LA MARGINALIDAD DEL RUIDO ASOCIADO AL TRANSPORTE EN LA METODOLOGÍA DE ANÁLISIS DE CICLO DE VIDA

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Abstract

The Life Cycle Assessment (LCA) methodology is a comprehensive environmental impact assessment tool whose aim is to evaluate the most relevant environmental impacts of a product or service along its life cycle. However, LCA studies often fail to include some of the largest impacts of the product system under study. Such is the case of transport noise: despite being a major source of discomfort whose significance can be likened to that of other forms of environmental pollution, it is often neglected in LCA studies.

In this study, the causes for the marginality of transport noise in LCA are analyzed. Most of these causes stem from the special characteristics of noise as a pollutant (not just traffic noise but also noise from any other source), which are briefly discussed. The clash of these peculiarities with the limitations of LCA is thought to have seriously hindered the inclusion of noise within LCA.

The special characteristics of noise as a pollutant (site-dependency of impacts, human perception issues, non-linearity of impacts and limited availability of data) that have hindered the inclusion of noise within LCA appear to justify a specific treatment within the LCA framework to better accommodate the assessment of its impacts.

Keywords: *traffic noise; LCA; annoyance; environmental impact*

Resumen

El Análisis del Ciclo de Vida (ACV) es una herramienta de evaluación de impacto ambiental cuyo objetivo es evaluar los impactos ambientales más relevantes de un producto o servicio a lo largo de su ciclo de vida. Sin embargo, los estudios de ACV a menudo descuidan impactos importantes asociados al sistema-producto. Tal es el caso de ruido del transporte: a pesar de ser una importante fuente de malestar, cuya importancia puede compararse a la de otras formas de contaminación ambiental, es sistemáticamente marginado en los estudios de ACV.

Este estudio analiza las causas de la marginalidad del ruido del transporte en el LCA. La mayoría de estas causas se derivan de sus características especiales como contaminante (no sólo el ruido del tráfico, sino también de cualquier otra fuente), que se comentan brevemente. Se sostiene que el choque de estas particularidades con las limitaciones del ACV ha obstaculizado seriamente la inclusión de ruido dentro de la LCA.

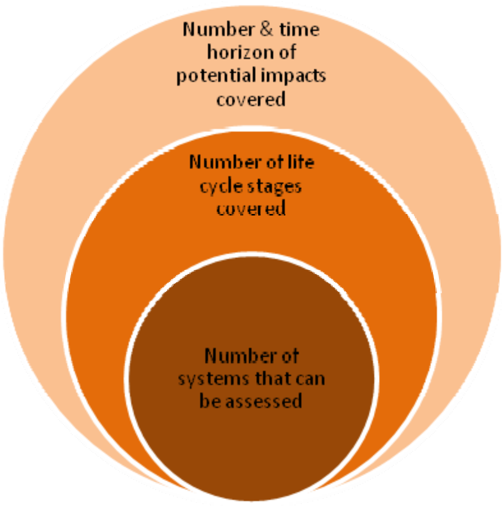
Las características especiales del ruido como contaminante (dependencia espacio-temporal de los impactos, cuestiones de la percepción humana, no linealidad de los impactos y disponibilidad limitada de datos) parecen justificar un tratamiento específico en el marco de ACV se adapten mejor a la evaluación de sus impactos.

Palabras clave: *ruido del tráfico; ACV; molestia; impacto ambiental*

1. Introduction. Overview of the LCA methodology

The Life Cycle Assessment (LCA) methodology (sometimes also referred to as Life Cycle Analysis, ecobalance or cradle-to-grave analysis) is one of the most widespread environmental assessment tools. In the ISO 14040 standard (ISO 2006), LCA is defined as the 'compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle'. The adoption of a life cycle approach means that (ideally) all the relevant impacts of the system under assessment should be taken into account, covering from the extraction of resources through to the production of raw materials, manufacturing, transport, use, maintenance and management at the end of life (reuse, recycling or final disposal). Comprehensiveness is therefore a defining trait of the LCA methodology (see Figure 1), not only because it can be applied to all sorts of product systems –not limited to manufactured goods, but also services- but also because it intended to evaluate all of the environmental burdens of the system under study with a long time horizon and in as many stages of its life cycle as possible. Through the use of LCA, the composition and amounts of pollutants generated by a system can be evaluated regarding their potential environmental impacts. Environmental impacts are subsequently grouped in a reduced set of environmental impact categories, of which noise is an example. Usual impact categories covered in LCA studies include global warming, acidification, eutrophication or fossil fuel depletion.

