Proceedings of the Institute of Acoustics & Belgium Acoustical Society
Noise in the Built Environment, Ghent, 29-30 April 2010

THE INFLUENCE OF TRIP BEHAVIOR ON ASSESSMENT OF THE QUALITY OF THE LIVING ENVIRONMENT

D. Botteldooren Acoustics Group, Dept. Information Technology, Ghent University, Belgium
L. Dekoninck Acoustics Group, Dept. Information Technology, Ghent University, Belgium
D. Gillis Ghent University, Belgium
D. Lauwers Ghent University, Belgium

1 INTRODUCTION

The impact of environmental noise on man has often been studied as an independent effect. Most environmental disturbances are however strongly correlated through their sources. Transport and industry not only produce noise but also emit air pollutants. Combined effects have often been mentioned as an important underexplored area of research. In addition, people are not staying at home passively experiencing their environment. The flexible human tries to cope with a disturbed person-environment relationship in many different ways[1]. Exposure to air pollutants may even be more important while participating in traffic than at the dwelling[2]. It has been suggested that the wider neighborhood is important for judging noise at home[3] and that the availability of open natural area with a suitable soundscape reduces noise[4] and helps psychological restoration[5] which in turn might be sufficient to eliminate most of the harmful effects of stress caused by everyday living and exposure at home. Finally one should not ignore the beneficiary aspects of accessibility of work, school, shopping, and recreation.

Embedding all these pieces of knowledge in a methodology for assessing the quality of the living environment and in particular the effect of road traffic on it, is not an easy task. In this paper a computational extensive Monte-Carlo type approach centered on the individual city dweller is proposed. The meaning of "quality of the living environment" is first unraveled in its components and suitable indicators are suggested for each of them. The methodology heavily relies on tracking all trips made by inhabitants. Thus a huge effort has been spend in finding a suitable calculation method for obtaining these trips. Finally some aspects of the model – mainly related to noise – are validated against survey results.

2 QUALITY OF THE LIVING ENVIRONMENT

2.1 Unravelling quality of the living environment

The quality of the living environment is an abstract concept that needs to be made more concrete. In earlier work[6], we started from analyzing what constitutes a good quality of life. Several of these aspects: accessibility of basic functions, health, social cohesion, have an environmental dimension. In a next step this top down analysis is complemented by a bottom up analysis starting from various effects of traffic and both are connected as shown in Figure 1.

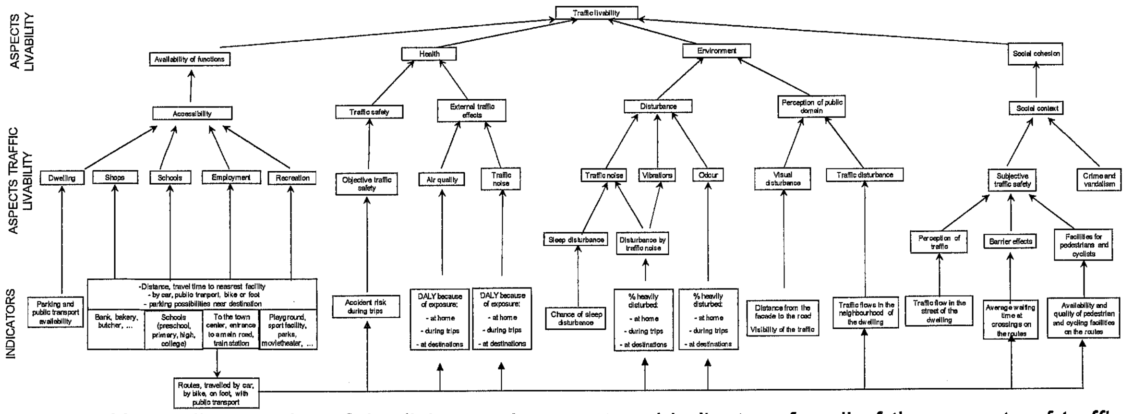

Figure 1. Unravelling quality of the living environment and indicators for all of the aspects of traffic livability

This methodological structure of indicators thus derived has some specific features that distinguish it from most other approaches for assessing the impact of traffic:

- The methodology is human centered since it starts from the quality of life of an individual person and later aggregates to a population.
- Exposure is not only considered at home, but also during movement and at the destination. Although this is generally believed to be more important for air pollution related health issues, there might be some effect for noise exposure as well.

