How urban noise can influence the learning-teaching process. Quantitative and qualitative evaluation

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Abstract— The aim of this study is to evaluate the impact of urban noise and noise generated inside the buildings of elementary schools and its influence on the performance of their students. The sample is consists of the school EB1/JI in Prozela and school EB1/JI in Currais. The first one is located near the International Airport Francisco Sá Carneiro and the other school is surrounded by an electrical substation, a mechanic workshop, and by a motorway A41, both in the municipality of Maia.

Keywords— Aircraf Noise, Urban Noise, learning-teaching, impact noise.

I. INTRODUCTION

THIS study aims to assess the impact of noise from outside as well as the noise generated within the school buildings taking into deliberation it´s influence on students' performance in two elementary schools. Were studied the effects of aircraft noise on teaching and classroom activity in an elementary school close to Francisco Sá Carneiro Airport and urban noise in another school near to major sources of noise, both by direct measurements and by a survey of teachers' and students' opinions.

II. NOISE IN SCHOOLS AND ITS IMPACT ON CHILDREN´S LEARNING ABILITY

Educational establishments in Portugal have been subject to an intensification of educational and technological equipment to help in the latest teaching methodologies. On the one hand, this situation provides a proactive action of the students with a recognized added-result from the educational system. On the other hand, it becomes imperative to prepare the physical environment for student and teachers receive these technologies and properly use them.

Fiorini [1] argues that the process of learning, the amount of given information is too large and, in fact, most of this information consists of new subjects for children. Thus, the attention that should be paid concerning the acoustic quality of the environment to ensure an adequate reception becomes very important. Intelligibility is reflected well in the process of speech reception by individuals. In this process, losses of any content transmitted may occur and these losses may be caused by several factors, including low-rate signal [2,3].

III. ACUSTIC STANDARDS IN THE CLASSROOM

The World Health Organization (WHO) has reference results, Table 1, concerning the maximum noise-level and reverberation (echo) time to be verified in schools.

The level of background noise of 35 dB (A), is based on the assumption that the sound produced during teacher's activity is equal to 55 dB (A), measured at 1 m distance.

Table 1. Reference results for maximum noise levels and reverberation time in schools, according to the WHO

	Noise Levels, dB L_{Aeq}	Reverberation Time, sec.
Classrooms	35	0.6
Outside areas for leisure	55	-

Source: [4]

In Table 2, presented by the *American National Standards Institute (ANSI)*, we can find references of noise levels measured in areas where learning activities usually take place, such as classrooms, libraries, auditoriums and other, assuming that these spaces are furnished / equipped yet unoccupied.

Table 2. Maximum levels of background noise and reverberation time in places where learning takes place - ANSI S12.60-2002

Room Volume	Background Noise Levels, dB $L_{Aeq,\ 1\ hour}$	Reverberation Time, sec.
< 283 m^2	35	0.6
> 283 m^2 and ≤ 566 m^2	35	0.7
> 566 m^2	40	-

Source: [5]

The BB 93 is a document produced by the *Department for Education and Skills*, which sets out recommendations on heating, electrical, ventilation and acoustic systems for school buildings. It takes into account several indicators of noise level, reverberation time and acoustic insulation, with respect to more than thirty different kinds of spaces.

Table 4 summarizes the legally admissible parameters at national level, with respect to the acoustic requirements for school buildings.

Table 3. Noise level limits in classrooms and reverberation times for a selection of school buildings - BB 93

	Noise Levels, dB $L_{Aeq, 30min}$	Reverberation Time, sec.
Primary School Classrooms	35 (*40*)	<0.6 (*0.5-0.8*)
High-school Classrooms	35 (*40*)	<0.8 (*0.5-0.8*)
Auditoriums (>50 people)	30 (*35*)	< 1.0

Source: [8]

Table 4. School Buildings (Decree- Law n.º 129/2002)

