Noise Level and its Perception by Commuters in Urban Buses of Curitiba

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ABSTRACT

The aim of this study was to evaluate the sound pressure level in commuter buses, as well as investigate the resulting hearing perception of commuters about the bus noise levels. This was accomplished by measuring the noise levels inside city buses as well as through a questionnaire completed by 808 commuters. This questionnaire requested information about vehicle characterization, noise perception inside the buses (noise presence, intensity, causes and effects), bus stations, and bus stops in different areas of Curitiba. The maximum noise level inside the vehicles was 81 dB (A), which is a high value since the World Health Organization (WHO) considers that a sound above 70 dB (A) may be harmful to human beings. The survey showed that although the noise was not considered as one of the main factors which cause discomfort in buses, commuters were able to identify the noise sources inside the buses. Commuters aslo complained about the noxious effects of the noise, such as irritability and headaches.

SOMMAIRE

Le but de cette recherche étais d' investiguer les niveaux de bruit présents dans les autobus urbains et d'étudier la perception auditive de ce bruit par les utilisateurs du transport en commun de la ville de Curitiba -Paraná - Brésil. Pour ce fairele niveau de bruit a été mesuré à l'intérieur de quelques autobus de la ville et un questionnaire a été rempli par 808 utilisateurs dans les gares routières et les arrêts d'autobus de différents secteurs de la ville, visant la caractérisation du véhicule et la perception du bruit à l'intérieur de celui-ci (présence, intensité, causes et effets du bruit). Le niveau maximum de bruit mesuré à l'intérieur de ces véhicules était 81 dB (A), valeur élevée étant donnée que l'Organization Mondiale de la Santé (OMS) considère qu'un bruit au-dessus de 70 dB (A) peut causer des dommages aux gens. L'analyse des réponses au questionnaire a permis de constater que le bruit n'est pas le principal facteur dérangeant à l'intérieur des autobus. Cependant, les utilisateurs sont en mesure d'identifier les sources de bruit à l'intérieur des véhicules et se plaignent des effets désagréables du bruit, comme l'irritabilité et les maux de la tête.

1. INTRODUCTION

In the last few decades, public transportation became one of the most important means of transportation in major cities; however the users' well-being has not always been taken into account. External factors, such as noise, temperature, humidity, comfort and hygiene are, most of the time, causes of countless complaints from passengers, mainly in commuter buses, since thousands of people rely on this means of transportation to travel to and from work, school or even to go out every day.

Urban noise originates from different emission sources such as industrial and commercial business, building sites and mainly traffic (CETEC, 1987). Research carried out in several parts of the world shows that the aerial, railway, road, or automobile traffic are the modes of transport that contribute most to the for increasing noise rate observed in major urban centers. (Hygge, 1993; Stanfeld et al., 1993); Ogusola et al. 1994; Orlando et al. 1994; Beyragued et al., 1998)

Other factors that contribute to the environmental sound pollution are: sound amplification in movies, theatres, show houses, children parties, social meetings and shopping malls, gymnasiums, electric and mechanical machinery, as well as churches, and neighbours. (Celani et al., 1991; Souza & Álvares, 1992; Jorge Jr, 1996; Lichtig & Carvallo, 1997; Lacerda, Morata & Fiorini, 2001)

It is well known that extended exposure to high sound pressure levels (SPL) may harmfully influence human health. High sound levels not only impact the hearing system, but also impact the organism as a whole. Intense and permanent SPL may cause a series of disturbances such as significantly altering people's sense of well-being, interfering with human metabolism, decreasing immunological resistance activities, and causing a series of psychological and physiological effects. (Stanfeld et al., 1993; Patwardhan et al., 1993; Asahina et al. ,1994; Evens et al., 2001; Kawwada, 1995; Koszarny, 2000).

World Health Organization - WHO (1997), ranks the impact of noise levels as follows: a) up to 50 dB (A) may be inconvenient, but the organism is able to adapt easily; b) at 55 dBA and above, the occurrence of mild stress and discomfort is possible; c) from 70 dB (A) up, the stress reactions are more noticeable and the organism starts a self consuming stage, with an increase in the occurrence of several pathologies; d) when the 80 dB (A) limit is reached, there is a momentary pleasure sensation, due to the endorphins liberation; and e) auditive protection is highly recommended when exposure exceeds 85 dB(A), especially if the exposure is prolonged. Damage to the hearing system due to constant exposure to high noise is cumulative and irreversible, thus being one of the most important causes of permanent acquired deafness.