Figure 1: Comprehensiveness is built into LCA



LCA is a valuable instrument for both governments –as it can guide environmental policing and contribute to more objective decision-making- and corporations–where it is used to identify environmental hotspots, optimize the use of resources and waste management

(Wrisberg *et al.* 1997)-. One of the main benefits of the life cycle approach is the avoidance of **problem shifting** (Guinée *et al.* 2001), which is the process whereby a given environmental burden of a system is either transformed into another, or transferred from one life cycle stage or geographical location to another, thus creating the impression that an environmental benefit has been attained (e.g. hybrid vehicles are perceived as being more environmentally friendly because they burn less fuel during their use stage, but they incorporate batteries that produce an environmental impact upon manufacturing or recycling).

Another one of the virtues of LCA is that it is not a fixed methodology, in the sense that there is not a single valid way to perform an assessment. In fact, LCA practitioners are often presented with several alternative choices when dealing with specific aspects of assessments. These situations have to be sorted out using research and scientific methods, and the choices made will have to be properly documented and justified.

2. Environmental noise

Environmental noise is unwanted sound that negatively affects human activities. This type of noise pollution is a major source of discomfort that is commonly experienced worldwide in outdoor living areas, inside dwellings, at the workplace, in classrooms or hospitals.

A study conducted in 1994 (Lambert & Vallet 1994) estimated that roughly 77 million people in the EU (i.e., 22% of its total population as of 1994) were exposed to a transportation noise level (L_{Aeq}) exceeding 65 dB during the day, which is widely considered unacceptable (Berglund 1999). In 1994, about 49% of Europeans lived in 'gray areas' that did not ensure acoustic comfort to residents and road traffic noise annoyed between 20% and 25% of the population (Lambert & Vallet 1994).

The way that environmental noise is dealt with varies largely across countries, because this is an issue with multiple cultural, economical and political implications. In the past few decades, environmental noise has become a very relevant environmental issue -especially in developed countries- for both policymakers and the general public. Exposure to noise (especially to environmental noise) is on the rise. This is true for both developed and developing regions of the world, and implies that noise exposure will be a major public health problem in the years to come (Passchier-Vermeer & Passchier 2000).

In the decade of the 1990s European institutions placed themselves at the forefront of the battle against environmental by developing a new framework for noise policy that was to be based upon shared responsibility between the EU, national and local level authorities, and including measures to improve the accuracy and standardization of data to help improve the coherency of the joint actions of EU member states. Following the publication of the Green Paper on Future Noise Policy (EC 1996), a comprehensive set of measures -which included the creation of a Noise Expert Network (whose mission is to assist the EC in the development of its noise policy) and, most importantly, the approval of the EC Directive on Environmental Noise (EuP 2002) - were approved.

2.1 Road traffic noise

Road transport of passengers and goods is inextricably associated to human activities. The benefits brought about by road transport towards the economic and social development of modern societies is out of the question. However, it is also true that these benefits come at the expense of adverse public health implications; road transport is known to be a large contributor to air pollution. It is also one of the main sources of It is also arguably the main source of intrusive sound emissions (EEA 2007, Eurostat 1995), both in terms of total sound power emitted and geographical distribution –which is practically akin to that of human population in modern societies. Despite large efforts to fight noise and its undesired consequences, the problem persists even in the developed regions of the world (like Europe) where strict environmental noise regulations have been adopted. Even though technical progress has made the vehicles of today much quieter than they were a few decades ago, this has been offset by the increase in overall traffic flows.

