NOISE MAPPING OF AN EDUCATIONAL ENVIRONMENT

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ABSTRACT

The purpose of this study was to perform computer-assisted noise mapping of an educational environment. The computer simulations were performed using SoundPLAN software. An analysis of the acoustic maps generated by the simulations indicates that contributions to the noise levels found on the campus originate mostly from three streets on campus, as well as from the roads surrounding the outer perimeter – the Green Line and the BR-277 highway. The computer-generated acoustic maps show that the noise levels within the campus exceed the limit of Leq = 50 dB(A) established for educational areas, according to the Brazilian standard for noise assessment in communities. Therefore, the noise maps indicate a critical situation of noise pollution on campus. However, despite this negative and concerning situation of noise pollution, the acoustic maps also reveal several "islands of acoustic tranquility" on campus. These "islands" can be observed adjacent to buildings where sound levels range from 45 to 48 dB(A) and from 48 to 51 dB(A), which are indicated in green tones on the acoustic maps.

SOMMAIRE

Le but de cette étude était de réaliser la cartographie du bruit assistée par ordinateur d'un environnement éducatif. Les simulations informatiques ont été effectuées en utilisant le logiciel SoundPLAN. Une analyse des cartes acoustiques générées par les simulations indiquent que les contributions aux niveaux de bruit mesurés sur le campus proviennent principalement des trois rues sur le campus, ainsi que des routes entourant son périmètre extérieur - la Ligne verte et le BR-277 autoroute. Les cartes générées par ordinateur montrent que les niveaux de bruit à l'intérieur du périmètre du campus de dépassent la limite de Leq = 50 dB (A) établie pour les zones d'éducation, selon à la norme brésilienne de bruit environnemental. Par conséquent, les cartes de bruit indiquent une situation critique de pollution sonore sur le campus. Cependant, malgré ces nuisances sonores, les cartes acoustiques révèlent également plusieurs «îlots de tranquillité acoustique» sur le campus. Ces «îlots» peut être observé près des bâtiments où les niveaux sonores s'établissent entre 45 à 48 dB (A) et entre 48 à 51 dB (A) et qui sont indiqués dans les tons verts sur les cartes acoustiques.

1. INTRODUCTION

The rapidly expanding urbanization around the world presents a common factor, which is the aggravation of environmental pollution – of gas emissions, water pollution and noise pollution. The noise that reaches urban populations is generated by various sources, which may be of a simple or complex nature, including the noise generated by transportation systems (road, railroad, air), noise generated by civil construction activities, noise generated by a wide variety of leisure activities such as cultural events, sports events, etc.

Many sectors of society are affected by noise, particularly noise that is generated by vehicle traffic. Traffic noise causes discomfort and irritation, especially during activities that require attention and concentration. In response to the increasing levels of urban and industrial noise pollution, numerous studies have focused on environments intended for activities that involve a cognitive load, such as educational and working environments [e.g. 1-7].

Various studies in different countries have dealt with the problem of environmental noise in educational areas [e.g. 8-13]. However, these studies have not involved the use of computer-assisted noise mapping as a tool for the diagnosis of noise in educational environments.

The buildings on the university campus under study are surrounded by on-campus streets used by cars and buses. The external perimeter of the university campus is surrounded by two expressways with intensive vehicle flows, namely, 1) the BR 277 expressway that links the city of Curitiba to the coastal area of the state of Paraná (southern Brazil), and 2) the Green Line, formerly called the BR 116 highway, which connects the country from north to south. This expressway is currently undergoing an urban transformation to become a major avenue in a new urban scenario in the city of Curitiba [14]. The above-described situation points to the need for and importance of monitoring the sound quality of the university environment – indoor and outdoor - since studies have shown that noisy environments affect the learning process and have negative effects on human health [e.g. 15-19].

The purpose of this work was to generate and analyze the results obtained through computer-assisted noise mapping of an educational environment, in particular a university environment. The environment under analysis is the Polytechnic Center of the Federal University of Paraná, located in southern Brazil. The university campus has a population of about 13,523 people, comprising students, teachers, and administrative staff. The evaluation of noise inside the campus was conducted through in situ measurements of equivalent continuous sound level Leq; noise maps were built using the software Sound Plan-6.2.

