Noise annoyance through railway traffic - A case study

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Introduction

Noise pollution is a daily reality both in developed countries such as the United States and the European nations and in emerging countries such as India, China and Brazil. The Brazilian rail network is used primarily for transporting bulk commodities, such as soybeans, from the country's producing regions to its shipping ports for export. On its route to the shipping port the railway line passes through Curitiba, the capital of the state of Paraná, south Brazil. The stretch of railway line that runs through the city covers about 20 km. On its route, through the city, the railway line crosses urban thorough fares and passes through residential neighborhoods. As a safety measure, trains blow their horn before they reach a railroad crossing. The trains pass through 40 crossings and blow their horn at least three times as they approach a crossing, thus blowing their horns at least 120 times as they pass through the city. Since an average of ten trains pass through the city each day, their horns are blown at least 1200 times per day.

The railway noise is a serious environmental problem, as reported in the lengthy study by Fields and Walker [1]. These authors evaluated the response to railway noise in residential areas in Great Britain, and reached the following conclusion: "*Noise is rated as the most serious environmental nuisance caused by railways*. The literature on environmental noise pollution contains several reports on railway noise in different countries, including the United Kingdom, the United States of America, Germany, etc. In Brazil, however, studies about railway noise are as rare as to be practically nonexistent, with a very exceptions, such as the work of Bunn and Zannin [2].

This paper describes an assessment of the annoyance caused by railway noise in a large Latin American city, based on noise measurements, noise mapping, and interviews.

Materials and Methods

The environmental impact, generated by railway noise in the city of Curitiba, was characterized based on several parameters: 1) noise level measurements at railroad crossings with the train horn blowing, 2) noise level measurements at railroad crossings without the train horn blowing, 3) noise maps showing the situation of noise pollution generated by train horn blowing, 4) noise maps without train horn blowing, 5) noise measurement at the receiver, i.e., inside the home of a resident in a neighborhood

affected by railroad noise, and 6) interviews with the population, of a district through which the railway runs.

The noise levels – equivalent sound pressure levels, L_{eq} were measured according to the Brazilian standard for noise assessment in urban environments, NBR 10151, at various points along the railway line. In addition to the L_{eq}, the maximum and minimum noise levels were measured. A BK 4231 sound calibrator and five Type 1 integrating sound pressure level meters (B&K 2270, B&K 2260 (two of this model), B&K 2250 and B&K 2238) were used for the noise measurements.

Advances in computational resources have led to the development of several software programs for analyzing environmental noise pollution. The SoundPLAN/6.2 software was used in this study for the calculations involved in noise mapping to evaluate the noise levels caused by the railway. The current literature contains several studies which used noise mapping as a tool for environmental impact assessment (see, for instance [2]).

The German prediction method for railway noise, *Schall*03, was used to calculate the noise generated by trains. In this method, the Mean Emission Level – MEL can be calculated in two ways: 1) From the data flow, and 2) From data entered directly into the software, e.g., noise measurements. In this study, noise mapping was performed by entering the measured noise levels as input data in the software. After entering this data, specific corrections must be made for the MEL, considering, among other factors, type of track, bridges, and railroad crossings.

To simulate the noise levels emitted by train horns, measurements were taken *in situ,* to enter them as input data into the software. After entering the railway data in to the software SoundPlan, an area of calculation must be chosen with a given certain grid (average number of calculation points). For an environment that is little urbanized, a grid spacing of 20 to 50 meters suffices for acoustic mapping. However, fora highly urbanized region, this grid spacing may vary from 5 to15 meters, conform indicated by SoundPlan. The grid adopted in this work was 5 x 5 meters in order to produce a higher level of detail of the noise levels on the acoustic map. The height of the grid used in the calculation was 4 meters, as recommended by the European Union. Directive 2002/49/EC relating to the Assessment and Management of Environmental Noise**,** 2002. No. L 189.

The simulated data were calibrated by placing a receiver point at the site where each noise measurement was taken. Measured and simulated levels were compared at the same height, in this specific case, 1.2 m. The calibration was based on the recommendations of the European Commission Working Group – Assessment of Exposure to Noise [3] for

which the expected uncertainty is 4.6 dB(A) [4] when measured and simulated values are compared.

To assess the degree of annoyance due to noise generated by train, interviews were conducted with the residents of neighborhoods that are crossed by the railway line. The researchers gave a questionnaire to each household. One respondent per household filled the questionnaire. After two weeks the researchers collected the questionnaires. One hundred and fifty questionnaires were distributed and 130 collected.