With technological progress, and the growth of cities, sound pollution is surpassing its limits and causing serious consequences to human health. Scientific research and preventive work have been elaborated in order to make the population aware of the damages excessive noise can bring to our health. (SOBRAC, 1992, Axelsson et al. 1995)

The current study's main objective is to investigate noise levels inside urban buses as well as to investigate the perception that the users have of the noise levels inside these vehicles. The research was conducted in the city of Curitiba, the capital of the state of Paraná located in southern Brazil. The city is also known as the "Ecological Capital" due to the constant concern for environmental preservation and self-sustained development demonstrated by the population and local authorities. The city has a strong world-class commuting system to serve its approximately three million inhabitants.

2. BRAZILIAN NOISE LEGISLATION

Brazil, like in several other countries, due to the concern with noise pollution has a set of federal, state, and municipal laws to deal with noise issues.

2.1 Federal Laws

The *CONSELHO NACIONAL DO MEIO AMBIENTE* – National environmental Council (*CONAMA*), incorporated to the *Secretaria Nacional do Meio Ambiente* -National Environmental Bureau, adopted the following resolutions:

The resolution No. 001, from March 8, 1990, determines the emission, patterns, criteria and guidelines, concerning any industrial, commercial, social or recreational activities, including political propaganda, backed by the Law no. 7804/89 - National Environment Policy. In this resolution the sounds and noises which propagate to the exterior and produce a noise level that is 10 dBA, above the baseline noise, without traffic, are considered harmful to the safety and the public serenity. In addition in absolute terms if the noise levels in the exterior is above 70 dB A, during the night, the noise will be considered harmful.

The resolution No. 002, from March 8, 1990, establishes the National Program for Education and Sound Pollution Control (*SILÊNCIO*), maintained by the Law No. 6938/81, which outlines the national policies towards the environment.

Number 1, from February 11, 1993, establishes the maximum noise limit for vehicles, backed by the following federal laws - No. 6.938, from 8/31/1991, No. 8.028, from 4/12/1990, No. 8.490, from 11/19/92 and the ordinance No. 99.274, from 6/6/1990.

Number 2, from February 11, 1993, establishes the maximum noise limits for motorcycles, scooters, tricycles, auto cycles, bicycles with auxiliary engines, backed by the law no. 6.938, from 8/31/1981, altered by the law No. 8.028, from 4/12/1990, No. 8.490, from 11/19/1992, and for the ordinance No. 99274, from 6/6/1990, bearing its internal regiment.

The Brazilian legislation, in Regulation No. 15 from of Labour State Department, Decree 3214/1978, establishes the maximum tolerance limit concerning the exposure to occupational noise, and foresees that a continuous exposure to noises above 85 dBA may cause permanent hearing losses and, above this level, increases of only 5 dB, warrant reduction of the exposure time by half. This legislation is applied in Brazilian industries only. The other work places do not have to comply.

The Brazilian Association for technical rules - *ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT)* has the Brazilian Registration Norma (*BRN*) 10.151 that sets the standards for evaluation of the noise acceptability in communities. It specifies a method for noise measurement, the application of the corrections for the measured levels (according to duration, spectrum characteristic and peak factor) and a comparison of the corrected levels, with a criterion that takes into account several environmental factors. The same Association also applies the Brazilian Registration Norm (*BRN*) 10.152 which establishes noise levels compatible with acoustic comfort in several environments.

2.2 State Laws

The Environmental Institute of Paraná Instituto - *Ambiental do Paraná (IAP)*, acts on behalf of the state of Paraná, and applies the guidelines of *CONAMA* and *ABNT* described above, without any additional resolutions on this subject.

2.2 Municipal Laws

Various city halls are setting a limit to the sounds and noise emission areas classified as residential zone (RZ), commercial zone (CZ), and industrial zone (IZ), among others. In each of the zones limits have been set for sound pollution according to the period of the day: day, evening or night.

The city of Curitiba, through its environmental legislation, Law Number 8.583 on urban noises, concerning the protection of well-being and public serenity, has divided the period into three durations: day time is from 7:00 a.m. to 7:00 p.m.; the evening is from 7:00 p.m. to 10:00 p.m.; and the night is from 10:00 p.m. to 7:00 a.m. According to the Municipal environment bureau, the noise limits in Curitiba are divided into zones according to the different areas of the City. The following noise limits apply: in the case of a strictly residential zone, a 55 dBA limit should be respected during the day period, 50 dB A during the evening period and 45 dB A during the night.