Element/place	**Regulatory minimum**
Between outside and recipient compartments	D2m,n,w≥28dB – in sensitive zones D2m,n,w≥33dB – in mixed zones (if there is no classification -- consider mixed zone)
Among recipient compartments obtained from other places within the building	L´n, w≤60dB if the local transmitter is a local corridor with large circulation, gymnasium, canteen or workshop L´n,w ≤65dB if the local transmitter is a classroom or a contiguous room
Medium time of Reverberation (between 500, 1000 e 2000Hz), T, with furniture and without occupation	$T \leq 0.15xV^{1/3}$[s] in classrooms, multipurpose rooms, libraries, canteens and gymnasium
Average equivalent sound absorption area (between 500, 1000 and 2000Hz), A, in halls of great circulation	$A \geq 0.25xS_{planta}$, where $A=\alpha_{med}$ x $S_{envolvente}$, with $\alpha_{med} = \alpha_{sabine}$ average between 500 and 2000Hz
In recipient compartments the result of LAr of the particular noise from the building equipments must be:	Libraries LAr ≤38dB(A) if the working schedule is intermittent LAr ≤33dB(A) if the working schedule is continuous Remaining recipient compartments* LAr ≤43dB(A) if the working schedule is intermittent LAr ≤38dB(A) if the working schedule is continuous

Source: [9]

IV. NOISE LEVELS AT EB1/JI PROZELA SCHOOL

The present study focuses on the elementary school EB1/JI Prozela. This educational establishment is located in the parish of Moreira da Maia, near the International Airport Francisco Sá Carneiro. This is the reason why this school was the subject of study in regard to assessing the impact of environmental noise (Fig. 1).

The building is a "Centenary Plan" type which consists in four rooms distributed for 2 floors. This school has 95 students enrolled, 5 teachers and 4 school assistants.

Source: Google maps

Fig. 1 Elementary School EB1/JI Prozela

A. *Methodology*

The methodology considered two types of evaluation: a subjective evaluation that consisted in the application of surveys to the school population and an objective evaluation that consisted in measurements of noise levels *in situ*. This *in situ* measurements was carried out by the use of two sound level meters of type 1 (S1 and S2), checked and calibrated by the Portuguese Institute of Quality (IPQ).These were programmed to collect the following noise indicators: L_5, L_{95}, L_{max}, L_{min}, LA_{eq}, L_{IT}.

(a)

(b)

Fig. 2 Measurements *in situ*: (a) outside; (b) inside

B. Measurement of Noise Levels in the Inside and Outside of the School

a) School "on"

According to Tables 5 and 6 presented below, resulting from the outside measurements with the school "on", it can be observed that there is a notorious influence of air traffic (airplanes) in a way that the LAeq results are significantly higher when compared to the period with higher airplane circulation. The obtained results within the interior of the school are significantly higher than the outside results, since to the level of noise reaching the facade of the building can be added the "indoor" noise.

Table 5. Outside measurements – School "on"

Mesurement Date	10-03-2010	11-03-2010
Mesurement location	Spot 1	Spot 2
Sonometer	S1	S1
LA_{eq}	53.2	54.3
L_5	56.6	54.3
L_{95}	42.7	43.7
Airplanes number	5/2/3	1/2/5
Calibration Values (dBA)	93.9/93.8	93.9/94.0

Table 6. Inside measurements – School "on"

Mesurement Date	10-03-2010	11-03-2010
Mesurement location	First Floor	Ground Floor
Sonometer	S2	S2
LA_{eq}	75.7	66.7
L_{max}	98.0	89.1
L_{min}	42.2	37.6
Calibration Values (dBA)	94.0/94.0/94.0	94.0/94.0/94.0

b) School "off"

Having in consideration that the following analysis (Tables 7 and 8) was based on a premise that the school is "off", this being without the presence of students, teachers and non-teaching staff, the obtained results, whether inside or outside the school building, were significantly lower than those that were observed during the "on" mode. It is important to mention that this analysis was only possible during night-time, for opening schedule purposes.

Table 7. Outside measurements – School "off"

Mesurement Date	26-04-2010	26-04-2010
Mesurement location	Spot 1	Spot 2
Sonometer	S1	S1
LA_{eq}	48.9	42.8
L_5	55.0	49.7
L_{95}	43.6	40
Airplanes number	3/5/1	1/2/2
Calibration Result (dBA)	93.8	93.6

Table 8. Inside measurements – School "off"