2. METHODS

An evaluation was first made of the site plan of the environment in question, using AutoCad R14 software. The measurement points were selected with a view to covering the university campus with its streets and the two major expressways adjoining it – the Green Line and the BR-277 highway - taking into account the topography, the distribution of the buildings, and the entry and exit roads of the campus.

Measurements were taken at 20 points and the duration of each measurement was of 15 minutes, according to the recommendation in the paper by Romeu and collaborators: "Street categorization for the estimation of day levels using short-term measurements" [20]. Figure 1 shows the map of the campus, highlighting the points where the measurements were taken.

The noise generated by vehicle traffic was simulated using SoundPlan version 6.2 software [21], employing the German standard RLS-90 in the calculations for the acoustic modeling of traffic noise [22]. The SoundPlan software works with the following input data to calculate the noise levels generated, for example, on highways: data traffic such as vehicle flows, percentage of light vehicles, road gradients and types of paving, land topography, location and physical characteristics of buildings, etc. [23].

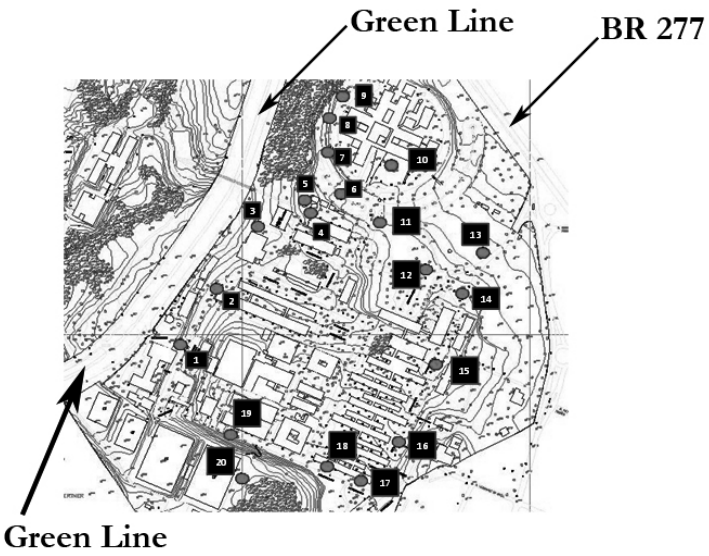

Figure 1. Plan-view highlighting the measured points listed in Table 2, and the two main expressways adjoining the university campus – Green Line and BR 277.

The environmental noise on campus was evaluated according to the criteria of the Brazilian NBR 10151:2000 standard – Acoustics – Noise assessment in populated areas to ensure the comfort of the community [24]. Table 1 lists the external noise levels as a function of the type of land use and period (daytime or nighttime), according to the Brazilian standard NBR 10151.

Table 1. Noise levels according to land use established by the Brazilian standard NBR 10151

	Noise level Leq dB(A)	
Type of Land Use	**Diurnal**	**Nocturnal**
Rural	40	35
Schools, Hospitals	**50**	**45**
Residential	55	50
Commercial	60	55
Industrial	70	60

Figure 2. BK 2260 sound pressure level meter – Measurement point no. 3, facing the Green Line, Leq = 71.7 dB(A) (see Table 2).

Figure 3. BK 2260 sound pressure level meter – Measurement point no. 20, green area of the campus, Leq = 51.4 dB(A) (see Table 2).

3. RESULTS

Table 2 lists the equivalent sound levels measured at each of the 20 points selected for the measurements, as illustrated in Figure 1.

Table 2. Equivalent sound pressure level at each measured point

Measurement Points	Leq dB(A)
1	61.4
2	62.3
3	71.7
4	58.7
5	59.0
6	56.2
7	58.3
8	58.2
9	58.1
10	56.1
11	56.6
12	67.3
13	70.5
14	58.9
15	65.9
16	65.6
17	59.0
18	58.7
19	58.8
20	51.4

To prepare the noise maps, the site plan of the university campus was entered into the SoundPlan 6.2 software program [21]. The contour lines were then modeled at every five meters of ground elevation, as well as the buildings containing classrooms and research laboratories. A sound level of 4.6 dB(A) was established as the maximum acceptable difference between the measured values and those calculated for the noise levels, as indicated by Licitra and Memoli [25].

