to pay per month and person for 1 dB(A) less noise in comparison to their present apartment, and *not* how many *percent* more rent they would be prepared to pay for a reduction in noise level of 1 dB(A). For comparison purposes, WEINBERGER et al (1991: 168, 111ff) converted the percentage rent increases to absolute rent increases in DM/month. This shows that a rent increase of 0.5% per dB(A) corresponds to an absolute value of +0.95 DM per month and dB(A), whilst a rent increase of 1.26% per dB(A) corresponds to an absolute value of +2.40 DM per month and dB(A). The percentage values of 0.5 and 1.26 quoted represent low and high values from numerous other studies on willingness to pay a higher price for a 1 dB(A) decrease of noise level. Thus the willingness to pay found by Weinberger of some 2 DM per month, person and -1 dB(A) amounts to a willingness to pay 1.05% more rent for an apartment that is 1 dB(A) quieter.

Hedonic pricing and contingent valuation do not measure the same form of willingness to pay. With hedonic pricing, the objective is to determine the number of money units per 1 dB(A) less noise that buyers or tenants *actually* paid, whereas in contingent valuation the *maximum* sum they would be prepared to pay for 1 dB(A) less noise is determined. Since, however, in the case of houses and apartments (in distinction to other consumer goods), the price is negotiated for each individual object, the seller being mostly in the stronger position, there is reason to believe that the actual and maximum willingness to pay lie very close together.

The various monetisation studies thereby appear to confirm that under the present conditions in Switzerland, the actual and the maximum willingness to pay amount to approximately 1% of the selling price or apartment rent for 1 dB(A) less of road traffic noise.

Let us repeat here that studies on the dependence on house prices on noise include the impairment component F2 in table 1. We assume here and in Chapter 5 that this impairment component F2 equals at a first approximation the sum of the impairment components A1 to E1 endured by the occupants, meaning that the market will transfer these costs in large measure to the providers of accommodation. But it is also conceivable that the monetary equivalent of the health impairment due to noise borne by the occupants is significantly higher than it is expressed in the actual price

reduction for noisy apartments, e.g. where such apartments are mostly occupied by those unaccustomed to a high standard of comfort.

### **3.4.3 Monetary equivalent of non-occurrence of health impairment due to road traffic noise**

A sizeable number of studies based on contingent valuation or conjoint analysis are concerned with monetisation of health impairment, whereby, however, other cases than sleep disturbance, interference with communication and cardiovascular effects, as enumerated in Chapter 3.1, are treated. No monetisation studies could be found that treated sleep disturbance or interference with communication. Studies were, however, found for cardiovascular effects. In this context, a recent study should be mentioned that gives figures for the social costs attributed to tobacco consumption in Switzerland.

In a study commissioned by the Swiss Federal Office of Public Health, VITALE et al. (1998) determined the total social costs of six diseases caused mainly by smoking (lung cancer, stroke, fatal heart attack, non-fatal heart attack, angina pectoris and chronic bronchitis). These 'total social costs' include – amongst other components - the intrinsic value of the loss of health. Based on 757 valid questionnaires from a stratified sample, VITALE et al. determined the monetary equivalent of lung cancer, fatal heart attack and chronic bronchitis in 1998 using contingent valuation. The participants were first presented with a description of the disease and then asked how many CHF they would be willing to pay from their own resources for a hypothetical medicine that would reduce during 12 months the risk of contracting the disease to 5% of current average risk in Switzerland. The results of a regression analysis of the answers showed the average maximum willingness to pay for the reduction in the risk of contraction by 100'000/100'000 during one year. The corresponding amount is 512'500 CHF for lung cancer, 236'000 CHF for a fatal heart attack, and 38'500 CHF for chronic bronchitis, at 1998 prices (Vitale et al., 1998: 82–87). In Chapter 5.2.3, the results of these studies are further analysed and discussed.

For reasons of clarity, we repeat here that the studies on willingness to pay cited above, as well as the procedures for determining DALY figures, are based on the intrinsic value of health, that is to say on field A in table 1. For the impairment components B, C and D in table 1, which are normally recorded in monetary terms, no monetisations and no units such as DALY or QALY are necessary, because the costs of treatment and nursing can be taken from the national health statistics. Moreover, in VITALE et al. (1998), these costs are referred to as *coûts directs* and are summarily calculated (VITALE et al. 1998: 100–102). The economic value of lost manpower caused by disease and premature death (field E in table 1) is given comprehensively for diseases related to smoking in VITALE et al. (1998: 25–60).

# 4 Methodical, ethical and practical considerations in monetising health impairment caused by noise

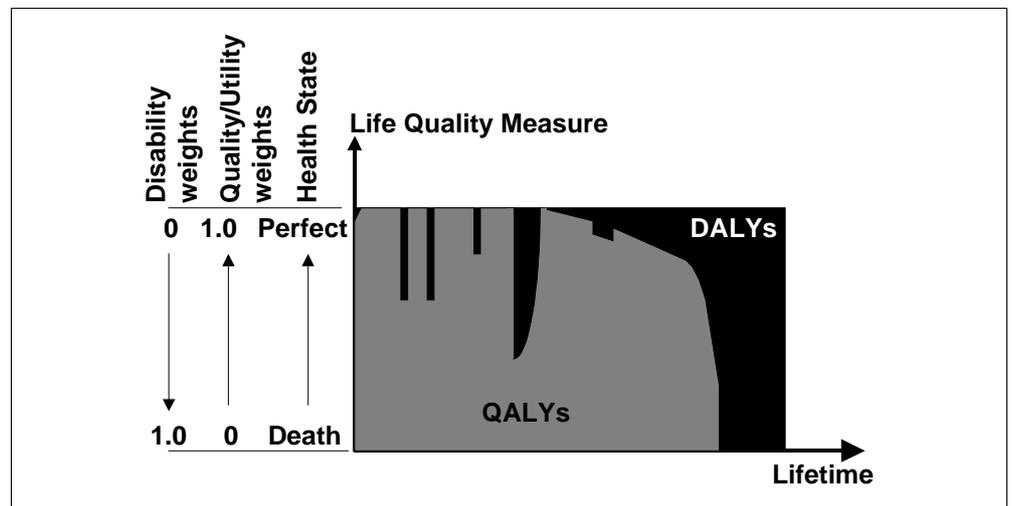
## 4.1 Disparity between health scales and monetary health evaluation

In view of monetising health impairment whose duration and intensity are expressed in DALY, we first discuss here significant differences between health adjusted life years (HALY) and monetary methods for assessing health. The term HALY contains both 'disability adjusted life years', DALY, which are of principal concern to us here, and 'quality adjusted life years', QALY, often used in the field of public health. Concerning monetary health assessment methods, our focus is on the methods for the determination of willingness to pay WTP based on stated preference, though where necessary other monetisation methods are also mentioned.

### 4.1.1 Health adjusted life years (HALY)

We shall restrict ourselves here to a discussion of the two most commonly used health scales. Further scales are listed, among others, in HOFSTETTER & HAMMITT (2002). By using HALY units, it is possible to convert any type of health impairment and premature deaths to equivalent life years. In figure 3, the difference between DALY and QALY is shown. Whereas QALY measures the actual state of health integrated over the years of life, DALY measures the loss of health with respect to perfect health and to a reference duration of life. Thus DALY units are in principle complementary to QALY units.

Fig. 3:  
Graphical representation of a hypothetical health profile for a prematurely deceased individual and the significance of the QALY (grey areas) and DALY (black areas) indicators. (Lifetime = Life years)



The simplest form of QALY can be stated as follows:

$$QALY = \sum \text{discount factor} * (H(Q) * \Delta t) \quad [a] \quad (1)$$

where  $Q$  represents the state of health during the time period  $\Delta t$ , and is regarded as constant over that period. In this,  $H(Q)$  is the value function of this state of health and is referred to as the 'quality weight'. As the equation shows, QALY is usually also discounted in order to take into account the time preferences of individuals and

the society. Variations of this approach and its theoretical justification are to be found in PLISKIN et al. (1980) and HAMMITT (2002).

In distinction, DALY represent the sum of years of life lost (YLL) due to premature death, and of years of life lived with a reduced level of health, weighted with the seriousness of the health impairment suffered (years lived with disability YLD). These years can be discounted and age weighted as follows:

$$\begin{aligned} \text{DALY} &= \Sigma \text{discount factor} * \text{age weighting} * (\text{YLL} + \text{YLD}) \quad [\text{a}] \quad (2) \\ &= \Sigma \text{discount factor} * \text{age weighting} * \\ &\quad (\text{SEYLL} + \text{disability weight} * \text{disability duration}) \end{aligned}$$

For YLL and YLD, a continuous discount factor of the form  $e^{-rt}$  can be used, where  $r$  is the discount rate and  $t$  the time difference compared to a reference point in time. Age weighting takes into account that society may attach a value to life years that varies with age. The years of life lost YLL through premature death are calculated, using standard life expectancy tables, in the form of 'standard expected years of life lost' SEYLL. In analogy to the calculation of QALY, the term YLD is calculated by weighting the disability duration with a 'disability weight'. Analogous formulae were developed by MURRAY & LOPEZ (1996:64ff) for continuous, and by ELBASHA (2000) for discrete age increments. In MURRAY & LOPEZ (1996), age weighting and discounting were in certain cases omitted.

As a first approximation, QALY and DALY may be regarded as complementary, that is to say the weighting factors DW and QW are approximately complementary (disability weight  $\approx 1 -$  quality weight). The following divergences from this must be mentioned:

- The methods for calculating disability weights vary<sup>6</sup>.
- DALY's reference are individuals living in full health up to the abrupt death after a standard duration of life, whereas with QALY, typical age-related health impairments and actual life years are considered.
- Age weighting is only performed with DALY, whereas QALY are never age weighted.

#### 4.1.2 Monetisation via willingness to pay WTP

WTP may be simply formalised as follows:

$$\text{WTP}(t) = V(\Delta Q, \Delta t) \quad [\$] \quad (3)$$

where  $V$  represents the value function of the change in the state of health  $\Delta Q$  during the time interval  $\Delta t$ . WTP thus represents the substitution rate between health and money. WTP could, for example, express a person's willingness to pay 1000\$ in order to stay in full health, instead of lying in bed with influenza for three weeks

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<sup>6</sup> The quality weights for QALY are often determined by the so-called 'time trade off' or the 'standard gamble' method, whilst the disability weights for DALY are determined from the 'person trade-off' method (see Hofstetter & Hammitt, 2001).

(see HAMMITT 2000 for further details on determining WTP in the case of a reduction in the risk of premature death).

The concept of willingness to pay WTP is embedded in the welfare economy, and therefore the resulting loss of value due to health impairment is expressed in monetary units being compatible, ideally, with money amounts of market transactions. With WTP the time factor is – however - neglected.

#### 4.1.3 Differences between HALY and WTP

The most prominent difference between HALY and WTP is clearly the unit of measurement. Whereas WTP is expressed in *monetary units* and is referred to a currency (and also to a reference year, in order to take account of inflation), HALY are expressed in *health weighted years*.

According to economic theory, it can be expected that a person's WTP for a particular good depends on his/her financial situation (income, assets, creditworthiness). Where monetisation studies ask participants to express their WTP for a particular good, it is normally assumed in practice that this WTP value stated (stated preference) is *dependent on the available yearly income* of the participant. HALY, on the other hand, take into account the seriousness of a health impairment *irrespective of the poverty or wealth* of the person. Thus for a particular case of health impairment, it can be expected that the relationship WTP/HALY is not constant among different socio-economic groups, but depends on respective material well-being of these groups.

Equations (1) and (2) show the *time dependency* of HALY. Thus a five year period of blindness produces a five times' higher amount of DALY than one year's blindness, subject to possible discounting and age dependency. This might be seen differently by those affected if, for example, they became accustomed to an chronic disease over time, and no longer considered it so disturbing, or, if they regarded short-period diseases as being of a transitional nature, and therefore less serious. WTP surveys using contingent valuation or conjoint analysis are – indeed - generally performed with healthy participants. But even an assessment by healthy persons could result in a WTP value that *does not rise in proportion to the duration of the disease*. In fact, some studies have found the WTP value to be proportional to the logarithm of the time (JOHNSON et al., 2000), or proportional to the square root of the time (MADDISON, 2000). Thus in the literature it is mostly assumed that HALY give merely an acceptable approximation for chronic health impairment, but should not be used directly in the case of acute conditions<sup>7</sup>. We shall not attempt to answer the question as to whether in reality the intrinsic health impairment rises in

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<sup>7</sup> Although it is recognised that the empirical results do not lend support to this approximation for chronic diseases, the discrepancy is nevertheless estimated to be small. The significance of this can be further reduced by regarding a single day, a single month, or several years, of lumbar complaints (for example) as separate types of disease.

proportion to, or at a lower rate than, the duration of the disease, but merely note the fact that there is a difference between HALY and WTP in this respect.

Whereas for HALY, either *no age dependency* (QALY and DALY(0,X)), or *fixed age dependency* (DALY(1,X)), of the impairment is assumed, with WTP no such static assumptions are made<sup>8</sup>. As, however, the age of respondents is mostly recorded in WTP studies, and is used as an independent variable in the regression analysis, WTP values can be characterised as *principally age dependent*. In practice, however, WTP studies are highly inconsistent with respect to the age dependency of WTP amounts stated by the participants.

The methods for the determination of disability weights or quality weights for HALY either compare the state of health to be weighted with death risk (standard gamble method), or with altered life expectancy (time trade-off method), or with an altered number of survivors (person trade-off method) (see HOFSTETTER & HAMMITT, 2001). Other methods determine disability weights for additional types of health impairment by interpolating between already existing disability weights for comparable health cases, e.g. MÜLLER-WENK (2002) for sleep disturbance and interference with communication. It is, however, typical for all HALY-oriented concepts to *normalise with respect to life years*, in other words, to add years of life lost due to premature death and life years 'partially lost' due to disease. In WTP methods, loss of life quality due to disease is not compared to the risk of death, but with the *marginal benefit of available income*. The reference for determining WTP amounts are therefore goods and services that could just about or no longer be bought when the available income alters. The determination of WTP for reduced risk of death and additional years of life is discussed in Chapter 5.4.

Within the limits of the present study, it may be stated that the difference between QALY and DALY is only slight, and that complementarity, i.e.  $DALY=1-QALY$ , is largely upheld. However, the fundamental differences described above between HALY and WTP lead to the conclusion that a generally valid conversion factor from QALY to WTP is not admissible. This is confirmed, for example, by BALA et al. (1998) who found no significant correlation between DALY and WTP for different individuals.

In consequence, it would be very difficult to identify a regression line on the basis of cases of disease with known DALY and WTP, with the intent to find a generally applicable conversion factor between DALY and WTP for all types of health impairment. Where, however, the involved types of health impairment persist equally long, and affect the various age groups in a comparable way, the methodical differences between WTP and QALY discussed here recede in importance. This justifies the procedure to be adopted in Chapter 5, where the monetary equivalent of a health impairment due to noise will be determined by extracting WTP values for other

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<sup>8</sup> In assessing mortality, an age independent WTP has often been used in the past (also see Chapter 3.2).

health impairments from existing studies, adapting these WTPs via the ratio of disability weights. The viability of this procedure has been further enhanced by selecting health impairments that are of similar severity.

Further information on the differences between HALY and WTP may be found in HAMMITT (2002).

#### **4.1.4 Maximisation of welfare and DALY**

Where the reduction in health impairment due to noise, and where environmental and health protection measures in general, are concerned, the objective is to optimise social welfare. The neo-classical approach in the economic theory is based on the premise that the social welfare function is an aggregate of individual preferences. Furthermore, it is assumed that individuals know what is best for them (consumer sovereignty), that individuals are capable of deciding rationally between alternatives (benefit maximisation), that only the *results* of actions/decisions are of consequence (consequentialism), and that the magnitude of the benefit should be used as the only decision criterion in the evaluation (welfare maximisation).

The above four hypotheses can be helpful approximations in simple and well understood situations. However, they appear to be problematic in the context of the health impairments of interest here, where the cause-and-effect paths and the decision situations are difficult to perceive for the individuals concerned. It is not surprising, therefore, that WTP studies in this field often show poor results because the above-mentioned four assumptions are incorrect for a majority of the participants.

