Perceived quality of the living environment and noise

Luc Dekoninck[1], Dominique Gillis[2], Dick Botteldooren[3]

[1] INTEC - Acoustics Group, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium, luc.dekoninck@intec.ugent.be

[2] Department for Mobility and Spatial Planning, Ghent University, Vrijdagmarkt 10/301, B-9000 Gent, Belgium, dominique.gillis@ugent.be

[3] INTEC - Acoustics Group, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium, dick.botteldooren@ugent.be

INTRODUCTION

In those regions of the world where primary living conditions are good and basic needs are easily fulfilled, the perceived quality of the local living environment is of growing concern. Traffic has an important impact on this perceived quality of the local living environment and as such also on the mental well-being of the population (Guite et al., 2006). Traffic influences the life of people in different ways: on the one hand, traffic is inevitable to guarantee accessibility to various types of functions, on the other hand, traffic noise, traffic emissions, road safety, etc. threaten health and well-being. Assessing this complex interplay requires a set of indicators (Botteldooren and Lercher, 2006) and suitable aggregation models (Botteldooren et al., 2006). It was previously noted that environmental sound plays an important role (Botteldooren et al., 2011) in the perceived quality of the living environment both in a positive and a negative way and therefore several of these indicators may be related to environmental sound.

Existing models tend to evaluate traffic liveability at specific dwelling locations on the basis of the characteristics of the nearest street (road width, bicycle facilities, etc.) and its traffic (e.g. traffic flow, traffic speed). The living environment is however not limited to the house and garden. Subjective assessment of the sonic environment may include the wider neighbourhood (Klaboe et al., 2005) or relax the adverse effect at home (Gidlof-Gunnarsson, A. and Ohrstrom, E. 2007). The effect of exposure during trips is even more pronounced for air quality where it was shown that in some cases the majority of exposure to air pollution and in particular to fine and ultrafine particles occurred while away from home (Int Panis et al., 2010). A model capable of quantifying the quality of the living environment should therefore not only take into account the dwelling but also the routes giving access to the dwelling and the nearby public space. For some aspects it may even be required to include an assessment of usual destinations such as the work environment.

Based on the above observations a model was designed by first unravelling the constituents of quality of life and then focussing on the factors that might be influenced by traffic – the result is sometimes referred to as traffic liveability. Then a methodology is proposed that has as a main focus to achieve a better quantification of exposure to different types of traffic impacts by including not only the exposure at the home address, but also the impacts during activities at other locations and the impacts during trips.

In this paper the proposed model is briefly described, before presenting some of the first results for the case-study of Ghent.

MODEL DESCRIPTION

Selection of an indicator set for 'traffic livability'

Existing methods split down the 'traffic livability' into the separate impacts, and define a set of indicators for each of them. As these indicators are usually assessed separately or at most aggregated by source, combined effects are not included in a straight forward way and neither is distributed exposure. The proposed model puts the person at the centre of the picture. Quality of life or well-being is explored and unravelled in basic components. By focussing on the role of the living environment and more specifically on the effect of traffic in it, a traffic liveability indicator is obtained. It has four components: accessibility of basic functions, health impact (traffic emissions, sleep disturbance, ...), effects on the living environment (noise annoyance, visual impact, ...) and effects on the social functioning of the neighbourhood (barrier effects). Each component is divided into some partial effects with their own specific indicators (Figure 1). Measuring traffic livability is realized by measuring the indicators and aggregating them to a global score.

