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Putting noise annoyance in the broader context of sustainable development

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ABSTRACT

Environmental health impact assessment (EHIA) of larger projects is a multidisciplinary process. Noise impacts such as annoyance, sleep disturbance, blood pressure related illness, mental health, or even the reduction of quiet areas, are an integral part of the EHIA. In the overall assessment they have to be contrasted to other benefits and costs.

In this paper we discuss the translation of the concept of sustainable development to noise impact. The concepts of equity and efficiency will be explored using the concept of sound utilization space. Methods based on exploring alternatives for the future society are considered. This leads us to a number of classical methods to put noise impact in this broader context: DALY, monetarisation, … but also to new ideas on using indicators for quality of life and perceived well-being.

These concepts were used for the impact assessment of the Brenner Base Tunnel project. Results from this EHIA will be used to illustrate the pros and cons of several techniques. In particular this paper also compares effect prediction and effect weighting based on exposure effect relationships and weights extracted from a multitude of international studies at one hand and from local relationships based on social surveys at the other hand.

1 INTRODUCTION

The reduction of annoyance in the community has been and still is the ultimate goal of any intervention, when a new transportation project is subjected to an EHIA. Therefore, exposure-response curves are provided by the Environmental noise directive (END). However, it was never assessed, whether annoyance is a good and reliable indicator for more serious health impacts nor how annoyance relates to similar more integrated indicators such as quality of life (QoL). Furthermore, over the last decade the concept of disability adjusted life years (DALY) was developed and translated to the broad field of environmental impacts [4] and has gained acceptance in administration and public policy: see the environmental reporting in the Netherlands [1] and the use in Switzerland [2].

These recent developments ask for a comparison of the various approaches used in the noise field. Because the various approaches could lead to different answers in EHIA a serious evaluation is mandated. It seems logical that this evaluation should be posited in the framework of sustainable development.

The aim of this paper is to outline a possible concept (*environmental utilization space)* and compare the various gains based on a recently completed EHIA of the Brenner Base Tunnel project, which used a multimethod approach covering the above mentioned concepts.

2 TRANSLATING SUSTAINABLE DEVELOPMENT

2.1 Sustainable development

Sustainable development (SD) has been defined as the art of fulfilling the needs of current generations without jeopardizing the ability of future generations to do so. To explore and

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implement these ideas several frameworks were proposed, for example the famous triangle: economic growth - conserving natural resources and environment - social development and equity. This model reflects the need for SD to consider a multi-dimensional way of thinking about the interdependencies among natural, social, and economic systems.

A concept that was introduced to investigate the limits imposed by the natural system on the development of the current generation is the *environmental utilization space* [1]. This notion is derived from the production possibilities set in economic analyses. It limits growth of an industry or economy just like human and financial resources. Environmental utilization space focuses mainly on those aspects of sustainable development that have low recovery potential or long recovery time. Depletion of natural resources and injection of dangerous substances into the environment are typical examples. Although noise – the topic of this paper – remains in the environment for a very short time after the source has been stopped, the (infrastructure) projects leading to the introduction of noise sources are often there for long. Hence, the notion of *sound utilization space* is explored in the next paragraphs.

Society and local communities can develop in many different ways. To recognize all consequences of the chosen path, an interesting thinking framework was developed. *Future scanning* consists in defining a number of possible (ambitious) options for future society. Scientific research can help understanding the complex interactions of natural, social and economic in such a future situation. It can help answering *what if* questions. It is then up to the community or their chosen representatives to eventually choose the most preferred future situation and accepts its consequences.

2.2 Sound utilization space

Because environmental noise is a local phenomenon, the notion of sound utilization space is developed bottom-up in contrast to the more usual top-down way of extracting available environmental utilization space. The basic unit of *sound utilization space* (SUS) is attached to a family. The SUS extends through the direct living environment and is limited by the range of audibility of neighboring units of SUS. Within its SUS a family has the freedom to control the sound climate. This means a right to produce sound as well as a right for silence. To fully cover the environmental noise problem, the notion of *common sound utilization space* (cSUS) has to be introduced. This common SUS can be used by everyone (to produce noise) and is typically managed by the government. Although the cSUS can be used by every citizen (initially without cost) it must be used efficiently (e.g. the noise emission of cars should be within economically reasonable limits). Having defined these notions, we can study interactions in a general conceptual way. In a context where emission (e.g. CO2) rights can be bought and sold, it is worth studying sound utilization space as a marketable good. Let us list a few possible interactions:

