A Profile of Street Noise in Dumaguete City, Philippines, 2008

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This paper contains the results of a research done on street noise in Dumaguete City, using 90 different observation points or locations. It includes data on sound pressure level (SPL), traffic density (number of vehicles per minute), and construction layout such as width of the street, make and construction type of buildings, and the presence of trees and open spaces beside the streets. The method involves measurement of the sound pressure level and traffic density using three runs in each location and solving for the correlation coefficient **r** between traffic density and sound pressure level. The results indicate that there is a high correlation (r = 0.7342) and thus, a marked relationship, between sound pressure level and traffic density. The results of the study also indicate that 20% (18 locations) of the observation points had SPL values of 75 dB and above. Furthermore, analysis of the data indicates that the SPL depends not only on the traffic density but also on the layout of buildings and roads and the presence of trees and open areas nearby. Also, a frequency analysis of the noise was done using a sound sensor in combination with a computer interface. This showed the traffic noise with the highest sound pressure level to be in the 200 Hz-400 Hz frequency range, generally.

KEYWORDS: street noise, sound pressure level, traffic density, construction layout.

INTRODUCTION AND RELATED RESEARCH

Research on noise is important because of the fact that in a given place, practically all residents are exposed to noise and are, therefore, subject to its deleterious effects. In 1975, Angela Kho conducted a study on Cebu-type of community noise that focused primarily on traffic noise. Her study, which was her master's thesis, aimed to formulate a valid relation between (a) traffic density and sound pressure level (SPL), (b) construction layout and SPL, and (c) noise rating number and SPL. From her data, Kho was able to obtain a relationship between SPL and traffic density which showed that SPL increases with the logarithm of the traffic density up to a certain point when saturation is reached. She also found that for Cebu City streets, buildings 5 storeys high give rise to a saturation in the sound pressure level well ahead of the density; that for buildings 2 to 3 storeys high, the SPL may be higher than 1 dB than when buildings are 1 storey high; that narrow streets are noisier than wide streets by about 2 dB; and, that in the streets, the noise rating is 4 units less than the SPL.[1]

In 1997, I conducted a study on street noise in Dumaguete City, the results of which were published in the *Philippine Physics Journal*, volumes 18 and 19 of the 1996 and 1997 issue.[2] An analog VIZ sound level meter was used in getting the data for 19 different locations in the city. The three noisiest streets, in descending order, were found to be North National Highway, Perdices Street, and Real Street (80-86 dB, 79-86 dB, and 78-85 dB, respectively).

In 2001 and 2002, as part of the "Resource and Ecological Assessment of Sogod Bay" project of the Silliman University Marine Laboratory, I also had the opportunity to conduct research on noise produced by a gravel-grinding machine sitting close to the mouth of Sogod Bay and which noise was believed by the fisherfolk in the area to be the cause of the disappearance of fish from Sogod Bay, as well as a source of noise disturbance to residents in the area. The research finding that is relevant to the present study is that the noise made by the gravel-grinding machine measured at the base of the mound where the machine rested, had a highest rating of only 66.8 dB and decreased inversely with distance from the machine.[3] This value is much smaller than noise caused by traffic.

In 2008, I undertook a second study on street noise in Dumaguete City, this time at 90 different street locations in the city. This study aimed to (a) measure the sound pressure levels, primarily due to motorized vehicle traffic at these 90 locations and to see if there is correlation between the SPL and the traffic density in these streets, (b) see how the construction layout was affecting the noise levels, and finally, (c) see how the noise levels in these streets compare with internationally set noise standards. The results of this research are reported in this paper.

The six streets with the highest sound pressure levels are Perdices Street, Locsin Street, Cervantes Street, Sta. Rosa Street, Real Street, and North National Highway. During the duration of the study, there was a re-routing of street traffic owing to the various road constructions going on that whole year and even beyond. This is one limitation to consider in the analysis of the results.

SOME THEORETICAL CONSIDERATIONS

Sound pressure level

Sound is produced when an object vibrates, causing a disturbance of the medium surrounding the object. This disturbance may come in the form of local changes in pressure, displacement, density or velocity of the individual particles of the medium. The human ear, on the average, senses vibrations as sound when these fall within the frequency range of 20-20,000 cycles per second (Hz). Frequencies above 20,000 Hz are perceived by people as a sensation of pain in the ear. Vibrations with frequencies lower than 20 Hz, generally, could not be heard by people anymore.

The threshold of hearing, which psychologically translates to the faintest sound that a person of normal hearing could hear, is dependent on both the intensity and the frequency of the sound. It has its lowest value for frequencies ranging from about 2,000 to 4,000 Hz, which means that the human ear is most sensitive in this frequency range.[4] This frequency range requires the least energy to produce the sensation of sound. At the lower and the higher frequency ranges, greater sound intensities are needed to produce the sensation of hearing.

