# Traffic Noise Measurement, Perception, and Modelling in a University Campus

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**Abstract:** Noise from vehicular traffic is an undesirable impact on communities, particularly for sensitive land uses types like schools and residential area. Noise standards are prescribed in order to help preserve the environment. In this study, noise measurements and traffic noise perception study are conducted in student dormitory areas. The result of perception survey is used to verify the current Philippine standards for land type AA, i.e., schools/hospitals. The data is further used to develop an empirical traffic noise model. Analysis of perception study revealed that students have a higher tolerance on noise levels compared to standard. This research also presents a multiple regression model for traffic noise, and demonstrates its practical application for planning and traffic impact studies.

Keywords: Traffic Noise, Noise Standard, Traffic Impact

## 1. Background and Objective

Traffic noise, or noise caused by motor vehicle traffic, is the second most hazardous type of pollution from mobile source. Noise is disagreeable and unwanted sound. Traffic noise is undesirable in affected communities because it can cause: (1) physiological harm such as hearing loss or even heart disease; (2) cognitive impairment or causing interruptive effect in understanding; and (3) disturbance of silence which could result to loss of sleep or even decrease in motivation.

The unit of sound is the decibel (dB). Traffic sound is measured in terms of the so called "A-weighted sound pressure level" (or dBA). It can be measured using sound level meters. For traffic noise, it is common to express sound measurements fluctuating over a period of observation in terms of "equivalent continuous noise level" or $L_{eq}$. This unit is also interpreted as "average energy" or "time equivalent level".

Taking $p_o$ as the reference pressure level (set to be equal to 20 μPa), and $p_a$ as actual sound pressure in Pascals (Pa) measured in a time period where $t_1$ is start time and $t_2$ is end time, the $L_{eq}$ is calculated using the equation below.

$$L_{eq} = 10\log\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \frac{{p_a}^2}{{p_o}^2} dt\right] \qquad \text{Equation (1)}$$

Sound pressure level of zero (0) dBA is the threshold of human hearing. Noise levels at around 60 dBA could cause annoyance and extended exposure to noise levels of around 70 dBA and higher could be detrimental to hearing and health.

Table 1. Philippine Noise Standard
(Maximum allowable noise levels, dBA)

| Area Category | Daytime (9am-6pm) | Morning (5am-9am) Evening (6pm-10pm) | Nighttime (10pm-5am) |
|---|---|---|---|
| (AA) Schools/Hospitals | 50 | 45 | 40 |
| (A) Residential | 55 | 50 | 45 |
| (B) Commercial | 65 | 60 | 55 |
| (C) Light Industrial | 70 | 65 | 60 |
| (D) Heavy Industrial | 75 | 70 | 65 |

*Source: Rules and Regulations of the National Pollution Control Commission (1978), Section 78, Table 1. Environmental quality standards for noise in general areas.*

Noise standards must be followed to ensure environmental wellness for the community. For residential areas, noise levels higher than 55 dBA during daytime, and 45 dBA during nightime are considered unacceptable. For institutional buildings like schools and hospitals, the acceptable standard is expectedly stricter at 50 dBA and 40 dBA during day and night time, respectively. Table 1 shows in more detail the noise standards for the Philippines.

The University of the Philippines Campus in Diliman has a relatively well-preserved area that is environmentally pleasing compared to other areas in Metro Manila. This study seeks to determine if traffic noise is perceived and how it affects the community in the campus, specifically in the dormitories, and if the sound or noise levels are within acceptable standard. An empirical traffic noise model is also developed from the field measurements.

Specific objectives of this study are:

i. measure traffic noise levels at the roadside and inside the dormitories.

ii. determine the dormer's perception of traffic noise

iii. compare observed noise levels with noise standard, and

iv. model traffic noise

## 2. Data Collection

### *2.1 Preliminary Survey and Site Selection*

A preliminary two-item questionnaire survey was conducted to determine which dormitories are affected by traffic noise, and identify specific dormitories where actual noise level measurements will be conducted.

There are eleven (11) dormitories inside the campus and they can be grouped into clusters as shown on the map below (Figure 1). The questionnaire items were: (1) Do you hear noise from passing-by vehicles whenever you are inside the room (Y/N?), and (2) Identify noise sources you hear inside your room and classify if tolerable or irritable.

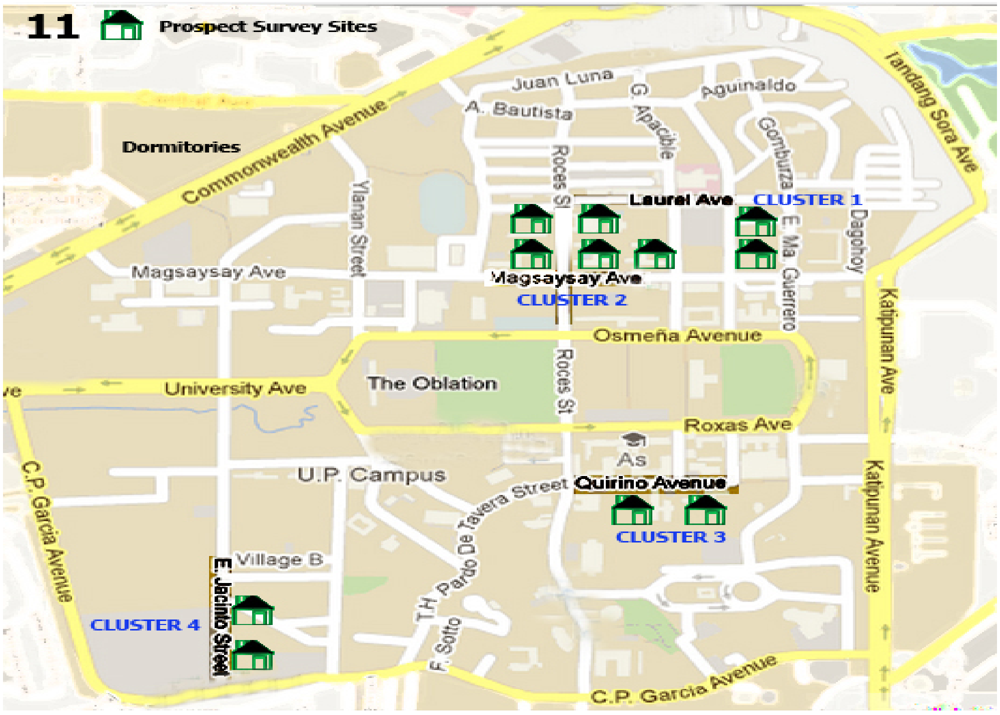



Figure 1. Location of 11 Dormitories in UPD Campus and Clustering Used in This Study.

Result of the preliminary survey is summarized in Table 2. From the result, it was decided that the actual noise level measurements will be conducted in four (4) dormitories representing the dormitories with the highest percentage of student residents who responded that traffic noise is audible inside their rooms. The dormitories are: International Center ("**IC**"), Molave Residence Hall ("**Molave**"), Sampaguita Residence Hall ("**Sampaguita**"), and Centennial Hall ("**Centennial**"). Incidentally, the top four also come from different clusters.