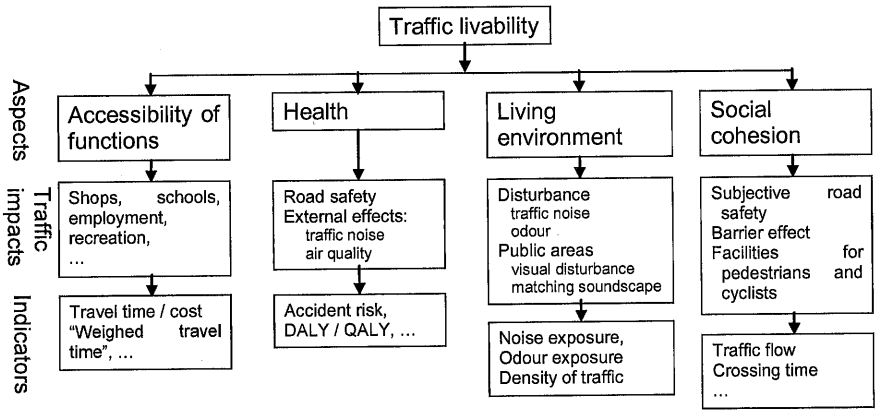


Figure 1: Definition of traffic livability, containing several types of traffic impacts, each with their own indicators

For the aggregation from the separate indicators to an appreciation of each aspect, and from the aspects to a global traffic livability evaluation, the Choquet integration is applied (Botteldooren et al., 2006). This method makes a weighted sum, giving most weight to the strongest components. This simulates human perception, as one extreme (positive or negative) aspect will dominate the perception and will rarely be compensated by one or more moderately good or bad criteria. This way, the model combines advantages from a weighted sum and a strongest component aggregation.

Methodology for the evaluation of the indicators

Rather than to assess the quality of the living environment using a dwelling based approach, the individual is used as a starting point. This implies the following choices:

- Traffic livability is measured by means of a broad set of indicators, representing different types of traffic impacts (accessibility, traffic noise, traffic emissions, ...). As such combined effects, positive and negative, are automatically included in the methodology.

- The evaluation is not done for an average person, but takes into account individual needs and travel patterns, sampled from the Flemish large-scale trip survey. This means that personal characteristics (age, marital status, professional activities, ...) and family characteristics (number and age of children, car availability, ...) and the consequent diverse mobility needs, are incorporated in the evaluation.
- The methodology reflects the daily activity pattern and trip pattern. Beside the traffic impacts at home, also the effects during the trips and at the destinations are included in the evaluation. This means that the evaluation of traffic livability covers the complete living neighbourhood, rather than limiting it to the dwelling itself or the street it is located in.

The trip behaviour survey

A major input to the model is the statistical trip behaviour of the population under study. For the area under study, the Flemish Trip Behaviour Survey (Onderzoek VerplaatsingsGedrag, OVG), a large scale survey collecting trip data by means of trip diaries covering the whole of Flanders, is used. The survey data consist of three data sets containing the family characteristics, the person characteristics and the personal trip data. The survey has been executed in 1994-1995 (OVG-1), in 2000-2001 (OVG-2) and in 2007-2008 (OVG-3) (Ministerie van de Vlaamse Gemeenschap, 1996, 2004, 2009).

OVG-1 and OVG-2 used the 'family' as basic entity. The surveys covered 2.500 families each, surveying all family members, representing about 8.000 persons. The methodology in this paper was elaborated using the data from these surveys. In the most recent trip survey OVG-3 the methodology was slightly modified: the survey now used 'persons' as the basic entity. It was therefore not used in the model.

Evaluation of the indicators by sampling the trip behaviour

As explained, the model starts from a person and all the trips it makes, the modes it uses and the destinations these trips lead to. As this information is not available on a person by person basis, a Monte Carlo simulation is used sampling random families and/or persons from the trip behaviour survey. The proposed methodology involves the following steps:

- First of all, a random household is sampled from the trip database. In the database a large set of characteristics are available about the household (composition, car availability, ...), its members (age, income, ...) and their daily trips (number, purpose, distance, ...). These parameters can be taken into account during the later evaluation, to simulate specific desires and appreciations. In the current stage this sampling is done completely random, but in a later stage some specific parameters could be taken into account to sample for example younger or older families, larger or smaller families, rather mediated or not, etc. according to the neighbourhood characteristics.
- For all the trips that are reported by this household, the next step is to select a logical destination. This destination is again sampled from a database of possible destinations per trip purpose. For school trips for example one of the schools in the area will be selected, for shopping trips one of the shops. GIS layers containing these data need to be collected for the area under study.