In LCA practice, most system product boundaries can be set in such a way that they include road transport activities at some point of their life cycle. For this reason, it is precisely road traffic noise has been the focus of several studies (Laflèche & Sacchetto 1997, Müller-Wenk 1999, 2002, 2004, Doka 2003) attempting to integrate the impacts of noise within the LCA framework.

2.2 Damages to human health attributable to noise

The effects of noise exposure on humans have been extensively assessed. The sense of hearing is a key warning and communications organ that remains permanently open to the environment, and is unable to deny access to sound stimuli –unlike eyesight, for example-. Thus, sounds from the environment are constantly perceived, whether awake or asleep, and trigger massive stimulation of the nervous system. Noise is thus a major environmental stressor whose effects are not solely psychological or behavioral; they may also be linked to more severe (i.e. somatic) health effects.

In this section, some background information is provided on the health effects that are most commonly related to environmental noise exposure, which are listed in the Guidelines for Community Noise published by WHO (Berglund 1999). Negative impacts of noise upon human health described in the paragraphs that follow include noise-induced hearing impairment, interference with speech communication, disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on residential behavior and annoyance; and interference with intended activities. Other effects for which the evidence is limited, such as changes in the immune system and birth defects (Paschier-Vermeer & Passchier 2000), are not discussed. A more in-depth analysis of annoyance is made of annoyance, since this health effect is taken as the basis for the proposed assessment methodology within the LCA framework.

3. Limitations of LCA in relation to noise assessments

As explained earlier, comprehensiveness is a defining trait of the LCA methodology: its strength comes precisely from the fact that it seeks to cover all the processes related to a system and to evaluate all of their potential environmental effects with a long time horizon and including all relevant environmental categories. Naturally, the all-encompassing nature of LCA means that many simplifications need to be made in order to make LCA workable, leading to a number of methodological limitations (Guinée *et al.* 2001) which may become especially apparent when traffic noise is dealt with within LCA:

- LCA cannot easily address localized impacts. Unlike other material emissions of pollutants that can travel long distances to their end-point, noise emissions are quickly attenuated and their effects disappear quickly after they are removed. The site- and time-dependency of impacts will therefore have to be weighed in.
- LCA has a tendency to regard all processes (and their environmental consequences) as linear. Noise is traditionally measured using a logarithmic scale, which poses few problems for acousticians and the like. However, this is a frequent source of trouble for

LCA practitioners –and also a serious one- which deserves individual discussion later in the text.

- LCA is focused on the environmental aspects of products, and typically disregards social, economic and other implications. Noise is a paradigmatic example of an environmental issue with multiple, intertwining implications in matters that range from public health to infrastructure planning or the way that leisure activities are carried out. This means that only a limited number of aspects can be covered in the assessments, and these should be selected carefully.
- LCA is science-based, but it involves a number of technical assumptions and value choices. Noise is no exception in this case, notably when it comes to the selection of noise indicators; even though noise could be described using many parameters (e.g. duration, loudness, frequency contents, intermittence, etc.), in practice only a few standardized noise metrics are used.
- LCA is limited by the availability of data. More often than not, data are unavailable, obsolete, non-comparable or of unknown quality. In the case of noise, the scarcity of data is usually the biggest problem LCA practitioners are faced with.

3.1 Potential causes for the marginality of noise in LCA

In this paper, the causes for the marginality of noise in LCA are analyzed. Most of these causes stem from the special characteristics of noise as a pollutant (not just traffic noise but also noise from any other source), which are briefly discussed. The clash of these peculiarities with the limitations of LCA is thought to have seriously hindered the inclusion of noise within LCA.

Non-linearities

Sound is created by local variations in pressure that propagate through a physical medium. These variations are perceived by the human auditory system in a very wide range. The threshold of hearing –that is, the smallest variation in air pressure that can be recognized by an average person- is conventionally set at 20 µPa. A sound pressure of approximately 100 Pa is so loud that it causes a strong feeling of discomfort and is often referred to as the threshold of pain.