Table 2. Result of Preliminary Survey

| Cluster | Dorm | Population | Sample Size | **Is traffic noise audible in your dorm? "YES" %** |
|---|---|---|---|---|
| 1 | Ilang-Ilang | 275 | 160 | 56 |
| | IC | 120 | 90 | 77 |
| 2 | Sanggumay | 124 | 94 | 71 |
| | Kalayaan | 516 | 220 | 58 |
| | Yakal | 386 | 193 | 68 |
| | Molave | 378 | 190 | 83 |
| | Ipil | 303 | 170 | 49 |
| 3 | Sampaguita | 260 | 155 | 75 |
| | Kamia | 363 | 187 | 62 |
| 4 | Centennial | 280 | 162 | 94 |
| | Kamagong | 68 | 58 | 67 |

The survey result also indicated that aside from traffic noise, “people chatting”, “gadget sounds”, “other dormitory activities”, and “nearby road construction” are other noise sources that tend to irritate the residents. However the number of respondents that found these sources *irritating* is generally low compared to those who found them *tolerable*.

### *2.2 Noise Level Measurement and Traffic Volume Count*

Field measurements of noise using sound level meters (SLM) mounted on tripods were conducted at the survey sites. Three (3) SLMs were deployed simultaneously at each dormitory and positioned at various distances from the road centreline with the third one inside a dormitory room. Figure 2 shows a typical survey deployment layout.

Vehicular traffic counts were simultaneously conducted with noise measurements. Vehicles were classified into: small cars, large cars, jeepneys, buses, small trucks, large trucks, tricycles, and motorcycles, and totalled per hour. The survey schedule and locations of SLM from the road centreline are summarized in Table 3.

### *2.3 Noise Perception Survey*

In order to assess the impact of actual noise levels in the dormitory, a noise perception questionnaire survey was administered to student residents simultaneously with actual noise level measurements. The required sample sizes per dormitory used to ensure sound statistical inference were the same as the ones shown in the 4$^{th}$ column of Table 2 presented earlier. The sample size was calculated using Cochran’s formula, for a 95% confidence interval (.05 margin of error) at an assumed variance of 0.25. The questionnaire used is shown in Figure 3.

Table 3. Location of SLM and Schedule of Field Surveys

| Dormitory | SLM Position | | Time of Field Surveys* (Simultaneous Noise Measurement, Traffic Volume Count, and Perception Survey) | | | |
|---|---|---|---|---|---|---|
| | No. | Distance from Road Centerline | 7-9 AM | 9AM-6PM | 6-10PM | 10PM-7AM |
| **IC** | 1 | 5 m | ✓ | | ✓ | |
| | 2 | 25 m | ✓ | | ✓ | |
| | 3 | 30 m | ✓ | | ✓ | |
| **Molave** | 1 | 5 m | ✓ | ✓ | ✓ | ✓ |
| | 2 | 25 m | ✓ | | ✓ | |
| | 3 | 30 m | ✓ | | ✓ | |
| **Sampaguita** | 1 | 5 m | ✓ | | ✓ | |
| | 2 | 20 m | ✓ | | ✓ | |
| | 3 | 30 m | ✓ | | ✓ | |
| **Centennial** | 1 | 8 m | ✓ | ✓ | ✓ | ✓ |
| | 3 | 13 m | ✓ | | ✓ | |

*Dates of Survey: Molave - 09/19/2012 (Wed), Sampaguita - 09/20/2012 (Thu), IC - 09/25/2012 (Tue), Centennial - 09/28/2012 (Fri).

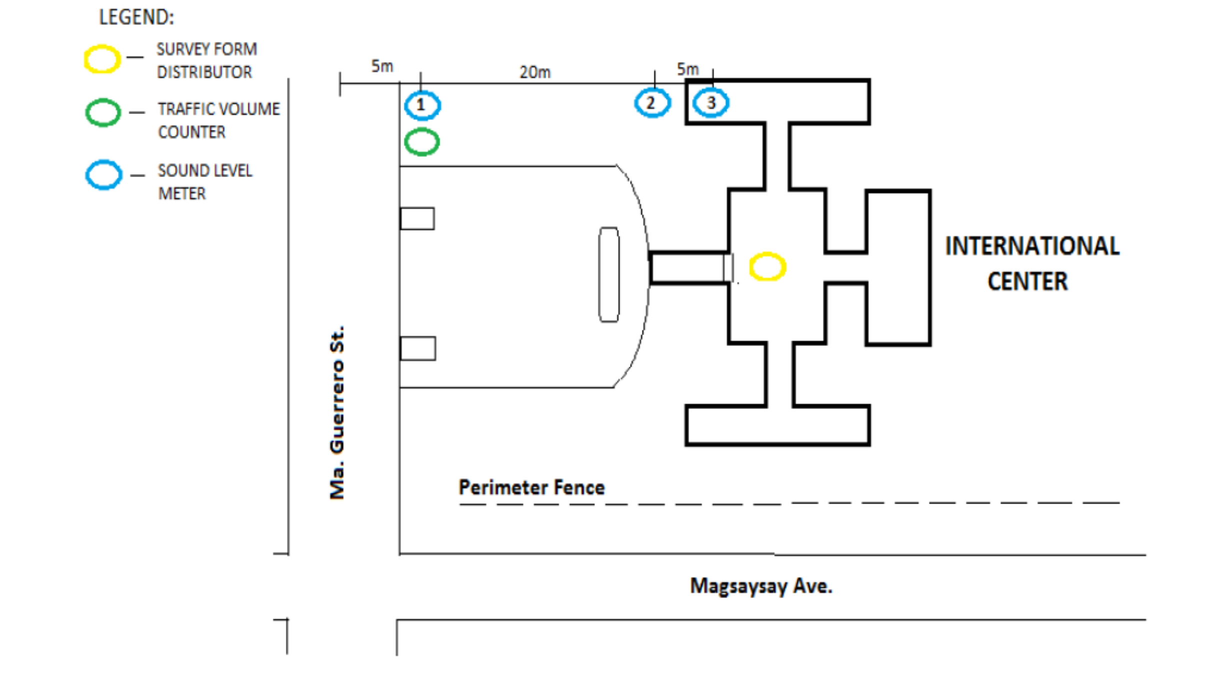



Figure 2. Field Survey Layout

## 3. Survey Results and Discussion

### *3.1 Noise Levels and Traffic Volume*

Hourly variation of vehicle traffic counts at roads adjacent to the dormitories, and noise levels measured ($L_{eq}$, in *dBA*) are presented in the following pages as bar and line graphs, respectively.

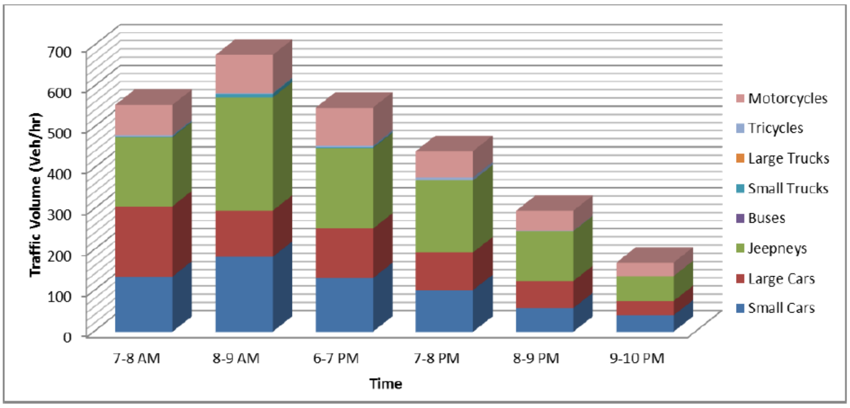
Traffic noise level decreases with distance away from the road centreline. Thus, as expected, sound level measurements have the highest values at Position 1 (roadside) and lowest at Position 3 (inside the dorm rooms) for all locations.