In the original method of MURRAY & LOPEZ (1996), the disability weights needed for the calculation of DALY using the so-called person trade-off method are determined by health professionals. In this method, a typical question asked is the following: please fix a figure for  $y$  such that alternative 1 is equivalent to alternative 2, whereby alternative 1 is characterised by prolonging the life of 1000 healthy individuals by one year, whilst alternative 2 prolongs by one year the life of  $y$  individuals having a reduced state of health due to a given type of impairment  $i$ . Thus the health professionals had to decide what is optimal for others, and not what is best for themselves. Such decisions represent 'altruistic' preferences, which are criticised as inadequate by welfare economists. However, it may safely be assumed that the inconsistency between DALY and classical economics is of only theoretical significance in our case. HOFSTETTER & HAMMITT (2001) conclude that the differences between altruistic and individualistic preferences are small. The questions in connection with noise-related health impairment are fairly insensitive to short-term considerations, and further, health impairment due to noise affects a large section of the population. Moreover, MÜLLER-WENK (2002) does not use the person trade-off method (PTO), but rather an interpolation between already existing disability weights that originally had been determined with PTO.

We therefore conclude that the altruistic elements in the DALY concept criticised by economists with a strong market economy background have no practical relevance in the case presented here. In addition, the postulated principle of consumer sovereignty can only be accepted with substantial reservations, so that this argument is insufficient to exclude expert assessments by health professionals.

## 4.2 The age dependency of years of life lost

Chapter 5.4 deals with estimates for the monetary equivalent of a statistical life, respectively, of one year of life lost (= 1 DALY). In the following, therefore, the age dependency of DALYs or years of life lost will be treated in more detail.

Figure 4 below shows the results for four different approaches to the determination of the monetary or non-monetary 'value of a statistical life' (VSL) as a function of age. The two *full* lines show *non-monetary* assessments, for which the ordinate *at the right* in years of life lost YLL applies. The *broken* lines show *monetary* assessments, for which the *left-hand* ordinate in 1000\$ applies. Assuming for the time being that the value of a statistical life could be dependent on the age at the time of the premature death, the abscissa is graded in the individual's age at death.

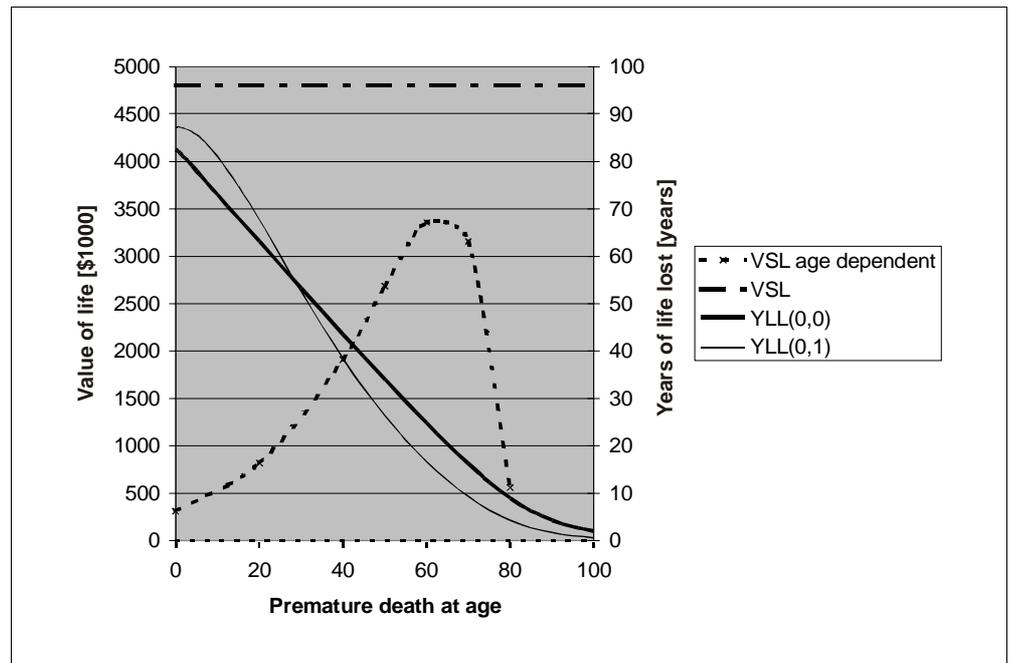
In the case of *non-monetary* assessment of years of life lost, the thicker of the two full lines shows the non-weighted number of years of life lost due to death at age X. This line is nothing other than the life expectancy curve of a reference population<sup>9</sup>. Additionally, as a variant of this, the thinner of the two full lines contains an age weighting in which the years of life in the 'productive' phase between years 15 and 60 are regarded as of greater value than those in childhood and old age. The age weighting contained in this thinner line represents exactly the type of age weighting that was performed by MURRAY & LOPEZ (1996) in the context of developing the DALY concept. One can see that this age weighting causes a relatively small change as against the thicker line without age weighting. The horizontal dashed and dotted line at the upper edge of figure 4 shows an initial case of *monetary* assessment. It represents the value of 4.8 million \$ taken from US EPA (1999) for loss of a human life, taken as independent of the statistical residual life expectancy at time of death. In distinction, the dotted line shows a monetary evaluation of years of life lost based on the consumer model (SHEPARD et al., 1984; NG, 1992), for which the \$ value of the loss of one year's life for a child and for an eighty year old is only small, whereas for a person of sixty years of age it rises to almost 3.5 million \$. The various consumer models differ mainly in the following aspects: whether money lending is possible, how high the assumed benefit discount rate is in comparison to the investment rate of interest, and whether there are surviving relatives (HAMMITT, 2000). The results of theoretical consumer models of this kind – which are admit-

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<sup>9</sup> This applies to Japanese women, which Murray & Lopez (1996) state to have the highest life expectancy in the world, and these were therefore chosen as the reference for assessing global health impairment.

tedly heavily simplified, and assume perfect markets and 'rational' players – are surprisingly similar to the small number of empirical studies based on questionnaires (JOHANNESSON et al., 1997a; CARTHY et al., 1999).

**Fig. 4:**  
Four assessment variants for years of life lost through premature death (HOFSTETTER & HAMMITT 2002).



Most of the studies in which the value of a statistical life VSL was calculated in monetary terms used the revealed preference approach (see Chapter 5.4), whereby the majority were wage risk studies. In these it is observed how much more wages employees receive at workplaces with a high risk of accident in comparison with otherwise comparable workplaces with lower risks. According to the US EPA the best estimate from such studies (including a small number of willingness to pay studies) was 4.8 million \$ at 1990 values (US EPA, 1999a). For Switzerland, BARANZINI & FERRO LUZI (2001) carried out an empirical study with two large samples of 8034 employees (Swiss Survey of Employees, 1995) and 22'888 employees (Swiss Survey of Income Structure, 1994). The resulting average amounts per life lost were 9.4 and 12.9 million CHF respectively. These were refined by including the age and the residual years of life of employees as separate variables. Table 3 shows the results of the particular analytical variant that uses the residual years of life without time discounting (columns 3 to 5). The model using age alone as independent variable is shown in columns 6 to 8. By definition, the results of the first model reflect the assumed residual years of life, that is, the three columns show the same value of 0.34 million CHF per statistical year of life lost. In the second model, however, the value of a statistical life declines more sharply than life expectancy. Without discounting, the resulting values per year of life lost are 0.38–0.23 million CHF. Thus for the data of Baranzini & Ferro Luzi, the sharp decline of the inverse U-function observable in figure 4 (dotted line) occurs here not from age

inverse U-function observable in figure 4 (dotted line) occurs here not from age 60 onwards but already before age 35.

Table 3: Wage risk study from two Swiss data sets with analytical models for age dependent values of a statistical life VSL (in million CHF at 1995 values), taking residual years of life or age as independent variables (BARANZINI & FERRO LUZI, 2001).

Age	a				20a	35a	50a
Remaining years of life	a	60a	45a	30a	60a	45a	30a
Swiss Survey of Employees, 1995	m CHF	15.46	11.59	7.73	17	10.67	4.33
Swiss Survey of Income Structure, 1994	m CHF	22.49	16.87	11.25	24.54	16.24	7.95
Weighted average of the two studies	m CHF	20.66	15.50	10.34	22.58	14.79	7.01
Per life year lost (without discounting)	m CHF/a	0.34	0.34	0.34	0.38	0.33	0.23

TELSER (2002) and TELSAR & ZWEIFEL (2002) cite a Swiss WTP study with 500 retired persons, in which the willingness to pay for hip protection to prevent fractures to the neck of the femur was determined, whereby the method of conjoint analysis was used. Table 4 gives the evaluation based on age of the respondents. This shows an age dependency with a steeper decline than that of residual years of life, that is to say that the CHF value of one year of life decreases with the age of the respondents. As the study was not directed toward this mode of evaluation, and the respondents regarded the carrying comfort of the hypothetical hip protection as the main aspect, the figures in table 4 should not be interpreted as an estimate of VSL, but simply as an indication of the age dependency of the value attributed to a year of life.

Table 4: Age dependent values for a statistical life VSL (in million CHF at 1999 inflation level) from TELSAR (2002) and the authors' calculation in years of life lost.

Age	A	70–75	76–85	86+
VSL	m CHF	2.9	0.8	0.37
Estimated residual years of life	a	13	8	4
VSL per year of life, without discounting	m CHF/a	0.22	0.10	0.09

The available data seem to imply that the monetary value of 1 DALY is principally age dependent, whereby the corresponding money amounts in childhood and in the second half of life are lower than in midlife. The consequence of this finding on the present study is as follows: It can be assumed that the age distribution of the sub-population in Switzerland living at increased levels of road traffic noise corresponds approximately to the demographic average of the whole population. It is, therefore, admissible to use age-independent population-averaged values for the monetary

equivalent of 1 life-year or DALY in the context of monetising disability adjusted life years caused by traffic noise in Switzerland. But the results are, however, not directly applicable to other health impairments occurring with particularly young or particularly old sub-populations.

### 4.3 Time discounting

The object of time discounting is to account for the fact that similar goods available today or in ten years' time are not of the same value for the interested persons. The majority of individuals prefer to have a good available immediately rather than later. The following three reasons are mostly mentioned to justify this preference for short-term availability: lack of foresight (or pure time preference), the uncertainty whether in view of the latent possibility of death the future will be experienced at all, and the decreasing marginal utility of the good. HOFSTETTER & HAMMITT (2001) show that from the point of view of social equity, these three reasons are inadequate to justify time discounting in the special field of health.

Time discounting in the health field nevertheless plays a role by virtue of the opportunity cost argument (WEINSTEIN et al., 1977; KEELER and CRETIN, 1983; GOLD et al., 1996). Applied to the field of health, this argument implies that, without discounting of health, health promoting measures would always be postponed as long as the money can be invested at a positive real rate of interest, and thus can be increased, enabling more extensive health promotion measures to be financed at a later time. Unwanted postponement of this kind cease to appear as advantageous only under the condition that future health is discounted at the marginal yield of alternative investment (WEINSTEIN et al. 1977), or if the social discount rate<sup>10</sup> is applied, as suggested by GOLD et al. (1996). Where health is concerned, HOFSTETTER & HAMMITT (2002) conclude that this social discount rate should only be applied if at the same time the value of a HALY or a VSL is treated as increasing with time.

In Chapter 5 of this study, the various approaches always determine the monetary equivalent of 1 DALY in CHF for the year 2000. Discounting for the purpose of making the results comparable is therefore not necessary. Assumptions on discounting must only be made for conversion from VSL to values of a year of life lost.

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<sup>10</sup> Whereby the real rate, i.e. the rate corrected to account for inflation in the health sector, should be used.

#### 4.4 Achievement of health improvement or toleration of health deterioration

Human beings have a tendency to take their current life as a basis of reference if they have to assess changes. In doing so, it seems that they attribute a higher value to a *non-deterioration* of their quality of life, health or current income than to an equal amount of *improvement* in these goods. Accepting this statement, the following cases of health impact due to changes in noise level may be distinguished:

- It is possible that health impairment could be reduced below the current level as a result of noise abatement measures leading to a reduction in the exposure level. People may then be asked how much value they would attribute to such an improvement in health. Alternatively, they may be asked what level of compensation they would require in order to compensate the negative value of waiving the health improvement.
- It is possible that health impairment could increase as a result of the higher sound level caused by additional traffic or emission. People may then be asked how much compensation they would require to compensate the negative value of this increased health impairment. Alternatively, they may be asked to say how much they would value an avoidance of this increasing health impairment.

If in these four cases it is attempted to express, in money units, the value accrual or the compensation for the reduction in value, one arrives at the willingness to pay WTP and the willingness to accept compensation WTA that are already presented in table 2 (Chapter 3.3). Where contingent valuation methods for the determination of the money sums are applied, this is mainly done for cells (1) and (4) in table 2. In other words, WTP studies investigate the monetary equivalent of the value of an improvement, while WTA studies investigate the monetary equivalent of compensating a deterioration.

In view of the above-mentioned tendency of human beings to place less value on improvements than on avoiding deterioration, we may expect that for comparable changes, money sums for WTA would tend to be higher than for WTP. In fact, in a review of published studies, O'BRIEN et al. (2002) find WTA/WTP ratios of 3.2 to 89.4 in the environmental field (n=7), 1.9 to 6.4 in the health field (n=2), 1.1 to 3.6 in safety studies (n=4) and 1.3 to 2.6 in other experimental studies (n=7).

In addition to this effect, the argument is put forward that since WTA questions are of an even more hypothetical nature than WTP questions, data out of WTA studies are less reliable than data out of WTP studies. This may be attributable to the fact that within WTA studies it is often unclear who should bear the costs identified, and there is often no equivalent substitute for the good to be valued. Further, WTA money sums can also be higher than WTP money sums since with the latter, the willingness to pay expressed by the respondents is usually rejected as being invalid if it appears that the amount of money mentioned is too high in comparison to the

income and assets of the respondent, whilst for WTA, this limitation does not apply<sup>11</sup>. For further causes of higher WTA sums, see MITCHELL & CARSON (1989).

In the face of the above discrepancy between monetary equivalents shown by WTP and WTA studies, O'BRIEN et al. (2002) propose the use of two limiting values for cost efficiency studies in the health field. The value of a QALY *gained* would then be e.g. \$50'000 and that of a QALY *lost* e.g. \$100'000.

In WTP and WTA studies, it is - at least at a conceptual level - clear whether the stated money sums refer to buying health improvement or accepting compensation for a health deterioration. In contrast, revealed preference methods produce money amounts on the basis of decomposing actually paid market prices into price components which can be allocated to the various properties of the traded good. In doing so, the rent differential between noisy and less noisy apartments, or the salary differential between a dangerous or a less dangerous type of job cannot be uniquely assigned to a gain or loss of health, since the regression analysis does not reveal that certain players will accept compensation for higher noise (or higher workplace risk) in the form of lower rents (or higher salaries), whilst others will spend more money on quieter accommodation, or accept lower wages in recompense for a reduction in risk. In these cases, no unique assignment to the four fields in table 2 is possible.

Because of the large differences found in the studies based on contingent valuation, Chapter 5.7 only distinguishes between the two cases 'gain of DALY' and 'loss of DALY'.

#### **4.5 Ethical aspects of contingent valuation CV as an assessment tool for environmental goods and health**

Contingent valuation (CV) as a method stems from the field of market research. By questioning a statistically relevant sample of people, the method's purpose is to determine how much money a particular good is worth to them, although the good in question is not (or not yet) available on the market. Profit-oriented companies use CV in order to establish what market participants would be prepared to pay for a certain new product with defined characteristics, assuming it were available on the market. The results of the CV are useful to the company in setting selling prices and quantities of future products.