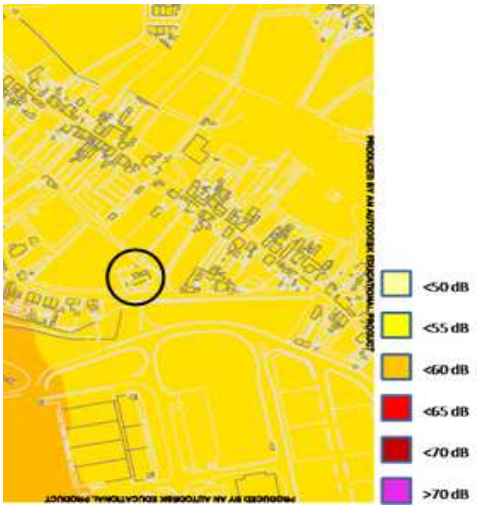
Mesurement Date	26-04-2010	26-04-2010
Mesurement location	First Floor	Ground Floor
Sonometer	S2	S2
LA_{eq}	37.7	34.3
L_{max}	68.5	63.7
L_{min}	26.0	23.2
Calibration Values (dBA)	94.0/94.0/94.0	94.0/94.0/94.0

c) Comparison of measured results and the L_{den} noise map

In agreement with the established in Portuguese Legislation, the acoustic zoning map classifies the land in two classes: "sensitive areas", which have allocated existent or foreseen residential uses, as well as schools, hospitals, recreation and leisure; and "mixed areas", which overlap the uses of sensitive areas plus other ones like retail shops and services, parking, etc.. This legislation forces the consideration of outdoor noise levels in the planning process, namely in the elaboration of zoning plans. According to the provisions of the law, sensitive areas may not be exposed to an equivalent continuous sound level in all day-time (A-weighted average sound level – Lden(A)), higher than 55 dB(A) and 45 dB(A) in night-time (period between 9.00 p.m. and 7.00 a.m., Ln(A)); mixed areas may not be exposed to a Lden(A) higher than 65 dB(A) in all day-time and 55 dB(A) in night-time; and sensitive areas close to an big infrastructure such an airport may not be exposed to a Lden(A) higher than 65 dB(A) in all day-time and 55 dB(A) in night-time.

If we analyze the charts presented in Figure 3 one can conclude that the school building under study is located in a sensitive area close to an airport and is exposed at noise levels of Lden <65 dB for the period that comprises day-evening-night and Ln <55 dB for the night.

(a)



(b)

Fig. 3 Noise maps, L_{den}(a) e L_n (b)

C. Perceptive evaluation

The impact evaluation of the noise in the learning process was carried out with two distinct surveys. One was conducted with a sample of 6 teachers and another one for 63 students from different grades (1st grade, 2nd grade, 3rd grade and 4th grade).

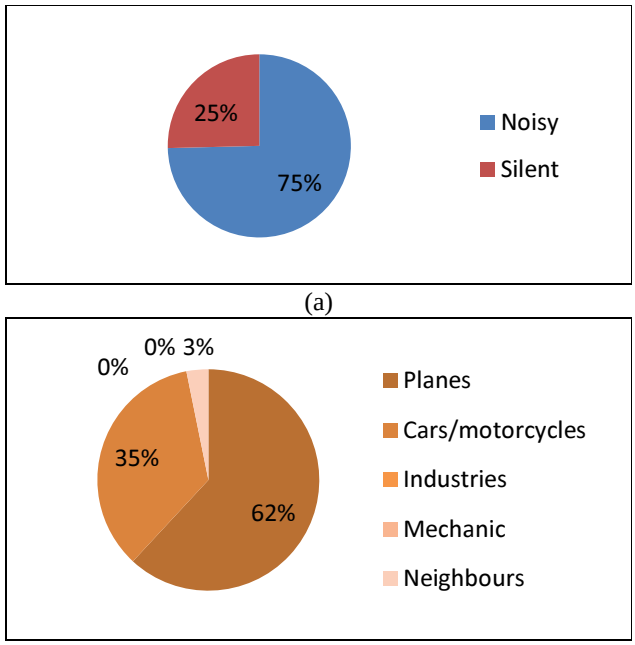
a) **Students´ Perception**

In this study, only 3 of the questions stated in the questionnaire will be stated, as well as its results and they intend to express the main indicators that shall be analyzed.

Thus, Picture 4a is representative of the question "Is your classroom noisy or quiet?", in which can be observed that 75% of students answered “NOISY” and the other 25% of the surveyed students answered “QUIET”.

This result is clearly influenced by the noise from the students attending classes and by the teacher. Moreover, it depends, in a rather subjective way on the subject that is being taught at the moment (requiring higher or lower concentration).

Regarding the question *"What is the noise coming from outside the school that you hear the most in your classroom?"* (Fig. 4b), the largest percentage of answers indicates airplanes (62%). This number is clearly influenced by the proximity to the Airport Francisco Sá Carneiro. Only 35% of students considered that cars and motorcycles were also significant in terms of noise-making and the rest 3%, consider that the neighborhood was to be blamed for the blare. Industries and workshops were not mentioned.