- *Renting* or *selling* private SUS between families: a family can temporally transfer its right to control the sound climate in its SUS to another family. It is not expected that this will be compensated financially. Rather a sort of barter is expected where the compensation is noise control on another day or just good neighborship.
- *Theft* of private SUS: when there is insufficient compensation for those that loose their right to control their sound environment, the term theft is appropriate. The government should in this case intervene in its police function and e.g. impose a financial compensation that allows restoring the SUS by e.g. sound insulation.
- Existing common SUS, new private SUS: What happens when a family chooses residence near an existing infrastructure (cSUS) and thus creates a new private SUS? It can be assumed in this case that this family has carefully considered all benefits and disadvantages of this location and thereby got compensated sufficiently for the loss of control over its SUS, either financially or because of other benefits. This situation

would not need any intervention by the government. If the use of the cSUS changes in a way that could reasonably be expected, one can still follow this line of reasoning. If the change is drastic and unexpected, the next paragraph applies.

- Existing private SUS, new common SUS: the family looses some of its right to control because of the new infrastructure or drastic increase in the use of this infrastructure. In the line of thinking that is being followed, this can be seen as a form of expropriation that should be compensated for in a fair way. The opposite situation could however also occur. Such a kind of planning gain could result in financial dues, e.g; to co-finance noise barriers, because of the increase in value of the property.
- The use of the common SUS by the (local) population is initially free of charge, but to enforce efficiency a cost per unit used could be introduced.
- A commercial activity, an enterprise, can be regarded as a private person in as far as acquiring SUS is concerned. When property is bought in an industrial estate it will automatically come with a larger SUS than when it is bought in a residential area. One could imagine within this frame of thought that additional SUS can be bought or rented from the families living nearby. Things get more complicated when the commercial activity makes extensive use of common SUS (road transport, air freight …). The government may need to acquire more common SUS by buying private SUS to accommodate this extensive use. It seems reasonable that part of the cost associated with this is recuperated from the extensive users.

2.3 Equity and efficiency

In the context of sustainable development equity is the fair division of available environmental utilization space between the members of the population. More specifically the use of natural resources and the pollution of the environment by discharging contaminants are envisaged. For local disturbances one could add to this a fair division of the burden of being exposed to the environmental stressor. Certainly there is some tension between the notion of marketable SUS and equity. If the right for control of the sound environment can be sold, this will automatically lead to an unequal distribution of the right to pollute and the quality of the surrounding noise climate amongst the population. Two considerations should be made when deciding on how to account for equity. Firstly, concentration of noise immission would be against the principle of equity in its basic definition. However, for the community as a whole, it might be the most efficient solution. Secondly, the strength of the notion of equity is strongly related to the place of its object in the chain of personal needs. Limited exposure to environmental noise is not amongst the most prominent needs of the human species. This discomfort is gladly traded for needs that are thought to be more important by some if these other needs are not completely fulfilled. Thus equity may as well be translated to an equal right to sell, rent, or give away ones right of control of ones sound environment.

Efficiency refers to the way the available resources (in this case the sound utilization space) are used. This notion creates the possibility for coexistence of the three aspects of sustainable development: economy, nature, social. Depletion of natural resources for the gain of social or economic welfare is allowed to some extend as long as efficiency is guaranteed.

3 INDICATORS

3.1 Long term goals

The impact of major infrastructure changes has to be embedded in long term goals for the development of the region. Notwithstanding the overall goal of sustainable development, some choices remain. They can best be grounded in formal future scanning. Let us consider two examples. 1) If future development of the region is fully governed by free market mechanisms – in other words, if policy is very liberal – a government will not influence society very strongly. Long term policy goals with respect to environmental noise will be limited to minimizing health impact and guaranteeing efficient use of machines and vehicles. Indicators used in environmental impact assessment of infrastructure plans should reflect these goals. 2) If this development is on the contrary governed by a very strong attention for nature, social development, maybe even at the expense of economic welfare, a government may have a stronger influence on society. Guaranteeing high quality of life in all of its aspects with respect for nature may be added to the long term policy goal. Indicators used for EHIA should again reflect these goals. In terms of the above described marketable sound utilization space, this development may require to impose restrictions on selling SUS.