Aggregating the building blocks of the quality of the living environment to a single indicator, benefits from using a non-linear aggregator rather than a weighted sum[6]. The importance of the different aspects included in the tree shown in Figure 1 is estimated on the basis of an open question on reasons why the interviewees in a 5000 person survey would or would not stimulate a friend to come and live in this neighborhood. Figure 2 shows the frequency with which various aspects are mentioned as negative or positive. Noise (quiet) and traffic bustle seem to be important both as positive and negative aspects. Accessibility of recreation facilities and schools help in the positive rating of e neighborhood, while (the lack of) subjective traffic safety is quite important in rating a neighborhood negatively. Neighborly support also scores relatively high both as a positive and as a negative driver. Based on these survey data and expert opinion the final weights in the aggregation are determined. Expert opinion amongst others resulted in a higher weight for health impacts which were not sufficiently included in a question on quality of the living environment in comparison to overall quality of life.

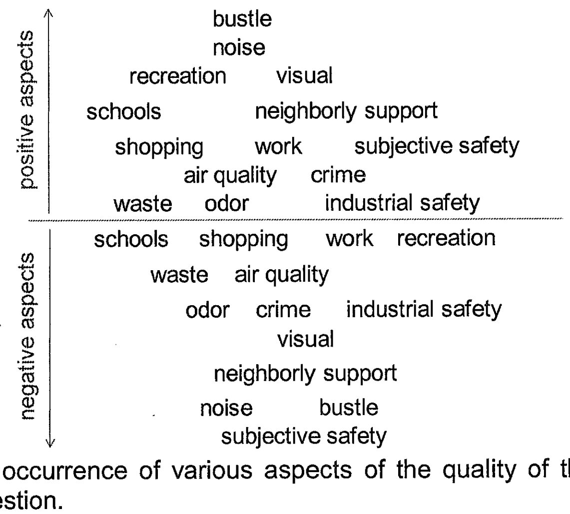

Figure 2. Frequency of occurrence of various aspects of the quality of the living environment in response to an open question.

2.2 Calculating and rating the driving indicators

Calculating the underlying indicators heavily relies on GIS (Geographical Information Systems). The driving geographical data include facilities (shopping, recreation, schools, etc.), housing and through traffic. Traffic with origin or destination within the study area will be obtained as part of the modelling process (see Section 3). Noise, odour and air pollution maps can be used for calculating exposure if available, but at least the component with local origin can also be calculated based on traffic maps.

Several large groups of indicators can be distinguished. Indicators related to accessibility are expressed as generalised travel times that take into account actual travel time and costs of making the trip. Indicators related to health are based on the DALY concept and indicators expressing disturbance are expressed in percentage of the population highly annoyed or sleep disturbance. Although the latter are often included in the DALY or QALY there is a methodological issue when comparing severity of health and disturbance which we prefer to avoid, especially because of the importance of disturbance by noise in the overall rating of the quality of the living environment. In the model, DALY and disturbance indicators are assumed to depend not only on exposure at home, but also on exposure during trips. Subjective traffic safety, in contrast to accident risks that are part of DALY, is assumed to depend mainly on the streets around the dwelling. Indicators relate to the ability to cross the street etc.

A final step before being able to aggregate the different indicators consists in a comparable rating. For this purpose we opted for a five point scale ranging from -2 to 2. Setting the range of the indicator for a given rating remains a difficult task. Often national or global averages can be used as a reference for this. For example, based on the Flemish average, a person with less than 10% chance of being moderately or highly annoyed by noise has the highest quality rating for the noise annoyance indicator while a person with over 50% chance of being moderately or highly annoyed receives the lowest quality rating.