Since the ration between the threshold of hearing and the threshold of pain is more than a million to one, it is apparent that direct application of linear scales (i.e., expressing noise quantities in Pa) would lead to unmanageable, awkward numbers. Moreover, because the human auditory system responds in a roughly logarithmical manner rather than linearly to noise stimuli, it is much more practical to express acoustic parameters as a logarithmic ratio of the measured value to a reference value. The unit of this logarithmic ratio is called the decibel or dB. Using a logarithmic scale instead of a linear one means that acoustic quantities are converted into a manageable scale where 0 dB corresponds with the threshold of hearing, and 130 dB is the threshold of pain. However, this brings a number of complications when dealing with noise in the context of LCA studies, which are discussed next.

Non-linearity of noise emissions/impacts

Quite possibly, the largest source of complications for the inclusion of noise impacts within LCA derives from the fact that noise is customarily expressed in decibels (dB), i.e. using a logarithmic scale. This is a very serious drawback (if one takes into account that the LCA methodology was devised to deal with linear impacts) because logarithmic quantities are not linearly additive. Rather, noise emissions are to be summated logarithmically as per Equation 1 (hence, the combined emission of two sources emitting 64 and 70 dB respectively would not be 134 dB, but rather 71 dB approx.). This applies to instantaneous noise emissions and equivalent (i.e., time-averaged) noise levels alike. Moreover, in the case of equivalent emissions, it applies regardless of whether noise emissions take place in simultaneous, sequential or random fashion (the latter being the case of traffic).

$$L_{combined} = 10 \cdot log_{10} \sum_i 10^{L_i/_{10}} \quad (1)$$

Adopting an incremental approach to noise assessments (that is, assessing just the effects caused by increases in traffic noise emissions which are directly attributed or allocated to the product system under study) has many benefits from an LCA viewpoint, but it does not help to overcome the difficulties posed by the non-linearities of noise emissions. Earlier methodologies for the assessment of traffic noise within LCA -most prominently, that of Müller-Wenk (Müller-Wenk 1999, 2002, 2004) – overlook this effect with the argument that it has a negligible impact in the accuracy of calculations. This holds relatively true when the increments in traffic flows considered are very small, but can lead to imprecision in other cases.

Finally, it must be noted that, even humans perceive noise in an approximately logarithmic manner, the way that humans respond to noise exposure (specifically regarding self-reported annoyance) is not exactly linear.

Effects of background noise/initial traffic upon calculations

Another particularity of noise as a pollutant lies in the key influence of background noise. The outcome of addition of a noise source in overall noise levels will have different effects depending on background noise. Adding a noise source to a quiet environment will lead to high increments of noise levels, while high levels of background noise will mask the effect of adding the same source.

This phenomenon is illustrated (for a traffic noise situation) in Figure 2, where the variations in equivalent noise emission levels due to equal increments in traffic flows (one vehicle per unit time) are represented for different initial traffic flows (which are responsible for background noise). In said figure, it can be observed that the increments in noise levels due to the addition of one vehicle per unit become increasingly smaller as initial traffic flows grow larger.

The relevance of this effect to the proper inclusion of the impacts of traffic noise within LCA studies is very high and should not be overlooked. A notable methodological limitation arising from it is that the assessments should be restricted to those situations where one type of noise source clearly predominates.

An especially controversial practice is the development and use within LCA studies of **generic impact factors** (i.e. factors calculated to give the environmental impact of driving one additional vehicle-kilometer) to be applied in any traffic situation; due to the aforementioned nonlinearities, it is not possible to accurately predict the increase in equivalent noise levels due to any increase in vehicle flows using a single, constant factor because it leads to a high level of uncertainty in the results (note the variation in the computed L_{eq} increments per additional vehicle per unit time in Figure 3).