3.2 Multi-disciplinary indicators

In view of the discussion above, it is necessary to define several indicators to assess the impact of large (infrastructure) projects. The discussion on sustainable development in the previous section makes it equally obvious that the indicators used should span several classical themes in the impact assessment procedure: environment (noise, odor, air quality), accessibility, … Science has to provide a suitable way to aggregate the indicators resulting from this classical disciplines into one overall indicator – at least one that takes into account as much aspects of the impact as possible. We will discuss two of these indicators: Dissability Adjusted Life Years (DALY), and Quality of Life (QoL).

Dissability Adjusted Life Years (DALY)

The DALY has been introduced [4] to allow comparing and aggregating various health impacts. As even in the most liberal development hypothesis of the region (see section 3.1) health and loss of life are to be considered, this is an important indicator. The most general formula for calculating DALYs [6] accounts for an age correction (switched on by *K*) and a time correction that accounts for the fact that near current situation and near future are rated more important by man. It is given by

$$DALY(r,K) = S \times \left\{ \begin{array}{l} \frac{KCe^{ra}}{(r+\beta)^2} \times \left[e^{-(r+\beta)(D+a)} \left[-(r+\beta)(D+a)-1 \right] - e^{-(r+\beta)a} \left[-(r+\beta)a-1 \right] \right] + \\ \frac{1-K}{r}\left(1-e^{-rD}\right) \end{array} \right\} \qquad (1)$$

where r is the discount rate, K is a parameter switching on age weighting, C is a constant for age weighting = 0.16243, a is the age at start of condition, β is a constant for age correction = 0.04, S is a disability weight giving severity (S=1 for death), and D is life expectancy at the age of effect if deathly or duration of effect. If age correction and discount rate are ignored – which is common practice – the formula reduces to a simple product *S.D.*

The DALY thus accounts for severity of the illness and its duration. It is nevertheless a linearly weighted sum of effects. This is acceptable as long as odd ratios for occurrence are very low, which is the case for health effects caused by environmental stressors. Attempts were made to include disturbance (e.g. noise annoyance) in the DALY framework – leading to Quality Adjusted Life Years (QALY). Adding effects that are not health effects in a classical sense does not come without practical problems. Finding suitable severity weights seems cumbersome. Numbers ranging from 0.01 [4] to 0.12 [5] are used in different studies. Based on valuation studies an additional estimate can be added. In Bjørner [7] the average willingness to pay for removing high noise annoyance is estimated at a couple of hundred euro per household per year or roughly 100 € per person per year. When this figure is compared to the cost of a lost year of life, which amounts to about 50.000 € [8], the ratio is 0.002. This is about five times lower than the value commonly used for *S*. The underlying reason for this large range could be related to the different future scenarios (Section 3.1) for the region not being made explicit when severity factors are estimated.

Quality of Life (QoL)

A new indicator is proposed to account more accurately for the quality of life aspect of the impact assessment. It could be used in addition to health related indicators such as the DALY – with the exclusion of annoyance. Direct questioning of the population with regard to their quality of life or their subjective well being is not advisable for two reasons. Firstly, it is not very easy for those questioned to ground such an abstract question. Secondly, modelling scenario impacts is more difficult the more abstract the effect is. Thus the QoL indicator was unravelled to its basic constituents. In this process we consider a society where basic human rights are fulfilled and take this for granted. Also we assume a Western Europe / North American type of society. Figure 1 shows the hierarchical construction of the QoL indicator. At the highest level, a good QoL includes: good health, a high quality job, low levels of external stressors, easy fulfilment of primary and secondary needs, and good social support. Each of these factors can be further unravelled. In Figure 1 this is done by referring to the questions (**Error! Reference source not found.**) used in a questionnaire used to assess the current QoL.