- For the collected trips, travel modes and destinations, the third step is to calculate a logical route from the dwelling to the destination. A standard route finding method can be used for this.
- Knowing the house location, destination locations, routes and transportation modes of all the trips and activities of each household member, it is possible to evaluate the effect traffic has on this person's life, health, and well being including these whereabouts.

By sampling a sufficient number of dwellings per street segment (or a sufficient number of households per dwelling), this method results in an aggregated perception of traffic livability, representing a realistic variety of activity patterns and transportation needs and covering the complete living space of the population, rather than just the dwelling location.

Estimating the demand for local traffic

As a by product of the trip model, the routes of all local car trips, bicycle trips and pedestrian trips can be totalized to an estimation for the local traffic generation by car, by bicycle and on foot.

For car traffic, this local traffic can be a valuable addition to the existing macroscopic traffic models, which focus on the main roads, and therefore lack detail about the local traffic on minor streets. This allows for a more accurate estimate of noise and air pollution levels in the urban area.

For bicycles and pedestrians, the method allows the estimation of the intensity and routes of the local bicycle and pedestrian flows, based on the local needs and destinations. This is important information for the evaluation of network quality.

CASE-STUDY FOR THE CITY OF GHENT

Area under study

The case study focuses on the city of Ghent, a 230 000 inhabitant city in Belgium. The study area includes the city centre as well as the surrounding suburbs. This ensures that different types of areas (more dense, more suburban), roads (from highway level, over major roads and ring roads to purely local roads) and livability problems (traffic noise, barrier effect, traffic safety, ...) are included.

Results

By means of some of the intermediate results the operation of the model is illustrated before focussing on the model results.

The fundamental model input consists of a set of GIS-layers concerning the road network (road design, bicycle infrastructure, ...), origin and destination points (dwelling locations, shops, schools, ...). Spatial traffic impacts (traffic noise, air quality, road accidents, ...) can be calculated as part of the model but as they were available, they were not recalculated in this case study. Another major input is the database from the Flemish Travel Behaviour Survey.

In the first part of the model, a household is sampled for each of the dwellings to be evaluated. Using the reported trip behaviour, a set of logical trip destinations is sampled, and the routes for the given travel modes are calculated. This first steps results in maps as shown in Figure 2, showing the simulated trips for two sampled households.

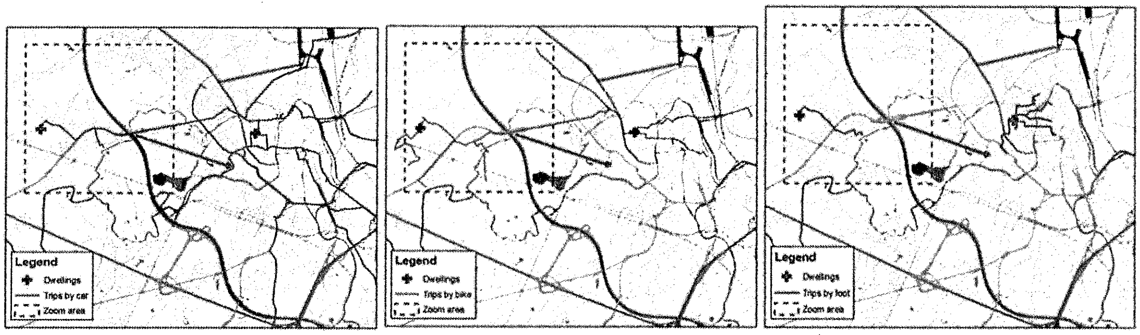


Figure 2: The calculated routes by the sampled households in two dwellings, including the trips by car (left), by bike (middle) and on foot (right)

In the next part of the model, the indicators for traffic livability will be evaluated by means of overlays of these routes with ‘emission layers’ of the different indicators (traffic noise, traffic emissions, traffic safety, ...), considering the dwelling location, the destination location and the route and mode of the trip. This way, a large set of indicators is evaluated, covering several aspects of traffic livability. Each indicator is evaluated for each sampled person living in the area under study. In the following aggregation step, the separate indicators are aggregated thematically. Traffic noise is incorporated in the model in two ways: it has an impact on the “Health” aspect (for the health effects by traffic noise, including sleep disturbance) and on the “Living environment” aspect (for the perceived annoyance by traffic noise).