3. METHODOLOGY

The transportation system in Curitiba offers a comprehensive range of routes and vehicles that connects the downtown area to the suburbs. The lines offered by the commuter system in Curitiba are: *interbairros* (routes that connect several neighbourhoods), *expresso simples* (buses that run in a special lane for buses only) and *biarticulado* (an extended version of the expressos), *ligueirinho* (with only a few stops, link the city's most crowded areas),, *alimentadores* (connect neighbourhoods to bus terminals) and *convencional* (regular type buses).

The objective of the current investigation was to determine the hearing perception of the noise present in Curitiba buses, a questionnaire was elaborated (Appendix 1) including items that addressed the following variables: (1) type of bus used (model and route); (2) commuter use habits (reason of use and for how long the person has used the bus system); (3) noise perception (noise presence, intensity causes and effects).

The questionnaire was applied during the months of June to September 2001, in different points of Curitiba (downtown, neighbourhood and suburbs), on every week day, between 8:00 a.m and 6:00 p.m. The sample included 808 users, who were chosen randomly in different bus stops around the city. The interviewees' average age was 26. 77 years; 67% were female and 33% male.

The 808 interviewees were approached in different bus stops, including: squares, bus stations, bus stops and "tube type" bus stops.

With the purpose of documenting the actual noise levels in the buses, noise was measured in some of the most frequently mentioned models, according to the norms recommended by *ABNT*. The criteria used in the measurement of the sound pressure levels were: A-weighting sound; slow detection mode; 8 hour exposure time conversion rate equals to 5 dB (5 dB exchange rate) and 85 dBA criterion level. The collected values were computed in the form of average equivalent level (leq) and three positions in the buses were given importance: front seats (close to the driver and to the engine), seats in the middle of the vehicle and back seats. The measures were taken twice, once with the vehicle stationary and the other with the vehicle in movement. In every situation, the engine noise was taken into account along with the noises made by passengers, other vehicles passing by, etc. The measurement instrumentation included: a of sound pressure level meter, Quest model 215, a callibrator Quest model CA 15 and a octave filter Quest model OB 45.

The data from the questionnaires were typed into electronic spreadsheets, for subsequent statistical treatment using the program LEXICAL SPHINX. The main data are synthesized in the tables and graph, which are shown and discussed below.

4. SURVEY RESULTS

The interviewees' average daily bus usage is 2.24 times a day, and the mean time spent on the bus daily is 54.35 minutes. Concerning the reasons for usage, 52.48% of the sample use buses to go to work, 37.13% go to school and 13.,24% to go out.

Results regarding vehicle type use are shown in graph 1. The total number is higher than the observations number since some users take more than one bus to get to their destination, so multiple answers were accepted.

In order to verify how important users think the physical agent "noise" is, they were asked to identify negative points observed inside the buses. The results are shown in Table 1. The total number of answers is higher than the number of interviewees due to multiple answers.

When asked about the noise intensity inside the vehicles, 28.96% of the sample considered the noise as excessive, 58.91% considered it as moderate and 11% considered it low. In addition 48.76% of the sample indicated that the noise caused inconveniences, whereas 49.01% answered that it did not.

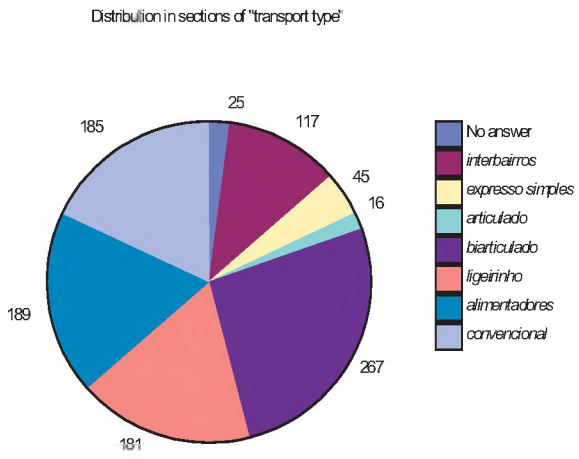

Figure 1: Number of interviewees using each bus type

Negative Points	Number of occurences	Percent of sample
Capacity	567	70.17%
Price	452	55.94%
Ventilation	335	41.46%
Schedules	331	40.97%
Noise	286	35.40%
Hygiene	219	27.10%
Comfort	181	22.40%
Lighting	36	4.46%
Other	45	5.57%

Table 1.: Negative points observed in the buses

The types of noise, users notice in the buses, are listed in Table 2. The total number of answers is higher than the number of interviewees due to multiple answers.