The noise maps for the daytime period were obtained upon completion of the internal calculation routine of the SoundPlan software, and are illustrated in Figures 4, 5, 6 and 7.

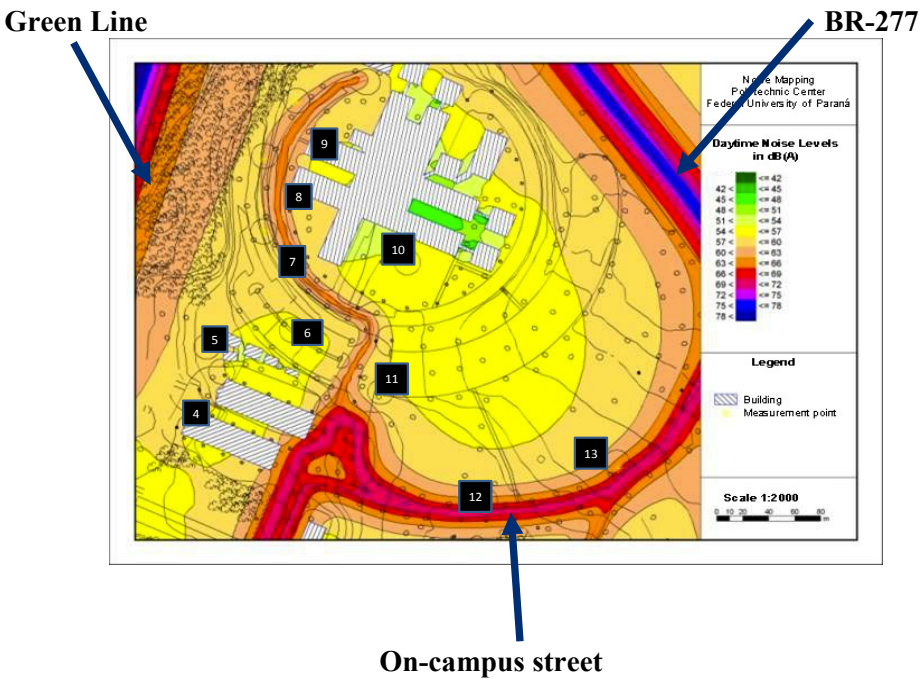

Figure 4. Noise mapping of the area where the classrooms of the Biological Sciences sector of the campus are located, adjoining the BR-277 and Green Line expressways. Identification of the measured points described in Table 2.

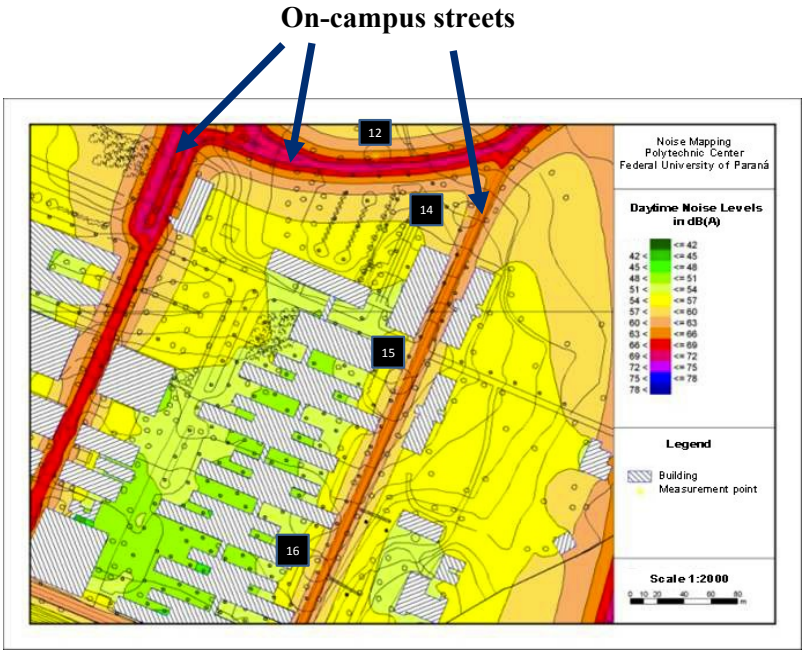

Figure 5. Noise mapping of the classroom buildings of the Technology sector of the campus. The arrows indicate the three major thoroughfares on the university campus. Identification of the measured points described in Table 2.