To present the results in the maps below a spatial average over all families living in a 200 m by 200 m area is calculated.

The evaluation of the health effects takes into account several types of traffic impacts. Figure 2 shows two of them: the health effects of road traffic noise and of traffic emissions. The map shows that the health impact of traffic noise is mainly concentrated in the south of the city, because of the concentration of two highways with the main entrance road to the city centre and the ring road. The map of the health effects of air quality shows that the highest effects are concentrated along the two highways in the south and along the main entrance to the city centre. It also shows a moderate not well localised effect in the city centre which is probably due to exposure during trips.

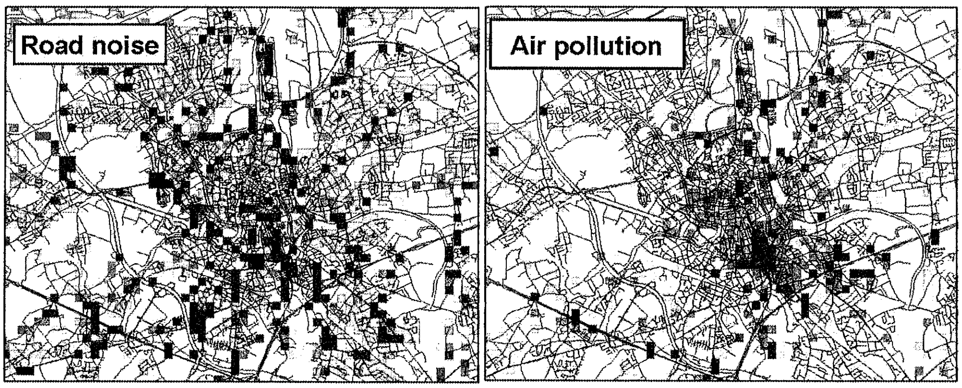


Figure 2: Illustrations of the health effects of traffic: a model plot showing good (green) to bad (red) evaluation of the health impact by road traffic noise (left) and traffic emissions (right)

The indicator "living environment" is mainly influenced by several types of annoyance. Figure 3 shows the annoyance caused by traffic noise and by traffic bustle. Whereas the first includes mainly annoyance at home, the latter also includes the annoyance because of traffic bustle during (the first part of) the trips from home, therefore covering the wider environment of the dwelling. Comparing the two maps, two differences can be observed. On the one hand the highways and main traffic arteries are an important source of traffic noise, but do not appear in relation to traffic bustle as they are not directly accessible from the dwelling. On the other hand many inhabitants live in quiet residential streets, with little annoyance by traffic noise, but do perceive the impact of traffic (bustle) as soon as they leave home (during trips) resulting in a larger area where this aspect of traffic liveability of moderate.