Noise source	Number of occurences	Percent of sample
Engine	351	43,44%
Opening of doors	177	21,91%
Traffic noise	176	21,78%
People talking	162	20,05%
Bell	153	18,94%
Announcer's voice	70	8,66%
Other	32	3,96%

Table 2: noise sources noticed by the interviewees

When questioned about looking for a specific place for sitting down in the buses, most people, 43.44%, reported not worrying about this. However, 26.49% preferred sitting down close to the doors, 13.61% preferred sitting down in the front seats, 7.8% in the middle seats and 10.27% in the back seats. When asked about the reason for this choice, 18.94% of the sample referred to comfort, 34.1% mentioned that they wanted to leave the vehicle quickly, and only 1.98% mentioned noise as the reason for their choice.

Interviewees were also asked if they noticed that noise inside the buses caused any noxious effects on their health. Table 3 shows the complaints related to the noise effects on users.

Effect / symptom	Number of occurences	Percent of sample
no symptoms	258	31,93%
Irritability	255	31,56%
Headache	201	24,88%
Lack of concentration	131	16,21%
Tinnitus	77	9,53%

Table 3: Effects of the noise on the bus users

Results show that 31.93% of the interviewees do not have any complaint regarding noise effects. Although 49.01% of the sample had not previously taken into account noise as a discomfort factor, 31.6% claim that noise in the buses causes irritability, 24.88% complain about headaches, and other complaints were also mentioned, including the ones literature indicates as being characteristic signs of exposure to high sound pressure levels.

The results of the noise level measurement are shown in Table 4. Predominant noise frequency in the vehicles is 31Hz. Sound pressure level is higher when the vehicle is in motion.

Moreover, the noise level is higher at the front of the buses, where the engine is located. The highest level found was 81 dB (A) in an *alimentador* type bus when in movement, and the lowest 58 dB (A) in a *biarticulado*, when it was stopped. In the vehicles that have announcing system the speech stimulus level during the messages presentation was 90 dB (A).

Bus type	Measure at the front		Measure at the middle		Measure at the back	
	A*	B*	A*	B*	A*	B*
Biarticulado	80	67	80	62	68	58
Ligeirinho	79	68	80	65	65	60
Alimentador	81	70	79	65	67	60
Convencional	80	68	80	67	68	61

* A represents vehicle in movement
* B represents vehicle stopped

Table 4: Sound pressure levels evaluation results in dBA according to the bus type and evaluation conditions

5. DISCUSSION

Hearing perception is an ability that depends on several capabilities, such as detecting sounds, discriminating, paying attention, selecting, analyzing, recognizing and understanding (Boothroyd, 1994). Selective attention is a very commonly used resource, whereby people concentrate their hearing attention on a certain stimulus in detriment of other stimulus.

Noise is linked to a non-pleasant sensation. Each being may present a different answer to noise, depending on their emotional state, the exposure circumstances, and their personality. This may explain the fact that most of our sample did not recognize noise as a negative point or a harmful agent to their health in the vehicles.

Noise was identified as a negative point inside the buses by 35.4% of the users. It therefore appeared in fifth place among the agents that cause discomfort to users; however, noise came right after the capacity, the price, the schedules and ventilation. Considering the fact that the

predominant age group sampled was formed by young adults it is possible that the users could have been exposed to different noise forms since childhood and, therefore, are not inconvenienced by its presence. In research done by *Jornal da Tarde de São Paulo* Newspaper on July 3, 2002 about the conditions in certain buses in the Capital, price, capacity, schedule and noise were also targets of numerous complaints.

Although they did not consider noise as a source of discomfort; most of the respondents could identify greatest noise sources in the vehicles. 43.44% of the interviewees indicated the engine as the main noise source, which is corroborated by objective measures showing that the front part, close to the engine, was the noisiest place in the buses. It appears that users, used to the bus noise, do not spontaneously identify it as a noxious agent to health or as a discomfort factor, however when questioned they could point out the greatest noise source. These results may explain why noise is known as the invisible enemy, not allowing victims to be aware of the harm, because unlike other pollution types, it doesn't leave any tangible trace.

The noise from vehicles is one of the main contributors to the high noise levels observed in urban centers, and the complaints filed by the populations in these centers. *CONAMA* Resolutions 01/93 and 08/93, which went into effect on January 1, 1995, demand that new vehicles should follow a series of technical requirements, such as respect maximum emission of vehicular noise. In spite of the demands placed on new vehicles, some vehicles in use may be very noisy, especially the oldest ones that are not maintained appropriately.