*International Center* (See Figures 4.1 and 4.2)

Highest traffic volume recorded was 677 veh/hr at 8-9 AM, and there were no buses, and large trucks observed. During the same hour, the highest observed noise level were also recorded: 72.3 dBA, 66.3dBA, and 57.8 dBA at positions 1 (roadside), 2, and 3 (inside the dorm), respectively. All sound levels measured during the counting period exceeded the allowable value of 50 dBA.

*Molave Residence* (See Figures 5.1 and 5.2, also Figures 8.1 and 8.2)

The road fronting this dorm was busier, with highest hourly volume of 1,020 veh recorded at 8-9AM. The afternoon peak traffic volume was only 861 veh/hr at 5-6PM. The observed number of buses and tricycles are very few and negligible. Again, the highest noise level recorded corresponded to the peak traffic hour with measured values of 73.6, 66.4, and 58.5 dBA at positions 1,2, and 3, respectively. Again, all sound levels violated the standard. The complete 24-hour sound measurements at roadside (position 1) are shown in Figures 8.1 and 8.2. The graph clearly shows that the sound level standard is exceeded regardless of time of day.



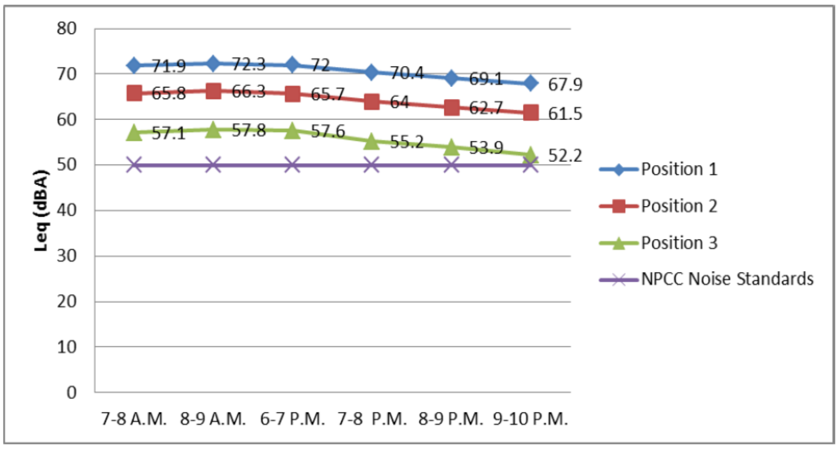



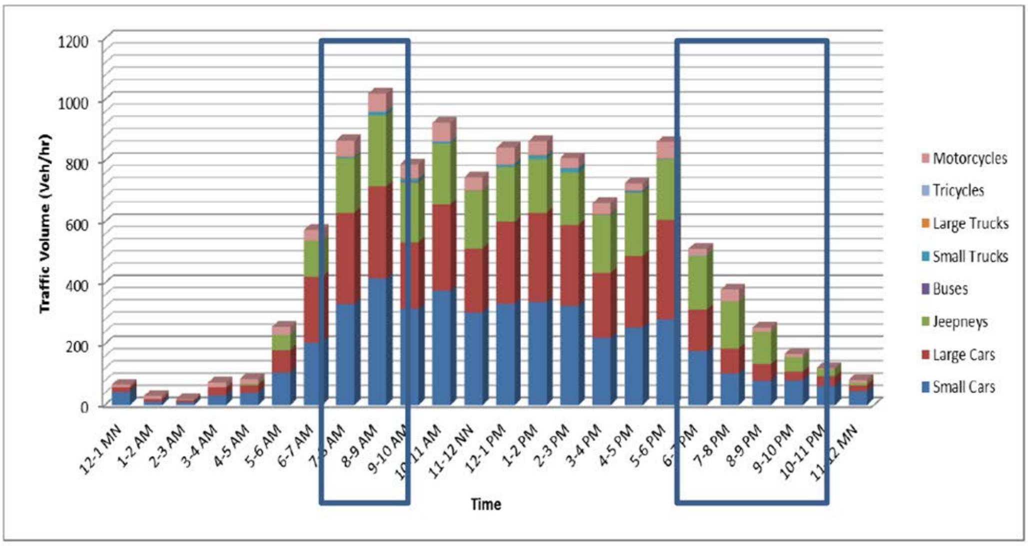

Figure 4.1 – top: **Hourly Variation of Traffic** – International Center
Figure 4.2 – bottom: **Noise Levels** – International Center

*Sampaguita Residence* (See Figures 6.1 and 6.2)

This dormitory registered the lowest traffic volume and noise levels among the study sites. Highest traffic volume is only 361 veh/hr at 8-9AM. There were no buses and large trucks, and negligible number of small trucks and tricycles were recorded. The corresponding sound levels during the peak hour of traffic were 70.4, 64.8, and 56.9 dBA at positions 1, 2, and 3, respectively; all above the minimum standard. At positions 1 and 2, despite the lower traffic volumes (lowest traffic volume recorded was 53 veh/hr), all sound levels exceeded the minimum standard. However, for position 3 (inside the dormitory), noise levels fell within standards but only during the evening observation periods (48. 5 and 45.3 dBA at 8-9 PM and 9-10PM, respectively) when traffic volume along the fronting road was low. From Figure 6.2, the sound level inside the dorm (position 3) is approximately equal to the standard (50 dBA) and the observed traffic volume was 127 veh/hr.

*Centennial Dormitory* (See Figures 7.1 and 7.2, also Figures 9.1 and 9.2)

Very high traffic volume and sound level measurements were recorded at this site. The dormitory is situated along CP Garcia Avenue, a major road that serves heavy volume of vehicles with significantly high number of small and large trucks. Twenty-four hour traffic count and sound level measurement for position1 (roadside) were implemented at this site and sound level readings throughout the 24-hr period are way above the minimum standard (Figure 9.1 and 9.2). The highest sound level was 87.2 dBA at 11AM-12NN with a corresponding traffic volume of 1,893 veh/hr. Highest traffic volume of 2,408 veh/hr was recorded at 5-6PM, and during the same period, the sound level recorded was 76.1 dBA. Although the direct relationship between traffic volume and sound level is still apparent, the noisiest hour did not coincide with peak hour for total traffic volume. However, closer investigation shows that the peak noise levels occur during periods with heavy volume of trucks. Inside the dormitory, the highest measurement was 63.3 dBA at 9-10PM (Figure 7.2).