3 ESTIMATING TRIP BEHAVIOR

The trips made by people in the study area have to be estimated for several reasons. Most importantly, exposure while making a trip either by car or by bicycle or on foot can be assessed only if it is known where people go. Simply taking a perimeter around the house does not work because the probability of ending up on a major road where exposure is high is simply higher. Moreover, the direction taken while leaving the dwelling will be more likely the direction of where schools, shops, etc. can be found, often a city center. Secondly, traffic intensity on local roads is rarely available in the study area. Aggregating all trips made by inhabitants and trips with a destination within the study area will yield a good estimate of the traffic on these smaller access roads.

The model proposed for obtaining all trips starts from several sets of input data: the location of dwellings (postal addresses); the location of shops, schools, employment and their size; the statistical database on travel habits of Flemish people. The latter database contains the number of trips, their purpose (hence destination), and the typical distance.

A first step in the modeling consists in generating all potential trips between dwellings and potential destinations. To reduce computational burden, dwellings are grouped per street segment and the origin of trips is assumed at the center of the street. Once all potential trips are thus constructed, a household is randomly selected from the database on travel habits and positioned at each of the dwellings. The travel habits of this particular Flemish family are used to select trips. Thus for example families with children will be assigned trips to schools and a school at a distance corresponding to the typical travel time will be used to select the destination. This information determines the trip completely.

The trips are used in different ways in the model. Firstly, all trips together constitute the local traffic that is added to the through traffic to obtain more accurate estimates of traffic intensities for smaller urban streets. Secondly, the trips are used to calculate exposure to air pollution and noise during travel for the members of every family included in the sample. Thirdly the trips determine the travel time to all essential destination and thus give an indication of accessibility of these destinations. Figure 3 shows, as an example, part of the city of Gent with thickness of streets corresponding to the intensity of trips made by inhabitants of the region passing on these streets. This map is based on a sample of 10% of the 350000 inhabitants of the study area. 300000 trips made by this synthetic population were selected from 24 10^6 potential routes that were first generated.