(a)

(b)

Fig. 4 Assessment of noise perception inside the classroom

When asked about the noise that they hear more in the classroom (Fig. 5), 75% of the students answered that it is for all intents and purposes the noise derived from the entire school that affects them the most. However, only 25% of the responses argue that it is, in fact, the noise coming from outside the school that disturbs the most. These results are justified by the indicators mentioned above, influenced mainly by the number of students, provision of school spaces (contiguous classrooms) and the teacher's pedagogy. On the other hand, it is inseparable from the dichotomy between the indoor noise and outdoor noise, since the outdoor noise influences the behavior of students and teachers in the classroom.

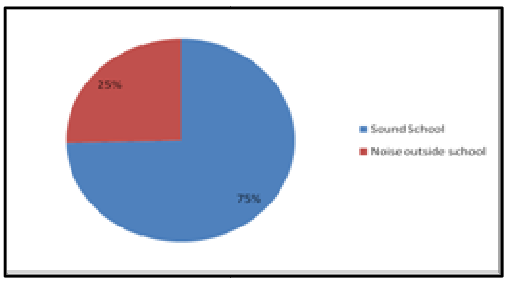


Fig. 5 Predominant noise within the classroom

b) Teacher´s Perception

Of all the inquiries made to teachers in this study we will address only two questions as we consider these to be the most pertinent for this analysis. In fact, the questions are related to discomfort coming issued from the outside noise and its interference in the classroom. As illustrated in Fig. 6, when asked about the annoyance caused by external noise, teachers

clearly indicate that the responsibility for that noise should be claimed by the airplanes. Still, in the scale of results assigned, the number of answers is based solely on the word "LOW", which demonstrates that despite the proximity to the airport, according to teachers, it is not significantly disruptive in the classroom. One factor underlying is that they got used to having this type of noise, as they lecture in this school for more than one year.

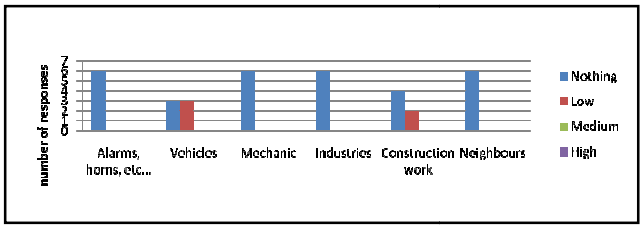


Fig. 6 Assessement of the perception of outside noise

Regarding the noise interference in the context of the classroom, it is perceptible a great number of different answers (Fig. 7). On the scale of results that has been used, it can be observed that the blare of all the students is a major noise that affects them most, as well as the noise from other classrooms. However, one should highlight the fact that the level of external noise was found to be “LOW” in the scale of results, which indicates that there is an interference of the noise levels caused by the take-off and landing of airplanes located near the school.

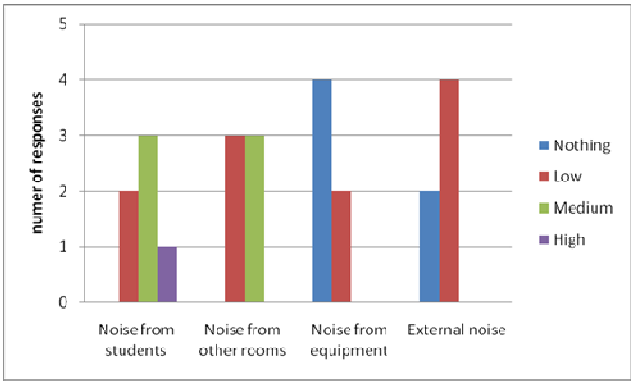


Fig. 7 Assessment of the perception of noise interferance in the classroom

V. NOISE LEVELS AT EB1/JI CURRAIS SCHOOL

The elementary school EB1/J1 of Currais is located in the Vermoim, an urban area close to Maia city centre. This school is surrounded by an electrical substation, a mechanical repair workshop, a production unit and has a close proximity to the A41, both in the municipality of Maia, as it can be observed in the satellite picture presented below.

This teaching institution will perhaps be subjected to significant levels of noise coming from several sources. It is therefore very interesting and totally appropriate to understand how different can the obtained results be, in each one of the building blocks of this study (Fig. 8).