Figure 2: Variations in overall Leq increments due to a one-vehicle-per-unit-time increment in vehicle flow occurring for different initial vehicle flows

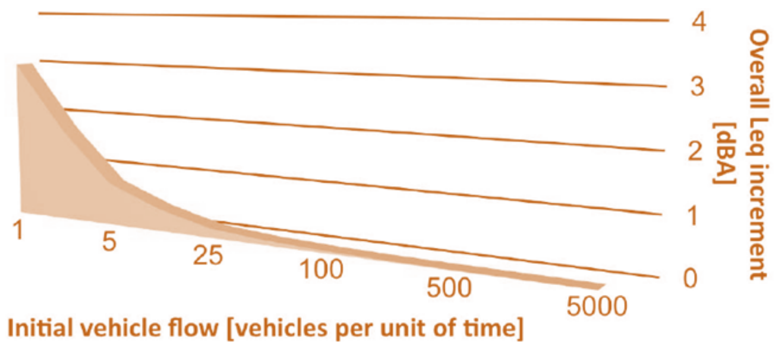
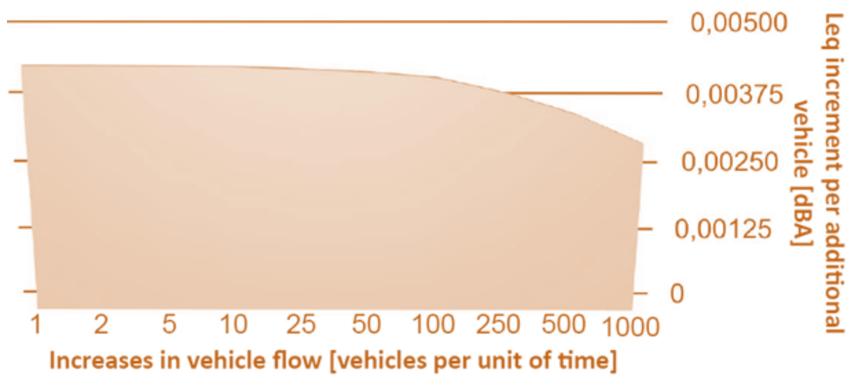


Figure 3: Computed Leq increments per additional vehicle per unit time for different increases in vehicle flows (initial vehicle flow is 1000 vehicles per unit time)



Site dependency

Another distinguishing trait of noise is that, unlike other types of pollution typically included in LCA studies (namely atmospheric pollutants that can travel very long distance), noise emission have a very localized nature, their impact being restricted to relatively small areas near the emission sources. This results in a greater influence of site-related parameters in noise assessment, as compared with other environmental impact categories that rely on site-independent toxicological and ecotoxicological studies (SETAC 1993, Guinée *et al.* 2001).

A problematic issue derived from this circumstance is that measured noise levels only refer to a specific point of measurement, with exposure levels that vary greatly along moderately short distances. This, coupled to the fact that the medium where noise propagates (i.e. ambient air) changes its properties through space, seems to suggest that the incorporation of some sort of propagation model –albeit a simplified one- is inevitable.

Furthermore, the impact of noise emissions is directly linked to the number of people affected by them. A key requirement for attaining a valid assessment methodology is to adequately estimate the varying population density figures in the areas affected by the product system under study.

Time dependency

Many noise emissions vary greatly with time, and their impacts are accordingly time-dependent. This is especially true for road traffic; typically most trips will take place during the day rather than at night time, and some periods of the day are distinctive *rush hours*. At the same time, some of the most serious health effects attributable to noise only become noticeable after long-term exposure to significant noise levels. Therefore, great care must be exercised to select the appropriate noise metrics in order to take temporal variations into account. Also, the choice health effects used to perform the assessments is crucially important. As will be explained later in the text, equivalent (i.e. time-averaged) noise levels and self-reported annoyance –which is a long-term indicator for the effects of noise exposure- will be the preferred noise descriptors and health effect to be used for the inclusion of road traffic noise in LCA studies.

Human perception issues/psychological factors

There exist a number of issues related to human perception and psychological factors that set noise apart from most forms of pollution. These are briefly discussed next.

Human perception issues

Not every type of noise is perceived alike. Besides the influence of background noise there are other issues related to the human perception of noise. Noise perception acuity varies across the audible range. Healthy individuals have greater auditory sensitivity in the central frequencies of the audible range, and are less responsive to low and high frequencies. For that reason, noise measurements are often frequency-weighted, meaning that critical frequencies are weighed. The frequency weighting that is most commonly applied is the so-called **A-weighting**, which is meant to mimic the average human ear response to noise stimuli. This frequency weighting characteristic is technically defined in the IEC 61672-1 standard (IEC 2005), and it is built into the logic boards of virtually every modern sound meter because the majority of noise regulations require that it be applied to the environmental measurements and used in reports.