The intensity of a sound wave in a specified direction is the time average of energy flow or power through a unit area, across a surface perpendicular to the direction of propagation.[5] To measure intensity, the sound pressure level (SPL) is used. This quantity is defined by the equation:

$$SPL = 10 \log (I/Io)$$

where I is the intensity of a given sound and Io is the reference intensity, i.e., the threshold of human hearing, equal to 10^{-12} W/m^2. The maximum intensity that the ear records as sound is about 1 W/m^2. Sound pressure level is expressed in decibels (dB) where 0 decibel corresponds to the level at the threshold of hearing and 120 dB, the level at the threshold of pain.

This equation shows the relationship between sound pressure level and intensity. The SPL varies with the logarithm of the intensity. The intensity, in turn, is proportional to the number of sound sources, which in this study is signified by the traffic density. The expectation based on theory, is thus, that the SPL will increase with increasing traffic density to a certain degree but at the same time will be affected by the construction layout, i.e., width of the streets, type of buildings, and presence of trees and open spaces.

Sound pressure level values associated with common sound sources (Table 1), is indicated here for reference.

Table 1.

Sound Pressure Levels (SPL) from Various Sources[6] (Representative Values)

SOURCE OR DESCRIPTION OF SOUND	SPL (DB)	INTENSITY (W/M^2)
Threshold of pain	120	1
Riveter	95	3.2×10^{-3}
Elevated Train	90	10^{-3}
Busy street traffic	70	10^{-5}
Ordinary conversation	65	3.2×10^{-6}
Quiet automobile 50	50	10^{-7}
Quiet radio at home	40	10^{-8}
Average whisper	20	10^{-10}
Rustle of leaves	10	10^{-11}
Threshold of hearing	0	10^{-12}

Noise standards

Commonly defined as undesired sound or as the totality of all sounds within the range of hearing to which the attention is not directed, noise can be defined also in terms of an important characteristic that it possesses, that is, noise is unpitched sound.[7] This is so since noise is made up of the combined sound output of many sound sources, emitting sound at various frequencies.

Noise is undesirable because it can be a source of (a) annoyance, (b) masking of desired sounds in a conversation, (c) hearing damage, nervous and physiological disturbances, and (d) accidents or injury due to inattention and lack of concentration caused by the noise. Very high intensity noise can cause permanent hearing damage. Protracted exposure to lower noise levels can cause gradual deterioration of hearing. Exposure to high-intensity noise can cause adverse effects to the ear (Table 2).

Table 2.

Adverse Effects to the Ear of High-Intensity Noise

ADVERSE EFFECT TO THE EAR	NOISE LEVEL
Discomfort	110 dB
Tickle	132 dB
Pain	140 dB
Immediate damage	150 to 160 dB

The World Health Organization (WHO) issued WHO Guidelines for Community Noise that included an authoritative guide on the effects of noise pollution on health. According to this document, noise pollution can bring about the following effects: a) noise-induced hearing impairment, b) interference with speech communication, c) disturbance of rest and sleep, d) psychophysiological, mental health and performance effects, e) effects on residential behavior and annoyance, and f) interference with intended activities. Vulnerable groups are people with decreased personal abilities (old, ill or depressed people); people with particular diseases or medical problems; people dealing with complex cognitive tasks; people who are blind or who have hearing impairment; fetuses, babies, and young children; and the elderly, in general.[9] Hearing damage can take place by constant exposure to noise above 85 decibels while permanent and irreversible hearing loss can result from prolonged exposures to high levels of noise, i.e., 110 decibels or more.

The United States Environmental Protection Agency (U.S. EPA) issued an EPA document, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," in order to "provide a basis for State and local governments' judgments in setting standards." This document identifies a 24-hour exposure level of 70 dB as the level of environmental noise that will prevent any measurable hearing loss over a lifetime and SPL levels of 55 dB outdoors and 45 dB indoors as the levels permissible to prevent activity interference and annoyance. The SPL levels recommended do not represent peak levels but average levels of SPL over an 8 or 24-hour period.[10]

With regard to the physical characteristics of street noise, specifically the frequency, Kho, in her study on street noise in Cebu City, found that the street noise spectrum showed a decrease in sound pressure level in going from the low frequencies to the high frequencies, which according to her, was expected and in agreement with previous studies made on the noise spectrum. The first four octave bands centered at 250 HZ, 500 Hz, 1,000 Hz, and 2,000 Hz. The significant implication that can be drawn from this fact is that the important frequencies for traffic noise are the low and middle frequencies and that, therefore, all frequencies can be masked.[11]