Results and Discussions

The trains passing though the city of Curitiba follow a pattern that is repeated at each railroad crossing. Shortly before reaching each crossing, the train blows its horn three times. Ten railroad crossings were evaluated, and noise measurements were taken at each of them in three different situations: A) Train passing with horn blowing, B) Train passing without horn blowing, and C) Surroundings of the railroad crossing without the presence of the train.
Figure 3 shows an example of a railroad crossing where a set of measurements were taken along the railroad, as described above. Each rail road crossing was assigned a number from 1 to 10, and the three different measurement situations were assigned a subindex (A, B, and C).
Table 1 describes the noise level measurements at various points along the railway line, for the situations described in Figure 1.

Figure 1: Measurement points along the railway line: A –Train passing with horn blowing, B –Train passing without horn blowing, C –Ambient noise without train passing

Table 1 Noise levels measured along the railroad and surroundings

Measurement site - Railway crossing -	Measurement situation	Characterization of the measurement	L_{min} dB(A)	L_{eq} dB(A)	L_{max} dB(A)
1	A	Train passing with horn blowing	90.1	108.3	121.4
	B	Train passing without horn blowing	62.4	79.8	91.0
	C	Ambient noise without train passing	48.3	59.9	76.2
2	A	Train passing with horn blowing	71.3	101.0	108.3
	B	Train passing without horn blowing	49.9	79.9	91.4
	C	Ambient noise without train passing	41.9	53.9	75.7
3	A	Train passing with horn blowing	74.5	109.8	115.6
	B	Train passing without horn blowing	60.0	80.0	93.4
	C	Ambient noise without train passing	46.5	59.4	78.6
4	A	Train passing with horn blowing	69.4	102.7	109.7
	B	Train passing without horn blowing	66.2	87.4	95.7
	C	Ambient noise without train passing	43.1	53.6	72.9
5	A	Train passing with horn blowing	86.2	108.9	115.1
	B	Train passing without horn blowing	66.5	84.3	90.9
	C	Ambient noise without train passing	50.3	57.9	73.0
6	A	Train passing with horn blowing	77.8	108.9	115.6
	B	Train passing without horn blowing	77.1	82.5	89.4
	C	Ambient noise without train passing	45.7	59.7	84.7
7	A	Train passing with horn blowing	61.1	100.0	109.9
	B	Train passing without horn blowing	71.6	80.8	87.0
	C	Ambient noise without train passing	55.0	70.5	87.0
8	A	Train passing with horn blowing	78.5	108.1	116.5
	B	Train passing without horn blowing	73.6	81.6	90.9
	C	Ambient noise without train passing	54.6	65.7	80.4
9	A	Train passing with horn blowing	67.2	105.9	112.6
	B	Train passing without horn blowing	64.9	82.3	93.4
	C	Ambient noise without train passing	51.4	62.7	86.4
10	A	Train passing with horn blowing	53.8	95.0	111.4
	B	Train passing without horn blowing	67.1	77.5	93.4
	C	Ambient noise without train passing	51.9	60.6	75.6

The simulated data were calibrated by placing a receiver point at the site where each noise measurement was taken. Measured and simulated noise levels were compared at the same height, in this specific case, 1.2 m. The calibration was based on the recommendations of Licitra and Memoli [5], whereby it is expected that the difference between the simulated and measured noise level does not exceed the value of 4.6 dB (A). Table 2 shows the measured noise levels and the noise levels calculated by the software SoundPLAN. As can be seen in Table 2 - last column to the right - the differences between simulated and measured values was below 4.6 dB (A).

Table 2 Comparison of measured and simulated noise levels

Measurement site along the railway lines	Measurement situation	Measured L_{eq} dB(A)	Simulated L_{eq} dB(A)	Difference between Measured and Simulated noise
1	A	108.3	107.5	0,8
	B	79.8	80.3	-0,5
2	A	101.0	100.2	0,8
	B	79.9	79.3	0,6
3	A	109.8	111.1	-1,3
	B	80.0	81.5	-1,5
4	A	102.7	103.2	-0,5
	B	87.4	88.2	-0,8
5	A	108.9	108.3	0,6
	B	84.3	84.7	-0,4
6	A	108.9	108.4	0,5
	B	82.5	83.1	-0,6
7	A	100.0	100.7	-0,7
	B	80.8	82.8	-2,0
8	A	108.1	109.2	-1,1
	B	81.6	83.3	-1,7
9	A	105.9	104.3	1,6
	B	82.3	82.9	-0,6
10	A	95.0	95.6	-0,6
	B	77.5	76.9	0,6