It is a satisfactory development that since 1970 the attempt has been made to adopt the instrument of contingent valuation not solely for environmental goods such as

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<sup>11</sup> It may be argued that for environmental goods (in distinction to consumer goods) it should be irrelevant how much surplus income is available to a respondent. In this case, a WTA study might be a better option than a WTP study. However, as long as it is unclear who has to pay the compensation sum in a WTA approach, and how this sum reduces consumption alternatives, there is a danger that the sums named by respondents do not correspond to real money values, so that corresponding data are not comparable with actual transactions.

air quality, water quality, quietness and biodiversity, but also for health (which is to some extent dependent on the quality of the environmental goods) and to determine the money value attached to these by the population. In doing so, however, the method has mostly been adopted without change. In particular, it was not adjusted to account for the fact that the valuation of environmental goods and human health is quite a different kettle of fish from that of common commercial goods such as chewing gum, detergents or cars. Thus in applying contingent valuation in the context of noise exposure and health impairment, certain problems of an ethical nature arise:

- Non-consideration of protesters. Those who are of the opinion that health, quietness, health impairment or noise exposure, cannot adequately be expressed in money units, will tend to express their opposition when asked to participate in a CV study. This attitude can manifest itself in a refusal to answer questions, or in entering extreme money amounts in response to the central question of willingness to pay. Generally, expressions of opposition of this kind are regarded as 'unusable' in CV studies, and are rejected. They therefore have no influence on the final conclusions of the study. From an ethical point of view this is problematic since it means that the opinions of persons favourable to monetisation are more heavily represented than those of persons critical of monetisation.
- Limited consideration of the poor. In CV/WTP studies, the so-called 'budget restriction' must be considered. When a person states a monetary equivalent of good health or good environmental quality that is 'too high' in comparison to his/her financial means, this response is qualified as 'unusable' and is therefore excluded from the statistical evaluation. The declared *willingness* to pay for the hypothetical good is thus ignored unless it is accompanied by an actual *ability* to pay. Though this may be acceptable in market studies for a good such as chewing gum, it is ethically questionable for environmental goods and the threat to health posed by them.
- Partial exclusion of persons with reduced reasoning ability. Heavy demands are placed on the abstract reasoning faculties of persons questioned in CV studies to absorb the information on the hypothetical market presented, and to keep this information constantly in mind while answering the questions posed. When the information typically presented to the respondents of CV studies is compared to the specifications of the PISA study (PISA 2002), it is immediately clear that the majority of respondents cannot adequately absorb the information on hypothetical markets contained in usual CV studies. It is, however, normal practice in CV studies to reduce the so-called 'hypothetical bias' by identifying those respondents who have not understood the information presented by means of control questions in the questionnaire. In cases where an additional instruction of the participant is unsuccessful, the willingness to pay of this participant is eliminated on the grounds of 'unsuitability' and ignored in the statistical evaluation. Note, however, that in practice the range of 'control questions' is so limited that non-comprehension of the hypothetical market can only be detected for a few of the respondents. An ethical problem therefore remains in CV studies, in that by rejecting non-comprehending persons, the opinions of those with above average reasoning ability are given greater weight than those of other citizens.

- Consideration of the opinions of those directly affected. In CV studies, the selection of respondents is generally done in such a way that the resulting group is in large measure representative of the total population in the geographical area selected. That is to say that in general, the proportion of respondents personally affected by a health risk or environmental impact to be monetised is small, and the willingness to pay of the personally affected has only a minor influence on the resulting average willingness to pay. This is justifiable. It should, however, be noted in this connection that the need for protection of those particularly at risk (the pregnant, the old-aged, etc.) must especially be considered in laying down exposure limit values in environmental legislation (cf. Article 13.2 of the Swiss Law relating to the Protection of the Environment). Since market oriented incentives based on CV studies are sometimes proposed as a better alternative to 'rigid' exposure limit values, the ethical problem arises as to whose values should find expression in the legislation on environmental impact and health risks. The values of the whole population, as in the case of CV-based incentives, or the values of persons particularly affected, as in the use of exposure limit values?

When the procedure for determining disability weights DW under the DALY concept (MURRAY & LOPEZ, 1996; STOUTHARD et al., 1997) is examined in the light of the ethical problems posed above, it becomes obvious that this procedure does - unlike the CV methods - not involve a systematic under-weighting of the attitudes of monetisation sceptics, and of the poor, the intellectually less able and those directly affected. This is not to say that the use of contingent valuation outside of commercial market research should be wholly rejected for ethical reasons, or that HALY systems should a priori be preferred for value analyses in the health field. There can be no 'right' or 'wrong' where ethical questions are concerned. However, it must at the very least be insisted that in the publication and use of CV results, explicit mention is made of the ethically relevant, implied, value judgements. It is not acceptable that these are concealed behind a pseudo-scientific facade.

#### 4.6 Further aspects of benefit transfer

In addition to the themes discussed above, PEARCE (2000) enumerates a series of contextual factors that should be taken into account when converting the monetary equivalents of benefits or damages taken from a particular study to other temporal, spatial or material contexts ('benefit transfer'). Whether, and to what extent, these factors must be included in any particular case is discussed in Chapter 5 for each individual transfer approach. The object at this point is simply to discuss what conditions apply to benefit transfer in the context of noise-related health impairment.

##### Type and magnitude of the 'good'

It is difficult to transfer monetisation results from one type of health impairment to another type of health impairment, if the involved types and durations of the impairments are very dissimilar, and if self-determination versus external determination is at stake. The main objects of this study, interference with communication

and sleep disturbance, are chronic health impairments of relatively low intensity with no identified premature fatal consequences. The cause is external and thus not under the control of the noise-affected persons. These persons can, however, influence the situation to a certain extent by making structural modifications to their dwelling or by moving house, but such influencing measures are not available to all socio-economic groups. From the median of previous studies, Hofstetter & Norris (2003) and Rowlatt (1998) give a factor of 2 for the supervaluation of involuntary and uncontrolled events, compared with the valuation of similar but self-controlled events, whereas other authors cite factors between 10 and 100.

**Risk versus duration**

A large part of the population is continuously affected by noise-related interference with communication and sleep disturbance. These two types of health impairment are hard to compare with diseases that are contracted with low probability, like tuberculosis. Thus monetisation studies in which the value of risk reduction for low risk diseases is determined cannot be directly applied. Instead of proposing factors for the corresponding benefit transfer, we simply state here the different structures of the involved health impairments, and that this fact may be useful in explaining the differences in the monetary values found in chapter 5.

**State of health**

According to PEARCE (2000), it is unclear whether the WTP for sick persons is lower, equal to or higher than that of healthy persons. Certain studies come to the conclusion that a particular disease is regarded as less serious by those affected than by others (e.g. DE WIT et al., 2000). This is not in contradiction to the assumption that those affected would be prepared to pay more for an improvement in health if this were genuinely achievable by medical treatment. Since, however, the disability weights used in this study were estimated by professionals, and the dependency of WTP on the state of health is regarded as unclear, this aspect will not be further pursued here.

**Sex**

It is not clear whether significant differences occur in stated WTP depending on gender. In contingent valuation studies - in which women often state higher WTP than men - it is noticeable that the risk reduction is often smaller for women (see Chapter 5.2.3). In wage risk studies - in which men often state higher WTA - it is possible that the corresponding difference is caused by non-controlled factors such as part-time work. Since men and women are affected to the same extent by noise disturbance, we shall not differentiate here between the sexes.

**Third parties affected**

Various studies (see PEARCE, 2000) show that the stated willingness to pay WTP for avoiding one's own death tends to be lower than for avoiding the death of family members or friends. Indeed, where all relatives and acquaintances are included, a significantly higher altruistic WTP could result than the individualistic WTP. This aspect could be of relevance to the method by which the statistical value of life is converted to DALY (Chapter 4.4).

Recapitulating, it is evident that any transfer of monetisation results from one study to another study has to account for differences in the type of disease and its inten-

sity, as well as for the characteristics of the persons affected (age, state of health and available income), the context (increase or decrease in health, other persons affected and voluntariness), and the methods applied. As the knowledge required for benefit transfer is very limited, the transfer of monetary equivalents found in the available studies on health impairment to the noise-related health impairments of our study must be regarded as approximate. More precise monetary equivalents for these noise-related health impairments could only be obtained from primary studies.

# 5 Proposal for monetising sleep disturbance and interference with communication caused by noise in Switzerland

In the following, the problem of monetising health impairment caused by road noise in Switzerland will be tackled and evaluated in the light of the findings of Chapter 4. From these, a best estimate for monetisation will be made.

## 5.1 Calculation via the noise dependency of rents

Chapter 3.4.2 of the present study shows that under Swiss conditions, and in countries with similar conditions, the market prices for apartments (including purchase or renting of apartments or houses) correlate significantly with the continuous sound level around buildings caused by road traffic noise. The market price reduction per additional dB(A) is in the region of 0.6 to 1.2%, or roughly 1%. Although it has to be assumed that the percentage price reduction per dB(A) increases more rapidly than the sound level, a linear approximation seems justified within a limited range of continuous sound level. The practical upper limit of validity for this can be put at 75 dB(A), since, for road noise, this level is seldom exceeded (cf. MÜLLER-WENK, 2002:29). A lower limit for the validity of this range is at the point where experience shows that a further reduction in the traffic noise would not be regarded as an improvement in quality in a residential area. This point cannot lie substantially lower than 50 dB(A) during the day, the latter being the daytime planning value for zones in the highest sensitivity level I according to Swiss noise abatement legislation (Noise Abatement Ordinance Annex 3 and art. 43). A sound level of 50 dB(A) corresponds approximately to a person speaking quietly, and according to the WHO Guidelines, results in 'moderate annoyance' under outdoor conditions (BERGLUND et al 2000:45). A willingness to pay for less noise has, however, been identified down to approximately 40–45 dB(A) during the day (WEINBERGER 1991:182).

What is the reason for the empirically observed price reduction for housed and apartments subject to noise? As the building is not physically damaged by noise, the reduction in price can only be due to the noise-related deterioration in the utility value as seen by the occupants. Either the occupants themselves participate in the market transaction (signing of a tenancy agreement or purchase of a house for their own use), or the presumed views of the occupants are kept in mind by the participants in the market transaction (purchase of a house for tenant occupation).

From the building occupants' point of view, the deterioration in the utility value of a noisy apartment/house is due to the fact that they observe or fear a deterioration in their well-being. At night-time, noise can cause disturbance to sleep, whilst during the day it can lead to interference with communication and contemplation. This fact is generally appreciated. However, the other health effects of noise given in the WHO Guidelines - and as discussed at the beginning of Chapter 3.1 - are less well known. Thus there is no reason to expect that the tenant or buyer, during the negotiation of the agreement, is aware of the possibility of noise-induced heart attacks or physical disturbance, or the likelihood of reduced productivity to the detriment of his/her employer. This means that main cause of reductions in the price of noisy

apartments observed in the market arises from the impairment components A1 in table 1, in particular for sleep disturbance and interference with communication.

However, the question remains open whether the intrinsic damage due to sleep disturbance and interference with communication experienced or feared by the occupants in fact equals the price reduction for the apartment resulting from noise. This equality condition is certainly not fulfilled where the market is not operative, for example due to a lack of information, insufficient supply or state regulations. Nevertheless we shall assume here that the price reduction of approximately 1% of the selling price or rent per 1 dB(A) is approximately equal to the reduced utility value as seen by the building occupants. This assumption is supported by the circumstance described in Chapter 3.4.2, that the price reduction of about 1% per dB(A) results both from rent analyses (hedonic pricing) and from CV studies.

As data are now available on the value loss of apartments per additional dB(A) (where «additional» refers to the threshold of 45–50 dB(A)) of continuous sound level around the building, we can calculate the value loss of all apartments in Switzerland due to road traffic noise, using data on the road noise level and the absolute price level of apartments. From this we can determine how high the marginal loss of value of all apartments is when the continuous sound level over the whole road network rises by 1 micro-dB(A). This loss of value can be related to the characteristic traffic mix in vehicle kilometres during the day and during the night for road vehicles of category 1 (cars, etc.) and category 2 (lorries, etc.) in Switzerland. For this characteristic traffic mix, MÜLLER-WENK (2002) shows that the resulting health impairment can be calculated in units of DALY/a on the one hand, and that – on the second hand - the resulting marginal increase in continuous sound level can be calculated in micro-dB(A), pertaining to the whole country. By combining these two data elements, the money equivalent of 1 DALY may be calculated in CHF. Multiplying this with the disability weights for sleep disturbance and interference with communication, the equivalent in CHF of one case of sleep disturbance, or one case of interference with communication, during the year may be calculated.

In the following, the above calculation is developed in detail for the year 1995 in Switzerland:

- On the basis of the data presented graphically in MÜLLER-WENK (2002, Figure 6, p. 29), approximately 1'900'000 apartments in Switzerland are burdened with a daytime road noise of 50 dB(A) or more. On a weighted average, the noise level of these apartments is 7.5 dB(A) higher than the threshold value of 50 dB(A), below which the price of the apartment is assumed to be independent of noise. It is assumed here, for simplicity purposes, that all apartments are rented, even if in reality a certain number of them are one-family houses owned by the occupants. According to the Swiss Statistical Lexicon (STATL, 2002), the monthly rent for the whole of Switzerland excluding supplementary costs, and including all apartment sizes, was 1036 CHF, or 12'432 CHF per year in 1996. As, of course, the rent reduction due to noise is already included in this survey, the average rent before reduction for the noisy apartments would be somewhat

higher. We assume that the noisy apartments do not differ significantly from the totality of apartments with respect to their non-noise attributes. If the noisy apartments (exposed to road traffic noise during the day of at least 50 dB(A)), which represent half the total number of Swiss apartments, are approximately 7.5 dB(A) times 1% cheaper than the average for all apartments, the yearly average rent of flats *before* noise deduction is  $12'432 / 0.9625 = 12'916$  CHF. This linear rent reduction of 1% per 1 dB(A) above the 50 dB(A) threshold is based on the published monetisation studies, as mentioned before. Thus for a rent reduction per dB(A) of 1% of the yearly average rent of 12'916 CHF, and given that the 1'900'000 apartments lying above 50 dB(A) (during the daytime) have a weighted average of +7.5 dB(A) of road traffic noise, the total rent reduction in Switzerland due to road traffic noise is  $12'916 * 7.5\% * 1'900'000 = 1840$  million CHF. This sum is significantly higher than the rent reduction in 1993 of 874.4 million CHF given in NEUENSCHWANDER & SOMMER (1998: 91) for the whole of Switzerland. Note, however, that this sum depends heavily on the positioning of the threshold noise level, and since the latter allows considerable leeway for interpretation, is very uncertain.

- The vehicle kilometres driven in the categories 1 (cars, etc.) and 2 (lorries, etc.) both at night (22.00 to 6.00 hours) and during the day (6.00 to 22.00 hours) are the originators of the rent reduction calculated above. This applies irrespective of the fact that the monetisation noise studies based on rents explicitly only cover the noise level during the day. From a 'marginal' standpoint, it may be stated that the 'topmost' micro-dB(A) of road traffic noise causes a rent reduction of  $12'916 * 0.000001\% * 1'900'000 = 245.4$  CHF for the whole of Switzerland. (If the threshold for the rent reduction due to noise were increased from 50 to 55 dB(A), the same calculation would lead to a total reduction of only 136 CHF. Conversely, if the threshold were to be reduced from 50 to 43 dB(A), the amount would rise to 387 CHF).
- On the basis of Swiss Noise Abatement Ordinance Annex 3, 1000 vehicle-kilometres of the current Swiss traffic mix may approximately be divided up as follows: 835 km in vehicle category 1 during the day, 68 km in category 1 during the night, 93 km in category 2 during the day and 4 km in category 2 during the night. For this vehicle-kilometre mix, we can calculate, by multiplication with the factors given in MÜLLER-WENK (2002, Figure 5, p.27), the theoretical rise in the yearly average noise level for the whole of the Swiss road network. The result is as follows:  
Rise in noise level during the day =  $0.835 * 0.050 + 0.093 * 0.50$   
= 0.08825 micro-dB(A)  
Rise in noise level during the night =  $0.068 * 0.86 + 0.004 * 8.4$   
= 0.09208 micro-dB(A)  
Thus the increase in the yearly average noise level amounts to approximately 0.09 micro-dB(A) during the day as well as at night, and corresponds to a yearly average rent reduction of  $0.09 * 245.4$  CHF, that is to say 22.09 CHF per year.
- Based on the above vehicle-kilometre mix, the resulting health impairment can be determined in the form of interference with communication during the day and sleep disturbance at night, by multiplying the vehicle-kilometres with the

factors in (MÜLLER-WENK 2002: Figure 15). The extent of health impairment in the form of heart attacks caused by noise is negligible and can here be neglected (MÜLLER-WENK 2002:52). The total health impairment due to the 1000 vehicle-kilometres therefore amounts to

$$0.835*0.00013+0.093*0.0013+0.068*0.0027+0.004*0.026 =0.0005170 \text{ DALY}$$

- Considering that a health impairment of 0.0005170 DALY results in a rent reduction of 22.09 CHF per year, and based on the disability weights of sleep disturbance and interference with communication (MÜLLER-WENK 2002: Figure 14), the monetary equivalents of these health impairments can be determined as follows:

Table 5: Monetary equivalents of sleep disturbance and interference with communication based on rent analyses, inflation level 1996.