METHODOLOGY

With the help of a map of Dumaguete City showing the roads and thoroughfares of the city, a total of 90 observation points were chosen for this study. To obviate ambiguity in the results, the locations were chosen away from street corners, and observations were made only in places where motorized vehicle counts could be made with greater accuracy and the street noise attributed mainly only to those vehicles that were passing the street. Accurate vehicle count was difficult to do at street corners, with vehicles coming in from and going towards different directions and different corners. Also, no data were taken on days when it rained as the noise from the rain added to the noise on the street. For the same reason, the locations chosen for the sound level measurements were those where the noise was mainly due to vehicular traffic. Thus, construction sites (building or road constructions) were avoided as well as tricycle waiting areas, where the vehicles were parked with engines running.

The 90 observation points were bounded on the west by Junob High School, on the east by Rizal Boulevard, on the south by Banilad-Sta. Monica crossing, and on the north by the Dumaguete Airport. For roads with long stretches such as Real Street and the North National Highway, several observation points were included.

Data needed for the study include three physical quantities: the sound pressure level, the traffic density, and the construction layout of the site. In this study, the street noise refers to the sound picked up by the sound pressure level meter when it is held at a distance of 1-1.5 meter from the edge of the road, with motorized vehicles moving along the road. The sound picked up is attributable mainly to the passing motorized vehicles as the sites chosen were such that other sources of noise were not significant. From the theory, the expectation is that the greater the number of motorized vehicles, the greater is the noise they cause. Here, the traffic density corresponds to the number of motorized vehicles passing the observation site per minute. Only motorized vehicles are counted and both directions of the traffic are taken into consideration. The construction layout refers to: a) the kind of structures in the area, the make and height of the buildings and where they are located, b) the width of the street, either narrow or wide, and c) the presence of trees and open spaces nearby that act as sound absorbers. Data representing these quantities and attributes were taken and recorded.

In this study, sound pressure level (SPL) measurements were taken continuously for one minute. This constituted about 40 to 45 different readings on the SPL meter per minute of observation. During the same minute, the number of motorized vehicles passing the location was counted and recorded. Three runs were taken at each observation point, both for the SPL and traffic density. Then the construction layout of the location was checked out according to the parameters mentioned earlier. The term 'motorized vehicles' includes tricycles, motorcycles, cars, jeeps, vans, cargo trucks, and other such means of transport. Recordings of the street noise were made but not at every location. Only sample values were taken.

For each trial, the average sound pressure level was computed. Since three trials were taken at each location, the average of the three averages of SPL readings represented the SPL value for a given location. The average traffic density count was also computed for each observation point.

To help define the limitations of the study and since the time during which the observations were done was expected to affect the data as road traffic has its peaks and lows in a day, the time when each measurement was taken was also noted and recorded. Whenever possible, the observations were done in the afternoon when workers and students go home from work and school, respectively.

The apparatus used in obtaining the sound level measurements was the Extech Digital Sound Level Meter, adjusted to the settings of "A" weighting, slow response, and 50 to 100 dB range. When set to 'A' weighting, the meter responds as a human ear would, boosting and cutting amplitudes over the frequency spectrum. This setting was chosen because the study was on noise level of city streets, a phenomenon that could have harmful effects on the hearing mechanism and the health of people. Slow response allows the device to take averages over each 500 millisecond duration. The range of 50 to 100 dB was found to be the most appropriate to use after preliminary measurements were taken in different locations as street traffic noise was found to range only from about 60 to 80 decibels.

Frequency analysis was done on the sample street noise recordings using a sound sensor to pick up the recorded noise and feeding the data to a computer using a Science Workshop 750 Interface. Graphs of Relative Amplitude vs. Frequency were obtained and printed.

RESULTS AND ANALYSIS

In this study, the factors considered to affect the sound pressure level at particular locations are the following:

a. traffic density;
b. presence of buildings in the site and number of storeys;
c. presence of sound absorbers such as open spaces and trees;
d. presence of sound reflectors such as concrete, tall buildings standing opposite each other;
e. width of the road (narrow roads can cause traffic flow clogging so the flow of traffic slows down, with engines of vehicles idling and constantly restarting, and, if tall buildings stand on each side of the road, may tend to confine the sound in the area due to the formation of standing waves; wide roads allow for smoother and faster traffic flow even if the traffic density is greater); and,
f. traffic flow conditions such as many vehicles but fast moving or fewer vehicles but slow-moving and constantly restarting from rest positions.

These factors were taken into consideration in the analysis of the results.