The railroad crossings listed in Table 1 are located in Urban Residential Areas for which Law 10625 of the municipality of Curitiba, which enacts laws about urban noise, establishes that daytime noise levels, from 7:01 a.m. to 7:00 p.m., should not exceed 55 dB(A). Thus, it is evident that the noise generated by passing trains exceeds the limits established by municipal legislation, resulting in noise pollution. To analyze the noise generated by rail traffic based not only on measurements, SoundPLAN was used to calculate noise maps for two situations: 1) Train passing with horn blowing, 2) Train passing without horn blowing. The results obtained from these simulations indicate how high the noise levels are. Figure 2 show the noise mapping in three dimensions, of when a train passes with its horn blowing.
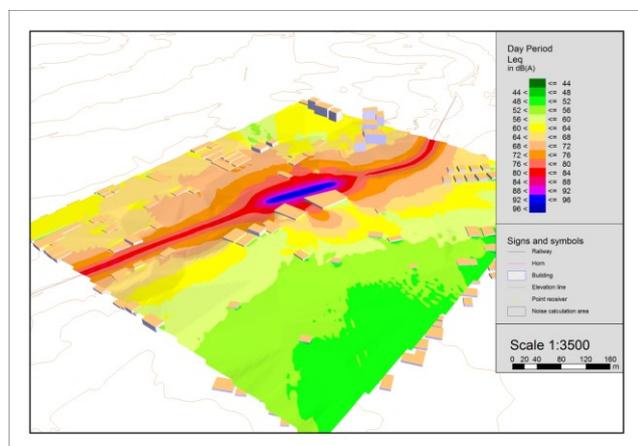

Figure 2: 3D noise map of the situation when the train is blowing its horn

The map in the above figure show that the passage of trains blowing their horns generates noise levels of 80 to 92 dB(A) at the facades of the homes closest to the railway line. Moreover, they indicate that the noise levels that reach the more distant homes range from 68 to 80 dB(A). Figure 8

also indicates that together with the train, the noise levels at the center line of the noise map exceed 96 dB(A). The noise maps were calculated based on railroad crossing no. 2 and measurement situation "A," as indicated in Table 1.

Curitiba's urban legislation establishes a maximum daytime noise level of 55 dB(A) for the area of this study, which is a residential area. Therefore, the situation is clearly one of noise pollution, since the noise levels generated far exceed the legally established limit. It should be kept in mind, as explained earlier, that trains pass through the city about ten times a day, blowing their horns about 1200 times as they approach the city's 40 rail road crossings.

The map in Figure 3, show the scenario when the train does not blow its horn. The noise emission level decreases significantly with the elimination of the blowing horn. The noise levels in the proximities of the rail line vary from 68 to 80 dB(A), in contrast with the situation with the horn blowing, when the levels varied from 80 to 92 dB(A).

The noise maps indicate the efficiency of this noise control measure, the elimination of the blowing horn. However, it is also clear that although the noise levels are drastically reduced, they still exceed the noise limits established by municipal legislation.
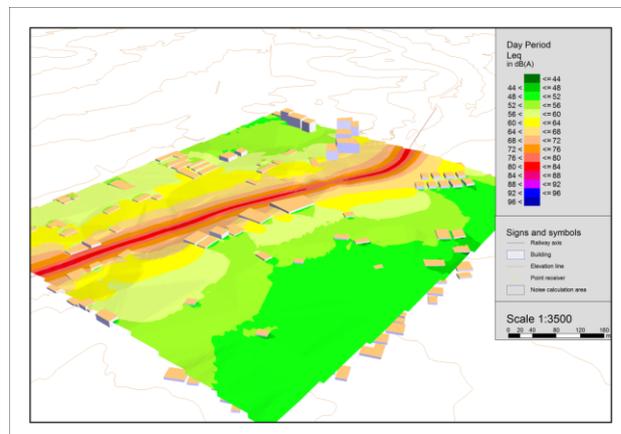

Figure 3: 3D noise map of the train passing without blowing its horn.

The analysis of questionnaires filled out by residents indicated that they are well aware of the problem of noise generated by the trains, since the majority, 62%, have lived there for one to five years, and 25% have lived there for over five 5 years. Only 18% of the respondents have lived there for less than a year.

Residents were asked to assess whether – *during the time they have lived there* – the noise has increased, remained the same or decreased. Among the respondents, 65% indicated that the noise has increased, 33% indicated that the noise has remained the same, and only 2% stated that it has decreased. With regard to the intensity of noise, 57% classified it as very intense, 35% as intense, and 8% as little intense.

When asked if the noise in the neighborhood bothers them, 84% answered *YES*, 15% answered *NO*, and 1% did not answer the question. Asked if they believe that environmental noise is harmful to their health, 98% of the residents answered *YES* and only 2% answered *NO*.

Residents were asked whether–*they find the noise irritating*, to which 92% answered *YES* and 8% *NO*.

The residents were asked whether noise leads to – *poor concentration*, to which 86% said *YES*, 13% answered *NO*, and 1% did not respond.

Residents were asked whether the noise causes–*headache*, to which 59% responded *YES*, 39% answered *NO*, and 2% did not respond.

