Effect of urban noise to the acoustical performance of the secondary school’s learning spaces – A case study in Batu Pahat.

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Abstract. Classrooms and laboratories are important spaces that use for teaching and learning process in the school. Therefore, good acoustical performances of these spaces are essential to ensure the speech or message from the teacher can be delivered to the students effectively and clearly. The aims of this study is to determine the acoustical performance of the teaching and learning spaces in public school that situated near to the traffic roads. The acoustical performance of the classrooms and laboratories at Sekolah Menengah Kebangsaan Convent Batu Pahat was evaluated in this study. The reverberation time and ambient noise of these learning spaces which are the main parameters for classroom design criteria were evaluated. Field measurements were carried out inside six classrooms and four laboratories unoccupied furnished according to the international standards. The acoustical performances of the tested learning spaces were poor where the noise criteria and reverberation times inside the measured classrooms and laboratories were higher than recommended values.

1. Introduction
Urban noise especially that generated from road traffic is the major noise pollutant that has affected surrounding populations in many cities. This environmental noise annoyance bring outs various effects to the human daily activities and health [1]. Many social-acoustic surveys were carried out over the century to evaluate the effects of traffic noise exposure to the nearby residents. In several studies, traffic noise is found to be the most critical effects on human sleep disturbances [2–5] and could lead to deterioration of subsequent daytime life quality such as tiredness, sleepy and low working performance [6]. Excess exposure to long-term high level of traffic noise can increase the risk to health diseases [7–9] as well as health problems.

From the social survey in London, the critical threshold for acceptable noise level based on the residents live near the traffic roads was range between 65 to 75 dB(A) $L_{10}$[10]. WHO has recommended the limit of noise level ($L_{eq(A)}$) outside dwellings for daytime to be 55dB(A) while 45 dB(A) is suggested as the limit during the night time to protect people from being seriously annoyed [11]. In Malaysia, the guideline for limiting sound level from road traffic has been set for different categories of receiving areas in order to protect the population from this environmental noise [12]. For the noise sensitive areas such as institutional or schools, Malaysian Department of Environment [12]
had limit the permissible sound levels outside these areas to the 50 dBA during the daytime from 7am to 10pm. However, there were still many institutions in Malaysia are facing with this urban noise problem [13,14]. Mohmadisa et. al.[14] had studied traffic noise levels outside five selected school environments in Batu Pahat. The results from their study showed that the noise level outside all studied school areas were exceed the permitted level that set by Department of Environment.

Although traffic noise measurement outside school environment can be used for assessing the urban noise impact to the children in the school, but it cannot be used to evaluate the efficiency of teaching and learning processes. The efficiency of the communication in classroom is depends on the acoustic conditions of the classrooms. High levels of noise in the classrooms will affect the concentration of the students. Excessive noise levels in the school area may affect the psychology and physiology of both teachers and students [15]. It can affect communications and more extreme can default hearing. Students will feel difficulty in paying attention and understanding the teaching information that given by their teachers [16]. Better acoustical design of learning spaces will ensure the efficient distribution of desirable sound inside the rooms. That’s mean when teachers are giving instructions to the students in the classrooms, the messages can be delivered to the students effectively and clearly. A good quality of sound in the classroom is importance for students’ audio comfort. Recent survey showed that higher physiological stress reaction happened on teachers and students who were exposed to noisy classrooms [17].

The acoustical performance of the classrooms very depends on the background noise and reverberation time of the spaces [18]. Both parameters are very importance in evaluate the speech intelligibility of the classroom. When the background noise of the classroom is high, teachers have to rise up their voice in order to increase the clarity of their speech. The contributions of background noise of a classroom include mechanical ventilation system, lighting systems and outdoor noises such as transportation, construction works, student activities at school field, neighboring classrooms and others. The reverberation time value of the classrooms should not be too long in order to avoid a masking effect.

Noise criteria (NC) curves are common noise evaluation curves that used for rating the noise inside the indoor environment. The recommended NC level for a classroom is NC 25 to NC 30 [18]. For the reverberation time, the recommendation values were different based on difference country or standards with difference derivations [19–21]. In overall, these standards or guidelines recommended the reverberation time of unoccupied classroom should be below 0.8 second.