The values of the sound pressure level and traffic density at each observation point (Table 3) are all average values, taken continuously over a period of one minute each, with three runs at each location. The results indicate that the noisiest locations were those along Perdices Street, in the downtown area, Locsin Street (downtown area), Cervantes Street, Sta. Rosa Street, Real Street, and North National Highway. Surprisingly, Real St. and North National Highway, although with greater traffic density, have smaller SPL values than those of the first four streets mentioned above. A check on the traffic condition in the data logbook indicated that traffic was slow and heavy at Perdices St. when the measurements were taken. This means a build-up of the SPL owing to the slow-moving traffic. On the other hand, at the North National Highway and Real St., traffic flow was faster and one side of the road consisted of open spaces. Open spaces inhibit the formation of standing wave patterns of the sound coming from the traffic. The presence of standing waves can contribute to greater noise levels as it takes longer for the sound to die down. Open spaces behave like sound absorbers, preventing noise build-up. The corresponding construction layout for the different observation points are shown in Table 4.

Table 3.

Sound Pressure Level and Traffic Density at the Chosen Locations

LOCATION	TIME	SOUND PRESSURE LEVEL (SPL, *in decibels*)	TRAFFIC DENSITY (*vehicles/min*)
1. Perdices St. (O.K. Mart)	3:35 pm	78.6	27
2. Perdices St. (Cang's)	2:45 pm	77.4	40
3. Locsin St. (Check-In Pension)	4:37 pm	76.8	35
4. Locsin St. (Metro Bank)	3:59 pm	76.7	30
5. Cervantes St. (Towards Redemptorist)	11:35 am	76.4	27
6. Sta. Rosa St. (O.K. Pensionne)	3:12 pm	76.2	35
7. Real St. (New Bian Yek)	2:48 pm	76	43
8. North National Highway (Jollibee)	3:14 pm	76	67
9. North National Highway (LBC)	3:23 pm	75.9	66
10. Cervantes St. (West City Elementary School)	11:24 am	75.9	31
11. Real St. (New Bridge)	3:58 pm	75.7	43
12. Silliman Avenue (PNB)	3:59 pm	75.6	35
13. Aldecoa Drive (Birdie's, SUMC)	4:25 pm	75.4	30
14. Cervantes St. (Police Station)	11:04 am	75.3	26
15. North National Highway (Yamaha Motors)	3:52 pm	75.3	47
16. Sta. Catalina St. (Post Office)	11:16 am	75.3	33
17. Flores Avenue (Looc Elementary School)	4:04 pm	75.2	28
18. Hibbard Avenue (Coco Grande)	3:05 pm	75	33
19. Real St. (Building 1, Public Market)	2:59 pm	74.9	49
20. Perdices St. (Old Bridge)	12:11 pm	74.7	34
21. North National Highway (St. Paul's University)	4:18 pm	74.6	44
22. San Juan St. (Spanish Heritage)	3:50 pm	74.6	17

Table 3. **Continued...**

LOCATION	TIME	SOUND PRESSURE LEVEL (SPL, *in decibels*)	TRAFFIC DENSITY (*vehicles/min*)
23. South National Highway (St. Louis)	3:18 pm	74.6	38
24. Perdices St. (Penshoppe)	5:12 pm	74.5	40
25. Negros Oriental High School	4:35 pm	74.4	20
26. Real St. (DuEkSam)	2:55 pm	74.3	45
27. Real St. (NORECO II)	3:01 pm	74.3	37
28. Sta. Rosa St. (City Lumber)	3:47 pm	74.2	39
29. North National Highway (Dumaguete Airport)	4:30 pm	73.9	47
30. Mabini St. (Side of Mercury Drug)	2:55 pm	73.6	20
31. Sta. Catalina St. (G. Uymatiao Construction)	10.51 am	73.6	24
32. San Jose St. (BPI)	2:37 pm	73.6	14
33. Perdices St. (Po's)	4:43 pm	73.6	24
34. NORSU (Near Main Gate)	4:43 pm	73.5	25
35. Legaspi St. (Limquiaco Building)	2:49 pm	73.5	24
36. Locsin St. (Hotel Palwa)	3:51 pm	73.5	29
37. San Jose St. (PHCCI Building)	11:13 am	73.4	26
38. Hibbard Avenue (National Book Store)	4:55 pm	73.2	37
39. South National Highway (Mangnao Elementary School)	3:33 pm	73.2	34
40. San Juan St. (Motoliance)	3:59 pm	73.2	13
41. Locsin St. (Tops and Bottoms)	10.59 am	73.2	27
42. Locsin St. (Police Station)	3:36 pm	73.1	26
43. Sta. Rosa St. (DCCCO)	3:20 pm	73	36
44. Flores Avenue (Hayahay)	4:00 pm	72.8	12
45. Siliman Avenue (Portal Building)	3:50 pm	72.8	31
46. Perdices St. (City Hardware)	3:05 pm	72.7	21
47. Locsin St. (ACSAT)	3:47 pm	72.5	18
48. North National Highway (NOPH)	4:06 pm	72.5	37
49. Sta. Catalina St. (City Central School)	11.25 am	72.3	26
50. Cervantes St. (Rejoice Hardware)	3.16 pm	72.2	27
51. Ma. Cristina St. (Tavern)	3:38 pm	72.1	19
52. San Juan St. (Centrum)	4:10 pm	72	19
53. San Juan St. (Image Bank)	4:23 pm	72	15
54. San Jose St.	3.28 pm	71.9	17