The residents were asked what time of the day they consider the most bothersome in terms of noise. The great majority, 88%, stated that the most bothersome time is the nighttime. Asked if the noise causes them–*insomnia*, 73% of the respondents answered *YES*, and 27% *NO*.

The respondents who answered *YES* when asked whether noise caused insomnia were asked to point out the main sources causing insomnia: 1) Trains 100%; 2) Automotive vehicles 61%.

The interviewees were asked how frequently – *their sleep is disrupted by noise*, to which 58% answered *Often*, 32%. *Sometimes*, 9%*Never*, and 1% did not answer. They were then asked whether–*sleep is interrupted by the noise of the train*, with 70% claiming that their sleep is *Interrupted Frequently*, 21% *Sometimes* 8%, *Rarely or Never*, and 1% did not answer.

As reported above, 88% of the interviewees indicated that the noise of the train is the most annoying during the nighttime. In view of this finding, measurements were taken of the night time noise generated by passing trains. To this end, a sound level meter was installed in a sound receiving location – the home of a resident. The distance from the railway tracks to the receiver site (the resident's home) is about 200 meters. As Figure 4 shows, the measurements started before 10 p.m. and ended after 6 a.m. A B&K 2238 sound level meter was used and the Measurements were taken with a *datalog* module (noise levels vs. time of measurement), with measurements recorded at 10 minute intervals.

Figure 4 indicates that two trains passed by the measurement location between 10 p.m. and 6 a.m., one at 10:10 p.m. and the other at 6:20 a.m. Both trains blew their horn, as evidenced by the high values of maximum sound level, L_{max}, and equivalent sound level, L_{eq}.

Figure 4 shows how high the noise level is when a train passes with its horn blowing, since the maximum sound levels reached nearly 80 dB(A) at the railroad crossing at 10:10 p.m. and 78 dB(A) at 6:20 a.m. The equivalent sound pressure level reached L_{eq}= 60 dB(A) at10:10 p.m. and L_{eq}= 58dB(A) at 6:20 a.m.

Curitiba's municipal Law 10625, establishes that the noise levels, L_{eq}, from 10 p.m. to 7 a.m. can not exceed 45 dB(A) in the region where the nighttime measurements were taken. Therefore, it is a clear violation of this law during the nighttime.

The measurement shown in Figure 4 proves what the residents claimed, that, the daytime periods from 4 to 6 a.m. and 6 to 8 a.m., and the night time period from 10 p.m. to mid night are the periods of greatest annoyance due to train noise. 37% of the respondents stated that the noise between 4 and 6 a.m. was the most annoying, while 43% stated it was between 6 and 8 a.m., and 35% claimed that the noise between 10 p.m. and midnight was the most disruptive.
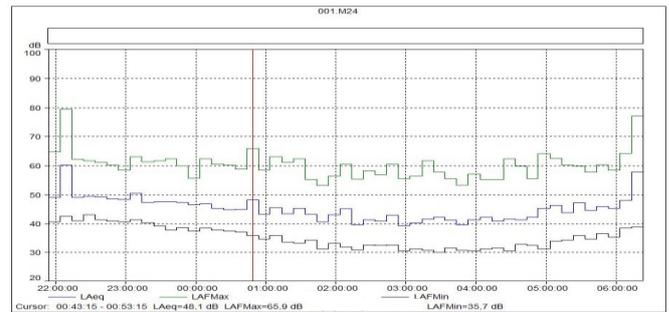
Figure 4: Noise levels as a function of the time of day. Nighttime measurements of train noise taken at the home of a resident.

Lastly, the residents were asked whether they believe that local noise can devalue their home, to which 69%responded *YES*, 28% *NO*, and 3% did not answer the question.

Conclusions

The present study evaluated the noise generated by railway in a large Latin American city. The measurements indicated that the noise levels generated as the train passes with its horn blowing are extremely high, clearly violating Curitiba's noise legislation. The noise mappings showed that a simple solution to control noise would be for the trains to pass through the city without blowing their horns. However, although the noise levels are significantly lower when the train's horn is not blown, they still exceed the levels established by municipal legislation.

The city has been suffering from this problem for decades. The solution to the problem would be to remove the railway line passing through the city. However, lack of resource sand of political will are two obstacles to the removal of the trains passing through residential areas within the city.

The residents were found to feel strongly affected by noise generated by passing trains. Train noise causes *irritation and annoyance*, *headache*s, *poor concentration* and *insomnia*. In terms of noise pollution, 88% of the respondents cited nighttime as the most critical time of the day.

This study showed that the vast majority of residents surveyed (69%) believe that the noise of the train can devalue their property. We would do well to keep in mind the words of Fields and Walker [1]: "*Noise is rated as the most serious environmental nuisance caused by railways*."

References

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