Type of health impairment	Calculation	Monetary equivalent in CHF
Sleep disturbance during 1 year	$0.055/0.0005170 * 22.09 \text{ CHF}$	2350
Interference with communication during 1 year	$0.033/0.0005170 * 22.09 \text{ CHF}$	1410
Monetary equivalent of 1 DALY	$1/0.0005170 * 22.09 \text{ CHF}$	42'727

This result means that the absence of noise-related sleep disturbance for one year may be valued at 2350 CHF (interference with communication at 1410 CHF), if the assumption is made that for apartments with a noise level above 50 dB(A) during the day, a rent reduction of 1% per 1 dB(A) increase in noise level corresponds precisely to the health impairment experienced or feared by the occupants in the form of sleep disturbance during the night and interference with communication during the day. These values refer to the inflation level of year 1996.

The results may be interpreted as follows:

- The above figures are based on the assumption that a price dependency resulting from noise exists for apartments having a noise level of 50 dB(A) and above, which means that 1.9 million apartments in Switzerland are affected by a reduction in price if a noise increase happens. If – on the other hand - the assumption was made that the noise dependent price existed only from a noise level of 55 dB(A) onwards (planning value for normal residential zones in Switzerland), 1.1 million apartments would still be affected, and the above calculated monetary equivalents would be reduced by half. Conversely, if the assumption was made based on the willingness to pay characteristic of WEINBERGER (1991:182), that the willingness to pay of tenants commences at a measured noise level as low as 43 dB(A) during the day, the above calculated monetary equivalents would augment by some 50%. There are, however, good reasons to regard a threshold level of 50 dB(A) during the day as the most appropriate value, while those of

55 dB(A) and 43 dB(A) during the day may be seen as the upper and lower extremes.

- The authors regard the results based on the calculation applied above as being fairly reliable. The magnitude of the price reduction per dB(A) of additional noise is quite well-founded, since it is based not only on hedonic pricing but also on contingent valuation, so that the deficiencies of the two methods become less significant. However, the use of average rents for the whole of Switzerland for the special group of apartments affected by noise cannot remain entirely unquestioned. The resulting error is, however, likely to stay within reasonable bounds, since apartments affected by noise mostly lie in central residential areas where the lower value resulting from noise is compensated by an added value due to better transport access. There are therefore no adequate grounds for the assumption that the average rent of apartments with a noise level above 50 dB(A) should be significantly lower than the average for all apartments. A matter of concern is the link from rent reductions due to noise per 1000 km road traffic mix to the number of cases and DALY values of sleep disturbance and interference with communication. The question is justified as to whether people in fact have these two kinds of health impairment in mind at the time they sign a tenancy agreement or give their answers in a CV-study. Without doubt, they do not have in mind the WHO catalogue of noise effects on health and regard noise more as an annoyance than a cause of health impairment. However, based on the totality of views expressed by the noise-affected persons, it becomes quite clear that their complaints have to be traced back to disturbance in the context of sleeping, telephoning, listening to music, conversation, concentrated thought and quiet reflection, and to nothing else. Thus subsuming these phenomena under the terms sleep disturbance and interference with communication (which are reasonably sizeable from a medical perspective), appears to be justified.
- The monetary equivalents calculated for sleep disturbance and interference with communication resulting from noise should be seen as marginal costs for incremental increases in the noise level above the current levels of year 1995. Note that noise production and noise exposure are subject to significant non-linearities. If zero traffic were taken as the starting point, the first 1000 vehicle kilometres would certainly produce noise, but no health impairment would result. As road traffic and road noise continued to increase after 1995, an additional 1000 vehicle-kilometres in later years will cause a noise level increase that is slightly lower than at year 1995 conditions. But this will hardly lead to smaller monetary equivalents per case than those calculated here for year 1995, since the health impairment tends to rise disproportionately.
- Note that the above calculations represent only the monetary equivalent of those impairment components (cf. table 1) that are felt by the noise-affected persons themselves. This is primarily the intrinsic value of the reduced well-being due to noise (loss of integrity, cell A1). Not included are the costs of possible reduced performance at the workplace as a result of sleep disturbance of employees, since performance deficits do not as a rule lead to a loss of their income, and must therefore be borne by the employer (cell E2). Further, it can be stated with respect to table 1, that noise-related rent reductions (cells F1 and F2) are in-

cluded in the monetary amounts of table 5, so that it would be incorrect to add noise-related property losses to these amounts. The remaining cells in table 1 contain relatively small amounts in the cases of sleep disturbance and interference with communication, so that they can be regarded at a first approximation as being equal to zero.

- If a monetary equivalent of 1 DALY is given in table 5, this is not to say that the monetary equivalent of any type of health impairment could be calculated by multiplying the monetary equivalent of 1 DALY with the disability weight of such health impairment. The comments of Chapter 4 on the structural differences between HALY and WTP should be kept in mind.

## **5.2 Calculation using the results of stated preference studies**

For the determination of the monetary equivalents of sleep disturbance and interference with communication resulting from road traffic noise performed here, it would be ideal if recent studies were available that treated precisely these two forms of health impairment for the area of the Swiss Confederation. As discussed in Chapter 3.4.3, the study performed by VITALE et al. 1998, in which the monetary equivalents of fatal and non-fatal heart attacks were determined as 236'000 CHF and 218'100 CHF (at 1995 values) respectively, would have been such an ideal case if we had included noise-related heart attacks into our study. Unfortunately, no monetisation studies are available for sleep disturbance and interference with communication.

As an alternative approach we try here to determine the monetary equivalents of sleep disturbance and interference with communication through a transfer based on monetary equivalents of other types of health impairment treated in published monetisation studies, even if these are less recent and cover other countries than Switzerland. The term 'transfer' signifies here that the sought-after monetary equivalent has to be converted from the available monetary equivalent based on the severity and duration of the respective health impairments, taking into account the possible socio-economic differences between the countries and the time periods involved. The best chances for a successful transfer can be expected with monetisation studies that are recent and determine - for Swiss conditions - the monetary equivalent of chronic diseases whose severity and type do not differ greatly from those of sleep disturbance and interference with communication. After discussing two particularly prominent foreign studies, attention will be directed toward recent Swiss studies.

### **5.2.1 The meta study of Pearce**

In an authoritative meta study submitted to the EU commission, PEARCE (2000) provides a comprehensive review of the current status of monetisation studies on the risks of disease and premature death in the various countries of Europe. The fundamental question posed by the EU commission is the following (PEARCE

2000:5) (quote): «The Commission wishes to know if it is valid to adopt a 'common' set of monetary values for health effects in EU-15 and Accession countries, or if there is a default value that can be varied according to geographical context. This is a question about the validity of the 'transfer method' or 'Benefits Transfer' (BT)». Pearce gave the following answer to this question (PEARCE 2000:10): «... It may be that values are transferable but.. much more information is required before meta-analyses can explain the variation in WTP across studies. ... A possible exception is some forms of morbidity where there may be adequate information for valid transfer». Thus according to Pearce, there are no generally valid monetary equivalents of the risks of premature death that could be transferred from one situation to another, whilst the position for disease risks is regarded as somewhat more favourable. As examples of monetary equivalents generally applicable in Europe, PEARCE (2000:14) cites the following intrinsic values of willingness to pay for disease avoidance:

- Hospital admission for treatment of respiratory disease 490 €
- Emergency room visit for relief from respiratory illness 253 €
- Three days spent in bed with respiratory disease 155 €
- One day with persistent cough 43 €
- One day with itchy, watering eyes 56 €
- One day of work lost due to stomach complaints 56 €

For these diseases, monetisation studies are available from various European countries. The critical comparison performed by Pearce showed only small deviations between the studies, so that their generality may be postulated for the whole of Europe. These diseases are all of low severity and of short duration, so that the question arises as to what results would emanate for a chronic disease lasting a whole year. If time-proportionality of the willingness were applicable, the case of 'three days spent in bed with respiratory disease' would lead to an approximate willingness to pay of 27'000 CHF for one year in bed with a relatively mild disease. However, there is no adequate evidence to confirm the time proportionality of willingness to pay (Pearce 2000: 17). PEARCE (2000: 16) does, however, cite (without further comment) the following equation of Maddison:

$$\ln(\text{WTP}) = 1.76 - 4.80 \cdot \ln(\text{QWB}) + 0.49 \cdot \ln(\text{DAYS})$$

This equation purports to provide generally valid WTP values in € based on the independent variables QWB (quality of well-being, ranging from 0=death to 1=full health) and DAYS (duration of disease in days). Note here the similarity of QWB and disability weight of the DALY system as measures of the intensity of disease, and the clear decrease of WTP per day for increasing disease duration. The equation of Maddison suggests that for a disease of 365 days' duration, the WTP only amounts to 11.4 times an identical disease of 3 days' duration. For the case of 'three days spent in bed with respiratory disease', this would amount to a willingness to pay of a mere 2500 CHF instead of the 27'000 CHF per year as calculated above. To circumnavigate this problem, it is certainly advisable to restrict WTP transfers to

diseases of the same duration. This implies, however, that the above WTP values of Pearce for the whole of Europe are not suitable for further use here.

### **5.2.2 Investigations of Viscusi on chronic bronchitis**

VISCUSI et al. (1991) determined the personal willingness to pay for the reduction in the probability of occurrence of chronic bronchitis lasting for a lifetime based on interrogation (stated preference). Somewhat prior to 1990, a survey was performed at a crossroad in a shopping mall of a US city whose population structure was regarded as representative of USA conditions, in which 389 passers-by agreed to sit at a computer, imbibe the information provided and answer questions, based on an interactive computer program. The respondents were asked to imagine that they could choose their place of residence either in area A or area B, which differed in their probabilities of contracting chronic bronchitis as well as in cost of living. They then had to state which area they preferred, whereupon the computer altered step by step the presented difference between the costs of living at A and B until the test persons indicated equivalence of the increase in living costs and reduction in the risk of contracting bronchitis. Complementary to this balancing between disease risk and money, the test persons were asked to compare the risk of bronchitis and the risk of a fatal car accident, since results obtained earlier by Viscusi had convinced him that the respondents found it easier to compare two health risks than to compare a health risk and a money amount, as usually required in CV studies. Viscusi's publication shows that about one-quarter of the 389 respondents gave answers from which it was explicitly evident that they had not understood the problem or simply did not take the exercise seriously. This gives rise to the suspicion that non-comprehenders and game players may also have been present among the remaining three-quarters of the participants, but were not detected because their answers were not crazy enough. Although the method chosen by Viscusi - to have the test persons interviewed by a computer rather than by a person - has the advantage to avoid undesired influence of the questioner on the respondents, the former has, however, no opportunity to motivate respondents to participate seriously in the survey, nor to effectively exclude unsuitable test persons.

There are two significant points to be mentioned in connection with the Viscusi study. Firstly, the monetary equivalent (based on median values of the responses) of avoidance of a fatal car accident is about three times higher than for avoidance of contracting lifelong chronic bronchitis, whereby it is interesting that 20% of the participants expressed the view that death by accident is less serious than contracting chronic bronchitis. This shows the extreme discrepancies of the responses obtained. Secondly, for the lifelong avoidance of chronic bronchitis the respondents stated to be ready to pay 457'000 \$ (median). To put this in simpler terms, one-thousand persons positioned exactly at the median would have accepted additional costs of 457 \$ during a year for living in a particular residential area to avoid lifelong chronic bronchitis with a probability of occurrence of 1/1000 during this year. However, this \$ amount depends heavily on the method of calculation. The content of 'lifelong chronic bronchitis' must be seen against the background of the average

age of the respondents of 33 years, whose remaining life expectancy amount to 40 years according to the death statistics. If the 457'000 \$ are divided by the 40 years of bronchitis to be expected, a monetary equivalent of some 10'000 \$ (at 1990 values) results for the avoidance of one year of chronic bronchitis.

The central point here is VISCUSI'S shift from 'money-risk trade off' to 'risk-risk trade off'. Viscusi asks respondents to weigh up the differences between two risks, starting from the presumption that the first of these, namely the prospect of death in a car accident, is familiar to Americans from their everyday lives. This case is therefore considered suitable as a basis of reference for other health impairments. Criticising the 'money-risk trade off' in the usual CV studies to be unsatisfactory, Viscusi arrived at this solution. His criticism of the method of contingent valuation is particularly clear in VISCUSI (1995: 172–174). According to VISCUSI, the method of weighing up health risks against money used in the usual CV studies does not provide reliable results for the following reasons:

- Money and health risk are two incommensurable items and difficult for the respondents to ponder. Due to the high level of insurance in the health sector, the respondents are not familiar with the relationship between money and disease avoidance.
- Respondents are not able to appreciate the significance of the low probabilities presented to them, and the subsequent numerical processing of the answers leads to massive distortion of WTP values. The money amounts thus obtained do not reflect the value the respondents attached to avoidance of a particular disease, but rather the probabilities quoted in the questionnaire that were not taken into consideration by the respondents.
- The use of money units as a measure of health is regarded by some people as morally injurious.

The criticism voiced by this author is noteworthy, since by virtue of his participation in a large number of CV studies, he disposes of very extensive experience in the field (cf. VISCUSI, 1993).

### **5.2.3 Recent Swiss monetisation studies of chronic diseases**

Notwithstanding the criticisms put forward by Viscusi, and which are shared in large measure by us, a number of recent CV studies on chronic diseases under Swiss conditions will be picked out from among the large number of existing studies.

Three methodically identical CV studies performed at the University of Neuchâtel are of particular interest in the present context, since they: (a) concern Switzerland; (b) were performed recently, and (c) were explicitly conceived for including the intrinsic value of health (field A1 in table 1) only (PRIEZ & JEANRENAUD, 1999; JEANRENAUD & PRIEZ, 2001; VITALE et al., 1998). The concluding publication (VITALE et al., 1998) presents the results of all three studies and was mentioned earlier in Chapter 3.4.3.

In all of the studies, the participants were asked to express their willingness to pay for a hypothetical inoculation having the effect of reducing by 95% the likelihood of the respondent to contract a given disease during one year following the treatment. The diseases were explained to the (healthy) respondents in brief on an A4 sheet, and statistical information was presented on how many persons per 100'000 inhabitants and year currently contract the disease. The increased likelihood of smokers contracting the diseases was also given. This work was commissioned by the Federal Office of Public Health. Table 6 shows key data from these studies.

Table 6: Intrinsic costs of 1 DALY based on three Swiss CV studies, inflation level of year 1998.