Source: Google maps

Fig. 8 Elementary School EB1/JI Currais

This school is composed of two main blocks. One of the building blocks is a "Centenary Plan" type which consists in four classrooms distributed for 2 floors. The other building block was built in 2009 and has three classrooms. The noise levels measurements were made in these two blocks.

D. Methodology

The methodology considered two types of evaluation: a subjective evaluation that consisted in the application of surveys to the school population and an objective evaluation that consisted in measurements of noise levels *in situ*. This *in situ* measurements was carried out by the use of two sound level meters of type 1 (S1 and S2), checked and calibrated by the Portuguese Institute of Quality (IPQ).These were programmed to collect the following noise indicators: L_5, L_{95}, L_{max}, L_{min}, LA_{eq}, L_{IT}.

Fig. 9 Measurements *in situ* (outside)

E. Measurement of Noise Level in the Inside and Outside of the School

a) School “on”

Outside the building blocks, concerning spot number 1 and given the proximity with the production unit, there has been an average noise level considerably higher than the noise level that was obtained in the spots number 2 and 3. In any of the considered measuring spots were obtained higher noise levels than the levels considered by law. Such fact confirms the

presence of different noise sources located within a walking distance from this school.

Measurements inside the old building present an average result that is significantly higher than the outside figures. Once again the conservation conditions of the building as well as the ongoing academic activities have clearly influenced the results. Strangely as it main seem the results collected in the new building are also high when considering its construction materials. The reason for obtaining these figures is essentially related to the student´s behavior and the fact there is a large glass structure outside the school building. It is also important to mention that this school offers a service of "overtime schedule", therefore it is common to have student´s in the outside play area at all times.

Table 9. Measurements in the outside – School "on"

Mesurement Date	14-06-2010; 17-06-2010	14-06-2010; 17-06-2010	14-06-2010; 15-06-2010
Mesurement location	Spot 1	Spot 2	Spot 3
Sonometer	S1/S2	S1/S2	S1/S2
LA_{eq} [dBA]	65.4	58.2	57.7
L_{max}/L_5 [dBA]	96.6/67.2	77.5/64.9	81.6/60.4
L_{min}/L_{95} [dBA]	59.2/55.2	47.5/50	49.9/49.6
Calibration Values (dBA)	93.9/94.0	94.0	93.0/94.0

Table 10. Measurements in the inside – School "on"

Mesurement Date	15-06-010; 16-06-2010	14-06-2010; 16-06-2010	15-06-2010; 17-06-2010; 16-06-2010
Mesurement location	First Floor (old building)	Ground Floor (old building)	Ground Floor (new building)
Sonometer	S2/S1	S2/S1	S2/S1
LA_{eq} [dBA]	74.6	71.7	69.9
L_{max}/L_5 [dBA]	96.8/75.8	94.5/68.6	88.2/72.0
L_{min}/L_{95} [dBA]	44.8/53.5	42.1/48.0	42.7/44.4
Calibration Values (dBA)	94.0/94.0	94.0	94.0/94.0

b) School "off"

Outside the school building and in the *off* mode, the reported results are quite similar to the figures collected in the *on* mode, suggesting the same degree of influence of several noise sources considering the school year. Moreover, due to the "overtime schedule" there has been a significant presence of students during the measurements, which may have contributed to the obtained results.

Measurements conducted inside the building, in comparison with the previous examples, present results substantially below to the results collected in the school while in the *on* mode.

Inside the building, the average results may vary between 41 dB(A) in the old building and 45.3 dB(A) by the new building. It is worthwhile to once again highlight the fact that the student´s presence during measurements is a condition that influences the results and does not enable the comparison with the WHO references.

Table 11. Measurement in the outside – School "off"

Mesurement Date	23-06-2010	23-06-2010	23-06-2010
Mesurement location	Spot 1	Spot 2	Spot 3
Sonometer	S1/S2	S1/S2	S1/S2
LA_{eq} [dBA]	65.9	58.3	60.2
L_{max}/L_5 [dBA]	78.6/62.3	77.6/67.2	75.4/65.8
L_{min}/L_{95} [dBA]	60.5/60	49.7/52.9	48.4/65.8
Calibration Values (dBA)	94.0	94.0	94.0

Table 12. Measurement in the inside – School "off"