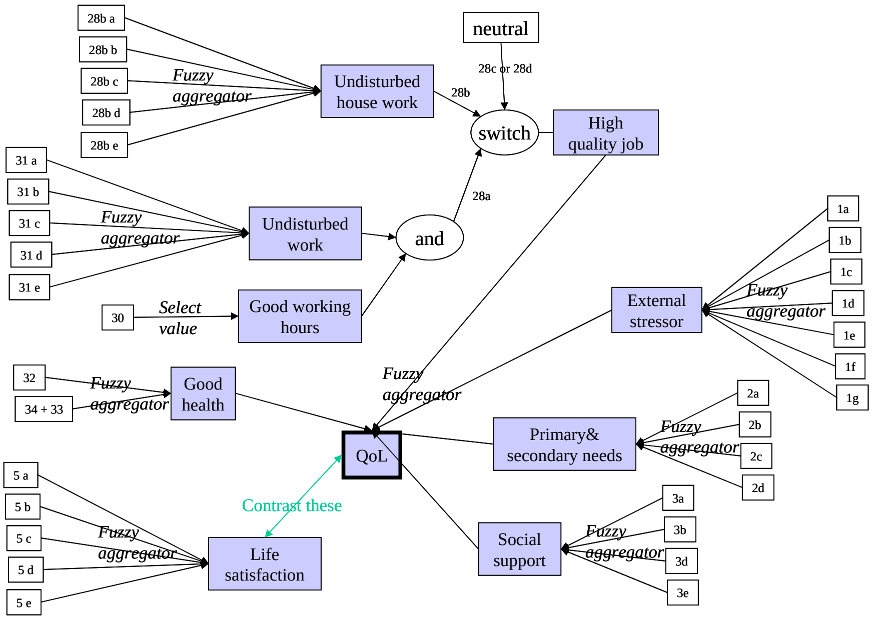

Figure 1: Layout of the construction of a quality of life indicator.

The QoL indicator involves several aggregations. There is some freedom in choosing the mathematical formula used to perform the aggregation. Nevertheless there are a few basic requirements: the aggregation must be monotonous, the result must be maximal (say 1) when all requirements are optimally fulfilled, and the result must be minimal (say 0) if none of the requirements are fulfilled. Moreover a bipolar scale is preferred to easily express the difference between factors with a positive and factors with a negative effect on QoL. The very broad class of fuzzy aggregators fulfills these requirements. For the indicator to be able to take into account all available knowledge additional requirements are added:

- The aggregation should have a saturating effect; that is, if several aspects score quite high, additional ones do not matter much anymore. This allows accounting for the observation made in Section 2.3 that noise pollution may be ignored in favour of other more appreciated aspects of life by some people.
- It should be possible to include cumulative effects between factors.
- For impact assessment weak separable is appreciated. If scenarios are close, it should still be possible to distinguish effects. This implies that ordinal scales used in

questionnaires will have to be translated to a cardinal scale.

In [10] we compared several aggregators and found that a 2-additive Choquet integral is the best choice. The aggregated value, C_μ, can be written in the following easily interpreted form:

$$C_\mu(f) = \sum_{I_{ij}>0} (f(x_i) \wedge f(x_j)) I_{ij} + \sum_{I_{ij}<0} (f(x_i) \vee f(x_j)) \left|I_{ij}\right| + \sum_{i=1}^{n} f(x_i) \left(v_i - \frac{1}{2} \sum_{j \neq i} \left|I_{ij}\right| \right), \qquad (2)$$

with v_i the weights in a linear weighted sum and I_{ij} the interaction between the i[th] and the j[th] factor in the aggregation. The sign of I_{ij} determines whether the AND ($\wedge$, implemented as a minimum) or the OR ($\vee$, implemented as a maximum) are used. The function $f(x)$ introduces the saturation effect. A suitably normalised sigmoid function (Eq.(3)) with α a positive factor that relates to the degree of saturation, is a good choice because of its continuity and because its inverse can easily be calculated.

$$f(x) = \frac{\dfrac{\exp(-\alpha x) - 1}{\exp(-\alpha x) + 1}}{\dfrac{\exp(-\alpha) - 1}{\exp(-\alpha) + 1}}, \qquad (3)$$