Disease	Chronic bronchitis	Fatal heart attack	Lung cancer
Source	PRIEZ & JEANRENAUD 1999	VITALE et al. 1998	JEANRENAUD & PRIEZ 2001
Disease characteristics	Difficulty in breathing, daily coughing, phlegm and pus discharge, loss of weight and general debility for at least 3 months per year. More frequent occurrence over age 45a. Duration: 24a for women, 20a for men	Immediate death or death within a few hours due to heart attack (ischaemic heart disease due to acute myocardial infarction). Age of incidence above 40	Pain, fatigue, loss of weight, coughing (blood), depression, typical age of incidence above 40, survival time 1–3 years (average 1.5 years)
DALY per case	6.82	10	16.1
Method of calculating DALY used here	Disability weight = 0.31 from de HOLLANDER et al. (1999) multiplied by 22 years duration.	Approximately 10 years of life are lost according to MÜLLER-WENK (2002).	Acc. to HOFSTETTER (1998:255), of which 15.8 applied to YLL
Number of questionnaires utilised	508 (from among 757 valid of total 858 interviews)	475 (from among 757 valid out of total 858 interviews)	541 (from among 757 valid out of total 858 interviews).
Median MWTP per case (at 1998 values in CHF)	13'000		208'700–317'700
Mean MWTP per case (at 1998 values in CHF)	38'500	236'000	512'500–600'000
Median CHF per DALY as of 1998	1900		13'000–19'700
Mean CHF per DALY as of 1998	5600	23'600	31'800–37'300

From this, it is interesting to note that respondents attached considerably more value to one year's protection from contracting lung cancer than to one year's protection from fatal heart attack. Thus they fear sudden death less than inescapable 'slow' death. Further, it is plausible that respondents found one year's protection against contracting chronic bronchitis (that would then last 20–24 years) to be considerably less valuable (CHF 38'500) than the protection against the two other diseases. However, the lower valuation of chronic bronchitis in comparison to lung cancer is by no means proportional to the subjective assessment of the 'seriousness' of these

two diseases which was separately indicated by the respondents (VITALE et al. 1998, Tab. 5.14).

The bottom row of table 6 shows figures for CHF per 1 DALY which differ significantly between the three studies. In contrast to this, it would - in principle - be expected that this ratio is more or less constant (under the reservation, however, of the methodical differences between WTP and DALY mentioned in Chapter 4.1).

The WTP values determined in the three studies must be treated with considerable caution, since the respondents probably have been overtaxed by the questions posed. The following reasons can be advanced for this:

- The questions were probably felt to be unrealistic by the respondents, since preventive inoculations are only available for infectious diseases, and since - in reality - the cost of inoculations is generally known to be low and far away from the intrinsic value of the avoided disease. It was also a demanding task for the (healthy) respondents to understand the descriptions of the diseases presented.
- The very small risk of occurrence, that is to say the statistical risk of contracting a disease (of the order of 100 new cases per year per 100'000 persons), the reduction of 95% in this risk by virtue of the inoculation, and the various time intervals involved (period of effectiveness of the inoculation of one year, differing durations of diseases and of years of life lost) may well have been too complex to be understood by the majority of respondents.

The respondents' inadequate perception of the very small risk can be tested by analysing the dependency of WTP on risk reduction for the cases of table 6.

The hypothesis that the respondents did not absorb and take into account the risk reduction data, can be corroborated, if we divide by the disease's severity the CHF amount mentioned by the respondents as adequate counter-value for the inoculation, and if the result of this division turns out to be roughly constant for all diseases, and not proportional to the disease-specific risk reductions.

The figures in table 7 confirm that the respondents probably did not comprehend the risk problem. The third row from the top gives the risk reduction effected by the inoculation, as communicated to the respondents: the inoculation is expected to save 47 out of 100'000 persons from the outbreak of lung cancer, whilst the corresponding risk reduction is roughly six times higher in the case of bronchitis. The second last row 'inoculation value' shows the average price in CHF the respondents declared to be ready to pay for the inoculation. This 'inoculation value' can be calculated backwards from the WTP shown in row 4, by multiplying this WTP with the risk reduction of row 3 (this being the reversal of the operation that was made in the monetisation studies in order to obtain the WTP figure, starting from the respondents' answers). The severity of the disease is characterized by the DALY figure in the third last row. On the bottom row of table 7, the 'inoculation value' for each disease is divided by the DALY figure of row 5. One sees that the three figures in the bottom row are approximately of equal magnitude, and not propor-

tional to the risk reductions of row 3. This supports the suspicion that the respondents omitted to take into account that an inoculation against lung cancer offers only a low reduction in risk, whereas for heart attacks it is medium, and for bronchitis large.

Table 7: Comparison of characteristic values given in VITALE et al. (1998) and in table 6.

	Lung cancer	Bronchitis	Heart attack
Risk reduction for men	0.000078	0.000256	0.000085
Risk reduction for women	0.000016	0.000190	0.000056
Risk reduction averaged	0.000047	0.000223	0.0000705
Mean WTP (table 6)	512500	38500	236000
DALY (table 6)	16.1	6.82	10.0
'Inoculation value'	24.09	8.59	16.64
Inoculation value per DALY	1.50	1.26	1.66

In view of the fact that in WTP studies, the monetary equivalent of WTP for the non-contraction of a disease is calculated according to the equation:

$$\text{WTP} = \text{willingness to pay stated by respondents} / \text{risk reduction achievable,}$$

the calculated amount for WTP will increase greatly if the risk reduction is very small. Thus if the willingness to pay for the inoculation stated by respondents, divided by the seriousness of the disease, is about equal for different diseases (as is the case on the bottom row of table 7), the calculated WTP for non-contraction of the disease becomes approximately inversely proportional to the risk reduction. Note, however, that the risk reduction value is an arbitrary assumption made in the context of the contingent valuation test method, and should have no effect whatsoever on the WTP for non-contraction of the disease.

The above mentioned effect is well documented in the scientific literature and is known as 'insensitivity to scope', i.e. the answers recorded do not take into account the value of risk reduction (see for example MITCHELL & CARSON 1989, and VISCUSI 1995:174, as mentioned above). Thus the persons interviewed, whilst they unquestionably take the seriousness of the various diseases into account, do not consider the differing and very low probabilities of occurrence. The various attempts that have been made to improve the communication of probabilities to respondents in CV studies, for example in the form of graphics, promise more satisfactory results, but they cannot eliminate the effect (HAMMITT, 2000b).

Owing to these problems in connection with hypothetical questions in CV studies, the results of the three studies shown in table 6, and discussed in Chapter 5.7,

cannot be regarded as being among the best estimates. Despite this, and for reasons of completeness, we have included in table 16 the monetary equivalents of sleep disturbance and interference with communication that arise from the benefit transfer for bronchitis (mean 5600 CHF per DALY according to table 6) and for lung cancer (mean 37'300 CHF per DALY according to table 6).

We will now mention another recent Swiss CV study carried out by SCHWAB & SOGUEL (1995) in which the intrinsic costs of health impairment from road accidents were determined. The method used is the same as in the studies by Jeanrenaud, Priez and Vitale, whereby the critical comments made above also apply to this work. This study is of particular significance, since the intrinsic costs of death and injury due to road accidents determined in it are included in the external costs of road traffic published periodically by the Swiss Federal Office for Land Development, and therefore are susceptible to be summed up with noise-related health costs in order to calculate the total health cost of road traffic.

As part of the Schwab & Soguel study, a pre-test was performed in 1994. A representative sample of 500 persons of both sexes with stratified age distribution and social group, residing in the cantons of Neuchâtel, Fribourg and Jura, were questioned by interviewers concerning their willingness to pay for a hypothetical facility that would reduce by 50% their risk of becoming the victim (or alternatively a *relative* of a victim) of a traffic accident. The respondents were presented with six categories of health consequences of the accident:

DEC	sudden death
PER	persisting brain damage following hospital treatment lasting many weeks
PAR	lifelong moderate invalidity following hospital treatment lasting many weeks
LEG	lifelong slight invalidity following hospital treatment lasting many weeks
NSE	after a short stay in hospital, health impairment lasting one year and then disappearing
NHO	slight impairment for a few weeks, without hospital stay.

Apart from brain damage, no other types of injury were explicitly mentioned, and the consequences of the accident were described to the respondents non-specifically in the form given above. The statistical risk of these accident consequences was stated in the form of annual probability of occurrence in the canton of residence of the respondents. The willingness to pay had to be stated either from the perspective of the victim or that of a victim's relative, whereby each respondent was asked to state his/her willingness to pay for avoiding two of the six accident consequences mentioned above, and to provide the relative weighting of all six accident consequences by arranging these on a scale (visual analogue scale). The limitation to two questions on willingness to pay was made in order to avoid excessive strain on the respondents.

Table 8 shows the monetary equivalents for the intrinsic value of avoidance of the above-mentioned six accident consequences, based on a statistical analysis (median values in CHF for 1994).

Table 8: Median values of WTP in CHF (inflation level 1994) for the avoidance of accident consequences (SCHWAB & SOGUEL 1995: 99).

Type of accident consequence	DEC	PER	PAR	LEG	NSE	NHO
Value in CHF as seen by the victim	1'696'790	1'732'092	1'044'938	316'756	117'878	6'788
Value in CHF as seen by relatives of victim	2'047'274	2'089'185	1'273'773	397'367	152'382	11'239

It is an exceptional feature of the Schwab & Soguel study that the loss of life and health is evaluated not only from the customary perspective of the victim, but also from that of the victim's relatives. In analogy to the studies treated above, we focus our attention on the victim's perspective, whereby we give priority to the non-fatal accident consequences. Considering that the average age of the respondents was 43 years (SCHWAB & SOGUEL 1995:101), the residual life expectancy in the cases of the lifelong impairments PER, PAR and LEG was approximately 35 years, while the duration of the impairment NSE was 1 year. When dividing the CHF amounts of table 8 by these durations, it is immediately apparent that the WTP value per year of persistent impairment is extremely high in the case of NSE, in comparison to the impairments resulting from PER, PAR and LEG, the latter ones having been described to the respondents as more serious and persisting over a lifetime, that is to say approximately 35 years. We therefore suspect that in stating their willingness to pay, respondents placed insufficient weight on the duration of the impairment. On the additional question of the relative severity of impairments, respondents namely stated the following (median) values: 95 (DEC), 100 (PER), 85 (PAR), 60 (LEG), 40 (NSE), and 15 (NHO) (SCHWAB & SOGUEL 1995:78). If we now consider that non-occurrence of the small impairment NSE (severity weight 40), lasting not more than one year, was purportedly worth 117'000 CHF to the respondents, it is not plausible that respondents with an average age of 43 years should place a value of 'only' 316'000 CHF on non-occurrence of the more severe impairment LEG (severity weight 60), which is one-and-a-half times more severe and has an expected duration of 35 years. We conclude here that the respondents were clearly overburdened, when they were asked to state their willingness to pay in question 7 of the questionnaire, having to bear in mind the severity and duration of the health impairments as well as seven further important criteria presented by the interviewer. This was undoubtedly too much for the respondents (cf. Schwab & Soguel 1995:152/153). Although the study was performed with commendable care and professional competency, the results nevertheless suffer from the fundamental problem characterising all CV studies, namely that they demand an ability to conceive a hypothetical market that exceeds the reasoning power of the majority of citizens. This limitation cannot be resolved by further expanding the explanations and remarks by the interviewer.

Due to the problem of hypothetical questions in CV studies, the results of Schwab & Christe will not be counted among the best estimates in chapter 5.7. It is nonetheless worthy of note that the slight impairment NSE lasting one year implies a monetary equivalent per DALY of 40/95 times 117'878 CHF, or approximately 50'000 CHF per DALY, if the values for the relative severity of DEC (95) and NSE (40) determined by Schwab & Christe are used to approximate the disability weight of NSE. This amount of 50'000 CHF is very close to the 42'727 CHF per DALY obtained from the analysis of apartment rents (see table 5). Such comparisons will have to be made also for the other accident consequences, if the accident costs calculated according to Schwab & Christe are added to the noise costs obtained from apartment rent analyses, in order to determine the external costs of road traffic in Switzerland.

### 5.3 Calculation via limit values from medical practice

As mentioned in Chapter 2.3, cost efficiency of therapies and drugs in heavily regimented health systems is calculated in money units per QALY, and then compared to limit values which are considered to be just acceptable to society.

In Canada, there is a tendency to regard drugs and therapies costing less than Can\$ 50'000/QALY as inexpensive, those in the range Can\$ 50'000–100'000/QALY as acceptable, those in the range Can\$ 100'000–150'000/QALY as expensive, but acceptable in certain cases, and those over Can\$ 150'000 as unacceptably expensive. It should, however, be noted that these thresholds are not officially published. HAMMITT (2000) states that treatments and medicines not exceeding USD 50'000–100'000/QALY are regarded in many parts of the USA as cost effective and therefore suitable for application. In the international literature, USD 50'000/QALY is often cited as an acceptable limit value for treatment. In England and Ireland, these values have been converted to local currency and adjusted for inflation<sup>12</sup>. AZIMI & WELCH (1998) identified 65 papers published between 1990 and 1996 that investigated medical interventions for cost effectiveness, and they expressed the corresponding costs in the form of costs per QALY or life year. Those studies which had recommended the studied medical interventions from a economic viewpoint, quoted values of between USD 400 and USD 166'000 per QALY. However, all but one studies with costs above USD 61'500/QALY indicated that they had been sponsored by industry. Papers not recommending an intervention on the grounds of inadequate cost effectiveness cited costs of between USD 61'500 and USD 11'600'000/ QALY or life year.

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<sup>12</sup> «If the cost is over £36'000 per QALY, the Health Departments [in UK] will not withdraw the drug, but the manufacturers will have to adjust their price to ensure the cost remains below the threshold.» ([www.smj.org.uk/0202/beta\\_interferon.htm](http://www.smj.org.uk/0202/beta_interferon.htm)) and «A therapeutic intervention with an ICER (the incremental cost effectiveness ratio) less than \$50'000/QALY is frequently considered cost effective [in Ireland]... The cost effectiveness threshold for the National Institute of Clinical Excellence (NICE) in the UK is estimated in the region of ST£32'000.» ([http://www.imj.ie/news\\_detail.php?nNewsId=2368&nVolId=92](http://www.imj.ie/news_detail.php?nNewsId=2368&nVolId=92))

No comparable rules of thumb are available in Switzerland for determining the economic acceptability of therapies. F. Gurtner of the Federal Social Insurance Office stated in a written reply that in Switzerland there are no absolute requirements on the economic efficiency of therapies, but only relative requirements. This implies that where inexpensive therapies are not available, more expensive (and sometimes *very* expensive) therapies, costing much more than CHF 50'000 per QALY, must be borne by the social insurance system. GURTNER & ZÜLLIG (2001) give three reasons for this:

1. a cost limit per QALY disadvantages the old-aged and is problematical due to deficiencies in determining the quality weights;
2. a cost limit in the case of social insurance would actually lead to an undesired two-tier medical system;
3. due to the decentralised organisation of the Swiss health system, cost limits of this kind would presumably not lead to greater justice in the health service.

In distinction, NORDMANN et al. (2000) – a team of Swiss medical scientists – cite the range USD 61'500 to 166'000/QALY or life year based on AZIMI & WELCH (1998) as economic limit values. As these values have not been subjected to public debate<sup>13</sup>, but were derived from scientific studies, they seem to us insufficiently well-founded to be used as Swiss limiting values.

If, due to the lack of Swiss limit values, the Anglo-American values were to be applied to Switzerland (this is problematical because of cultural differences), this would mean that therapies costing less than CHF 75'000 to CHF 150'000 per QALY would be regarded as cost effective (HAMMITT, 2000). Table 9 shows the corresponding monetary equivalents for health improvements in the noise sector under the assumption that a QALY lost corresponds precisely to 1 DALY.

Table 9: Limiting cost values from Anglo-American regions applied to health impairment caused by noise according to HAMMITT (2000). Inflation adjusted to 2000.

Endpoint	Calculation	Monetary equivalent in CHF
1 DALY	Approximately set to 1 QALY	75'000–150'000
Sleep disturbance for 1 year	0.055 * 1 DALY	4125–8250
Interference with communication for 1 year	0.033 * 1 DALY	2475–4950

One should bear in mind that these limit values for costs apply to medical therapies and therefore for an *improvement* of health. On the basis of chapter 4.4, it can be assumed that financial compensation in return for accepting a *deterioration* in the state of health would be higher.

<sup>13</sup> In the view of F. GURTNER, Federal Social Insurance Office, it is conceivable that publifora, i.e. fora of randomly selected citizens, could perform these evaluation procedures.

