Measurement and prediction of traffic noise in residential areas

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Abstract

In urban areas, traffic noise is generated from three basic sources, the engine block, the exhaust system and the contact between the tire and the road. The goal of an engineer to either increase roadway capacity or improve traffic flow may often conflict with a neighbourhood's goal to be free of congestion, pollution, and traffic noise. Controversies involving traffic noise are often based on mis-information, or perception, not on facts, good engineering, or reality. Resident's perceptions of road-based noise on urban road segments in the central area of Xanthi, Northern Greece, have been examined. An effort has been made to link disturbance from road-based noise and house type, proximity to noise source, resident activity patterns, speed limit variations, traffic composition and type of road surfaces. Traffic counts covered weekend and working days. Different types of vehicles were grouped in a way that would give the influence of heavy vehicles to the generated noise levels. A social inquiry was also conducted. Questionnaires were completed covering subjects such as the type of the house, the number of persons living in the house, the ages and profession, the annoyance of the inhabitants from various noise sources, etc. The traffic and noise measurements were related to the replies of the citizens. A variety of possible noise mitigation measures can reduce the noise impacts of the existing roadway network.

1 Introduction

Sound is any change in air-pressure which is audible to people. The pressure is measured in Pascals (Pa). The threshold for the human hearing is about 0,00002 Pa. Sound intensity is expressed by the square of the sound pressure in watts per square meter, W/m^2. The smaller audible intensity is about 10-12 W/m^2. For

practical purposes a conversion scale is required, which can express noise and for this reason the decibel (dB) scale is used. A dB is equal to 1/10 of a bel, which in turn is the logarithm of the ratio of two particular sound intensities. A sound measured in dB is ten times the logarithm of the squared ratio of two sound pressures. Typical noise intensities are given in table 1. With a reference pressure as a starting point, there are at least three dB ranges:

- If the reference pressure is taken to be 20 μPa, then a sound level of 95 dB will expressed as 95 dB SPL (Sound Pressure Level). The use of this separate range is appropriate for industrial noise measurements. In practice, the industrial noise is measured with instruments and the sound levels are expressed in dB(A) giving a frequency response, which is about the same with that of the human ear (Miedema [3]).
- In hearing measurements, the reference pressure is depended on the frequency, as the pressure of faint noise, which is heard by healthy young persons in the frequency under question. To avoid mentioning the pressure in each frequency, the hearing levels of noise are referred as 45 dB HTL (Hearing Threshold Level).
- The third dB range refers sound levels in the hearing threshold of an individual in a given frequency. This is the range of sensation level, SL. Thus, when a person has reduced hearing with a hearing threshold in the frequency of 45 dB HTL, a tone 25 dB above this threshold, e.g. 70 dB HTL, is said to be in the level of 25 dB SL for that person.

Table 1: Typical noise intensities

	Pressure (Pa)	Decibel (dB)
Hearing threshold	0.00002	0
Quiet office	0.002	40
Noise from an alarm clock positioned 1 m away	0.2	80
Engine room of a ship	20	120
Turbo-jet engine at 25 m	200	140

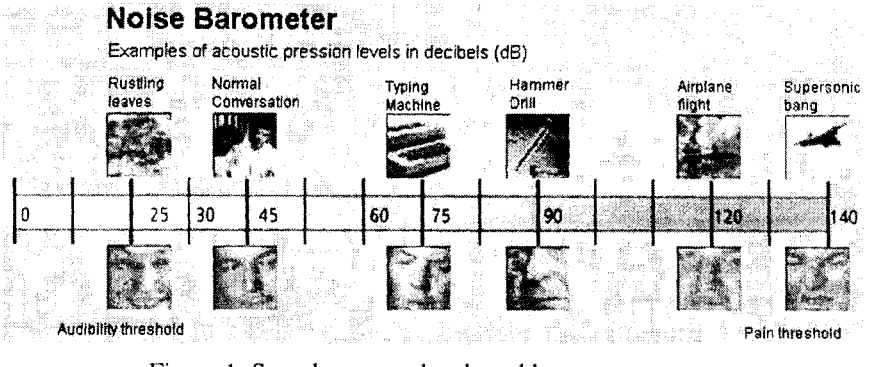

Figure 1: Sound pressure levels and human annoyance

Sources of noise in the community have changed over the years as transportation, industrial, commercial and domestic activities have changed. A booming economy combined with increased levels of air travel, car ownership and powered domestic equipment and with higher expectations for quiet are some of the factors, which have resulted in noise being a significant community issue.