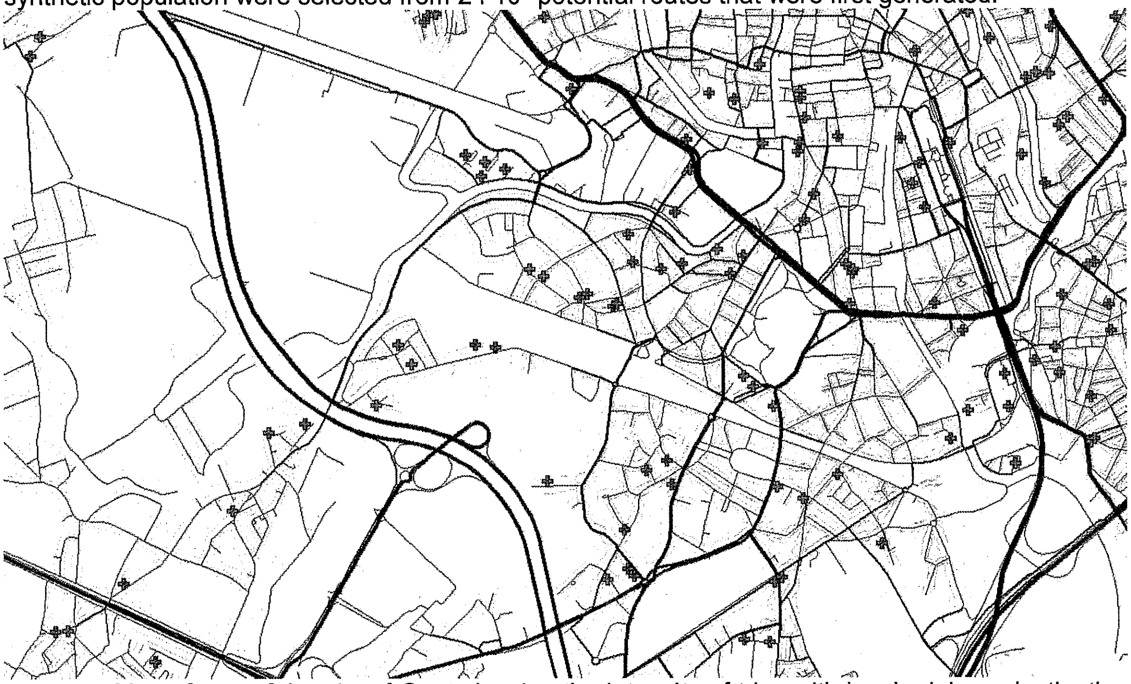

Figure 3. Map of part of the city of Gent showing the intensity of trips with local origin or destination as line thickness on a background of grey dots of dwelling addresses; crosses are survey point used in Section 4.

4 COMPARING RESULTS TO SURVEY DATA

4.1 Noise annoyance

Although the model described above is theoretically sound, many constants and relationships need to be quantified. In order to obtain the required relationships the data from a Flemish survey on the quality of the living environment (SLO)[SLO] are reanalysed. Gent was used as a test area for the model. From three consecutive surveys 425 correctly answered questionnaires were gathered within the study area. Figure 3 gives an impression of the density of survey points. Trip behaviour and liveability indicators were calculated for 50 households at each of the addresses of the survey since specific travel behaviour of the people questioned in the SLO-surveys was unknown and thus averages based on dwelling location alone were used.

A first sub-model to be tested is concerned with noise exposure. In this sub-model, the influence of noise exposure after leaving the dwelling is still not well known. An ISO standard question on noise annoyance by street traffic with a five point answer scale was included in the survey. The question refers to "in and around your home" as a place identifier. For statistical power we will further consider moderate, high and extreme annoyance combined. When plotted against Lden at the most exposed façade, the annoyance level does not drop down at very low exposure levels as one could expect, for example from meta-analyses results[8] (Figure 4). Thus we included a measure of exposure during trips. Many alternatives were studied and eventually some preference was given to the linearly averaged level encountered the first 300m of the trip for trips on foot or by bicycle. As a very rudimentary model for annoyance, it was assumed that trip exposure would only influence annoyance when exposure was higher during the trip than at the dwelling façade. Exposure effect relationship from[8] was also used for exposure during the trip and a strongest component model was used to combine predicted annoyance at the dwelling and during the first 300m of the trips. In Figure 4 it can be seen that this very simple model for including exposure during walking or biking trips already gives a significantly better correspondence with the survey, in particular at low exposure levels at home. Before getting too excited about this result, one should keep in mind that there is always the possibility that the low exposure levels at the dwelling are an artefact of the noise maps used for determining noise levels at home.

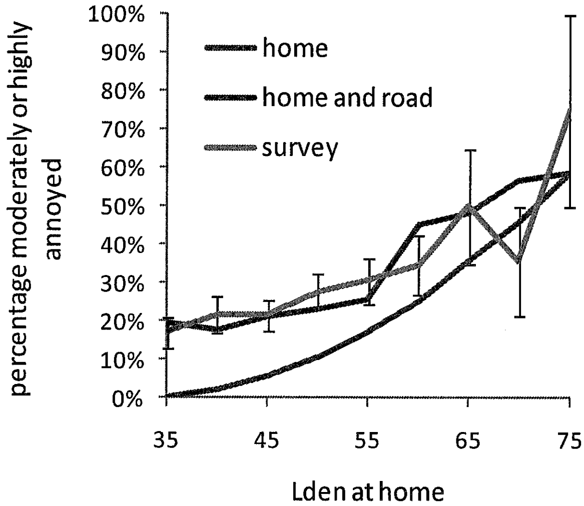

Figure 4. Percentage of the population moderately to highly annoyed by street traffic noise; standard model[8], combined model (see text), and survey results are shown

4.2 Traffic bustle

Traffic bustle is often mentioned in relation to local liveability (Section 2.1). It was assumed that the traffic intensity in the street in front of the house was an important objective parameter for estimating subjective traffic bustle and thus also subjective traffic safety. This hypothesis is tested in conjunction with the trips model by plotting the answers to a question in the survey about the amount of traffic against the intensity of traffic obtained from the trips model explained in Section 3 (Figure 5). Traffic intensities below 125 vehicles/hour are judged normal by a majority of people while intensities over 500 vehicles/hour are clearly very high to most of the inhabitant's standards. This result is more pronounced than a similar analysis on the full survey (13000 respondents) and traffic intensities obtained from nation-wide traffic models. This proves the advantage of using local trip simulations to obtain traffic intensities.