Mesurement Date	15-06-010; 16-06-2010	14-06-2010; 16-06-2010	15-06-2010; 17-06-2010; 16-06-2010
Mesurement location	First Floor (old building)	Ground Floor (old building)	Ground Floor (new building)
Sonometer	S2/S1	S2/S1	S2/S1
LA_{eq} [dBA]	42.3	41.0	45.3
L_{max}/L_5 [dBA]	67.5/52.2	58.9/48.9	66.0/46.1
L_{min}/L_{95} [dBA]	33.2/35.9	28.5/32.1	30.4/34.1
Calibration Values (dBA)	94.0/94.0	94.0	94.0/94.0

c) Comparison of measured results and the L_{den} noise map

Should we overlap the noise map with the cartographic map of the area subjected to study, one comes to the conclusion that this school building is located in an area subjected to noise levels considerably higher than the reference figures stated in the law.

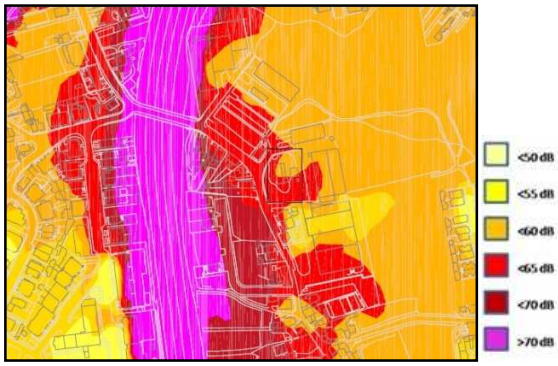


Fig. 10 (a) Noise maps, L_{den}

Fig. 10 (b) Noise map, L_n

F. Frequency Spectrum

With the performed measurements obtained whether in the inside and outside of the school building, in the *off* mode, there has been not only the intention to characterize the surrounding noise, but also the accomplishment of a frequency spectrum to assess the tone of such noise.

Based on the analysis of low frequencies through the graphics obtained by the performed measurements and confirming that the bandwidth in question is higher to its contiguous, it can be concluded that the bandwidth to be considered and analyzed is located at approximately 50Hz.

In one of the previous measurements, and taking into consideration the values within this spectral bandwidth, higher than the contiguous, it has been proved the existence of a tone in the noise level obtained.

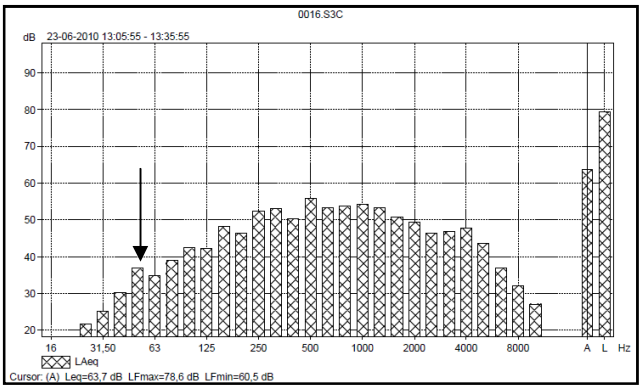


Fig.11 Frequency Spectrum of EB1/JI Currais – measurement performed outside the school building, in the *off* mode

By analyzing the graphics (Fig.12, 13 and 14) obtained through the measurements performed inside the building, for frequency bandwidth raging between 30 and 60 Hz, there are no registered results.

This fact proves that the figures registered in the outside are not perceived inside the building. For that reason, we can conclude that the facades of the building completely insulate these frequency bandwidths.

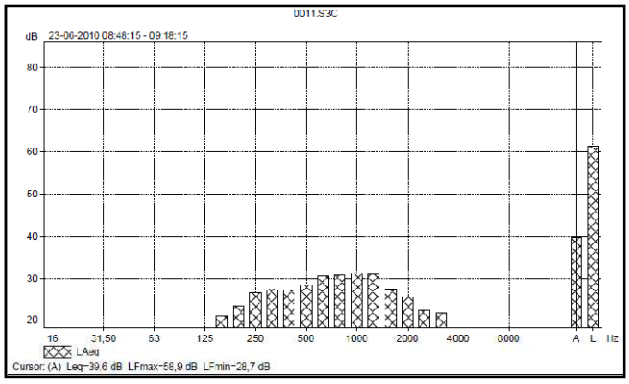


Fig.12 Frequency Spectrum of EB1/JI Currais – measurement performed in the ground floor, outside the old school building in the *off* mode, spot 2