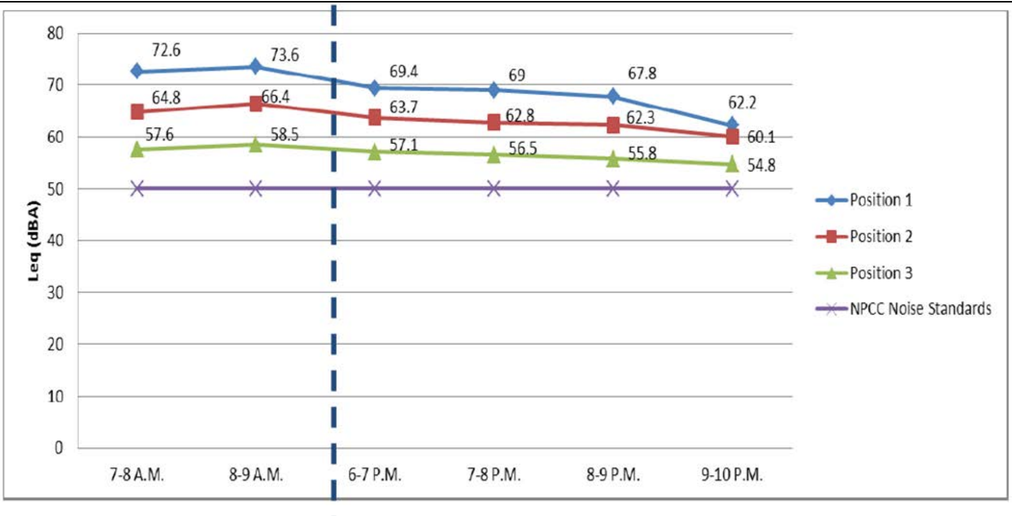
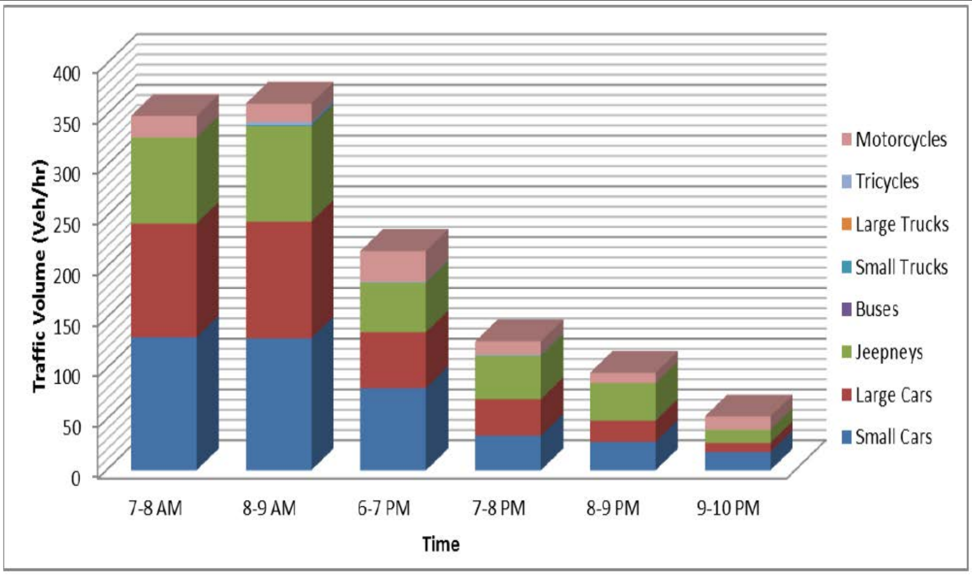




Figure 5.1 – top: **Hourly Variation of Traffic** – Molave
Figure 5.2 – bottom: **Noise Levels** – Molave



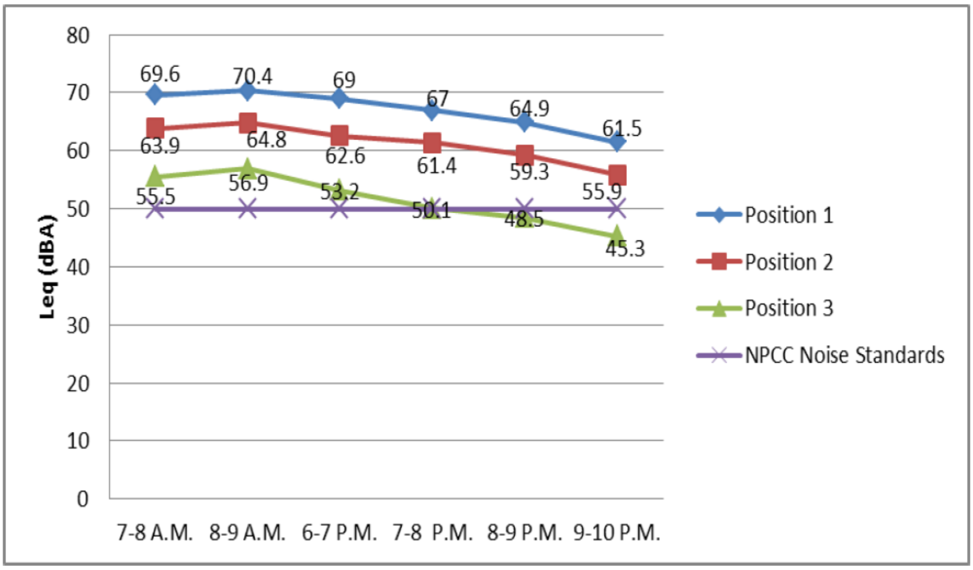
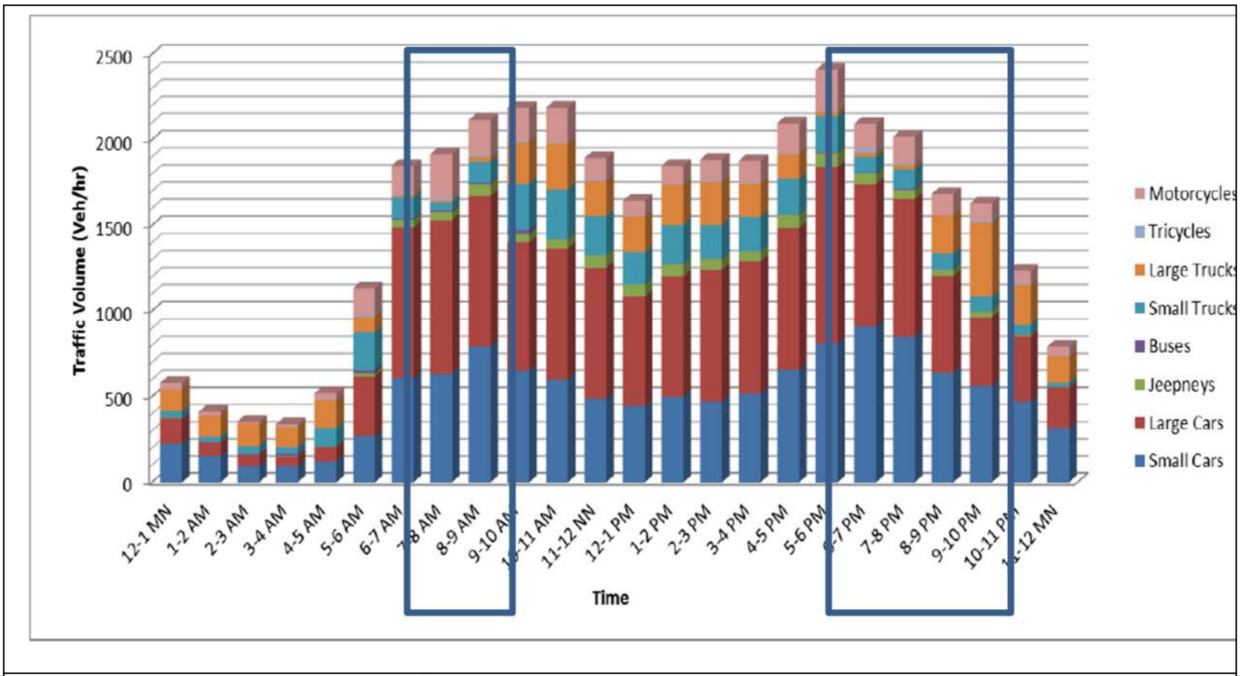