Annoyance is a term used to describe the negative feelings associated with noise (Fields [1]). Figure 1 shows different noise levels and human responses to them. Since annoyance can mean different things to different people at different times, it is not meaningful to define annoyance any more precisely. Reported annoyance is normally understood to mean annoyance reported using a particular scale and therefore has a precise meaning in terms of that scale.

It has been found (Athanasopoulou, [2]) that noise-induced general annoyance and sleep disturbance are the most widespread effects of environmental noise on the population of Xanthi. A system of noise metrics must be developed in such a way as to be able to assess these effects within communities in residential areas no matter what the type of noise source is. Using exposure-response relationships based on empirical data, physical noise exposure metrics could be adjusted in such a way that source-dependent differences in these relationships disappear.

2 A survey on noise impacts

The dominant feature of the present noise situation is pollution from traffic noise (i.e., noise from road, rail and air traffic). The extent of noise pollution in Xanthi has remained roughly the same over the past few years. Although remedial work on the road network to reduce noise has led to local reductions in pollution, in the case of the vehicles themselves there is a trend underway which counteracts to the efforts for noise-control. Heavy motor vehicles (with broad tires) are being equipped with more powerful engines; hence they produce more noise, thereby aggravating the noise exposure for those affected. In order to have a better approach to the problem a survey was made along with traffic counts and noise measurements in central districts of Xanthi, Northern Greece.

Residents in the surveyed area were called to answer a questionnaire comprised of five parts. The questions in the first part related different personal characteristics such as the age, the profession and the level of education. Data about the type of the building and the state of economics of the household were collected in the second part of the questionnaire. Part three asked the habitants to characterize their neighborhood and to point out the most serious problems. The effects of the most important sources of noise were investigated in part four. In part five, the person who answered the questionnaire gave his/her opinion about the noise in his/her working place, if he or she is occupied outside the house.

The ages of the people responded to the questionnaire were not particularly high; only 15 percent of them were over 60 years old. Thirty nine percent of the respondents had ages ranging between 40 and 60 years, 20% were between

25 and 40 years old, while 26% fell in the range 18-25 years The mix of those participated in the survey comprised of men and women in a ratio of about 2:1. Specifically, 63 percent were male and 37% were female persons. The data collected showed that the level of education could be characterized as medium. Lower level education included only 17% of the sample, mostly older people. Fifty six percent of the people who participated in the survey had completed second grade schools, while 27% were those of higher education. This last figure is easily explained, since in the area reside many students. This fact also explains why 56% of the questioned individuals do not work, while 44% answered that is working. It must be noticed that most of the persons who responded to the questionnaire live in the area for several years. The ages of people in the area were grouped in 6 categories as shown in table 2.

Table 2: Age distribution of the persons living in the area of survey

Age (years)	Percent in survey (%)
6 and under	6
7-15	9
16-29	30
30-59	44
60 and over	11

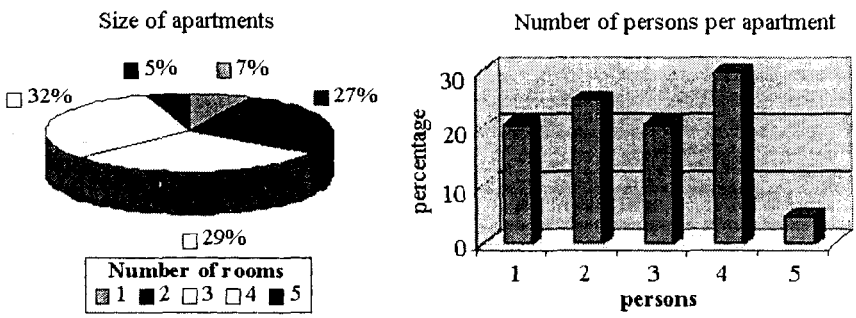

Figure 2: Proportional distribution of rooms and persons in the surveyed apartments

The majority of the dwellings were apartments, a fact that greatly represents the character and pattern of the area, since it is a central part of the town where many apartment buildings exist. Families live in most of these apartments. Thus, they are described as rather medium-sized. As shown in figure 2 the mean occupancy of the apartments is 3 to 4 persons per apartment.