Monetarisation

Economists prefer to express the external cost introduced by a project or an activity in terms of money for easy comparison. The external cost is composed of several contributions $E = E_{immat} + E_{med} + E_{prod}$, where E_{prod} is the loss of productivity, E_{med} are the direct medical cost related to possible illness, and E_{immat} is an immaterial cost – due to loss of life or illness. E_{prod} and E_{med} depend on local economic situation including labour cost but can relatively easily be quantified. The immaterial cost E_{immat} for illness and loss of life expresses the same information as the DALY. It could even be estimated by multiplying calculated DALYs by the cost of one life year lost. The contribution to E_{immat} related to perception based effects (e.g. annoyance) is often extracted from stated preference (in particular willingness to pay studies) or hedonic pricing (e.g. analysing house prices). These methods sample the average opinion of the population on the importance of noise and its effects. In their position paper [12] from 2003 the WGHSEA concludes that road traffic noise could for the time being be valuated at 25 € per dB (L_{den}), per household per year within a range of applicability between 50/55 dB(A) and 70/75 dB(A). The spread in the data leading to this value is discussed by Navrud [13]. In this document a range between 2 and 99 euro/household/dB/year is derived for road traffic noise. Noise valuation studies are at the end of the effect chain and it is quite surprising to see how carelessly these studies define noise effects. Moreover, it is generally assumed that this cost is a global constant whereas it becomes clear from the discussion in Sections 2.3 and 3.1 that a strong dependence on satisfaction of other factors that contribute to quality of life and on the evolution of the region, are to be expected.

4 THE BBT PROJECT

4.1 Introduction to the project

A research project was carried out to support the EHIA of the Brenner Base Tunnel project. It encompassed epidemiologic studies in adults and children. The adult studies provided a broad data input about prevalence of annoyance, interference, QoL, health and disease endpoints [11]. One obvious goal was to compare the potential gain from building the tunnel in terms of public health impact. For this purpose two scenarios (development “as is”= no BBT, building the tunnel = BBT) were defined and compared with the current situation. The most important difference is, that with the implementation of the Brenner Base Tunnel all fright trains will go through the tunnel during nighttime, which results in a substantial reduction of night-time noise. The calculations below show the comparative impact using different indicators.

4.2 Disability adjusted life years: DALY

The calculation of DALY in this case study includes Ischemic Heart Disease (IHD) as the only classical health effect. Its calculation is based on local statistics for hospital admission and death and on exposure-effect relationships taken from [14]. The calculated DALY intervals for the current situation and the two scenarios are shown in Table 1. These numbers should be put in the context of an overall population of 47511 in the area.

Table 1: number of DALY caused by noise in current situation and two scenarios.

	Current	no BBT	BBT
IHD death	0.32 - 1.01	0.45 - 1.16	0.21 - 0.54
IHD illness	0.04 - 0.34	0.05 - 0.39	0.02 - 0.18
Sleep disturbance	3.7 - 37.4	4.1 - 41.0	3.0 - 30.4
Annoyance	17 - 174	19 - 190	15 - 152

The uncertainty intervals are rather large and determined by the following factors: *IHD death*: discount rate between 0 and 0.03; threshold for effect between 55 and 60 dBA; *IHD illness*: discount rate between 0 and 0.03; threshold for effect between 55 and 60 dBA, severity S between 0.35 and 0.5; duration D between 0.037 and 0.1; *Sleep disturbance and annoyance*: severity factor between 0.002 and 0.02. Sleep disturbance and annoyance contribute in a dominant way to the overall number of DALY.

4.3 Quality of life: QoL

The construction of a QoL indicator for the area under investigation in this project was based on a phone survey with 2002 carefully chosen inhabitants. Amongst other, the survey contained the questions found in **Error! Reference source not found.**. The weights used in the aggregation were derived by the EHIA-expert and can be found in [10]. It would have been better to derive these weights in a more formal way by the population (or their representatives) in line with the discussion in Section 3.1. The saturation factor α in Equation (2) was set equal to 5.

The project to be evaluated is believed to affect mainly air quality, noise, and odor. For air quality and odor the main changes are due to changes in road traffic intensities while for noise, rail traffic is an important contributor as well. For estimating the impact on the QoL indicator three critical assumptions are made. Firstly it is assumed that only the most important source (rail, highway, or other roads) determines overall annoyance, which corresponds to the strongest component model for cumulative exposure and thus includes its shortcomings. Secondly, it is assumed that changes can be described by exposure-effect relationships that are derived from a static situation. Thirdly, L_{den} is assumed to be a suitable exposure indicator. The latter two, although they have been criticized in the past, are quite common in current practice. A linear regression forced through the point (40dBA, 'not at all') is used to derive the localized exposure-effect relationship from the survey. The slope of this curve is then used to estimate the expected noise annoyance of every individual in the survey in the two scenarios considered. A similar methodology is followed for odor and air pollution. Figure 2 shows the predicted noise annoyance and the predicted QoL in the current situation and the future scenarios. QoL can theoretically span values between -1 (extremely bad) till 1 (extremely good) but in the study area values between -0.4 and 0.2 are encountered. People that have currently lesser or sizeable reason to complain about noise see their situation slightly worsening in a future scenario without BBT. Average QoL is clearly lower for people that currently report having more reason to complain about noise, but no difference is observable between scenarios. When focusing on particularly exposed villages (Figure 3), a very small decrease of QoL in a situation without the BBT project can be observed for those that were very annoyed by noise in the current situation. The disappointingly small effect of the project on average QoL of the inhabitants of the area is partly due to the small change in noise annoyance (and perceived air quality and odor), although the noise level drops by up to 8 dBA at particular locations and to the saturating effect of the aggregation of noise annoyance in the overall QoL. The latter makes that small changes at high annoyance levels induce hardly any change in QoL.