Figure 6.1 – top: **Hourly Variation of Traffic** – Sampaguita
Figure 6.2 – bottom: **Noise Levels** – Sampaguita



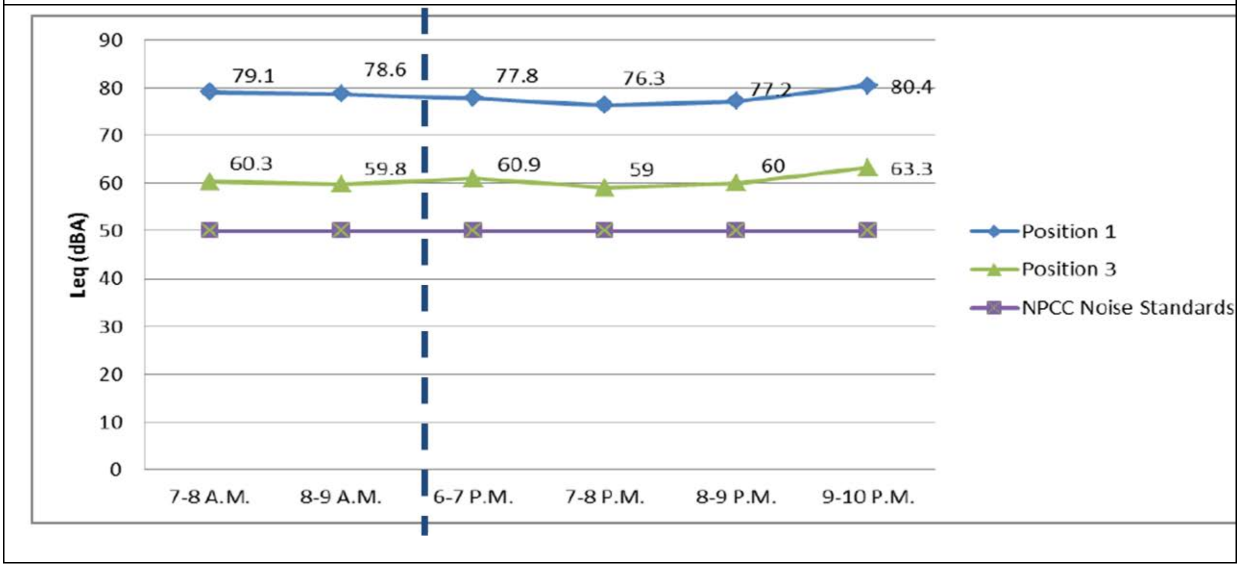
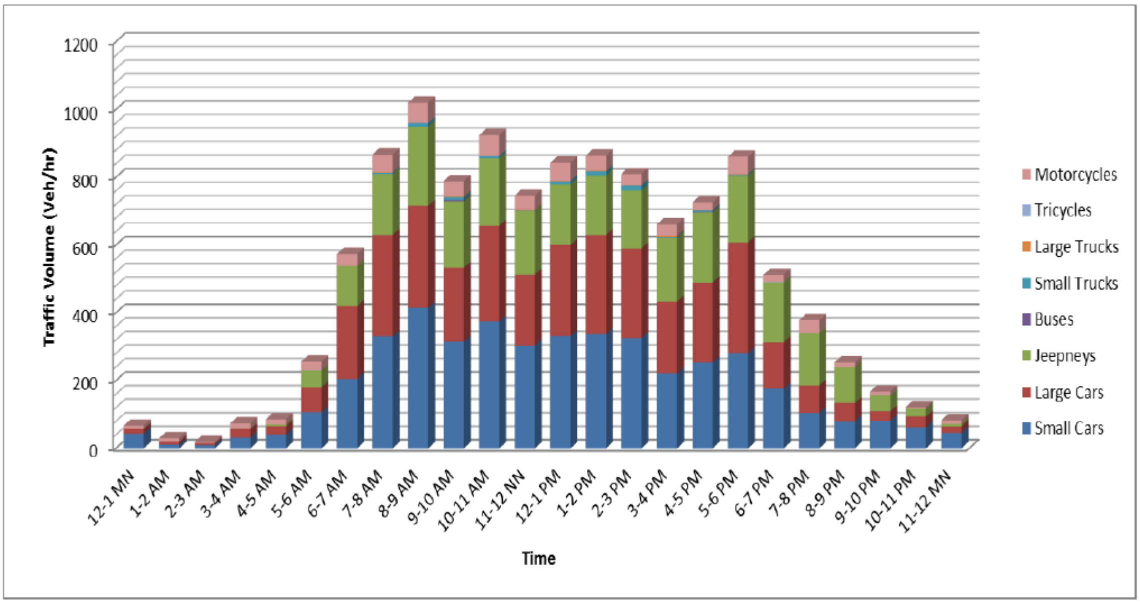




Figure 7.1 – top: **Hourly Variation of Traffic** – Centennial
Figure 7.2 – bottom: **Noise Levels** – Centennial

Molave (24 hours)