Forty eight percent of those questioned denied to enunciate their monthly income. Only 2.43% declared an income under 100000 drachmas, while 19.51% stated they have an income of 100000 to 300000 drachmas. An income ranging between 300000 and 500000 drachmas was stated by 24.39% of the households and 4.88% stated they have an income of over 500000 drachmas.

According to residents' opinion, the area is characterized as "good". In particular, 15% answered the region is very good, 48% considers it is good, 32% fairly good, while only 5% classified its neighborhood as "not good". These findings are rather normal, taking into account that the area is in the vicinity of the town's center with modern buildings and appropriate road network. However, residents mentioned substantial problems. It must be noted that the answers given have much in common, indicating that people in the area have a uniform perception for the problems in the area. Thus, 23% answered that is annoyed by the noise, the same percentage is annoyed by the traffic, 17% feels air pollution is a major problem, 17% mentioned the waste products as a nuisance and 20% complain because of the lack of parking places.

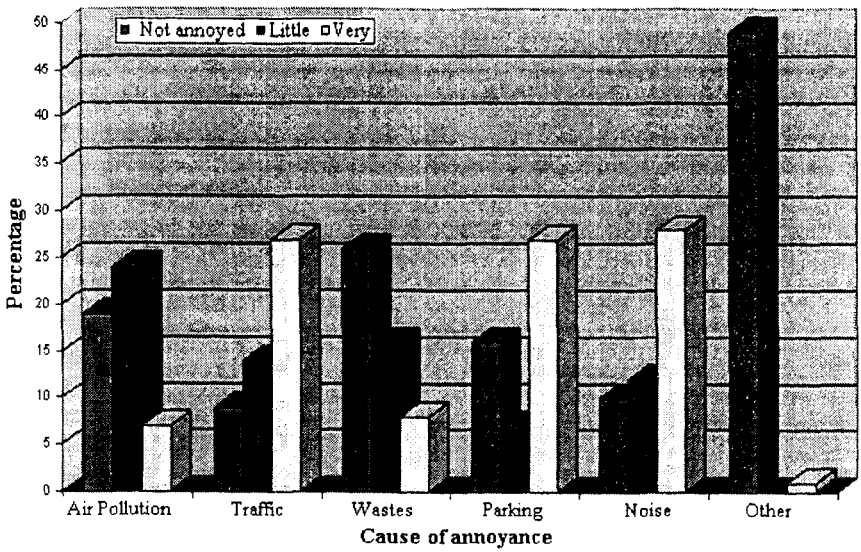

Figure 3: Causes of annoyance and people's perception

In surveys, it is common practice to specify the degree of general annoyance in a population by the "percentage of the population that is highly annoyed" (% HA). A subject is considered to be highly annoyed if he (or she) rates his (or her) degree of general annoyance on a scale from 0 to 100 with a score of 72 or over. ('Not at all annoyed' is at the lower end of the scale and 'extremely annoyed' at the upper end). This measure of general annoyance is also used in this report.

In part four of the questionnaire, where the most common sources of noise are depicted, the opinions are again consistent. To the question "how much are you annoyed by noise in the neighbourhood" most of those answered gave a grade ranging between 70 and 90.

According to the residents, particularly important sources of noise for the area under consideration are the traffic, especially motorcycles, klaxon noises, and building construction works. On the contrary, sources of noise such as animal

voices, children games, air-conditioners, taverns do not bother the residents. The same holds true for the various appliances, as shown in figure 4.

It must be emphasized that most noise annoyance is recognized during the nighttime especially in summer months.