Table 3. **Continued...**

LOCATION		TIME	SOUND PRESSURE LEVEL (SPL, *in decibels*)	TRAFFIC DENSITY (*vehicles/min*)
	(Dumaguete Rural Bank)			
55.	Libertad St. (STI)	3.28 pm	71.8	12
56.	South National Highway (Natasha Homes)	3:41 pm	71.5	19
57.	Colon St. (Front of Mercury Drug)	2:48 pm	71.3	16
58.	Hibbard Avenue (ABC Learning Center)	3:38 pm	71.2	14
59.	Rizal Boulevard (DBP)	10:20 am	71.2	27
60.	San Juan St. (Mary Immaculate Church)	3:07 pm	71.1	8
61.	Hibbard Avenue (SUHS)	3:18 pm	71	24
62.	Silliman Avenue (PhilAmLife Building)	4:05 pm	71	16
63.	Hibbard Avenue (North City Elementary School)	3:45 pm	71	17
64.	Dumaguete-Valencia Road (HyperMart)	4:28 pm	70.8	20
65.	Ma. Cristina St. (Panda Ice Cream)	4:35 pm	70.7	16
66.	Legaspi St. (Plaza Ma. Luisa)	11:09 am	70.6	23
67.	Dgte-Valencia Road (Junob Elementary School)	4:07 pm	70.5	13
68.	Locsin St. (Foundation University Dorm)	3:58 pm	70.5	14
69.	Rizal Boulevard (Bethel Guest House)	10.32 am	70.3	18
70.	Dr. E. Meciano Road (Foundation University)	4:08 pm	70.2	12
71.	Hibbard Avenue (Villareal Hall)	3:40 pm	70.2	26
72.	Colon St. (Side of Quezon Park)	11:32 am	70	4
73.	Rizal Boulevard (CAP Building)	10:10 am	69.8	30
74.	Silliman Avenue (Silliman President's Home)	4:17 pm	69.2	21
75.	E. J. Blanco Road (Royal Oaks International School)	3:52 pm	68.7	15
76.	South Nat'l Highway (Sta. Monica Crossing)	3:50 pm	68.7	18
77.	Colon St. (Gold Label Bakeshoppe)	3:07 pm	67.7	7

Table 3. **Continued...**

LOCATION	TIME	SOUND PRESSURE LEVEL (SPL, *in decibels*)	TRAFFIC DENSITY (*vehicles/min*)
78. Colon St. (Fire Department)	11:42 am	67.6	6
79. Katada St. (Opeña's)	3:30 pm	67.5	8
80. Dumaguete-Valencia Road (Bishop's Palace)	4:18 pm	66.2	14
81. Rovira Road (Royal Suites Inn)	3:28 pm	66	12
82. Looc By-Pass Road (Paya Bldg.)	4:18 pm	65.7	10
83. Lukewright St. (Slaughterhouse)	12:02 pm	65.7	7
84. Noblefranca St. (Holy Cross High Sch.)	2:56 pm	65.6	4
85. Rizal Boulevard (Sunny Electrical)	11:53 am	65.3	10
86. San Jose St. (Sans Rival)	2:26 pm	65.1	3
87. Mangnao (Dumaguete City High School)	3:25 pm	64.3	4
88. Motong Road (Aly Mae)	3:15 pm	64.3	9
89. Dr. V. Locsin St. (Dumaguete Christian Church)	10:40 am	62.4	6
90. Acias Pinili St. (Mormon Church)	3:00 pm	61.5	6

The locations with the 10 highest values of traffic density were:

a. North National Highway (Jollibee), 67 vehicles/min;
b. North National Highway (LBC), 66 vehicles/min;
c. Real St. (Building 1 of Market), 49 vehicles/min;
d. North National Highway (Dumaguete Airport), 47 vehicles/min;
e. North National Highway (Yamaha Motors), 47 vehicles/min;
f. Real St. (Du Ek Sam), 45 vehicles/min;
g. North National Highway (St. Paul's University), 44 vehicles/min;
h. Real St. (New Bian Yek), 43 vehicles/min;
i. Real St. (New Bridge), 43 vehicles/min; and,
j. Perdices St. (Cang's Department Store), 40 vehicles/min.