Moreover, noises with tonal content (that is, noises featuring pressure peaks in localized, narrow frequency bands which translate into buzzing sounds) are more annoying than noises with a more homogenous frequency content (ISO 1987), and they are accordingly penalized in environmental noise regulations (usually by adding a 3 to 5 dB penalty to the measured level when pure tones are identified). The same is true for impact noise (featuring unusually high peaks) or repetitive noise (the proverbial dripping faucet that will not let one sleep).

Another significant perception issue (which could arguably be classified as a psychological factor as well) regarding environmental noise is that the same type of noise emission will be reported as more annoying if it takes place during the evening or at night rather than during the daytime, even after the influence of background noise is excluded. This has to do with the different intended activities for different time periods (quietness is expected at night and also in the evening, which makes any unwanted sound more irritating). In general terms, noise is more annoying to the receiver when it is perceived not to fit with current intentions (e.g. the loud music that is ruining the neighbor's yoga session is perfectly acceptable to the party-goers upstairs). It has also been argued that health effects of noise may be mediated by reactions to noise such as annoyance and dissatisfaction; evidence would suggest that negative subjective reactions to noise predict health outcomes over and above the prediction available from noise exposure itself (Job 1997).

Psychological and cultural factors

Another possible explanation for the lack of interest elicited by environmental noise studies within LCA may be associated with psychological and cultural factors. Environmental noise –especially traffic noise- is such constant presence that it ends up being accepted as an inevitable tradeoff for general economic and technical progress. It should also be taken into account that the diffuse nature of the impacts of noise discourages further research on the matter.

Other causes for the marginality of noise in LCA

Last but not least, the marginality of noise in the LCA methodology may find other causes in the fact that the foundations of modern LCA practice were set (SETAC 1993) by individuals whose scientific background was in toxicology and chemistry and who did not initially have environmental noise in mind. In this way, a certain negative bias towards noise is to be found at the core of LCA. The fact that numerous LCA practitioners share this type of background certainly does not help either, but this has been no obstacle for the development of a number of interesting methodologies that will be reviewed next.

3.2 Modeling health damages of noise

We have shown that noise can induce a large number of health effects. A **health damage model** is required in order to measure the damages of traffic noise upon human health (or, for that matter, the damages caused by any type of environmental pollution). Said model will be used able to predict the health burdens associated with different levels of exposure to traffic noise.

Measurement of impacts to human health. DALY units

DALYs (Disability-Adjusted Life Years) are a unit of measure of impacts upon human health. The DALY framework was developed by the WHO (Murray & Lopez 1996) to make large-scale assessments of the overall health status of large populations, as well as to establish science-based public health policies.

DALYs can be defined as '*a time based measure which adds together years of life lost due to premature mortality with the equivalent number of years of life lived with disability or illness*' (Lopez *et al.* 2006) (Equation 2).

$$DALY = YOLL + YLD \quad (2)$$

The DALY scale is thus an aggregate of fatal and non-fatal human health impairments. The health burden due to fatal disease is accounted for with the years of life lost (YOLL), i.e. the difference between the age of the deceased person and the probable life expectancy (in absence of disease). Non-fatal diseases (morbidity) are computed using the years lived with disease (YLD); each disease has a severity weighting or disability weight (DW) ranging between zero and one, where zero is perfect health and one is death. The DW is thus a conversion factor for health impacts. DW values –which are estimated by expert panels-, express the health impairment attributed to a disease.

Disability weights are listed in tables published by the WHO that weigh the relative importance of a health condition with respect to death. For example, an individual living ten years with a non-fatal disease having a DW of 0.5 will lose 5 DALY.

DALYs can be used outside health policing contexts to estimate how many life-years are lost due to premature death or lived with an impaired health status. DALYs were first introduced in LCA studies with the Eco-indicator'99 method (Goedkoop & Spriensma 1999).