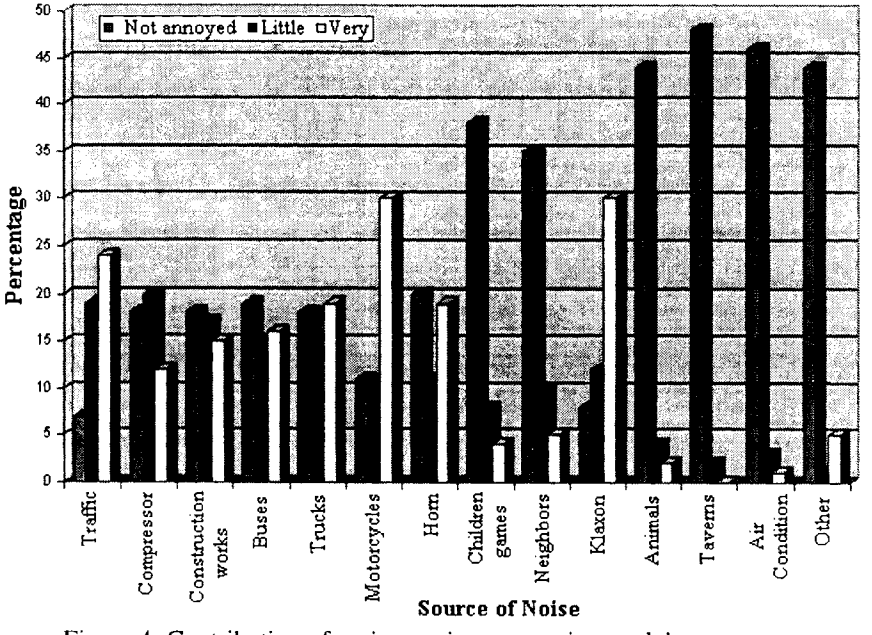

Figure 4: Contribution of various noise sources in people's annoyance

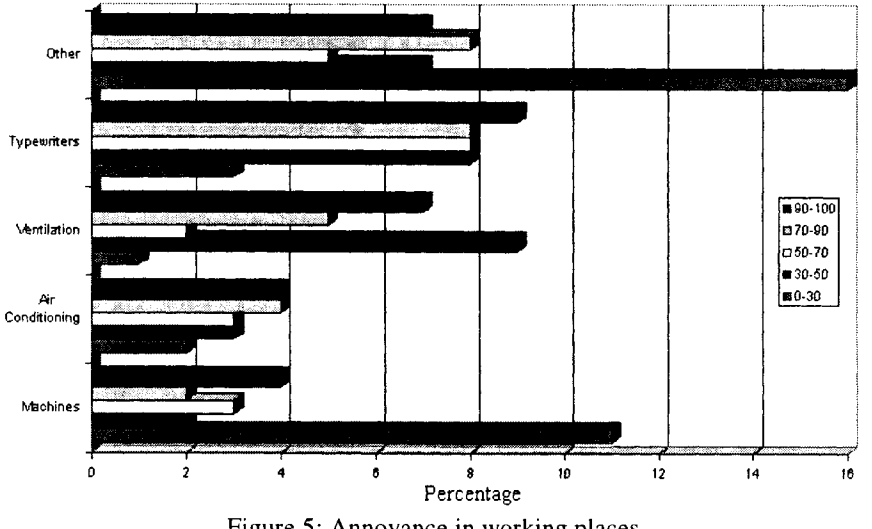

Figure 5: Annoyance in working places

No specific conclusions could be drawn from the last part of the questionnaire, where the respondents were asked to comment their working place from a noise point of view. That's because most of them stated that they don't have a paid job. Among those who have a job, the majority considers that noise is not the primary source of annoyance in the place they work. The data are plotted in figure 5.

3 Traffic counts

Traffic counts were conducted in 21 intersections within the area of interest. They lasted 16 hours, starting at 7:00 and ending at 23:00 hours. They covered both working days and weekends. The main findings are:

- passenger cars were over 70% in the total mix in all roads covered and over 85% where turning movements are a possibility
- motorcycles have a remarkable percentage ranging from 8% to 39%. The higher percentages were found during noon hours, mainly because students and younger workers are moving these hours
- buses in the traffic volume did not exceed the 2.5% and are evenly distributed during the day, with the exception of the last 3 hours of the counts
- trucks were not uniformly distributed in all roads. The larger numbers occurred in broader roads and in roads having asphalt pavements
- the peak hours were between 13:00 and 15:00 hours

For those living in roads with heavy traffic volumes, the noise annoyance is especially stressful, irrespective the height of the building, the road geometry and the characteristics of pavement. Motorcycles are thought to be very annoying to people living in ground floors or in apartments which face the road.