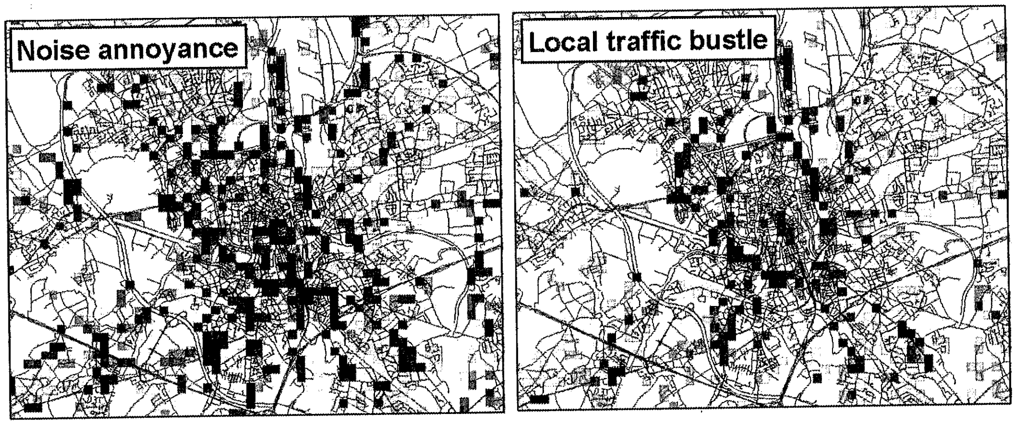


Figure 3: Illustrations of the effects of traffic on the living environment: a model plot showing good (green) to bad (red) evaluation of the annoyance by traffic noise (left) and traffic bustle (right)

The resulting total appreciation of traffic livability is presented in Figure 5. Again some well-known problem areas appear from this plot, such as the inner city ring road, some radial arteries and the highways and railroads passing near the city. As one could expect the overall indicator; less extremes are observed since it seems all neighbourhoods have at least some positive aspects.

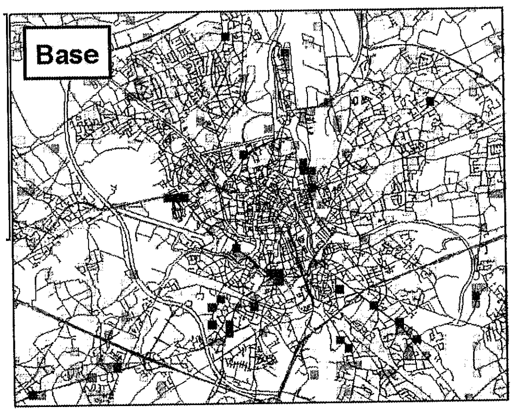


Figure 4: Map of the average traffic livability, green = good, red = bad

Relation to the reported satisfaction

In order to assess the quality of the proposed model, the model results are compared to the data from a Livability Survey (SLO, "Schriftelijk Leefbaarheids-Onderzoek"). This large scale survey asks people from the whole of Flanders –amongst others – to report their appreciation of their living environment on a five point bipolar scale. For the further analysis, only the survey data from the Ghent area are used.

In Figure 6 the resulting traffic livability appreciation from the survey and the model are grouped into five satisfaction classes. Figure 6a shows that the traffic livability model gives a very good reproduction of the reported satisfaction from the SLO-survey: the majority of the people (about 65%) are satisfied to very satisfied (classes 1 and 2) while only 10% states to be dissatisfied or (very) dissatisfied (classes -1 and -2).

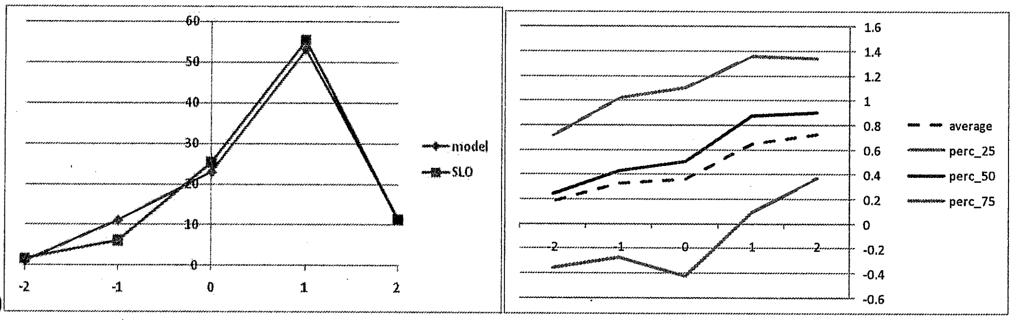
a)  b)