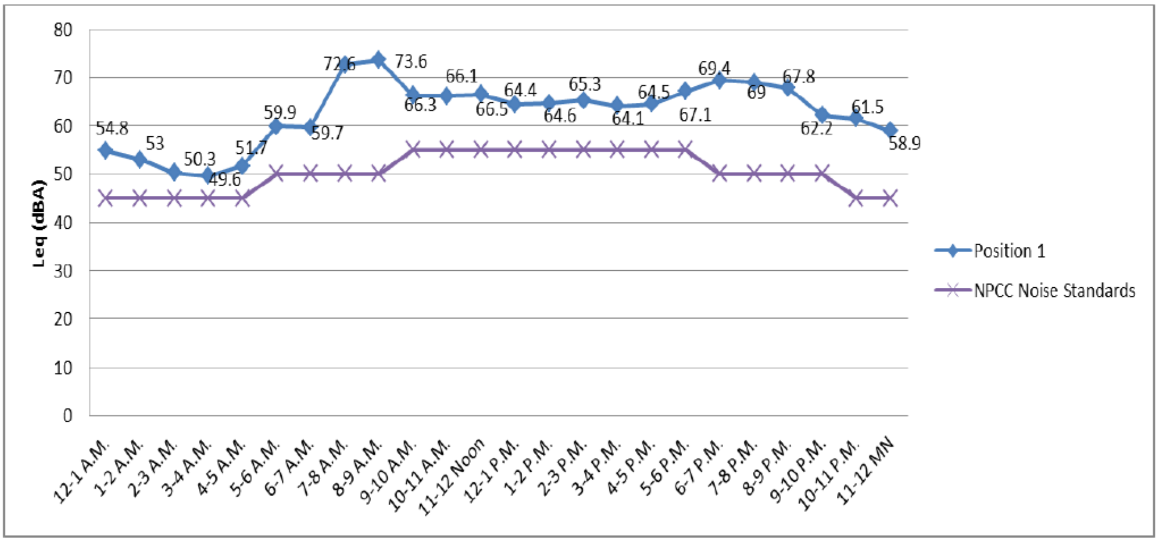
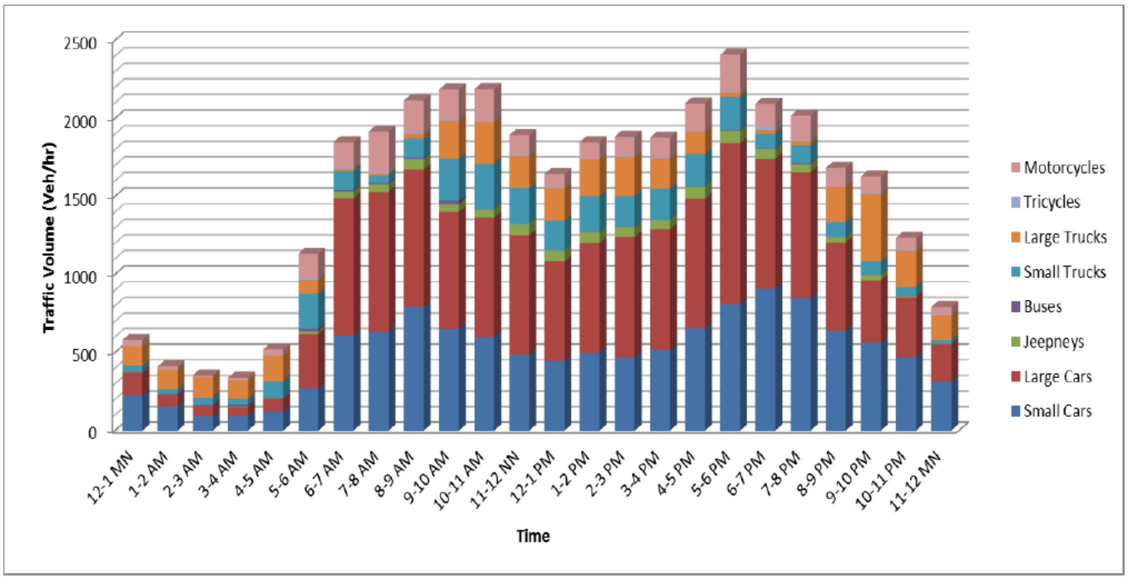




Figure 8.1 – top: **Hourly Variation of Traffic** – Molave [24 hours]
Figure 8.2 – bottom: **Noise Levels** – Molave [24 hours]

Centennial (24 hours)



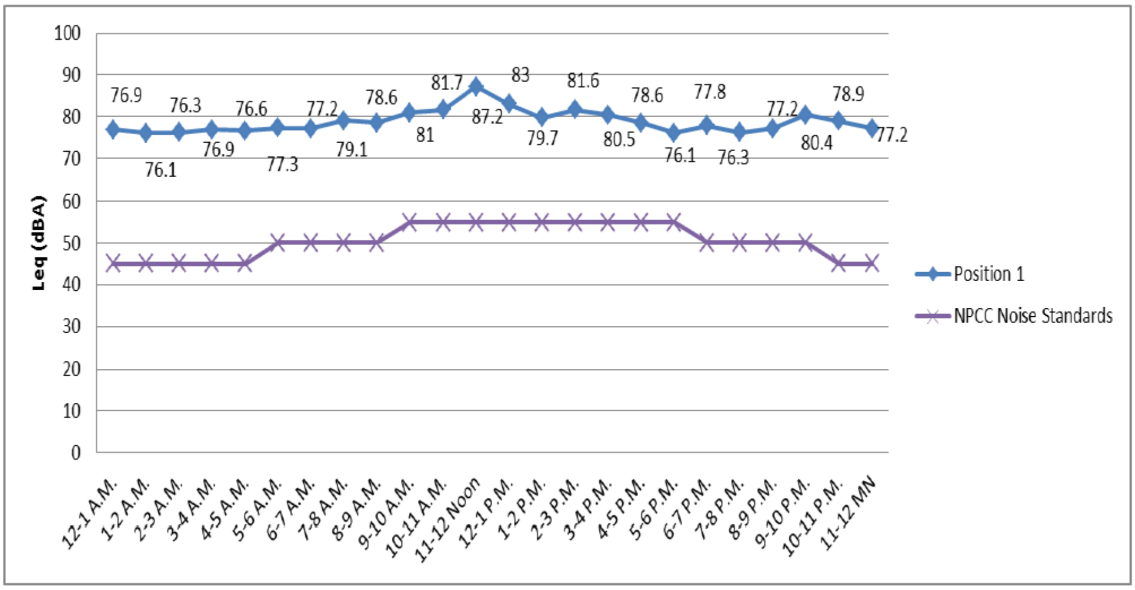




Figure 9.1 – top: **Hourly Variation of Traffic** – Centennial [24 hours]
Figure 9.2 – bottom: **Noise Levels** – Centennial [24 hours]

### *3.2 Perception of Noise*

The table below shows a summary of the range of noise level measurement inside the dormitory rooms, side by side the result of the noise perception survey. The range of noise levels all exceed the allowable standard of 50 dBA, except for the lower range values (minimum of 45.3 dBA) observed in Sampaguita dormitory.

| Dormitory | Measured Noise Level, $L_{eq}$ (*dBA*) | | | Noise Perception | |
|---|---|---|---|---|---|
| | Min | Max | **Mid-range** | Unheard or Tolerable (%) | **Irritating (%)** |
| Centennial | 59.0 | 63.3 | **61.2** | 48 | **52** |
| Sampaguita | 45.3 | 56.9 | **51.1** | 94 | **6** |
| Molave | 54.8 | 58.5 | **56.7** | 86 | **14** |
| IC | 52.2 | 57.8 | **55.0** | 92 | **8** |