A recent study showed that the traffic noise levels outside the school environment of Sekolah Menengah Kebangsaan (SMK) Convent, Batu Pahat was about 70 dBA during day time for both working and non-working days [14]. The noise levels about 20 dBA exceed the recommended value set by Malaysian Department of Environment. Thus, investigation on the effects of this urban noise to the acoustical performance of the teaching and learning spaces of this school is needed. This study aims to determine acoustical performance of the learning spaces in high school that located next to heavy traffic roads. The background noise and reverberation time inside the 6 classrooms and 4 laboratories of this secondary school were investigated.The acoustical performance of tested classrooms and laboratories were compared with the recommended values.

2. Learning spaces and measurements
Field measurement was conducted at SMK Convent, Batu Pahat during the school holiday on weekday and office hours. The location of this school was next to heavy traffic road of Jalan Tan Swee Hoe as shown in Figure 1 with the latitude of 1º51’45” U and longitude of 102º57’0” T. A total of ten learning spaces in this school were surveyed in the present study. Six unoccupied furnished classrooms and four laboratories at different location of the school environment were measured as shown in Figure 2. The example of indoor environment of the tested learning spaces are illustrated in Figure 3. All the classrooms that chosen for the present study were located at the first floor while all laboratories were located at the ground floor of the buildings. Wooden desks and plastic chairs were used in all classrooms in this school while tables and chairs in laboratories were made of wood and finished with paint. The classroom can occupied about 30 students while each laboratory can occupied about 40
students. Table 1 summarizes the measured learning spaces conditions and information which related to the acoustical performance of the spaces. Natural ventilation with ceiling fans were used in all classrooms and laboratories in this school. Since the layouts of the learning spaces in this school were similar, the materials, sizes and number of windows and doors were not present in details.

![Figure 1](image1.jpg)

**Figure 1.** Outside view of the studied area.

![Figure 2](image2.jpg)

**Figure 2.** Measured learning spaces (classrooms and laboratories).

![Figure 3](image3.jpg)

(a)  (b)

**Figure 3.** Indoor environment of the (a) classroom and (b) laboratory.
Table 1. Summary of learning spaces information and conditions.

| Learning spaces | Dimension (length X width X height) | Desk/Table | Chairs | Partition/wall between the spaces | External landscape          |
|-----------------|------------------------------------|------------|--------|---------------------------------|-----------------------------|
| Classroom 1     | 9.0 m X 7.0 m X 3.4 m              | Wooden     | Plastic| Wooden                          | Light traffic and heavy traffic |
| Classroom 2     | 9.0 m X 7.0 m X 3.4 m              | Wooden     | Plastic| Wooden                          | Light traffic               |
| Classroom 3     | 9.0 m X 7.5 m X 3.6 m              | Wooden     | Plastic| Concrete                        | Garden                      |
| Classroom 4     | 9.0 m X 7.5 m X 3.6 m              | Wooden     | Plastic| Concrete                        | Garden                      |
| Classroom 5     | 9.0 m X 7.0 m X 3.4 m              | Wooden     | Plastic| Wooden                          | School's field and light traffic |
| Classroom 6     | 9.0 m X 7.0 m X 3.4 m              | Wooden     | Plastic| Wooden                          | School's field and light traffic |
| Laboratory 1    | 12.0 m X 7.5 m X 3.0 m             | Wooden     | Wooden | Concrete                        | Light traffic and heavy traffic |
| Laboratory 2    | 12.0 m X 7.5 m X 3.0 m             | Wooden     | Wooden | Concrete                        | Light traffic               |
| Laboratory 3    | 12.0 m X 8.8 m X 3.6 m             | Wooden     | Wooden | Concrete                        | School's field and light traffic |
| Laboratory 4    | 12.0 m X 8.8 m X 3.6 m             | Wooden     | Wooden | Concrete                        | School's field and light traffic |

A sound level meter was used in the study to capture the background noise levels and reverberation time inside the classrooms and laboratories. For the background noise measurement, a measurement point was sufficient to capture the ambient noise of the enclosed space. Reverberation time is depend on the volume and sound absorption of the room. Since the room layout and dimension for some classrooms were same, only 3 classrooms were tested to examine the sound decays of the rooms. Reverberation time measurements were carried out according to the ISO 3382 [22] using Brüel&Kjær Type 2250 sound level meter, Brüel&Kjær Type 4260 omni-directional sound source and Brüel&Kjær Type 2734 amplifier. In classrooms, a total of 4 measurement points were chosen to capture the reverberation times of the room while 5 measurement locations were set in the laboratories to record the sound decays. The sound level meter was put at different heights, 1.2 meter and 1.6 meter above from the floor, and at least 1 meter away from all walls in order to capture the reverberation time of whole enclosed space and avoid the reflections sound from the walls.