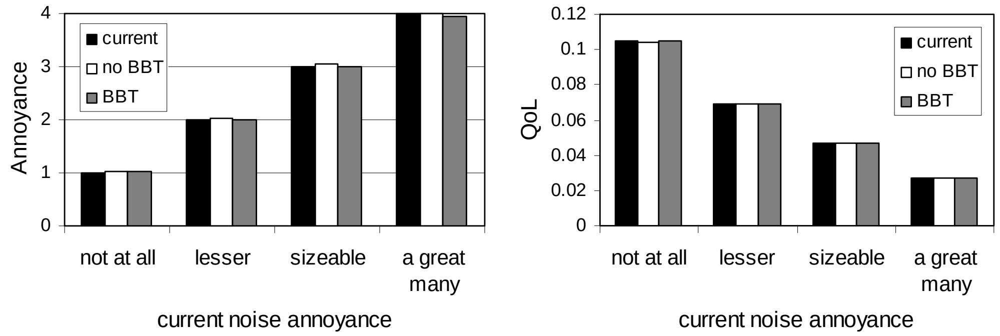

Figure 2: Average annoyance (left) and QoL (right) in two scenarios and current situation as a function of current degree of noise annoyance.

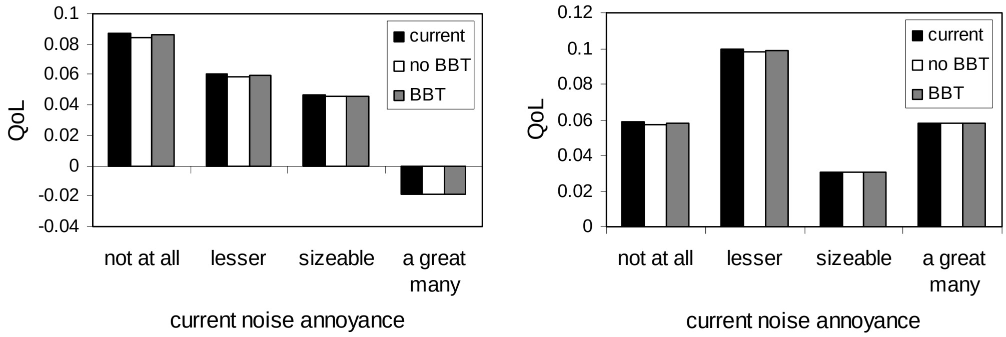

Figure 3: Average QoL in two scenarios and current situation as a function of current degree of noise annoyance in the villages of Freienfeld (left) and Matrei (right).

4.4 Monetarisation

Immaterial cost for classical health effects are estimated based on the number of DALY multiplied by the cost of one life year lost. Other costs are estimated on the basis of cost of medical treatment found in literature. The result is shown in Table 2.

Table 2: Valuation of the external cost of traffic in the study area

E total (1000 euro)	Current	no BBT	BBT
IHD death	16 - 94	22 - 108	10 - 50
IHD illness	21 - 54	30 - 67	14 - 31
BP treatment	385 - 426	536 - 593	245 - 272
depression	171 - 1956	184 - 2127	158 - 1741

Cost of loss of quality of life (immaterial) due to annoyance can also be estimated on the basis of DALY. A more accurate estimate is obtained by valuating the QoL indicator calculated in Section 4.3. If the difference in value between extremely bad and extremely good quality of life is estimated the same as the cost of a life year (50000euro), then an additional cost caused by the autonomous evolution and by the evolution with the project can be estimated. Both results are compared in Table 3. Although both approaches yield comparable order of magnitudes of change, there is a significant difference between the evaluations of the scenario with BBT. While on the basis of DALY a significant improvement compared to the current situation is predicted, the approach based on QoL still predicts an additional cost, though smaller than without the project.