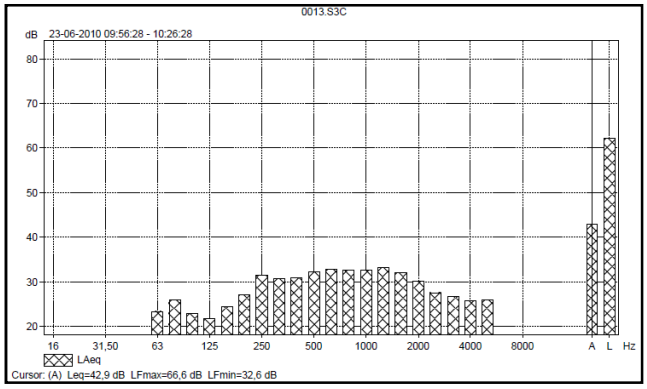


Fig.13 Frequency Spectrum of EB1/JI Currais – measurement performed inside the old building, in the first floor in the *off* mode, spot 2

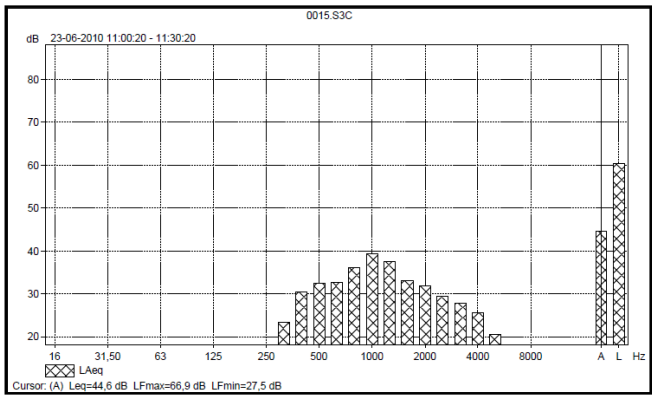


Fig. 14 Frequency Spectrum of EB1/JI Currais – measurement performed inside the new building, in the ground floor in the *off* mode, spot 2

G. Perceptive evaluation

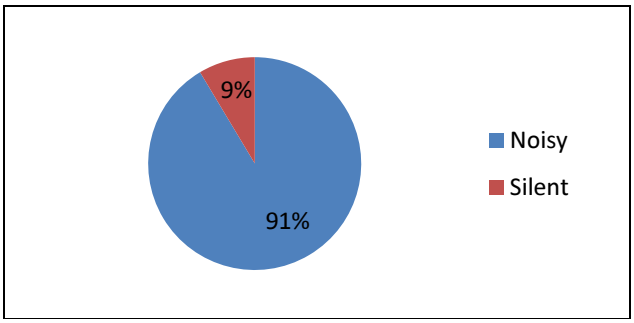
The impact evaluation of the noise in the learning process was carried out with two distinct surveys. One was conducted with a sample of 9 teachers and another one for 105 students from different grades (1st grade, 2nd grade, 3rd grade and 4th grade).

a) **Students´ Perception**

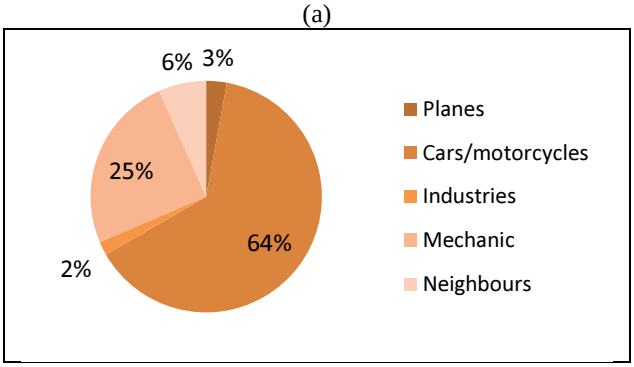
Fig. 15 a) represents the graphic referring to the question: "Is your classroom noisy or silent?", in which can be observed that 91% of students answered that the classroom is noisy compared to 9% of the sample that stated that the classroom is actually silent.

This result is justified based on two prevailing factors.

One is directly related to the location of the school building, which as previously described, is surrounded by major sources of noise, and the other relates to the student´s behavior.