Of these 10, only North National Highway (Jollibee), North National Highway (LBC), Real St. (New Bian Yek), and Perdices St. (Cang's) made it to the first 10 locations with the highest street noise levels (Table 1). On the other hand, narrower streets with smaller traffic densities,.i.e., Locsin St. (35 and 30 vehicles/min), Cervantes St. (27 and 31 vehicles/min), and Sta. Rosa St. (35) vehicles per minute made it to the top 10 in street noise level. This indicates that aside from the traffic density, the construction layout of the area and the road width are important factors to consider in evaluating street noise. The presence of open spaces, such as those at Dumaguete Airport, St. Paul University, and the New Bridge must have contributed to the absorption of the noise coming from the vehicles, thus lowering the noise level in these locations. The wider roads along Real St. are also mitigating factors in street noise. On the other hand, Locsin, Cervantes, and Sta. Rosa Sts. are narrower and with the presence of buildings on both sides of these streets, sound dissipation must have taken a longer time, contributing to reverberation effects and thus resulting to higher noise levels.

It is also important to note that in those locations with open spaces and trees, like those fronting Rizal Boulevard, S.U. President's Home, Villareal Hall, Plaza Ma. Luisa, Hypermart, and S.U. High School, the noise levels were generally lower than in those places with a similar number of vehicles but are without trees or open spaces. Examples of places with low traffic densities but high traffic noise are: San Juan St., Spanish Heritage (17 vehicles/min, SPL=74.6), Mabini St., Mercury Drug (20 vehicles/min, SPL=73.6), San Juan St., Motoliance (13 vehicles/min, SPL=73.2), and Libertad St., STI (12 vehicles/min, SPL=71.6). These locations are beside generally narrower roads flanked by buildings.

Table 4.

Sound Pressure Level and Construction Layout at the Chosen Locations

LOCATION	CONSTRUCTION LAYOUT (ONE SIDE/OTHER SIDE)
1. Perdices St. (OK Mart)	concrete bldgs. on both sides
2. Perdices St. (Cang's)	concrete bldgs. on both sides
3. Locsin St. (Check-In Pension)	concrete buildings both sides
4. Locsin St. (Metro Bank)	2-storey concrete bldgs. on both sides
5. Cervantes St. (towards Redemptorist)	concrete bldg.; concrete wall
6. Sta. Rosa St. (OK Pensionne)	concrete bldgs. both sides

Table 4. **Continued...**

LOCATION		CONSTRUCTION LAYOUT (ONE SIDE/OTHER SIDE)
7.	Real St. (New Bian Yek)	concrete bldg.; wooden bldg.
8.	North Nat'l. Highway (Jollibee)	concrete bldg.; open space
9.	North Nat'l. Highway (LBC)	concrete bldg.; open space w/ trees
10.	Cervantes St. (West City Elem. Sch.)	wooden house; open space w/ trees
11.	Real St. (New Bridge)	open space both sides
12.	Silliman Avenue (PNB)	concrete bldg.; trees
13.	Aldecoa Drive (Birdie's, SUMC)	wooden bldg. and houses both sides
14.	Cervantes St. (Police Station)	concrete bldg.; trees
15.	North Nat'l. Highway (Yamaha Motors)	concrete bldg.; wooden house
16.	Sta. Catalina St. (Post Office)	trees and open space; concrete bldg.
17.	Flores Avenue (Looc Elem. Sch)	concrete fence; open space
18.	Hibbard Avenue (Coco Grande)	concrete buildings both sides
19.	Real St. (Bldg. 1, Public Market)	concrete buildings both sides
20.	Perdices St. (Old Bridge)	open space both sides
21.	North Nat'l. Highway (St. Paul's)	wooden house w/ trees; open space w/ trees
22.	San Juan St. (Spanish Heritage)	wooden bldg.; wall
23.	South National Highway (St. Louis)	concrete bldg.; open space & trees
24.	Perdices St. (Penshoppe Bldg.)	concrete buildings both sides
25.	NOHS	concrete walls with trees; open space with trees
26.	Real St. (Du Ek Sam)	concrete buildings both sides
27.	Real St. (NORECO II)	concrete buildings both sides
28.	Sta. Rosa St. (City Lumber)	wooden buildings both sides
29.	North Nat'l. Highway (Dumaguete Airport)	open space
30.	Mabini St. (side of Mercury Drug)	concrete buildings
31.	Sta. Catalina St. (G. Uymatiao Construction)	wooden buildings both sides
32.	San Jose St. (BPI)	concrete buildings both sides
33.	Perdices St. (PO's)	concrete buildings both sides
34.	NORSU (near main gate)	concrete bldg. and trees; open space w/ trees
35.	Legaspi St. (Limquiaco Bldg.)	concrete buildings both sides
36.	Locsin St. (Hotel Palwa)	concrete buildings both sides
37.	San Jose St. (PHCCI Bldg.)	concrete bldg.; concrete wall & trees
38.	Hibbard Avenue (National Book Store)	concrete buildings both sides
39.	South National Highway (Mangnao Elem. Sch.)	concrete wall & open space; wooden house
40.	San Juan St. (Motoliance)	2-storey wooden buildings both sides
41.	Locsin St. (Tops and Bottoms)	concrete buildings both sides
42.	Locsin St. (Police Station)	wooden house; concrete bldg. w/ trees
43.	Sta. Rosa St. (DCCCO)	concrete bldg.; bahay-kubo