Table 3: Change in external cost due to loss of quality of life

cost increase (1000 euro)	no BBT	BBT
on basis of DALY	100 to 1857	-145 to -2697
on basis of QoL	1123	724

5 CONCLUSIONS

The conclusions of an EHIA with respect to noise can be put in the broader context of sustainable development in different ways. The concept of Sound Utilization Space was introduced to formally ground the interpretation of sustainable development. By interpreting the right to control ones sound environment as a commercial good, it becomes easier to compare it to other commodities. This allowed us to discuss equity from a different point of view.

Long term goals for the development of a region can be quite different between regions. One can expect that independently of the trajectory preferred for the development of a region, preventing loss of life and illness is always an issue. Thus a multidisciplinary indicator such as the DALY (restricted to classical health effects) should be included in major EHIA studies.

The weight that is given to external stressors (noise, odor, bad air quality) may be more strongly dependent on the region. In particular a compensation effect can be expected with regard to the fulfillment of other needs. In line with the modified view on equity this could be taken into account in the impact assessment. A first attempt was made to construct an indicator that includes a multitude of aspects of quality of life. This QoL indicator is based on a local survey and an estimate of the effects taking into account the local exposure-effect relationships. It was shown by a case study that the QoL indicator puts changes in the average QoL of a population caused by even a mega-project in perspective. Valuation of these small changes nevertheless results in the same order of magnitude of changes as other indicators would result in.

6 ACKNOWLEDGEMENTS

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Table 4: Questions used in the Brenner Pass questionnaire.

nr.	Question
32	When you think about the past 12 months, how would you assess your general health status? (very good, good, acceptable, less good, bad)
33, 34	Do you suffer from a chronical disease? If yes, does this illness influence your daily work / activities? (extremely, strongly, moderately, a little, not at all)
28 a	How often do you feel during your housework disturbed by Noise? (never, seldom, sometimes, mostly, always)
28 b	--- by Vibrations? (never, seldom, sometimes, mostly, always)
28 c	--- by Odour/exhaust fumes? (never, seldom, sometimes, mostly, always)
28 d	--- by Dust/dirt? (never, seldom, sometimes, mostly, always)
28 e	--- by Heath/cold/dampness? (never, seldom, sometimes, mostly, always)
31 a	How often do you feel at your workplace disturbed by Noise? (never, seldom, sometimes, mostly, always)
31 b	--- by Vibrations? (never, seldom, sometimes, mostly, always)
31 c	--- by Odor/exhaust fumes? (never, seldom, sometimes, mostly, always)
31 d	--- by Dust/dirt? (never, seldom, sometimes, mostly, always)
31 e	--- by Heath/cold/dampness? (never, seldom, sometimes, mostly, always)
30	Do you work: 2 shifts during the day/ also during the night (22h-06h)/ on Saturday or Sunday / normal working hours during the day
1a	Please think about your community - Do you have reasons to complain about air pollution? (not at all, lesser, sizeable, a great many)
1b	--- about noise? (not at all, lesser, sizeable, a great many)
1c	--- about odor? (not at all, lesser, sizeable, a great many)
1d	--- about waste disposal? (not at all, lesser, sizeable, a great many)
1e	--- about landscape deterioration? (not at all, lesser, sizeable, a great many)
1f	--- about the volume of traffic? (not at all, lesser, sizeable, a great many)
1g	--- about industry and small enterprises in your neighborhood? (not at all, lesser, sizeable, a great many)
2a	Please think about your community - How satisfied are you with shopping possibilities? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
2b	--- with variety of (recreational) activities? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
2c	--- with kindergarten and schools? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
2d	--- with public transport? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
3a	Please think about the direct neighborhood (200m) of your house - How satisfied are you with the appearance / the attractiveness of the neighborhood? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
3b	--- with the quality of living in the neighborhood? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
3d	--- with the general safety of the neighborhood? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
3e	--- with the neighborly support in the neighborhood? (very satisfied, quite satisfied, neither satisfied nor unsatisfied, rather unsatisfied, very unsatisfied)
5a	Please give your degree of consent with following statement - In most aspects my life meets my expectations. (completely agree, agree, rather agree, agree nor disagree, rather disagree, disagree, disagree completely)
5b	--- My living situation is perfect. (completely agree, agree, rather agree, agree nor disagree, rather disagree, disagree, disagree completely)
5c	--- I am quite happy with my life. (completely agree, agree, rather agree, agree nor disagree, rather disagree, disagree, disagree completely)
5d	--- Till now, I achieved most of the things in my life that I consider important. (completely agree, agree, rather agree, agree nor disagree, rather disagree, disagree, disagree completely)
5e	--- If I could live my life again, I would hardly change anything. (completely agree, agree, rather agree, agree nor disagree, rather disagree, disagree, disagree completely)