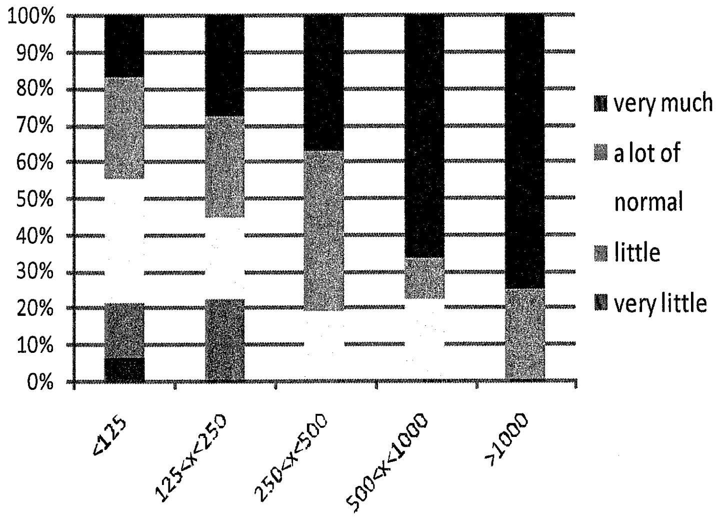

Figure 5. Subjective evaluation of the amount of traffic as a function of different classes of traffic intensity in vehicles per hour during the day obtained from the local traffic model

5 CONCLUSIONS

In this paper, a model is proposed for assessing the quality of the living environment from an inhabitant centered perspective. A particular feature that distinguishes the proposed model from most of its peers is that it accounts for the trips that people take and the exposure to air pollution and noise during these trips. Many of the sub-models require additional research to be fully quantified. This paper illustrates how some of the sub-models were validated against survey data.

6 REFERENCES

1. D. Botteldooren, P. Lercher, "Soft-computing base analyses of the relationship between annoyance and coping with noise and odour", J. of the Acoust. Soc. of America, 115 (6), pp. 2974-2985 (2004)
2. P. Berghmans, N. Bleux, L. Int Panis, V.K. Mishra, R. Torfs and M. Van Poppel, "Exposure assessment of a cyclist to PM10 and ultrafine particles," Science of The Total Environment 407 (4) 1286-1298. (1 February 2009)
3. R. Klaeboe, "Are adverse impacts of neighbourhood noisy areas the flip side of quiet area benefits?," Applied Acoustics 68, 557-575 (2007)
4. A. Gidlöf-Gunnarsson and E. Öhrström, "Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas," Landscape and Urban Planning 83 (2-3), 115-126. (19 November 2007)
5. T. Hartig, G. W. Evans, L. D. Jamner, D. S. Davis, T. Garling, "Tracking restoration in natural and urban field settings," Journal of Environmental Psychology, 23 (2) Restorative Environments, 109-123. (June 2003)
6. D. Botteldooren, A. Verkeyn, B. De Baets, P.Lercher, "Fuzzy Integrals as a Tool for Obtaining an Indicator for Quality of Life," Proceedings of the IEEE World Congress on Computational Intelligence (WCCI) 2006, Vancouver, Canada, Jul. 2006
7. Report "SLO1-meting: Eindverslag", i.o.v. Ministerie van de Vlaamse Gemeenschap – Afdeling Algemeen Milieu- en Natuurbeleid, 2004
8. H. M. E. Miedema and C. G. M. Oudshoorn, "Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals," Environmental Health Perspectives 109 (4), 409-416. (Apr. 2001)