As the method of determining the limit value for costs cited above is by no means transparent, it cannot be excluded that these contain both the intrinsic value of improved health (field A1 in table 1) and the regained performance in the employment sector, attributable to the therapy (fields E1 and E2). In fact, public debates on the socially acceptable costs of therapy tend to include not only the intrinsic value of the improved state of health attributable to the therapy, but also take into account that a person who is healed can take up employment again, so that invalidity or dependents' pensions would no longer need to be paid. It therefore appears necessary to adjust the values in table 9 to exclude components outside of field A1. If the rough assumption is made that in half the cases the therapy leads to renewed employment, and that an average annual income of CHF 60'000 (inflation adjusted to 2000) were then be achieved, this would amount to CHF 30'000 per QALY, or 20–40% of the sum in table 9.

If now the value for 1 DALY in table 9 is reduced by the regained work performance in the employment sector, a reduced monetary equivalent of CHF 45'000 to CHF 120'000 per QALY remains for the intrinsic value of the improved health (see table 10).

Table 10: First approximation of WTP values for the elimination of health impairment due to noise derived from limiting cost values in Anglo-American regions. The monetary equivalent refers to the intrinsic value of health. Inflation adjusted to 2000.

Endpoint	Calculation	Monetary equivalent in CHF
1 DALY	Approximately set to 1 QALY	45'000–120'000
Sleep disturbance for 1 year	0.055 * 1 DALY	2475–6600
Interference with communication for 1 year	0.033 * 1 DALY	1485–3960

If the values in table 10 are to be utilised, the following points must be considered:

- The values were transferred directly from Anglo-American conditions and represent only an implicit social consensus. In Switzerland, there are no limit values for costs for medical therapies (at least from the viewpoint of the Swiss Federal Office of Public Health), and the direct transfer of Anglo-American values is questionable.
- The correction made for the additional health impairment components presumably contained in the Anglo-American limit values for costs is very rough.

## 5.4 Calculation via value of a statistical life

As indicated in Chapter 4, it is possible to derive the value of a statistical year of life from the value of a statistical life, VSL. In the following, we shall take a closer

look at the determination of VSL values, and bring together certain results and problems connected with VSL.

Most of the studies for the determination of VSL values adopt econometric methods to determine the relationship between income earned and workplace risks borne, isolated from all other variables affecting income (wage risk studies). Other studies are based on buying patterns in purchasing cars (MOUNT et al., 2000) or buying safety devices such as airbags, in which an assessment is made of how much money the reduced risk of accident is worth to the buyers. In other words, the attempt is made in these studies to derive the value of a change in risk based on the real market behaviour of employees and consumers (hedonic pricing). The obvious advantage of these methods is in avoiding the hypothetical questions that occur with CV methods as described above in sufficient detail. On the other hand, the methods of hedonic pricing are based on somewhat risky assumptions: firstly, market participants are assumed not only to know, but also to understand, the mortality risks of the alternative decisions they are being asked to take; secondly, variables that correlate highly with the risk of mortality, such as the risk of injury, are treated as if they were negligible; and thirdly, those players who accept higher risks neither have an above-average tendency to take risks, nor are they more talented than the average, which would make them less vulnerable to risk<sup>14</sup>. The values resulting from the studies therefore often only apply to a subset of the population, e.g. wage earners, car buyers, etc., and are difficult to apply to other groups.

Wage risk studies analyse workplace risks, income level and other variables characterising the workplace and the employees. This can be illustrated by a simplified example as follows: 1000 employees with a risk of fatality due to work of 1 per thousand per year each receive an income of CHF 70'000 per year for work A. Another group of 1000 employees earn yearly incomes of only CHF 60'000 for work B, which apart from the risk of fatality is the same as work A. The fatality risk for work B is lower, namely 0 per thousand. Thus the 1000 employees doing job A each receive a risk premium via income of CHF 10'000 per year, or a total of 10 million CHF. Since the difference in the risks of the two jobs amounts to 1 per thousand, this leads to one fatal accident per year in the group doing job A, against zero fatal accidents in the group doing job B. Thus the risk premium of 10 million CHF corresponds exactly to one premature death. In order to express the fact that one case of premature death results from 1000 individual fatality risks of 1 per thousand per year each, the term 'value of a *statistical* life' is used, in our example amounting to 10 million CHF.

Since in industrial countries, and even more so in countries with an extensive service sector, total workplace risks have been reduced, and the differences in the risks of comparable work have become small. Consequently, small risk increments to

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<sup>14</sup> This is known as the healthy worker effect. Whilst employees prone to disease (and in this case to accidents) quit the high risk jobs, but still contribute to the risks recorded in the statistics, healthy and 'talented' employees remain in the job and have a decisive effect on income levels.

income lead to high values of statistical life. Since: (a) employees are often not aware of the risks involved in their work; (b) other hardships associated with the work are not always assessable, and (c) employment is by no means a free market (due, for example, to the trade unions, unemployment, administrative costs that must be borne by employees changing jobs, moving house, etc.), wage risk calculations are subject to large uncertainty.

Most studies do not determine the value of a statistical life VSL directly, but rather the value of a change in mortality risk. As shown in table 11, the VSL values brought together in meta-analysis lie astonishingly close and are mostly within one order of magnitude of one-another. Notwithstanding this, if all of the analysed market transactions as well as the costs resulting from legislative provisions were taken into account, the range would vary between <0.0 USD to over 20 billion USD per year of life (TENGS et al., 1995).

Table 11: Breakdown of meta studies.

Meta studies	Type	VSL	Reference year
Van den BERGH et al. 1997	10 USA and 1 UK wage risk studies	USD 3.86 million (best estimate)	
DESVOUSGES et al. 1998	28 wage risk and 1 CV study, all USA	USD 3.6 million (0.4–6.8 USD million)	
DAY, 1999	16 wage risk studies (10 USA, 2 Canada, 4 UK)	USD 5.63 million (best estimate)	
US EPA, 1999	21 wage risk and 5 CV studies	USD 4.8 million (1.56–8.04 million = ± 1 SD)	1990 USD
EXTERNE, 1999		USD 3.031 million	1990 USD
MILLER, 1990	34 safety market, 3 CV and 2 other markets, all USA	USD 3.472 million	1995 USD
Author's calculations based on MILLER, 2000	3 European wage risk studies	USD 3.226 million	1995 USD
Author's calculations based on MILLER, 2000	11 European CV studies	USD 3.490 million	1995 USD
PEARCE & HOWARTH, 2000	WTA (wage risk)	USA: £ 2.9–4.6 million UK: £ 2.4–2.9 million	£1997
PEARCE & HOWARTH, 2000	WTP (CV, CRM)	USA: £ 1.2–2.2 million UK: £ 3.3–5.3 million	£1997
PEARCE & HOWARTH, 2000	WTP (market)	USA: £ 0.9–1.0 UK: £ 0.5–2.8	£1997

A generous interpretation of table 11 shows that the differences both between studies performed in the USA and Europe, and between wage risk and contingent valuation, are small. A more detailed enquiry shows that in those studies that included PEARCE & HOWARTH's (2000) results, the ratios of CV/wage risk for studies performed in the UK are greater than one, whereas for studies performed in the USA they lie below one. In our own calculations based on the European studies

referenced in (MILLER 2000), the CV-based values are slightly higher than the wage-risk-based values. This result, however, would appear to arise from the particular choice of studies: Had the Swiss study performed by BARANZINI & FERRO LUZI (2001) mentioned in Chapter 4.2 been included, this result would have been reversed.

In the absence of a detailed analysis of all of the primary studies, we conclude from table 11 that a robust average value for a VSL is in the region of 4 million USD at 1990 values, corresponding to 5.27 million USD at 2000 values or 8.9 million CHF inflation adjusted to 2000. The question arises in this connection as to whether this VSL could contain not only the intrinsic value of healthy years of life (field A1 in table 1) but also other health impairment components, such as the lost income E1 resulting from premature death. We think that at least in the case of wage risk studies, prevailing in table 11, loss of employment due to premature death is unlikely to have had an effect on income level, since in the countries concerned, income compensation payments following premature death due to employment are the norm. If it is indeed the case that the augmented risk of death in particular professional activities is expressed in the relative income level, the only cause making sense in this connection is the aversion of employees to premature death, and not the transition from earned income to dependents' pensions as a consequence of such a premature death.

It is not, however, the monetary equivalent of a statistical life VSL that is of interest here, but the monetary equivalent of a (statistical) Value of a Life Year (VOLY). If one wanted to find out in a dependable way from the studies given in table 11, what value the market or survey participants would attach to one future year of life gained or lost, additional information would be required on the age of the participants, whether they were aware of their life expectancy at the time of the market transaction or survey, and whether they weighted the value of their future life years equal to, higher than, or lower than the value of the life year immediately before them.

The available studies do not permit final conclusions in this respect, as Pearce noted as well (PEARCE 2000:29). In this somewhat unsatisfactory situation, we shall make the rough assumption that the VSL values in table 11 apply to an average residual life expectancy of 40 years. In the case of wage risk studies, this is an acceptable average value for developed countries, whilst for buyers of risk reducing goods, the average residual life expectancy would be expected to be lower. Furthermore, we shall assume that respondents quote the intrinsic value of future healthy life years equal to, or slightly lower than, the intrinsic value of the healthy life year immediately ahead of them. Following PEARCE (2000), the necessary discounting of future life years may be done in two ways: (1) discount rate 0%, e.g. value of future life years the same as today, and (2) 1% discounting of future years. Based on the estimated VSL of 8.9 million CHF given above, and a residual life expectancy of 40 years, this results in a statistical monetary equivalent per VOLY of 222'500 CHF in 2000 at a discount rate of 0%, and of 271'000 CHF in 2000 at a discount rate of 1%.

At a discount rate of 0%, the 8.9 million CHF are simply divided by the 40 years of life lost, whereas at a discount rate of 1%, the result in CHF per VOLY is somewhat higher, since the lost years of life lying in the distant future are first discounted before being placed in the denominator. The remaining values in table 12 are derived from the VOLY monetary equivalents.

Table 12: Monetary equivalent of noise-related health impairments, derived from a statistical year of life (VOLY), without age weighting, with a discount rate of 0% (lower CHF value) or 1% (upper CHF value). Inflation adjusted to 2000.

Endpoint	Calculation	Monetary equivalent in CHF
1 DALY	Approximately set to 1 VOLY	222'500–271'000
Sleep disturbance for 1 year	$0.055 * 1 \text{ DALY}$	12'200–14'900
Interference with communication for 1 year	$0.033 * 1 \text{ DALY}$	7300–8900

The introduction of age weighting, for instance according to JONES-LEE et al. (1999), would not affect this calculation, since there, for 40 year-olds, the age weighting is set to unity.

The discount rates used in table 12 for discounting future years of life do not represent the lower and upper bounds in actual cases. Certain authors use higher discount rates (e.g. 3%), so that for a given VSL, the value of a present-day VOLY is significantly higher. HUBBELL (2002), for example, figures out 284'000 USD per VOLY of 1999 (= 496'000 CHF in 2000), starting from a VSL of 6.1 million USD of 1999. MARKANDYA (1998) starts from a VSL of 4 million USD and calculates VOLY for discount rates of 3% and 11% corresponding to some 200'000 USD and 415'000 USD respectively. EC (1999) starts from a VSL of 2.2 million EURO in 1990, and uses a median discount rate of 4%, resulting in a VOLY of 110'000 € in 1990. With respect to the lower bound of the discount rate, note that discount rates below 0% are also conceivable.

To assess their applicability to Swiss conditions, the results in table 12 based on VSL values taken from the international literature given in table 11 will now be compared to the results of recent Swiss studies. The risk study on Swiss employees (BARANZINI & FERRO LUZI, 2001) mentioned in Chapter 4.2 calculates the monetary equivalent of 1 VOLY for 40 year-olds at a discount rate of 0% to be about 300'000 CHF in 1995, as shown in table 3. This value is some 40% higher than for the same discount rate of 0% used in table 12.

Further, the CV study by SCHWAB & SOGUEL (1995) quotes VSL and VOLY figures that have already been discussed in Chapter 5.2 in connection with non-fatal road traffic accidents. As shown in table 8, Schwab & Soguel quote for the fatal accident DEC a willingness to pay on the part of the victim of CHF 1'696'790

(median value). Assuming a discount rate of 0% and a statistical residual life expectancy of 35 years of a person dying at an average age of 43 years, this VSL value results in a monetary equivalent for the present-day VOLY of 48'500 CHF (inflation adjusted to 1994). If future years of life are discounted at 3%, this figure rises to 79'000 CHF. Of course, the critical remarks in chapter 5.2.3, directed toward the study of SCHWAB & SOGUEL (1995), also apply here: Note especially our suspicion that the participants in this contingent valuation study did not pay sufficient attention to the *duration* of the health effects of the hypothetical accident event, and thereby tended to disregard the number of years to be lived as an invalid and the number of years lost due to premature death, in comparison to the acute accident effects. In this light, the low VOLY values of SCHWAB & SOGUEL (1995) shown in table 12 appear to be explicable.

Thus neither the results of BARANZINI & FERRO LUZI (2001) nor those of SCHWAB & SOGUEL (1995) call the figures quoted in table 12 fundamentally into question.

In view of the uncertainty in the discount rate for future years of life shown in table 12, it may be of interest to mention that the assumption of an extremely high discount rate of 4% would lead to an increase in the monetary equivalent of 1 DALY to 450'000 CHF.

## **5.5 Calculation via actually paid prices for aesthetic plastic surgery**

The uncertainties arising in Chapters 5.1 to 5.4 in the determination of the monetary equivalents of 1 DALY, of sleep disturbance and of interference with communication, may be attributed primarily to fundamental problems in connection with the monetisation methods of hedonic pricing, wage risk analysis, contingent valuation and conjoint analysis. Interest therefore centres on answers to the question as to how much people would *actually* be prepared to pay for avoiding an imminent, or eliminating an existing, health impairment. Since in the Swiss medical system the costs of therapy are only to a small extent borne by the patient (and for this reason patients' payment patterns only permit limited conclusions to be drawn on the intrinsic value they attach to health), those sectors of the medical system are of particular interest in which the social insurance companies do not carry the costs, so that patients must carry these themselves. A case in point is the application of therapies for cosmetic reasons, in which the well-being of persons is impaired not by the poor functioning of bodily organs, but by virtue of their abnormal external appearance.

Where a person's external appearance lies outside the range deemed 'normal' and 'appealing' by his/her social surroundings, he/she will feel exposed and isolated. This can lead to a significant impairment in well-being, which, under a widely-cast definition of health, must be regarded as a disease in exactly the same way as 'ac-

tual' physical and mental diseases. Nonetheless, the resulting costs of treatment are generally not carried by the social insurance companies.

In this context, the authoritative tables of MURRAY & LOPEZ (1996:39) are of importance. They contain the facial blemish known as 'vitiligo on face', and attribute a disability weight DW of 0.02 to it. This means that vitiligo is explicitly recognised to be a kind of health impairment, and not merely an annoyance. Vitiligo on face is a non-pigmented white area of the face, defined by Murray & Lopez as follows (quote): «The individual has 10% of the face afflicted, and this condition is evident at a distance». A whitish facial blemish of this kind represents a state of health that neither inhibits the physical functioning of a person nor causes him/her bodily pain, so it is not a disease in the customary sense. But inasmuch as a whitish area in the face is judged by the person's social surroundings to be an anomaly, his/her social functioning is nonetheless affected. This leads to social ostracism, causing permanent suffering to the person concerned<sup>15</sup>. According to the WHO definition of health, such a person is no longer in full health, since here, social functioning is impaired for bodily reasons. Consequently, Murray & Lopez determined a disability weight for this condition.

For the purposes of the present study, it would be of interest to know how much a person affected would be prepared to pay in order to eliminate the appearance of vitiligo in his/her face, that is to say, to make it invisible to the person's social surroundings. In view of the fact that the DW for sleep disturbance caused by traffic noise (= 0.055) is just under three times higher than for vitiligo on face, multiplication of the measured willingness to pay of vitiligo patients by a factor of 2.75 could provide an indication of the willingness of (other) patients to pay for the elimination of their sleep disturbance.