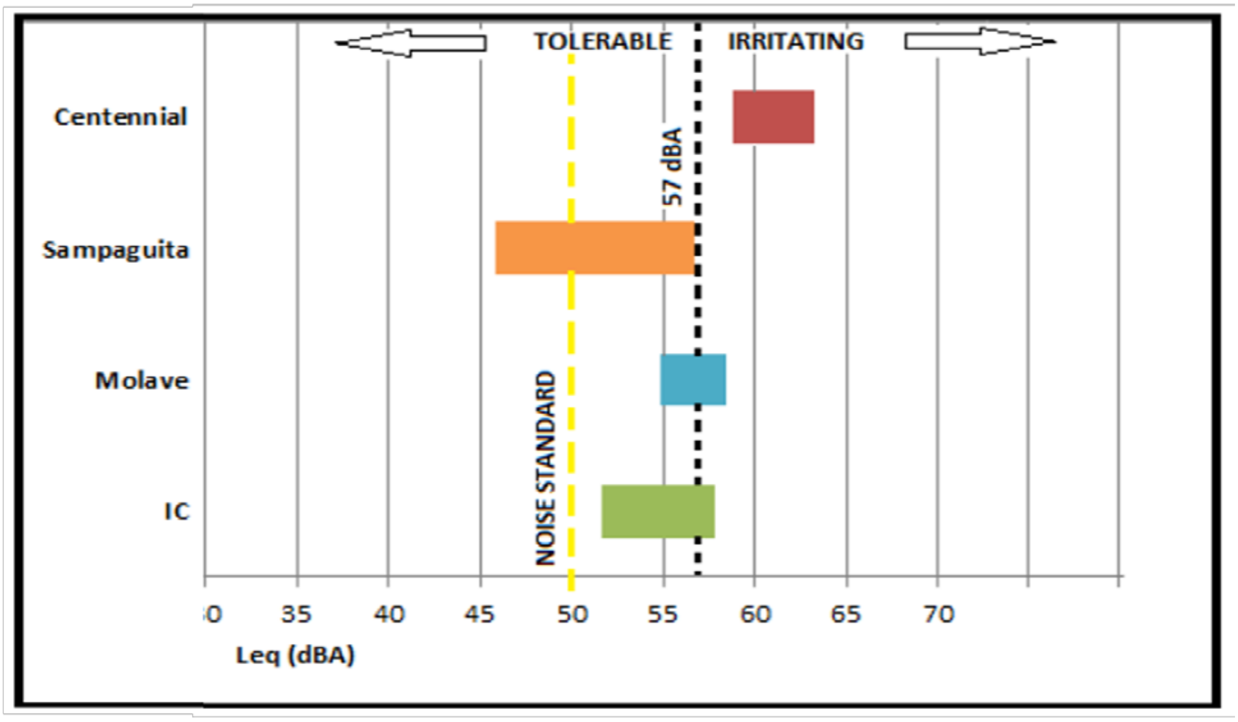



Figure 10. Observed Noise Levels ($L_{eq}$) and Perception

The perception survey revealed that:

(1) the percentage of students irritated by traffic noise in a particular dormitory increased with the measured noise levels (see 3rd column in the table for mid-range as representative values), and

(2) high percentage of students still found the noise levels imperceptible or tolerable in spite of levels above the minimum standard.

Figure 10 graphically summarizes the range of measured sound levels in the four dormitories. Also shown in the graph are lines to indicate the noise standard and the apparent boundary between tolerable and irritating levels. In this study, the maximum noise level of around 56.9 dBA in Sampaguita is still generally imperceptible or tolerable to 94% of the student residents. Based on this, it could be deduced that tolerable noise level is at least 56.9 dBA, or approximately 7dBA above the prescribed noise standard (50 dBA) for residential areas.

## 4.0 Modelling Traffic Noise

### 4.1 Data

The data obtained from simultaneous field measurement of sound levels, and classified traffic counts were used to develop a traffic noise model using multiple linear regression. The database consisted of 120 hourly data points (total for all four dormitory locations) consisting of variables listed below.

Table 5. List of explanatory variables

| | |
|---|---|
| L | $L_{eq,}$ Equivalent continuous sound level in dBA - explanatory variable |
| D | Distance from road centerline (regardless if sound level meter is indoor or outdoor) |
| Q | Total hourly traffic flow, in veh/hr |
| CARS | Number of cars |
| PUJ | Number of public utility jeepneys |
| BUS | Number of buses |
| TRUCK | Number of trucks (further classified into small and large) |
| TC | Number of tricycles (motorcycle with side car for public transportation) |
| MC | Number of motorcycles |
| I | Dummy variable for distance to account for indoor measurement (1 if sound level meter is indoor, and 0 if outdoor) |
| t | Truck ratio (total number of trucks, over Q) |

4.2 Analysis of Variables

Inspection of the correlation values confirmed the expected direct relationship between total number of vehicles Q and sound (or noise) level L. In particular, TRUCK, CARS, and MC had the next highest correlations with L, other than Q. The observed negative correlation for PUJ was deemed insignificant because of the very low absolute value of the coefficient. It was noted also that vehicle types that have high correlation with L are also highly correlated with each other, i.e. CARS are highly correlated with TRUCK and MC, and TRUCK is also substantially correlated with MC.

The expected negative relation between sound level and distance D was also evident. It is consistent with the "inverse square law" for sound which states that under ideal conditions the mean-square sound pressure level varies inversely as the square of the distance from the source. Ideal condition means no reflecting surfaces, no background sound, no interference, and no other possible causes of attenuation. The conditions during field measurement is deemed not ideal for the inverse square law, thus the dummy variable I was included in the analysis to consider the attenuating effect of indoor conditions.

Table 6. Correlation table

| | *L* | *D* | *Q* | *CARS* | *PUJ* | *BUS* | *TRUCK* | *TC* | *MC* |
|---|---|---|---|---|---|---|---|---|---|
| L | 1.00 | | | | | | | | |
| D | -0.23 | 1.00 | | | | | | | |
| Q | 0.78 | -0.15 | 1.00 | | | | | | |
| CARS | 0.72 | -0.17 | 0.99 | 1.00 | | | | | |
| PUJ | -0.04 | 0.18 | 0.03 | 0.00 | 1.00 | | | | |
| BUS | 0.46 | -0.13 | 0.49 | 0.47 | -0.26 | 1.00 | | | |
| TRUCK | 0.77 | -0.17 | 0.75 | 0.67 | -0.34 | 0.48 | 1.00 | | |
| TC | 0.64 | -0.06 | 0.66 | 0.65 | -0.18 | 0.51 | 0.56 | 1.00 | |
| MC | 0.68 | -0.08 | 0.90 | 0.89 | 0.03 | 0.57 | 0.62 | 0.70 | 1.00 |

4.3 Result of Multiple Regression Analysis

The model formulation that best fits the data is given in the equation below followed by a table showing the statistical result of regression analysis.

$$L = 37.98 - 4.43 Log\ D + 12.34\ Log\ Q + 22.88t - 204.92\left(I / D\right) \qquad \text{Equation (2)}$$

Table 7. Regression statistics

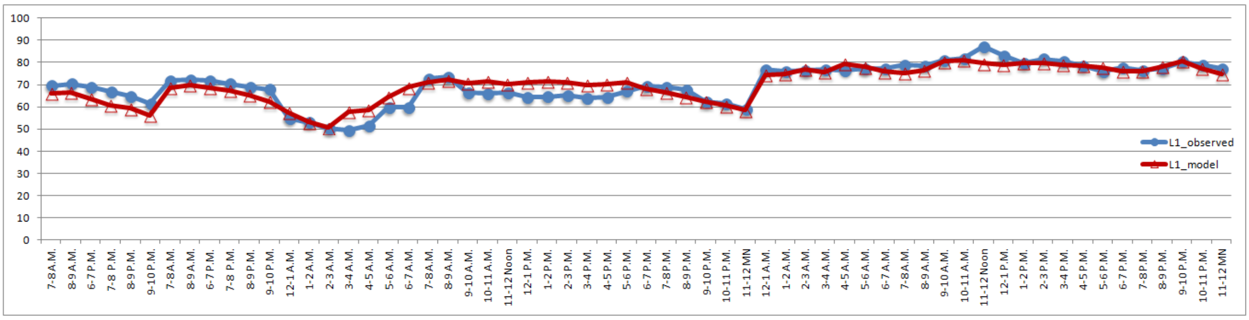
| *Regression Statistics* | |
|---|---|
| Multiple R | 0.934989055 |
| R Square | 0.874204533 |
| Adjusted R Square | 0.869829038 |
| Standard Error | 3.179107572 |

| | |
|---|---|
| Observations | 120 |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* |
|---|---|---|---|---|
| Intercept | 37.98 | 2.19 | 17.33 | 7.32E-34 |
| Log_TOTVEH | 12.34 | 0.68 | 18.26 | 8.98E-36 |
| Indoor/Dist | -204.92 | 11.79 | -17.38 | 5.98E-34 |
| TRUCK_Ratio | 22.88 | 2.38 | 9.60 | 2.23E-16 |
| Log_Dist | -4.43 | 1.12 | -3.95 | 0.000133 |

## 4.4 Validation Plots

Figure 11 graphically shows the satisfactory performance of estimating sound levels using the regression model by comparing with observed measurements.