CN7: The Effectiveness of Community Noise Reduction/Noise Mitigation Techniques

09:20–12:00 • ROOM: Kauai

CHAIRS:
Irene van Kamp, Netherlands
Hideki Tachibana, Japan

09:20–09:40

604...*Invited*

Putting noise impact into the broader context of sustainable development

Dick Botteldooren
Department of Information Technology, Ghent University, Belgium

Additional Authors: Peter Lercher

Environmental impact assessment (EIA) of larger projects is a multidisciplinary process. Noise impacts such as annoyance, sleep disturbance, blood-pressure related illness, mental health, or even the reduction of quiet areas are an integral part of the EIA. In the overall assessment, they have to be contrasted to other benefits and costs. In this paper, we discuss the translation of the concept of sustainable development to noise impact. The concepts of equity and efficiency will be explored using the concept of sound utilization space. Methods based on exploring alternatives for the future society are considered. This leads us to a number of classical methods to put noise impact in this broader context: DALY, monetarisation, but also to new ideas on using indicators for quality of life and perceived well-being. These concepts were used for the impact assessment of the Brenner Basis Tunnel project. Results from this EIA will be used to illustrate the pros and cons of several techniques. In particular, this paper also compares effect prediction and effect weighting based on exposure effect relationships and weights extracted from a multitude of international studies on one hand and from local relationships based on social surveys on the other hand.

09:40–10:00

779...*Invited*

Noise-mitigation efficiency of barriers

Mats E. Nilsson
Stockholm University, Sweden

Additional Authors: Birgitta Berglund

To create acceptable sound environments in residential areas along heavily traveled main roads and railways, a common procedure is to improve facade insulation. The environmental target is to reduce the sound levels of traffic noise indoors with windows closed. Shielding barriers or shielding buildings would also reduce sound levels outdoors and indoors with open windows. A conventional noise barrier was found to reduce the sound level as well as residents' noise annoyance outdoors and indoors up to distances of 100 m to a main road and residents' disturbances of speech communication outdoors up to 75 m. The extent of annoyance indoors, but not outdoors, agreed well with published synthesized annoyance curves. The outdoor annoyance was higher than stipulated by the curves. Shielding of road traffic noise by buildings reduces the sound level and changes the frequency spectrum. Outdoor differences of 15 dB between exposed and shielded sides of highly exposed buildings would correspond to approximately a 10 dB difference in residents' loudness. It is concluded that noise-mitigation efficiency of barriers and shielding buildings is overestimated if assessed only as sound level reduction. Complementary measures are necessary that take into account the change in qualitative content of the sound environment.

10:00–10:20

838...*Invited*

A longitudinal study of response to nighttime traffic load

A.L. Brown
Griffith University, Australia

Traffic management was undertaken to reduce trucks using an urban corridor. The traffic management strategy was such that it could only affect the night-time truck flows on the corridor; truck traffic in the day-time hours, and other vehicle traffic at all hours, would remain unchanged. A longitudinal panel study was used to measure residents' response to the change. This provides an experimental setting in which to examine community response to a changed noise environment. The change was in one component of residents' noise exposure only - their night-time traffic noise load - and they remained exposed to otherwise daily high levels of noise exposure. The panel study showed highly significant and enduring reductions in resident annoyance with noise - both for night-time annoyance and for overall annoyance. This was remarkable given that reductions in the frequency of truck movements at night proved to be relatively small, and conventional measures of their road traffic noise exposure (eg L_{eq}) remained unchanged. This suggests strongly that communities benefit far more from small reductions in night-time truck flows (hence small reductions in night-time noise events from heavy vehicles) than would be predicted from the resultant changes in conventional noise exposure measures.

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