According to Swiss dermatologists, no successful therapy exists for vitiligo. Nonetheless, commercially marketed medicaments for vitiligo do exist, for example Novitil that is applied to the affected skin (<http://www.dermabest.com>). In response to our enquiry, the manufacturer Dermabest Inc. in Toronto/Canada provided the following information:

- Typically, a substantial improvement or complete healing are achieved after six months of using Novitil. This assumes otherwise healthy persons with average skin tanning properties who expose themselves moderately to the sun.
- In order to make an existing (static) vitiligo blemish of 15 cm<sup>2</sup> in area invisible, 125 ml of Novitil must be applied over two months.
- Where Novitil is used to make vitiligo invisible, the effect is permanent. It cannot, however, be excluded that new depigmentation may occur at other points.
- In November 2002, 125 ml of Novitil cost USD 79.95 incl. postage and packing.

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<sup>15</sup> Vitiligo and its therapy are described in <http://www.niams.nih.gov/hi/topics/vitiligo/vitiligo.htm>.

If, based on the following data, we now assume that the buyers of Novitil believe that by applying this medicament for 12 months a vitiligo blemish of 15 cm<sup>2</sup> can be made invisible for the rest of their lives, the willingness to pay for the elimination of vitiligo (and thus of the intrinsic value of the absence of vitiligo) could be calculated as follows:

Willingness to pay for eliminating vitiligo =  $12 \times 0.5 \times 79.95 = 480\$ = 700 \text{ CHF}$

Considering that the medicament purportedly eliminates vitiligo for the entire residual life expectancy, those with a residual life expectancy of 40 to 60 years express a willingness to pay for the absence of vitiligo of about 10 to 20 CHF per year. This is very low for the elimination of a health impairment with disability weight 0.02, and would result in an unrealistically low monetary equivalent of the absence of sleep disturbance (DW 0.055) and interference with communication (DW 0.033).

From this it may be concluded either that in ignorance of the actual maximum willingness to pay of vitiligo patients, the manufacturer sells the medicament much too cheaply, or that most patients do not really believe that the medicament will heal them in the manner advertised, and without side effects, so that the manufacturer can only achieve the desired turnover by demanding a very low price. Thus the price paid for Novitil therapy does not allow valid conclusions to be drawn on the intrinsic value of the absence of vitiligo for one year.

More representative information is now available on the sums paid by the affected persons for other types of cosmetic interventions in the region of the face, as published by the American Society for Aesthetic Plastic Surgery ASAPS (<http://www.surgery.org>). Interventions frequently carried out in the USA on the face are for example:

- Modification of undesired facial contours by injecting bovine collagen. According to ASAPS, this out-patient intervention was performed 1'098'000 times in the USA in 2001. To ensure an enduring effect, it must be repeated every three to six months, and costs an average doctor's fee of USD 350 in the USA per treatment (at 2001 prices), plus a supplementary charge to cover the costs of operating theatre, anaesthetics, tests, medicines, etc.
- Correction of an undesired nasal form by operative intervention (rhinoplastics). According to ASAPS, this out-patient or semi-resident (i.e. discharge from hospital in the evening of the operation) intervention was performed 177'000 times in the USA in 2001, and costs an average of USD 3745 (at 2001 prices) plus the above mentioned supplementary charge. Interventions of this type are mostly performed on young adults (47% of age 28–35 and 23% of age 35–50), and their effect endures for the residual life expectancy of some 40 years.
- Lifting of drooping upper eyelids. According to ASAPS, this intervention was performed 246'338 times in the USA in 2001, and on average costs USD 2510 (at 2001 prices) plus the above mentioned supplementary charge. These inter-

ventions are mostly carried out on older adults, their effect enduring for the residual life expectancy of about 20 years.

While the above medical interventions do not address vitiligo on face, they do concern modifications to the appearance, and, as far as the affected person is concerned, their effect is roughly comparable to the elimination of vitiligo. It is a matter of judgement as to how serious an oversized or crooked nose, or a conspicuously wrinkled face, should be regarded in comparison to vitiligo covering 10% of the face. Now, if one assumes that the severity is judged by the person affected as roughly the same in these three cases ( $DW = 0.02$  as for vitiligo), the following estimates for the monetary equivalents in CHF for health impairments with  $DW = 0.02$  may be made:

- Assuming a supplementary charge of 200% of the surgeon's fee, collagen treatment costs  $2 \times 350\$ \times (100+200)\%$ , or 2100 USD per year, corresponding to some 3000 CHF at 2001 prices. For nasal correction, the yearly cost is  $(1/40) \times 3745\$ \times (100+200)$ , or 280 USD, corresponding to some 420 CHF at 2001 prices. For lifting of the eyelids, the yearly cost is  $(1/20) \times 2510\$ \times (100+200)\%$ , or some 380\$, corresponding to some 550 CHF at 2001 prices.
- In view of the large number of operations performed in the USA each year, it may safely be assumed that the intrinsic value of an unblemished face or an inconspicuous nose is at least of the order of the costs mentioned above from the point of view of most of those affected, since otherwise, the high number of treatments shown in the statistics would not come to pass. It is of course conceivable that the intrinsic value could be higher than the price paid, for example where the maximum willingness of a significant fraction of patients to pay is higher than the market price demanded, or where the intrinsic value of the health improvement is not adequately expressed in the maximum willingness to pay on the part of the patient. We shall assume in this connection that the sales acumen of the American 'beauty (plastic) surgeons' is sufficiently well advanced for these to position their price demands in the region of the maximum willingness to pay of the majority of patients. In contradistinction, the experience with contingent valuation lends support to the conjecture that patients do not adequately express the value of health improvements for years of life in the distant future in their maximum willingness to pay. Noticeable in this respect is the comparatively low market price of nasal correction and lifting of the eyelids when expressed in terms of residual life expectancy per year. It is difficult to imagine that patients would assign a ten-times lower negative value to a poorly proportioned nose or drooping eyelids than to a wrinkled face. It is much more plausible that patients were too little cognizant of the many years of life ahead of them without the burden of a conspicuous nose or unsightly eyelids. This problem does not arise in the case of collagen injections, since these are only effective over a number of months and must then be renewed. We shall therefore assume that the market price of two collagen injections per year is equal to the intrinsic value of an unblemished face for the duration of one year, since this price lies in the region of the average maximum willingness to pay of the market, and since this maximum willingness to pay corresponds well to the intrinsic value of the

improvement to health, because no future life years must be taken into consideration by the involved persons. Based on these assumptions, the monetary equivalent of an inconspicuous face per year may be set at some 3000 CHF (at 2001 prices).

- The question remains as to whether the disability weight DW for a wrinkled face prior to collagen injection should really have the same value of 0.02 as for a face affected by vitiligo. The tables shown in MURRAY & LOPEZ (1996) provide no guidance on this. As a rough approximation, we shall assume here that patients regard a wrinkled face as being somewhat less disturbing than a vitiligo blemish, so that a tentative DW of 0.01 to 0.02 will be applied to the former.

Based on this, it may further be concluded that the intrinsic value of the absence of sleep disturbance due to noise would amount to approximately 8000 CHF per year assuming a DW ratio of 0.055/0.02, and twice the above value assuming a DW ratio of 0.055/0.01. Subjectively, and assuming that people would be prepared to pay 700–1300 CHF per month in order to obtain an undisturbed sleep, the above value is felt to be on the high side. A possible reason for this seemingly high monetary equivalent could lie in the presumption that people are prepared to disburse particularly large sums of money for the elimination of deficiencies in their outward appearance.

Table 13: Monetary equivalents of health impairments derived from payments for cosmetic interventions. Inflation adjusted to 2001.

Endpoint	Calculation	Monetary equivalent in CHF
Sleep disturbance for 1 year	$0.055/(0.01-0.02) * 3000 \text{ CHF}$	8000–16'000 CHF
Interference with communication for 1 year	$0.033/(0.01-0.02) * 3000 \text{ CHF}$	5000–10'000 CHF
Monetary equivalent of 1 DALY	$1/(0.01-0.02) * 3000 \text{ CHF}$	150'000–300'000 CHF

## 5.6 Calculation via actually paid prices for medical therapies in the narrow sense

If the transition is now made from the medical periphery of cosmetic treatment to medical therapies 'in the narrow sense' for 'normal' diseases, the problem arises that those affected do not generally pay for this themselves, since the medical costs are borne by the social insurance companies. In the Swiss system, there are two exceptions to this: (1) the costs of preventive inoculations and dental treatment are not generally borne by the health insurances; and (2) for all treatments whose costs are borne by the health insurances, patients must carry an annual deductible ('Franchise') that they may be selected by the insured in the range of between 400 to 1500

CHF per year, and must also contribute 10% of the costs of treatment ('Selbstbehalt'). We shall treat here two cases that could be useful for the determination of the intrinsic values of health states.

### 5.6.1 Inoculations to prevent influenza

Inoculations to prevent influenza are carried out each autumn and offer to healthy adults below age 65 the prospect of remaining free of the 'Influenza-Like Illness' (ILI) the following winter with a probability of 68–90% (BAG 2002:10). The number of ILI cases expected among the Swiss population each winter is estimated at 100'000 to 300'000, i.e. 1500 to 4500 cases per 100'000 persons. This risk applies to persons in the age range of 15–65 years, whereby for children the risk is greater, and for 65 year olds smaller (BAG 2002:4/5). ILI is accompanied by high-fever lasting approximately 3 days, followed by a convalescence period of one to two weeks. For healthy adults between 15 and 65 years, complications involving hospital treatment or death have a very low probability of occurrence (BAG 2002: 5), so their influence on the decision whether to inoculate or not is regarded as slight. The BAG (2002) brochure was distributed to Swiss doctors and is likely to represent the basis of doctors' information to patients wishing to inform themselves on the risk situation and the severity of ILI before deciding whether to have themselves inoculated. The inoculation against influenza becomes effective the following winter. Its price was about 25 CHF in autumn 2002, to be paid by those under 65 years of age themselves.

We shall make the provisional assumption that adults of age 15–65 years considering inoculation made their decision for or against this mainly on the basis of the costs (25 CHF) to be borne by themselves and the intrinsic value of being spared an (uncomplicated) ILI, and on the assumption that the inoculation would reduce the likelihood of contracting ILI the following winter from 1500–4500 per 100'000 head of the population to 32–10% of these values respectively. If this assumption is valid, the persons opting for inoculation would express the opinion that the reduction in the probability of contracting ILI the following winter by 1020–4050 per 100'000 is at least worth the payment of 25 CHF. Following the usual interpretation, these persons implicitly declare that avoidance of contracting ILI with probability =1 has an intrinsic value of at least CHF  $25 \cdot 100'000 / (1020 - 4050)$ , or CHF 617–2450. According to STOUTHARD 1997 (appendix, table A.1, diagnostic group 31), the disability weight DW of an influenza episode of two weeks' duration is equal to 0.16 over the two weeks. Under the not entirely unproblematic assumption of proportionality to time, this leads to an averaged DW of 0.006 for 1 year with 2 ILI weeks and 50 healthy weeks.

From this, a DW ratio of  $0.055 / 0.006 = 9.2$  results between a sleep disturbance of one years' duration due to noise, and an influenza episode without complications of two weeks' duration followed by 50 healthy weeks. Based on a conversion via this DW ratio of 9.2, the monetary equivalent of the avoidance of sleep disturbance during one year can be calculated at CHF 5676–22'540. These figures would in-

crease proportionally as soon as we assume that the true willingness to pay WTP for the influenza inoculation is higher than the CHF 25 actually paid. It is quite conceivable that persons considering an influenza inoculation would be prepared to pay much more than 25 CHF, all the more as nobody seems to refuse the inoculation once its price has been disclosed.

As discussed further above, this calculation of the intrinsic value for the avoidance of noise-related sleep disturbance may be questioned on the grounds that financial considerations play a minor part in the decision of those wishing to be inoculated. Further, we have to consider that, in analogy to the criticism of CV studies voiced in Chapter 5.2.3, those wishing to be inoculated do not take the probability of contracting the disease into account, i.e. do not consider it rationally. Notwithstanding this, the 617–2450 CHF calculated for the intrinsic value of avoidance of two weeks of influenza are not felt to be unrealistic.

Table 14: Monetary equivalents of health impairments derived from payments for influenza inoculation. Inflation adjusted to 2002.

Endpoint	Calculation	Monetary equivalent in CHF
Sleep disturbance for 1 year	$0.055/0.006 * (617-2450)$ CHF	5000–22'000 CHF
Interference with communication for 1 year	$0.033/0.006 * (617-2450)$ CHF	3000–13'000 CHF
Monetary equivalent of 1 DALY	$1/0.006 * (617-2450)$ CHF	100'000–400'000 CHF

### 5.6.2 Therapy for obstructive sleep apnoea syndrome (OSAS)

The term 'Obstructive Sleep Apnoea Syndrome' (OSAS) denotes a cessation of breath lasting at least ten seconds, and occurring five to forty times per hour, during sleep, due to a temporary collapse of the respiratory tract in the larynx. As a result, the quality of sleep deteriorates, and those affected find themselves exhausted and prone to falling asleep the next day (ZINGG, 2002). At the end of each breathing interruption period, the OSAS patients emit very loud snoring sounds that may cause sleep disturbance with the partner of the OSAS patient if sleeping in the same room, very comparable to a sleep disturbance caused by road noise penetrating into the sleeping room (MCARDLE et al. 2001). OSAS can be effectively avoided if during night-time sleep the patient wears a face mask connected to an appliance that maintains a minimum pressure in the respiratory tract, thereby preventing the collapse (nasal continuous positive airway pressure nCPAP). In the area served by the cantonal hospital of St. Gall, patients can rent nCPAP appliances, whereby the fee per day in 2002 was 5 CHF, plus a one-time installation charge of 722 CHF and a yearly charge for technical assistance of 74 CHF. The rental for the appliance is charged to the health insurance on a quarterly basis, whereby patients are advised in

connection with the proposal of nCPAP therapy that their own share of the rental price amounts to about 20 CHF per month (i.e. the 10% cost contribution he/she must refund to the health insurance).

Where patients decide to use the appliance in awareness of the costs involved, they are effectively expressing their judgement that the transition from probability 1 to probability 0 of the occurrence of continuous OSAS sleep disturbance, coupled with the transition from probability 0 to probability 1 of having to bear the annoyance of the appliance, is worth to them at least 240 CHF per year. Contrary to what a casual bystander might suppose, the annoyance of having to wear the mask connected to the appliance via a tube seems to be considered by most patients as negligible in comparison to the benefit obtained from the therapy, since only a few percent of patients decide not to continue using the appliance for this reason (ZINGG, 2002:61).

If attention be directed for the moment to OSAS patients not having a sleeping partner, OSAS sleep disturbance can be compared to that due to road traffic noise, despite the different causes. If at a first approximation the disability weight DW of the OSAS sleep disturbance is now set equal to that due to noise, i.e. to 0.055, the monetary equivalent of (at least) 240 CHF per year calculated above also applies to sleep disturbance due to noise.

Table 15: Monetary equivalents of health impairments derived from payments for nCPAP therapy. Inflation adjusted to 2002.

Endpoint	Calculation	Monetary equivalent in CHF
Sleep disturbance for 1 year	$0.055/0.055 * 240 \text{ CHF}$	at least 240 CHF
Interference with communication for 1 year	$0.033/0.055 * 240 \text{ CHF}$	at least 150 CHF
Monetary equivalent of 1 DALY	$1/0.055 * 240 \text{ CHF}$	at least 4400 CHF

It is probably realistic to qualify an intrinsic value of 240 CHF for the avoidance of sleep disturbance for one year as unrealistically low. This can only be interpreted as signifying that the therapeutic appliance is worth considerably more to the patients affected than they have to pay for its use. Considering that the public health insurance bears the major part of the costs of the therapy, namely 90% minus a possible part falling under the annual deductible, it would indeed be alarming if the nCPAP therapy were only worth the patients the small fraction of the costs they must carry themselves. Therefore the avoidance of sleep disturbance by means of nCPAP is likely to be worth to a responsible OSAS patient at least ten times the 240 CHF per year determined above.