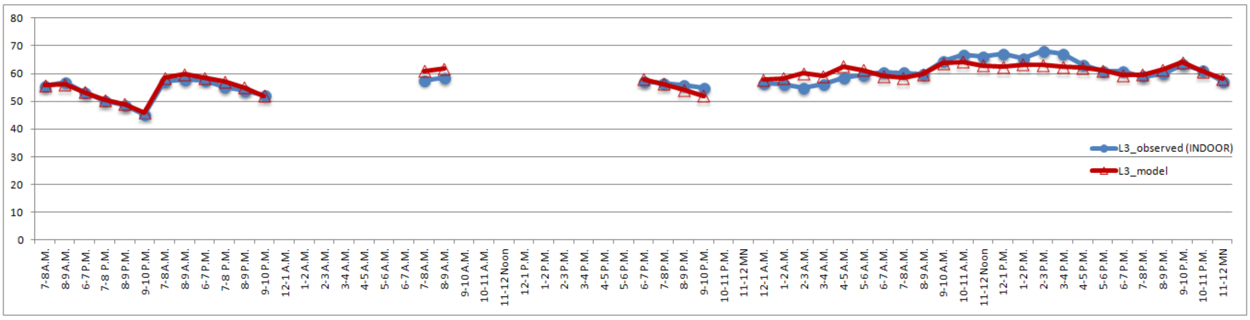




Figure 11. Plots of observed vs model values of sound levels

## 4.5 Model Application

Using the empirical model shown as Eqn. 2, the graph of outdoor roadside sound level (10m from road centreline) versus traffic volume and truck ratio can be plotted to obtain a chart (see Figure 12) that is useful in estimating the impact of traffic. In Figure 11, the Philippine daytime noise level standards for different land use categories are depicted, as well as the observed tolerable noise level for AA obtained from the perception study.

This chart could be used as aid in traffic impact studies. For instance, traffic volume of 100 veh/hr with a truck ratio of 0.1 will result to an estimated noise level of about 61 dBA, which exceed the standard for commercial land use.

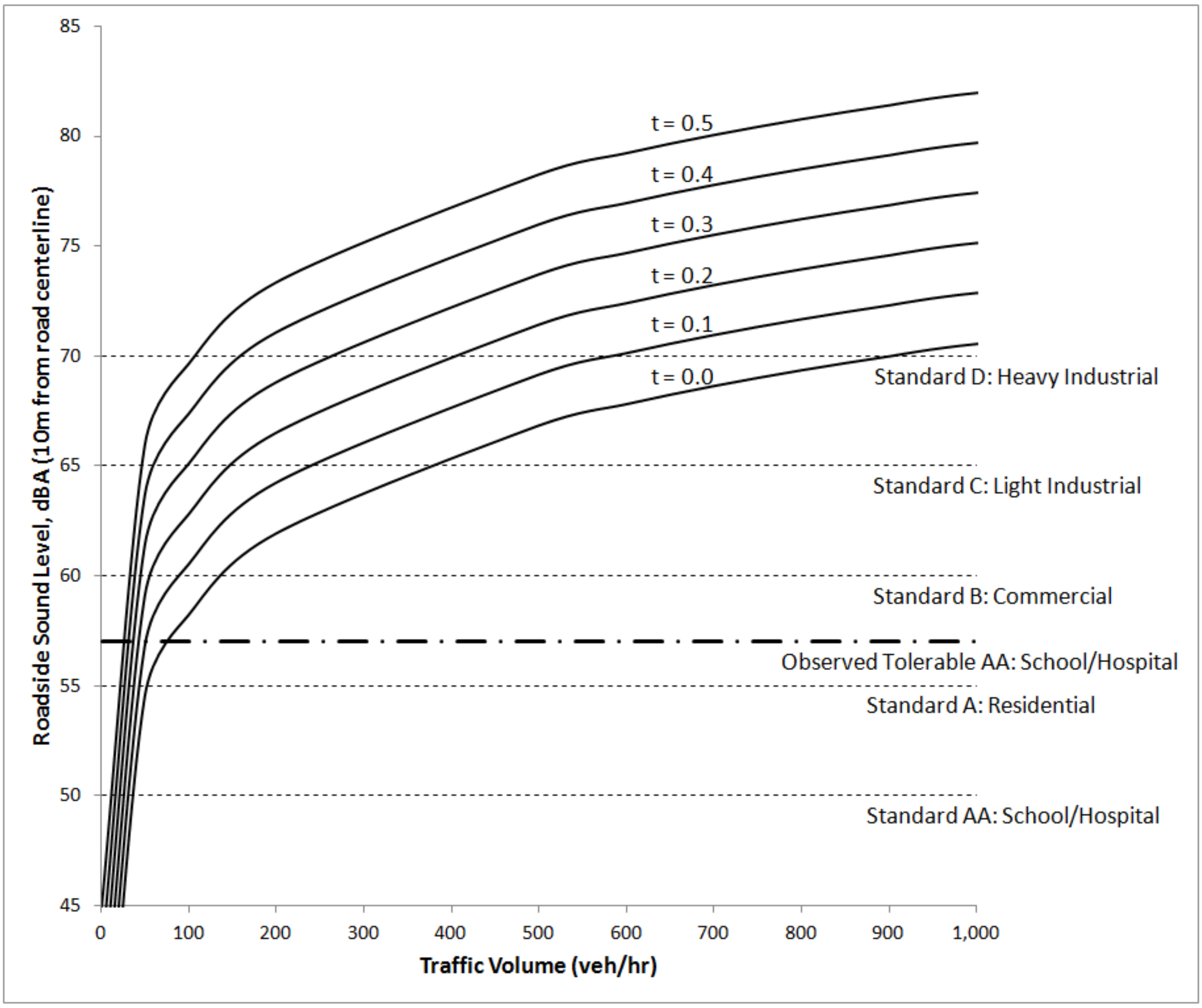



Figure 12. Roadside Sound Level vs Traffic Volume and Truck Ratio *t* (outdoor)

## 5.0 Conclusion

This study provided evidence for the following conclusions:

1. Observed traffic sound levels vary directly with traffic volume and percentage of trucks

2. Traffic noise levels are high in dormitories; noise standards are generally exceeded inside the campus dormitories.

3. Traffic noise is perceived inside the dormitories but most students find them imperceptible or tolerable even if the levels had exceeded Philippine noise standard.

4. Tolerable level of perceived traffic noise is around 7 dB higher than the standard.

5. An empirical model for estimating roadside traffic noise is developed as a function of total traffic volume, truck percentage, distance from the road centreline and using a dummy variable for outdoor/indoor location.

6. The empirical model could be used as a practical tool in estimating roadside noise impact of traffic, and is therefore useful in traffic impact studies.

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