Table 4. **Continued...**

LOCATION	CONSTRUCTION LAYOUT (ONE SIDE/OTHER SIDE)
44. Flores Avenue (Hayahay)	open space; wooden building
45. Siliman Avenue (Portal Bldg.)	concrete buildings both sides
46. Perdices St. (City Hardware)	concrete building; wooden building
47. Locsin St. (ACSAT)	concrete building; concrete wall
48. North Nat'l. Highway (NOPH)	concrete wall and trees; open space w/ trees
49. Sta. Catalina St. (City Central School)	trees; open space
50. Cervantes St. (Rejoice Hardware)	concrete buildings both sides
51. Ma. Cristina St. (Tavern)	concrete buildings both sides
52. San Juan St. (Centrum)	concrete buildings both sides
53. San Juan St. (Image Bank)	2-storey building; 1-storey building
54. San Jose St. (Dumaguete Rural Bank)	concrete buildings both sides
55. Libertad St. (STI)	concrete building; wooden house
56. South National Highway (Natasha Homes and Park)	open space w/ trees both sides
57. Colon St. (in front of Mercury Drug)	concrete buildings both sides
58. Hibbard Avenue (ABC Learning Center)	concrete building; wooden house
59. Rizal Boulevard (DBP)	concrete building and open space; open space
60. San Juan St. (Mary Immaculate Church)	concrete buildings both sides
61. Hibbard Avenue (SUHS)	concrete building; trees
62. Silliman Avenue (Philamlife Bldg.)	concrete building; open space
63. Hibbard Avenue (North City Elem. Sch.)	wooden house; concrete wall and trees
64. Dumaguete-Valencia Road (Hypermart)	open space both sides
65. Ma. Cristina St. (Panda Ice Cream)	concrete building; wooden house
66. Legaspi St. (Plaza Ma. Luisa)	concrete building; open space w/ trees
67. Dumaguete-Valencia Road (Junob Elem. Sch.)	open space w/ trees both sides
68. Locsin St. (F.U. Dorm)	wooden house; trees
69. Rizal Boulevard (Bethel Guest House)	concrete building; trees and open space
70. Dr. E. Meciano Road (Foundation Univ.)	concrete building and trees; open space
71. Hibbard Avenue (Villareal Hall)	open space and trees both sides
72. Colon St. (side of Quezon Park)	concrete building; open space and trees
73. Rizal Boulevard (CAP Building)	concrete building; open space
74. Silliman Avenue (S.U. President's Home)	concrete building; trees
75. E. J. Blanco Road (Royal Oaks Int'l. Sch.)	concrete bldg. & wall; open space w/ trees
76. South Nat'l Highway (Sta. Monica Crossing)	concrete houses and trees; open space w/ trees

77.	Colon St. (Gold Label Bakeshoppe)	concrete buildings both sides
78.	Colon St. (Fire Department)	concrete buildings both sides
79.	Katada St. (Opena's)	concrete buildings both sides
80.	Dgte-Valencia Road (Bishop's Palace)	concrete house; open space w/ trees
81.	Rovira Road (Royal Suites Inn)	open space w/ trees both sides
82.	Looc By-Pass Road (Paya Bldg.)	concrete building; concrete wall and trees
83.	Lukewright St. (Slaughterhouse)	concrete wall; open space
84.	Noblefranca St. (Holy Cross High Sch.)	concrete buildings both sides
85.	Rizal Boulevard (Sunny Electrical)	concrete building; wooden houses
86.	San Jose St. (Sans Rival)	wooden building; open space and building
87.	Mangnao (Dumaguete City High Sch.)	concrete house; wooden house
88.	Motong Road (Aly Mae)	concrete wall; trees
89.	Dr. V. Locsin St. (Dgte Christian Church)	concrete building; wall w/ vines
90.	Acias Pinili St. (Mormon Church)	wooden house w/ concrete wall; open space

A computation of the correlation coefficient between street noise as indicated by the sound pressure level and the traffic density was made. It yielded a correlation coefficient value of $r = 0.7342$. This value signifies a high correlation and marked relationship between the two quantities.[12] Thus, traffic density is a major contributing factor to street noise but is not the sole cause for its large magnitude.