Figure 5: a) Frequency distribution of the traffic livability evaluation according to the traffic livability model and the reported satisfaction in the SLO-survey; b) Relationship between the reported satisfaction from the SLO-survey (x-axis) and the calculated evaluation (y-axis) according to the traffic livability model, showing the average and median value and the 25- and 75-percentile values

For a more detailed comparison of the results, the model results are reduced in order to make both sets geographically comparable. The dwellings of participants of the SLO-surveys are located, and from the model only the simulated persons that are in the immediate vicinity of the SLO-surveys are retained. This guarantees that both datasets represent the same geographical dwelling locations. The model results are split into five classes, according to the reported satisfaction in the corresponding SLO-survey dwelling. This allows comparing the calculated traffic livability to the reported satisfaction. The results are visualized in Figure 6b, where the horizontal axis contains the reported satisfaction (SLO-survey) and the vertical axis shows the statistical indicators of calculated appreciation according the model.

From this comparison it can be concluded that the model reproduces extremely accurately the statistical distribution of reported appreciation of the living environment. On an individual basis, the prediction has to be imprecise because of the random factors involved in reproducing the trips and route choice.This explains the large spread in Figure 6b. The average trend between reported and modelled quality of the living environment is however still monotonous.

CONCLUSIONS

In this paper, an innovating model is presented for objectively assessing traffic livability. Whereas classic methods focus on the traffic impacts at the dwelling location, the proposed method puts the person in the centre and incorporates the whole activity pattern, and the corresponding trip behaviour in the evaluation. This is reached by a Monte Carlo simulation of households, including their reported trip behaviour, according to a trip behaviour survey.

By construction, the model should outperform other approaches because it includes known effects such as the influence of the wider neighbourhood or exposure to air pollution during trips. The model accounts for positive as well as negative effects of traffic and in particular it accounts for them at the level of an individual. Combined exposure is accounted for on a trip by trip basis and saturation effects are accounted for on a person by person basis because of the Choquet integral used in the aggregation. Thus it can be expected that the non-physiologic part of effects of combined exposure is accounted for.

Application of the traffic livability model in a case-study for the city of Ghent, shows that the model offers a realistic reproduction of the reported satisfaction with the living environment obtained from a Flemish livability survey on a statistical level. The model is not suitable for predicting an individual's appreciation of the living environment since trip behaviour and choice of destinations is only included on a statistical basis.

The model can be used to evaluate a set of policy scenarios that affect infrastructure, traffic management, land use, or even personal behaviour.

REFERENCES

Botteldooren D, Lercher P (2006). Putting noise annoyance in the broader context of sustainable development. In: Proceedings of the 35th International Congress and Exposition on Noise Control Engineering (Inter-Noise 2006) Honolulu, Hawaii, 03-06 December 2006.

Botteldooren D, Verkeyn A, De Baets B et al. (2006). Fuzzy integrals as a tool for obtaining an indicator for quality of life. In: Proceedings of the IEEE World Congress on Computational Intelligence (WCCI), Vancouver, Canada.

Botteldooren D, Dekoninck L, Gillis D (2011). The influence of traffic noise on appreciation of the living quality of a neighborhood. Int J Environ Res Public Health 8: 777-798.

Gidlof-Gunnarsson A, Ohrstrom E (2007). Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. Landscape and Urban Planning 83: 115-126.

Guite HF, Clark C, Ackrill G (2006). The impact of the physical and urban environment on mental well-being. Public Health 120: 1117-1126.

Int Panis L, de Geus B, Vandenbulcke G et al. (2010). Exposure to particulate matter in traffic: a comparison of cyclists and car passengers. Atmospheric Environ 44: 2263-2270.

Klaboe R, Kolbenstvedt M, Fyhri A et al. (2005). The impact of an adverse neighbourhood soundscape on road traffic noise annoyance. Acta Acustica Acustica 91: 1039-1050.