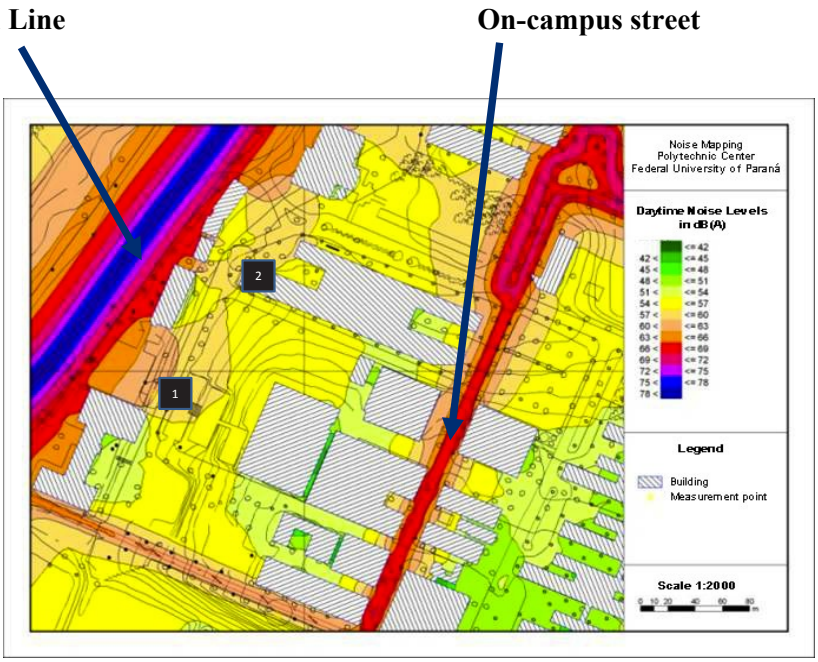

Figure 6. Noise map of the buildings with classrooms and laboratories located adjacent to the Green Line. Identification of the measured points described in Table 2.

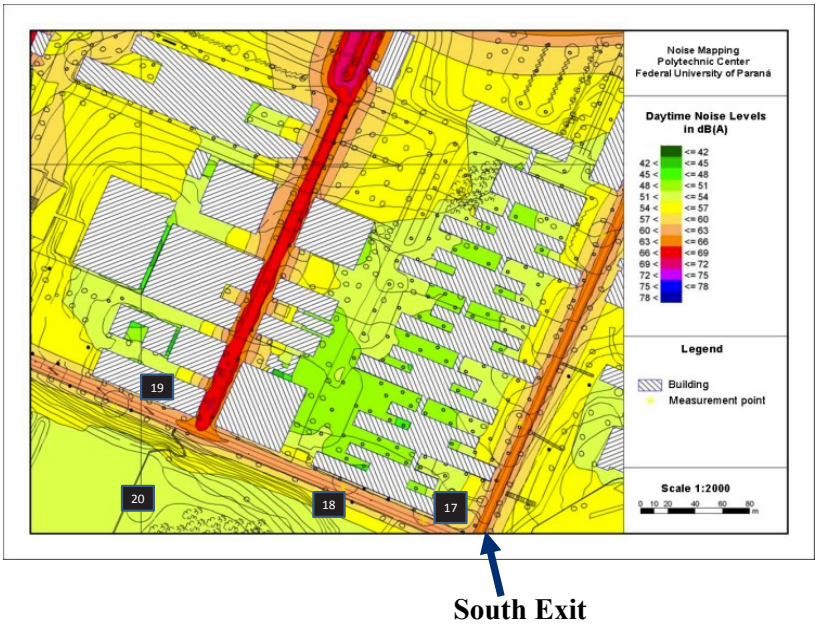

Figure 7. Noise map of the main classrooms close to the south exit from the campus. Identification of the measured points described in Table 2.