Annoyance curves

A number of dose-response functions have been developed for noise exposure. Most of these relate long-term noise exposure levels to annoyance levels. In 1978, Schultz (Schultz 1978) used data from several social surveys to synthesize a relationship between community noise exposure and the prevalence of annoyance. This relationship was updated in 1991 by Fidell et al. (Fidell *et al.* 1991) using the findings of social surveys conducted since the publication of Schultz's curve. The 1978 relationship provided a good fit to new data, and so this type quantitative dosage–effect relationship has been adopted as a standard way of predicting noise-induced annoyance. This dose-effect function relating environmental noise level exposure and annoyance was subsequently updated in (Miedema & Vos 1998, 1999).

The most recent of such dose-effect functions are found in (Miedema & Oudshoorn 2001). In these study, dose-response functions were obtained to relate L_{DEN} exposure levels (as measured at the most exposed façade of dwellings) to self-reported (i.e. drawn from surveys) annoyance. These dose-response curves were derived from a large international archive of noise annoyance studies covering about 60,000 people exposed to environmental noise (Miedema & Oudshoorn 2001).

Annoyance as a primary indicator of noise impacts within LCA

In previous methodologies aimed at assessing road transport noise within LCA (Doka 2003; Müller-Wenk 1999, 2002, 2004), the impacts were totaled in terms of DALY. However, the benefits of this approach-a solid conceptual framework for DALY units, the possibility of aggregation with other human health impacts-are somewhat diluted when dealing with noise, partly due to the unique characteristics of noise as a pollutant: unlike CO_2, for instance, noise emissions ought to be attached to particular spatial and temporal coordinates in order to become truly meaningful. Moreover, the different attitudes of receivers towards noise are a relevant input that should be factored in. This triple dependency –for site, time, and receiver-arguably justifies the adoption of a particular treatment within LCA. It also has major implications in the selection of indicators. Self-reported community annoyance is proposed herein due to the following reasons:

- **Prevalence**: of all health effects of environmental noise described in the literature, annoyance –followed by sleep disturbance- is the most widespread (EuP 2002, Berglund 1999).
- **Quality of dose-response functions**: While the relationship between annoyance and environmental noise seems solidly established, the same cannot be said about other non-auditory health effects (Babisch 2005, Maschke 2002), excluding sleep disturbance.
- **Antecedence/concomitance with other impacts**: noise acts as an environmental stressor (Miedema 2007) with effects ranging from mild annoyance to increased risk of myocardial infarction. As far as the more severe effects are concerned, causality links are difficult to establish because they are usually the consequence of a large number of factors (not only environmental, but also genetic or behavioral) which are difficult to isolate. It seems plausible, however, to assume that there is a certain relationship of antecedence and concomitance between annoyance (and also sleep disturbance) and the more severe health effects of environmental noise: annoyance precedes the onset of the more serious health effects and accompanies them; it could hardly be argued, e.g., that an individual whose immune system were significantly affected by environmental noise would not report to be annoyed by noise. Thus, annoyance could be thought of as a proxy indicator (a 'signal flag') for more severe health effects. Also, by choosing an indicator that measures one of the lesser—yet the most widespread and thoroughly described—consequences of exposure to environmental noise, a conservative, preventive stance is built into assessments.

- **Intelligibility***:* Since noise annoyance is so commonly experienced, it is much more easily understood by non-experts than the complex rationale behind DALY units, thus rendering it a valuable indicator to support decision-making or present assessment results to the general public. The superior intelligibility of annoyance (as compared to DALY) is further supported by the fact that it prominently featured by the EC Directive on Environmental Noise as an indicator of the impact of environmental noise.

4. Conclusions

Noise may well be one of the most pervasive issues affecting human well-being and yet it is largely ignored in everyday LCA practice. The special characteristics of noise as a pollutant (relevance of spatial data, human perception issues) appear to justify the adoption of a distinct indicator, namely 'number of annoyed persons'. Incorporating annoyance as the preferred indicator for the impact of traffic noise upon human health is thought to make assessment results more intelligible and readily applicable to decision making in matters like infrastructure policing and urban planning, whilst placing the focus on damage prevention.

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