3. Results and Discussions

3.1. Background noise / Noise Criteria (NC)

Figure 4 shows the comparison of background noise between six classrooms at one-third octave band central frequencies. From the graph, the background noise at classroom 1 and classroom 2 were slightly higher than other classrooms. This may due to the facts that these classrooms were located next to the residential road and main road of Jalan Tan Swee Hoe. Combination of the traffic noise from both roads made the background noise at classroom 1 and classroom 2 get higher value around 8 dB to 14 dB compared to the classroom 3 and classroom 4 which is only exposed to the traffic noise from the main road only as shown in Figure 2. From the graph, the lowest frequency in each of the classroom give the higher value of the background noise. This is affect from the traffic noise which produce lower frequencies of sound.

The background noise of all tested laboratories was shown in Figure 5. From the graph, the data obtained from laboratory 4 were slightly higher at range of frequency 800Hz to 1.25 kHz octave
bands. Higher value of background noise obtained in this laboratory may due to the facts that the distance between the laboratories 4 with the school field was very near which was approximately 4.6 m from laboratory wall. Besides, there were some students playing softball at that school field during the field measurement was conducted. One can conclude that, the background noise of the spaces inside the school not only depend on the traffic noise but also depends on the noise from the school field. Thus, the teaching and learning process in the laboratories can be interrupted by the noise produced from the school field.

For the spaces like laboratories or classrooms, the recommended Noise Criteria (NC) value is between NC 25 – NC 30 [18]. However, the results obtained in this secondary school showed that all measured learning spaces were exceed the recommended value. This indicated the urban traffic noise and surrounding noise gave the great impact to the learning spaces indoor environment.

![Figure 4. Background noise (NC curves) of measured classrooms.](image-url)
3.2. Reverberation time

Figure 6 shows the average of reverberation time for classroom 2, classroom 4 and classroom 6. From the graph, classroom 4 obtained higher reverberation time compared to other classrooms. This may due to facts that volume of this classroom was bigger than other two classrooms where classroom 2 and classroom 6 have the same design and space volume of 214.20 m³ while classroom 4 has the space volume of 244.35 m³. Besides, the higher value of sound decays recorded in classroom 4 probably because of the condition inside the classroom which had poor sound absorption. Based on the field observation, there was no curtain and notice board inside this classroom.

Based on recommended value, reverberation time for room with volume of 200m³ - 300m³ should be below 0.8 second, but almost all measured classrooms had the longer sound decay than it should be except classroom 2 at 4 kHz and 5 kHz. The speech intelligibility in these spaces can be said was very poor especially classroom 4 which obtained longer reverberation time than a classroom should be.

Figure 7 illustrates the average sound decays for all measured laboratories. At the lower frequencies, the value of reverberation time for laboratory 1, 2 and 3 were equivalents which are in range 1.0 s to 1.7 s and the time for sound to decays for laboratory 1, 3 and 4 were rose sharply between 125Hz to 200Hz. This may due to time decays at those octave band frequencies influenced by the multi reflections inside the laboratories. Based on 4 tested laboratories, laboratory 1 and 2 obtained lower reverberation time because the volume of these two laboratories were smaller than that volume of laboratory 3 and 4. Besides, there were some wooden furniture that placed inside these two laboratories which can increase the total absorb of the spaces and this made the sound decays become shorter. According to the results obtained from this study, the overall reverberation time values for all laboratories were higher than recommended value.
Field measurement on acoustical performance of classrooms and laboratories in a public high school in Batu Pahat was carried out. Two importance parameters (reverberation time and background noise) for evaluating the audio comfort of the classroom was tested. A total of 6 classrooms and 4 laboratories were tested for its ambient noise. The background noise inside the learning spaces is influenced by the outdoor traffic noise and school’s recreation activities from other students. All measured learning spaces obtained higher noise criteria (NC) levels than recommended value of NC 25 to NC30. This will create poor classroom acoustic condition when the background noise in the rooms are so high that they would interfere with learning and teaching process.

The evaluation of spaces in term of speech performance (reverberation time) for 3 tested classrooms and 4 laboratories was done in this study. The results showed that all tested learning spaces except classroom 2 exceed the recommended value of 0.8 second. This implied that the level of speech intelligibility of the spaces was low. Students may not be able to hear the instructions or massages from the teachers clearly.

As a conclusion, the acoustical performances of classrooms and laboratories in SMK Convent Batu Pahat were unsatisfied as places for teaching and learning process. This may affect the speech understanding, attention, concentration, academic achievement and also student’s behavior in classroom.
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