Ministerie van de Vlaamse Gemeenschap, Departement Leefmilieu en Infrastructuur, Onderzoek Verplaatsingsgedrag – Analyse opdracht – Eindverslag, 1996.

Ministerie van de Vlaamse Gemeenschap, Departement Leefmilieu en Infrastructuur - Mobiliteitscel, Onderzoek Verplaatsingsgedrag Vlaanderen 2, 2004.

Ministerie van de Vlaamse Gemeenschap, Departement Mobiliteit en Openbare Werken, Onderzoek Verplaatsingsgedrag Vlaanderen 3 – Verkeerskundige interpretatie van de belangrijkste tabellen, 2009.

Environmental exposure – annoyance relationships in black and gray urban areas

R. Klaeboe

Institute of Transport Economics, Gaustadalléen 21, NO 0349 Oslo, Norway, rk@toi.no

It is quite seldom to find individuals who are only annoyed by a single type of urban environmental exposure, and extremely rare to find individuals that cherish or complain about only a single aspect of urban living quality. In black and gray urban areas exposed to high and intermediate noise levels, people are usually multi-exposed and react adversely to more than one type of environmental exposure. Nevertheless, different classes of exposures and aspects of urban life are often studied in isolation, and exposure-annoyance relationships estimated separately and with disregard of urban context. Measures to reduce and alleviate the various quality of life impacts are also often undertaken by authorities focusing on one type of exposure at a time. In this paper we summarize some results and insights from Norwegian socio-acoustic and socio-environmental research containing elements of a broader conceptual framework.

INTRODUCTION

In the 1996 EC green paper on noise exposure and the cost to society defined three noise exposure classes (EC 1996). Black areas that have an equivalent exposure level of L_{den} above 65 dBA, gray areas levels lie between 55 dBA and 65 dBA, whereas green areas have noise levels below 55 dBA. According to the EEA 60 % of the EC population exposed to more than 55 dB live in gray areas (EEA 1999). This is somewhat less than the ca. 70 % estimated in the Green Paper –See Figure 1.

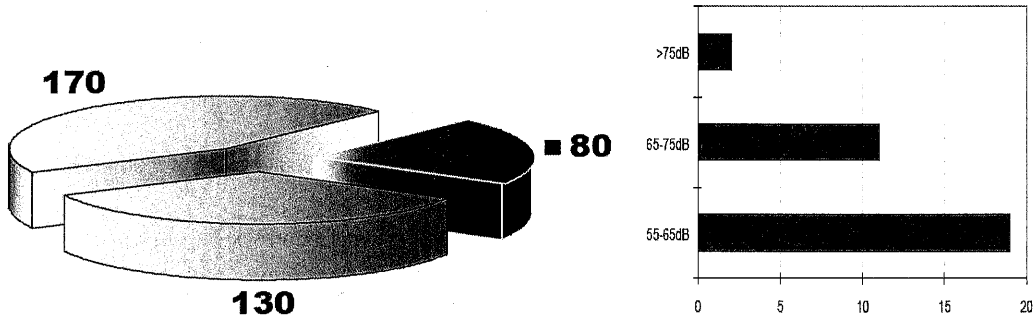


Figure 1: Share of citizens in different exposure intervals (L_{den}), EC 1996, EEA: http://www.eea.europa.eu/data-and-maps/figures/estimated-percentage-of-population-exposed-to-different-road-trafic-noise-levels

Both The Netherlands and Norway have information on the changes in population noise impacts over time (Berg 2011; Statistics Norway 2007). With the caveat that there are several methodological challenges in comparing noise exposure over time, both sets seem to confirm the finding in the EC 1996 green paper that "*the numbers of those acutely exposed are decreasing but the overall problem is getting worse*". Modern policies to reduce noise in urban areas thus need to address noise problems in gray areas. I argue here that this means taking more of the urban context into account and to cherish the benefits of reducing annoyance for all citizens -- not only those severely annoyed.