4 Measures for noise abatement

Any ordinance on protection against the noise primarily aims to restrict or decrease the noise at source and, in the second place, to slow down its propagation. The limitation of noise poses certain problems in practice. To restore, for example, the traffic noise level of 73 dB(A) on a transportation corridor, to the value of alarm of 70 dB(A), it is necessary to reduce the circulation by half. If the limiting value of emission of 60 dB(A) is to be respected, the circulation must be reduced by 95%. Noise abatement criteria for various land use activity categories are shown in table 3.

However, the reduction of traffic volume is not the only means of attenuating sound pollution. Another alternative consists in moderating the traffic, i.e. to reduce the emissions of noise by lowering the speed of circulation. Roadways could also be covered with "quieter" asphalt, or cars could be equipped with less noisy tires. Emissions not possible to vanish can be fought on the level of their propagation by constructing noise barriers. This method could not be admitted whenever the protection of sites or historic buildings is opposed to it. Measures of replacement are then necessary, e.g. in the form of insulating windows.

Table 3: Noise Abatement Criteria

Activity Category	Description of Activity Categories	Hourly A-Weighted Sound Level dBA, Leq(h)
A	Lands where serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.	57 exterior
B	Picnic areas, recreation areas, playgrounds, active sport areas, parks, residences, hotels, schools, churches, libraries, and hospitals.	67 exterior
C	Developed lands, properties, or activities not included in Categories A or B.	72 exterior
D	Undeveloped lands.	--
E	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.	52 interior

5 Conclusions

Measuring environmental noise in practical situations is complicated due to noise from intervening human activities, variations in noise situations from day to day and requirements for noise-source specific measurement results.

It is recognized that noise from neighboring dwellings and from activities in the near vicinity is an important cause of general annoyance. However, non-acoustical factors play a role in people's appraisal of such noises to a larger extent than in the case of traffic noise. Therefore, it is considered difficult to predict general annoyance in these situations. Further psycho-acoustical surveys may be able to reveal important acoustical, psychological and social variables in this respect (Kryter [4]). A large number of factors determine whether sounds from neighboring dwellings, which are heard actually cause annoyance. The following factors were found to play a role:

- the age of the respondents (young people below the age of 30 and the 30-59 group is annoyed most. The reason for annoyance between these groups are probably very different;
- individual sensitivity to noise;
- understanding with the neighbors;
- tolerance regarding hearing sounds from neighbors;
- degree of satisfaction with the dwelling in general and with its state of construction (including sound insulation in relation to outside and inside ones own dwelling) in particular;
- degree of satisfaction with the residential area.

In most instances, the determination of special characteristics of noise requires advanced acoustical instrumentation. However, a proper assessment of

these special characteristics, which is relevant in only a minority of cases, is necessary and unavoidable to prevent underestimation of the levels of general annoyance and sleep disturbance.

It is common practice to determine noise exposure for local, regional or national purposes either by using calculation methods or by extrapolating the results of representative samples of measurement results. In both instances this requires specific expertise, which is sometimes beyond the knowledge of the users of the system. However, any system for the reliable estimation of noise-induced adverse effects would also require such expertise.

Noise can be emitted from various sources. In urban areas, traffic noise is generated from three basic sources, the engine block, the exhaust system and the contact between the tire and the road. The goal of an engineer to either increase roadway capacity or improve traffic flow may often conflict with a neighbourhood's goal to be free of congestion, pollution, and traffic noise. The two objectives do not have to be mutually exclusive. Controversies involving traffic noise are often based on misinformation, perception, or anecdotal evidence, not on facts, good engineering, or reality.

The city of Xanthi, Northern Greece, has moderate traffic problems and the circulation of vehicles is rather easy. The vehicle fleet is composed mainly of light vehicles. However, citizens often complain about the traffic noise. This could be attributed to the geometric characteristics of streets and the arrangement of buildings across them. A good relationship between the traffic measurements and the expected noise levels was found. A variety of possible noise mitigation measures can reduce the noise impact of the existing roadway network.

References

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