4. CONCLUSIONS

Although there are numerous studies on acoustics employing noise mapping, conducted around the world, none have utilized computer-assisted noise mapping in an educational environment [e.g. 14, 23, 26-37].

In 2011, the Journal Applied Acoustics published a special edition on the subject – "Noise Mapping", volume 72, Issue (8) – and none of its 19 articles dealt with noise mapping in Universities. Of these papers, only one has used, albeit en passant, noise mapping to evaluate noise levels in secondary schools of London [38]. In 2013, a book on the theme has just been published - "Noise Mapping in the EU", with 18 chapters, of which none focuses on noise mapping in educational areas [39].

The computer-assisted noise mapping conducted in this study allowed us to understand the problem of noise pollution surroundings and inside the university campus. On the basis of this study, we arrived at the following conclusions and suggestions.

We had assumed that the noise inside the campus would come primarily from the adjoining expressways – the Green Line and BR-277. However, the sound maps indicated that this assumption may be innacurate. The Green Line and BR-277, allied to the campus's three main roads, are the main factors responsible for the noise levels generated on the campus. These levels are explained by the enormous number of vehicles – especially heavy vehicles such as trucks (mainly around the campus), buses and service vehicles, as well as light vehicles such as passenger cars -, that circulate around the campus and inside the campus.

The Brazilian NBR 10151 standard establishes a maximum value of Leq = 50 dB(A) as the criterion for noise exposure in outdoor environments, particularly in educational settings. An analysis of the noise maps indicates that many of the buildings housing classrooms and laboratories are located in areas where noise levels range from 54 to 63 dB(A). Thus, it can be concluded that the noise pollution on campus is a cause for concern. On the other hand, despite this negative and concerning situation of noise pollution, the maps also reveal several "islands of acoustic tranquility" on the campus. These "islands" are located next to buildings where the noise levels range from 45 to 48 dB(A) and from 48 to 51 dB(A), which are indicated in green tones on noise maps 4 to 7.

As a measure to curb the noise pollution to which these buildings are subjected, a suggestion would be to improve the sound insulation of their facades. Zannin and Ferreira [40] demonstrated that the sound insulation – the apparent weighted sound reduction index [41] – measured at the facades of the classrooms of the Technology Sector on this university campus, was = 19 dB. This value is low, considering the requirements of the DIN 4109 for classroom facades, which is = 30 dB [42].

An important administrative solution would be to reduce the vehicle speed limit. This measure was recently implemented and the current speed limit on the Green Line is 70 km/h. To ensure compliance with this speed limit, several radars have been placed along the Green Line. However, at the time this study was conducted the speed limit was not yet in effect. An administrative measure that would further contribute to curbing noise pollution effect would be to aim for the reduction of vehicle emissions (noise and exhaust) by means of compulsory vehicle inspections.

As a form of environmental education, it would be important to conduct awareness campaigns for drivers both inside and outside the university campus, to encourage them to reduce their driving speed and avoid the unnecessary use of car horns. Another instructive measure would be to place signs indicating the existence of a noise sensitive area, i.e., an educational area.

The methodology here employed can be specifically applied to educational environments with layouts similar to that of the campus studied in this paper. In any case, the findings allow us to warn against the error of building educational facilities next to busy highways. In Spain, in the city of Málaga, in the Sixth Iberic Congress of Acoustics, Perea-Pérez et.al. (2010) [43] have shown similar results, from a study conducted inside an University campus also surrounded by highways with great vehicle flow, and whose internal roads also display heavy traffic. Likewise, this Spanish campus also deals with a severe noise pollution problem.

Computer-assisted noise mapping is an important tool for evaluating and interpreting environmental noise, providing information that can be used by public authorities for the mitigation of environmental noise in general, and in particular for educational environments.

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