(a)



(b)

Fig. 15 Assessment of noise perception inside the classroom

Concerning the question "What type of noise coming from outside the school that you hear most in your classroom?"(Fig. 15 b)), the highest percentage of answers lies in the noise coming from vehicles (64%) and workshops (25%). These results definitely express the performed measurements. Pertaining to the noise from vehicles, these answers have validated the close proximity to either a municipal street or the nearby A41. With reference to the noise coming from the workshops it has been proved that this is perceived by students inside the classroom.

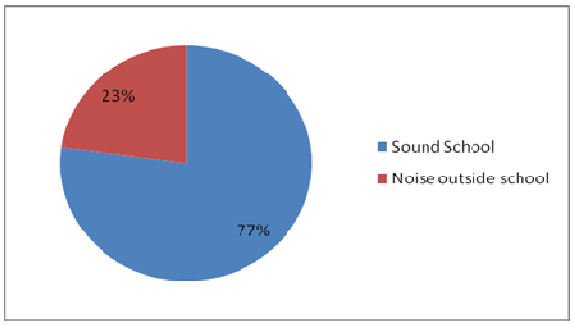


Fig. 16 Predominant noise within the classroom

When questioned about the type of noise that was perceived within the classroom (Fig. 16), about 77 % of the enquired students have replied that it is essentially the noise coming from the school (on its own) that affects them the most and only 23% have pointed out the noise coming from outside the school.

Exactly like in the other schools, students have perceived the noise produced by their activities as being the type of noise that affects them the most considering other types of noise sources, which justifies the obtained results.

b) Teacher´s Perception

As illustrated in Fig. 17, when asked about the annoyance caused by noise coming from outside, the teachers recognized as major sources of noise the workshops, the vehicles and the industries in a scale of AVERAGE, which supports the existence of these sources of noise in the proximity of the school building.

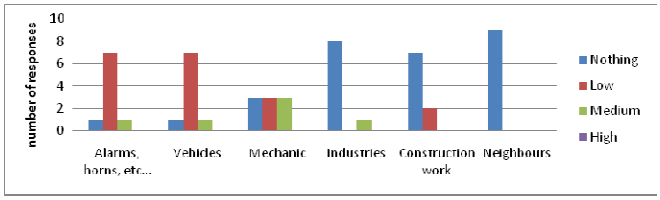


Fig. 17 Assessement of the perception of outside noise

The graphic presented in Fig. 18 shows that the main interference in the classroom environment results from the noise produced by the students themselves, either in the classroom subjected to this study or the contiguous classrooms, in a scale of HIGH. It should also be noticed that it is assigned in a scale of AVERAGE, the importance concerning the type of equipment that is part of the school building. Finally, it is important to highlight the significant number of replies (7 answers) concerning the annoyance caused by the outside noise, in a scale of LOW, which demonstrates that despite not being significant, these noises really are perceived during school activity.

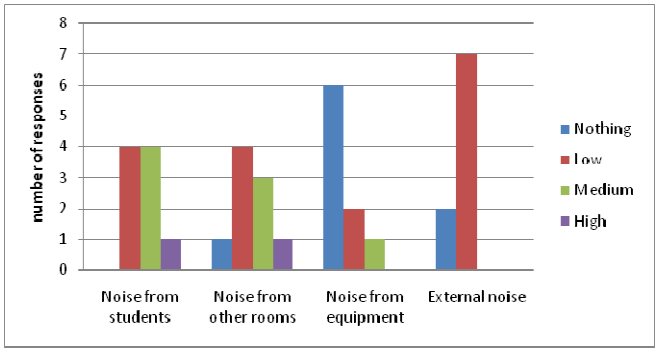


Fig. 18 Assessment of the perception of noise interferance in the classroom

VI. CONCLUSION

There are innumerous factors that can have an influence on the noise-levels that were obtained during this study. Having in consideration that every procedure was dully accomplished within each technical norm, we can conclude that indeed this school presents and respects the normal-levels of noise, established for the local area. However, these levels can definitely have a consequence in the teaching-learning process of the students that are enrolled.

The proximity from a major infra-structure such as the Francisco Sá Carneiro Airport, or an electrical substation, a mechanic, plant and a main road infra-structure are crucial factors in obtaining important noise-levels.

It can also be concluded that the existence of social factors such as the urgent need of special educational support for some students is, indeed, an influential factor of the noise-levels that are below to the levels taken as normal.

The surveys have proved to be fundamental for the validation of the obtained measurement results a, through this perceptual evaluation there is a clear identification of a convergence of results collected and how noise is perceived by users of space.

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