In this study, noise levels of moving buses exceeded 70 dB(A), a level considered by WHO as a stressful factor for the human organism. In a research carried out by Carvalho (1997) about sound pollution in the urban buses of Belo Horizonte (Br) the noise levels found also exceeded the limits of WHO. Similarly, a research carried out by Patwardhan et al (1991) found high sound levels (from 89 to 106 dB) in drivers' booth.

An important issue to consider is that the average time spent on the bus is 54,35 minutes (to go to work, to go to school or to go out), and users present a series of complaints attributed to the noise, as for instance irritability (31,56%), headache (24,88%), lack of concentration (16,21%) and tinnitus (9,53%). In addition, bus drivers with a work day of approximately 6 hours should not be forgotten, as they could be the most harmfully affected people being exposed to increased noise effects. They are at risk for hearing loss due to occupational noise exposure, an effect documented by Talamini (1994) and Patwardhan et al. (1991). Therefore the inclusion of this professional category in the hearing loss prevention programs should be considered extremely important.

Vehicular traffic noise control measures are necessary and should involve a wide urban planning effort that promotes changes to the volume and the composition of the traffic, changes in the drawing and road pavement. Reduction of the runway width can reduce noise levels in buildings and on sidewalks due to the reduction of the traffic. The pavement type has a significant effect on urban noise, because it can reduce the noise levels by 3 to 5 dBA. Irregular material surfaces are likely to create an increase in the noise level (Barbosa et al. 1998).

Other alternatives for controlling vehicular noise include the limitation of the speed, with the installation of radars and electronic speed bumps, as well as increased awareness regarding driving style. Lower driving speeds lead to lower engine rotations and consequently, less noise. The exhaust of vehicles should be inspected in a careful way and car pooling areas should be created in the suburbs of the metropolises. Downtown, only light trucks should be allowed and in established schedules. Maintenance of streets and highways should be frequent. (Rapin, 1992)

Some noise control measures are being applied by several companies in the capital; however the initiatives are still very small and need wide administrative planning.

6. CONCLUSIONS

The data presented in this research show that most Curitiba bus users are not inconvenienced with the noise inside the vehicles and they do not recognize it as a noxious agent to their health. However, if there were more campaigns about hearing health, and the damages caused by noise, people may pay more attention to it and consequently they would demand solutions to fight it. Such steps could change this study's results.

Curitiba commuters' participation in this study represented an essential dimension of the evaluation process of the noise inside the vehicles. The hearing perception of the population was a precious instrument in the sense of alerting everyone who is involved with hearing health, that the noise is really an invisible enemy and that every day we are more and more habituated with it.

Future research on this subject, should look into the understanding of the population on the effects of urban noise. Professionals should initiate campaigns to guide and to inform the public regarding the noxious effects of noise, as well as possible steps to control this pernicious and noxious agent.

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APPENDIX 1

Survey Questionnaire

USER IDENTIFICATION

Name: Age: Gender:
Address: Profession:
Route used: Number of times a day:
Time spent on bus daily:
Why do you use the bus:
( ) transport from home to work
( ) transport from home to school
( ) to go out
( ) other

ROUTE IDENTIFICATION

Route:
Bust type: ( ) *interbairros ( ) expresso simples ( ) articulado·*
( ) biarticulado ( ) ligeirinho ( ) alimentadores ( ) convencional

Place of interview:

QUESTIONS

How long have you used the public transit in Curitiba?

Which are the negative points you identify in the commuter system?

( ) capacity ( ) hygiene ( ) noise ( ) price
( ) schedules ( ) comfort ( ) ventilation ( ) illumination
( ) other

Which aspects in the bus system do you believe are harmful to your health?

( ) hygiene ( ) comfort ( ) noise ( ) ventilation
( ) illumination ( ) other

Do you look for a particular seat when sitting on the bus?

( ) no ( ) in the front seats ( ) in the middle
( ) in the back seats
( ) close to the exit doors

Why?
( ) comfort ( ) it`s close to the exit ( ) lighting ( ) noise
( ) other

How would you rate the noise level in the buses?

( ) low ( ) moderate ( ) excessive

Does this noise annoy you?
( ) yes ( ) no
Which noise is the most inconvenient for you?

( ) engine ( ) people talking ( ) traffic noise
( ) bell ( ) opening of the doors ( ) the announcer's voice
( ) other

Does the noise interfere with your communication with other users on the bus?

( ) yes ( ) no

For you, the noise in the bus causes:

( ) irritability ( ) lack of concentration ( ) headache
( ) tinnitus
( ) nothing ( ) other

The noise in the bus makes impossible for you to:

( ) nothing ( ) talk ( ) read ( ) study
( ) rest ( ) listen to music ( ) other