In view of the close relationships existing between sleep disturbance due to road traffic noise, sleep disturbance due to OSAS, and sleep disturbance of a healthy person due to snoring of its sleeping partner being a OSAS patient, it would be

interesting to perform a supplementary study in which patients were asked to state their maximum willingness to pay for an nCPAP therapy. Contrary to the persons questioned in CV studies who have difficulty in comprehending the hypothetical market and its associated probabilities, those affected by OSAS should have no difficulty in understanding the situation, and also have an intimate relationship to the costs (see Chapter 7).

## 5.7 Best estimate from among the methods presented

The objective of this chapter is to provide a best estimate for the intrinsic costs of sleep disturbance and interference with communication. As explained earlier, these best estimates cannot simply be taken as the arithmetic means of the values obtained in the preceding sections. Table 16 provides a compact synopsis of the results of the monetisation approaches presented. On this table, it is indicated (a) whether the values refer to a gain or loss of health (G/V), (b) which of the fields in figure 3 are covered, and (c) under what assumptions the figures were calculated. The figures given were taken from the results of Chapters 5.1 to 5.6 and, where necessary, adjusted for CHF inflation to year 2000 using the Swiss Index of Apartment Rents or the Swiss Consumer Price Index.

Table 16: Summary of the estimates made in Chapters 5.1 to 5.6 expressed in CHF per 2000 (# signifies that a clear assignment to WTP (gain of health) or WTA (loss of health) is not possible since both cases occur, e.g. certain tenants are prepared to pay more for a quiet apartment, whereas others are prepared to accept increased noise against compensation through lower rents).

Method	Interference with communication CHF(2000)/ year	Sleep disturbance CHF(2000)/ year	Gain (G)/ loss (V)	Fields in Tab.1 covered	Critical assumptions	Origin of data
Analysis of noise dependency of rents (hedonic pricing)	<b>1450</b>	<b>2410</b>	V/G (#)	Mostly A1	<ul style="list-style-type: none"> <li>perfect market, i.e. no dearth of apartments, no removal costs, and unlimited mobility of the property</li> <li>occupants are aware of disturbance by noise</li> <li>marginal costs</li> </ul>	Tab. 5, corrected for rent inflation from 1996
Benefit transfer from cosmetic interventions (market costs)	<b>5000–10'000</b>	<b>8000–16'000</b>	G	A1	<ul style="list-style-type: none"> <li>price for bovine collagen treatment equal to the marginal willingness to pay</li> <li>disability weight of undesired face contours = 0.01–0.02</li> </ul>	Tab. 13
Benefit transfer from influenza inoculation (averting behaviour)	3000–13'000	5000–22'000	Avoidance of V	Mostly A1	<ul style="list-style-type: none"> <li>those inoculated bear average risk and are aware of this</li> <li>inoculation costs = marginal benefit</li> </ul>	Tab. 14
Benefit transfer from appliance for OSAS (market costs)	>150	>240	G	A1+ E1	<ul style="list-style-type: none"> <li>own costs = marginal benefit</li> <li>annoyance can be disregarded</li> </ul>	Tab. 15

Benefit transfer from bronchitis (contingent valuation)	190	310	Avoidance A1 of V		<ul style="list-style-type: none"> <li>hypothetical questions were understood and taken seriously</li> <li>marginal willingness to pay</li> </ul>	Tab. 6 last row x DW with inflation from 1998
Benefit transfer from lung cancer (contingent valuation)	1260	2090	Avoidance A1 of V		<ul style="list-style-type: none"> <li>hypothetical questions were understood and taken seriously</li> <li>marginal willingness to pay</li> </ul>	Tab. 6 last row x DW with inflation from 1998
Benefit transfer from mortality risk/value of statistical life years (wage risk, contingent valuation)	<b>7300–8900</b>	<b>12'200–14'900</b>	V/G (#)	Mostly A1	<ul style="list-style-type: none"> <li>changes in mortality risks were understood</li> <li>changes in mortality risk correspond to change in life years</li> <li>VSL = 8.9 million CHF, discount rate 0% to 1%</li> <li>conversion to low disability weights is permissible</li> </ul>	Tab. 12
Medical marginal costs (averting behaviour)	2475–4950	4125–8250	G	A1+ D1+ E1+E2	<ul style="list-style-type: none"> <li>Anglo-American limit values transferable to Switzerland</li> <li>limit values correspond to social preference</li> </ul>	Tab. 9
Medical marginal costs after elimination of performance difference in the employment sector (averting behaviour)	<b>1485–3960</b>	<b>2475–6600</b>	G	Mostly A1	<ul style="list-style-type: none"> <li>Anglo-American limit values transferable to Switzerland</li> <li>limit values correspond to social preference</li> <li>corrections for gain/loss framing and salaries are acceptable</li> </ul>	Tab. 10

In view of the assessment of critical assumptions made in table 16, and for the following reasons, only the four estimates given in bold type will be further considered. In case of inoculations against influenza, the 'buyers' are probably not aware of the actual risk involved, and the price of the inoculation does not correspond to their maximum willingness to pay. For the appliance to combat OSAS, the data available till now represent merely a lower estimate, and are thus of little value. The benefit transfer from CV studies on bronchitis and lung cancer is not to be recommended owing to reservations concerning the relevant primary studies. Finally, the marginal medical costs version without elimination of the salary component is not considered further.

The selected estimates, highlighted above in bold type, are shown again in table 17.

Table 17: Best estimates for monetary equivalents of health impairments due to road noise (intrinsic value of loss of bodily integrity). Inflation adjusted to 2000.

Method	Interference with communication CHF(2000)/year	Sleep disturbance CHF(2000)/year	Gain(G)/loss (V)	Fields in tab. 1 covered	Critical assumptions	Origin of data
Analysis of noise dependency of rents (hedonic pricing)	1450	2410	V/G (#)	Mostly A1	<ul style="list-style-type: none"> <li>perfect market, i.e. no dearth of apartments, no removal costs, and unlimited mobility of the property</li> <li>occupants are aware of disturbance by noise</li> <li>marginal costs</li> </ul>	tab. 5, corrected for rent inflation from 1996
Benefit transfer from cosmetic interventions (market costs)	5000–10'000	8000–16'000	G	A1	<ul style="list-style-type: none"> <li>price for bovine collagen treatment equal to the marginal willingness to pay</li> <li>disability weight of undesired face contours = 0.01–0.02</li> </ul>	tab. 13
Benefit transfer from mortality risk/value of statistical life years (wage risk, contingent valuation)	7300–8900	12'200–14'900	V/G (#)	Mostly A1	<ul style="list-style-type: none"> <li>changes in mortality risks were understood</li> <li>changes in mortality risk correspond to change in life years</li> <li>VSL = 8.9 million CHF, discount rate 0% to 1%</li> <li>Conversion to low disability weights is permissible</li> </ul>	tab.12
Medical marginal costs after elimination of performance difference in the employment sector (averting behaviour)	1485–3960	2475–6600	G	Mostly A1	<ul style="list-style-type: none"> <li>Anglo-American limit values transferable to Switzerland</li> <li>limit values correspond to social preference</li> <li>corrections for gain/loss framing and salaries are acceptable</li> </ul>	tab. 10

Table 17 shows that the highest of the monetary equivalents selected as 'best estimates' is approximately equal to seven times the lowest 'best estimate'. It does not appear to be possible at the present time to weigh up the weaknesses of the different monetisation methods, in such way that one approach could be singled out as 'best of best'. The comparison does, however, reveal that the large number of apartment rent studies show much lower monetary equivalents of sleep disturbance and interference with communication than the likewise very large number of VSL studies.

We shall not calculate the arithmetic means of the estimated value shown in table 17, but shall limit ourselves to providing lower and upper estimates of the monetary equivalents in rounded form for the two health impairments considered, based on the totality of information given in table 17 (adjusted for CHF inflation to 2000):

<b>Interference with communication, per year</b>	<b>Low estimate: 1500 CHF</b>	<b>High estimate 9000 CHF</b>
<b>Sleep disturbance, per year</b>	<b>Low estimate: 2500 CHF</b>	<b>High estimate 15000 CHF</b>

It is important to note that these monetary equivalents are based mainly on studies in which the money value of an *improvement in health* was determined. Referring back to the significant distinction made in table 2, these monetary equivalents are to be interpreted as *Swiss society's maximum willingness to pay for health improvements, and therefore for reductions in the noise level*. If, however, monetary equivalents should be required for the remaining cases in table 2, especially for *compensation of health degradation to be borne, or for increases in the noise level*, we expect on the basis of the discussion in Chapter 4.4 that the above *estimates* would have to be *increased*. However, we have decided for the moment not to make quantitative estimates of these increases.

In Chapter 6, these methods are applied to the results of the analytical model of MÜLLER-WENK (2002) in order to calculate the intrinsic damage to human health caused by 1000 kilometres of the various road vehicle types.

## 6 Health impairments due to road traffic noise in monetised form

In certain decision situations, it may be useful to have money amounts representing the health impairments caused by road traffic noise. Such figures can be developed by linking the results of chapter 5.7 with the analytical model of MÜLLER-WENK (2002), which contains modules for the propagation, exposure, effect and damage analyses, each of which referring to two vehicle categories (cars, lorries) and two time periods (daytime, night-time). This damage analysis is based on the 'disability adjusted life years (DALY)' health scale. Using these data sets, we shall now express in terms of money the noise-related health loss consisting of sleep disturbance and interference with communication.

Table 18: Monetisation of sleep disturbance and interference with communication in ct. = 0.01 CHF (inflation adjusted to 2000) per vehicle kilometre, for cases of sleep disturbance and interference with communication taken from MÜLLER-WENK (2002: Box 11).

	Category: private cars, delivery vans, light motorcycles		Category: lorries, busses, tractors, heavy motorcycles	
	Low estimate	High estimate	Low estimate	High estimate
Additional cases of interference with communication per 1000 vehicle kilometres, daytime	0.0038	0.0038	0.038	0.038
Additional cases of sleep disturbance per 1000 vehicle kilometres, night-time	0.049	0.049	0.48	0.48
Monetised health loss due to additional interference with communication, in ct. per vehicle kilometre daytime (6.00–22.00 hours)	0.57	3.4	5.7	34.2
Monetised health loss due to additional sleep disturbance, in ct. per vehicle kilometre night-time (6.00–22.00 hours)	12.2	73.5	120	720

The number of cases of disturbance shown in the first two rows in table 18 was taken from MÜLLER-WENK (2002: Box 11). The money amounts in Swiss cents per vehicle-kilometre of the last two rows are obtained through multiplication of the number of cases of disturbance by the low estimate of 1500 CHF for interference with communication and 2500 CHF for sleep disturbance, or by the high estimate of 9000 CHF and 15'000 CHF, as appropriate.

The discussion of table 18 now follows based on the low estimate (for the high estimate, similar observations apply). For private cars, the noise costs according to table 18 amount to 0.57 ct. per vehicle kilometre during the day, and 12.2 ct. per kilometre at night. Thus the noise costs at night are very high in relation to typical operating costs in the region of 50–70 ct. per kilometre. Note, however, that according to Annex 3 Number 33 of the Swiss Noise Abatement Ordinance, for private cars, 92.5% of the total distance is driven during the day, so that the

weighted noise costs for day and night amount to 1.44 ct. per kilometre, and these may now be compared to the operating costs. Note, also, that the noise costs in table 18 do not represent average costs, but marginal costs for small increases of traffic volume, starting from the current level of total annual traffic volume.

The noise costs in the lorry category are about ten times those for private cars, i.e. 5.7 ct. per vehicle kilometre during the day and 120 ct. per vehicle kilometre during the night. For lorries, 96% of the total distance is driven during the day, so that the weighted noise costs during the day and night amount to 10.3 ct. per kilometre.

These weighted figures can now be compared to the results of the National Research Programme NFP 41 'Traffic and Environment' (MAIBACH et al. 1999; MAIBACH et al. 1999a). For year 1995, MAIBACH et al. (1999a:A-15) quote noise costs of 1.03 ct. per kilometre for category 1 (private cars, delivery vans and motor scooters), and 10.34 ct. per kilometre for category 2 (heavy vehicles, busses, motorcycles). These figures lie in the region of the weighted noise costs for day and night operation in table 18 if the low estimates are taken. At first sight, this concordance is not surprising, since the figures of Maibach et al. and the 'low' values in table 18 are both based on studies on the noise dependency of apartment prices. However, on further consideration, the matching of figures is less self-evident, as discussed in the following.

In MAIBACH (1999a:A14,A15), the *average* noise costs per kilometre are calculated by dividing the noise-related value loss of Swiss apartments of 971 million CHF by the annual distance driven. Maibach et al. hereby set the noise threshold for value loss of buildings at the very high level of 55 dB(A), so that in our opinion the resulting 971 million CHF value loss due to noise is much too low. In contrast to the *average* noise costs, we have calculated in Chapter 5.1 the *marginal* noise costs for changes in traffic volume compared to 1995.

A second significant difference between Maibach et al. and the calculations performed here is that Maibach et al. established the relationship between apartment prices and noise based on hedonic pricing, in which the maximum willingness to pay of tenants and buyers of apartments does not show up. It is thus an open question how much money the freedom from noise in apartments is 'really' worth to the tenants or buyers. Contrary to this, the present study makes full use of the results of the CV results of WEINBERGER et al (1991), so that our figures reflect the maximum willingness to pay.

Irrespective of these very important differences, we note that the noise costs per vehicle kilometre stated by Maibach et al., and those designated as 'low' in table 18, do not conflict with one another, and such a non-contradiction is often taken as an indication of validity.

In distinction, the noise costs designated as 'high' in table 18 are about six times higher than those of Maibach et al. Thus if our upper estimates should prove to

represent the 'true' noise costs, this would imply that the investigations of the monetary costs of road noise, performed till now on the analysis of prices and rents of apartments, have significantly underestimated these noise costs. This would also provide grounds for the suspicion that in the Swiss studies on the external costs of road traffic noise, the noise costs could have been set too low in comparison to other external costs of traffic whose monetisation was performed with other methods than hedonic pricing of apartments.

## 7 Subsequent work

The wide range of willingness to pay cited in Chapter 5.7 for the avoidance of sleep disturbance and interference with communication, and the equally wide ranges of monetised health loss per vehicle kilometre cited in Chapter 6, are only of limited use in political decision-making and in arguing the necessity of measures. Figures with a narrower interval of confidence are required.

We expect to contribute to this by performing a primary study in co-operation with the sleep clinic at the St. Gall cantonal hospital. The objective of this study is to obtain more information on the willingness of patients with obstructive sleep apnoea syndrome (OSAS) to pay for the costs of an nCPAP therapy. The context within which OSAS patients take their buying decision is of interest here, since the following typical problems encountered with stated preference methods *do not* occur here:

- The health impairment at stake and the procedure for its elimination are very familiar to the OSAS patients, so that it is not necessary to work with hypothetical diseases and therapies as in usual WTP studies.
- No probabilities other than 1 and 0 are involved, so that the tricky problem of evaluating small probability differences does not show up.
- There is a realistic starting point for the process of approximation towards the maximum willingness to pay of the patient, namely the actual price to be paid for the nCPAP equipment. The payment is due at quarterly intervals, and it is fairly easy for patients to bring this expenditure into relation to their usual monthly earnings and expenses.
- The health impairment avoided and the payments for the nCPAP therapy refer to *the same* period. Patients are therefore not confronted with the difficult question of how much the future avoidance of the disease for the rest of their lives would be worth at present.
- The transfer of the monetary equivalent of sleep disturbance of OSAS patients to that of road-noise-related sleep disturbance is well justifiable and feasible, since despite the different causes, the disease symptoms are very similar, and the disability weights are likely to be equal or of the same order. Congruency would be improved even further if the sleep disturbance of the sleeping partner of the OSAS patient, caused by the patient's snoring, can be included in the analysis.

Consideration will therefore be given to performing a combined market price/contingent valuation study on persons actually suffering from sleep disturbance based on nCPAP appliances actually available on the market. We hope that such a study can reduce the wide range of variation found in Chapter 4.7.

Should the expectations placed in the above study prove to be justified, a suitable practical example of interference with communication could then be sought having the advantages of the OSAS phenomenon mentioned above. It is conceivable that hearing aids could represent a suitable application of this kind.

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