Also, the results indicate that the highest sound pressure level is 78.6 dB. There are 18 locations (20%) of the total number of observation points where the sound pressure level is 75 decibels and higher, well above the 70 dB noise level recommended by U.S. Environment Protection Agency as the limiting value that will prevent any measurable hearing loss over a lifetime. While none of the values has reached 85 dB, the sound intensity level the prolonged exposure to which can cause hearing damage, still the noise levels are of sufficient magnitude to induce annoyance, anxiety, disturbance to concentration and sleep, as well as increase the possibility of hearing loss.

The frequency analysis on the sample recordings of street noise showed that the maximum values of the sound pressure level corresponded to frequencies ranging from around 200 Hz to 400 Hz. The relative amplitude vs. frequency graphs also yielded high SPL values at other higher frequencies but not as much as that at the 200-400 Hz range. Figures 2 to 8 show sample graphs of frequency distributions of the street noise.

Table 5.

Data for Computation of the Correlation Coefficient, r

x	y	$(x-\mu_x)$	$(y-\mu_y)$	$(x-\mu_x)(y-\mu_y)$	$(x-\mu_x)^2$	$(y-\mu_y)^2$
27	78.6	3	6.6	19.8	9	43.56
40	77.4	16	5.4	86.4	256	29.16
35	76.8	11	4.8	52.8	121	23.04
30	76.7	6	4.7	28.2	36	22.09
27	76.4	3	4.4	13.2	9	19.36
35	76.2	11	4.2	46.2	121	17.64
43	76	19	4.0	76	361	16
67	76	43	4.0	172	1849	16
66	75.9	42	3.9	163.8	1764	15.21
31	75.9	7	3.9	27.3	49	15.21
43	75.7	19	3.7	70.3	361	13.69
35	75.6	11	3.6	39.6	121	12.96
30	75.4	6	3.4	20.4	36	11.56
26	75.3	2	3.3	6.6	4	10.89
47	75.3	23	3.3	75.9	529	10.89
33	75.3	9	3.3	29.7	81	10.89
28	75.2	4	3.2	12.8	16	10.24
33	75	9	3.0	27	81	9
49	74.9	25	2.9	72.5	625	8.41
34	74.7	10	2.7	27	100	7.29
44	74.6	20	2.6	52	400	6.76
17	74.6	-7	2.6	-18.2	49	6.76
38	74.6	14	2.6	36.4	196	6.76
40	74.5	16	2.5	40	256	6.25
20	74.4	-4	2.4	-9.6	16	5.76
45	74.3	21	2.3	48.3	441	5.29
37	74.3	13	2.3	29.9	169	5.29
39	74.2	15	2.2	33	225	4.84
47	73.9	23	1.9	43.7	529	3.61
20	73.6	-4	1.6	-6.4	16	2.56
24	73.6	0	1.6	0	0	2.56
14	73.6	-10	1.6	-16	100	2.56
24	73.6	0	1.6	0	0	2.56
25	73.5	1	1.5	1.5	1	2.25
24	73.5	0	1.5	0	0	2.25
29	73.5	5	1.5	7.5	25	2.25
26	73.4	2	1.4	2.8	4	1.96
37	73.2	13	1.2	15.6	169	1.44
34	73.2	10	1.2	12	100	1.44
13	73.2	-11	1.2	-13.2	121	1.44
27	73.2	3	1.2	3.6	9	1.44
26	73.1	2	1.1	2.2	4	1.21
36	73	12	1.0	12	144	1.0
12	72.8	-12	0.8	-9.6	144	0.64
31	72.8	7	0.8	5.6	49	0.64
21	72.7	-3	0.7	-2.1	9	0.49
18	72.5	-6	0.5	-3	36	0.25
37	72.5	13	0.5	6.5	169	0.25
26	72.3	2	0.3	0.6	4	0.09
27	72.2	3	0.2	0.6	9	0.04

Table 5. **Continued...**

x	y	$(x-\mu_x)$	$(y-\mu_y)$	$(x-\mu_x)(y-\mu_y)$	$(x-\mu_x)^2$	$(y-\mu_y)^2$
19	72.1	-5	0.01	-0.5	25	0.01
19	72	-5	0	0	25	0
15	72	-9	0	0	81	0
17	71.9	-7	-0.1	0.7	49	0.01
12	71.8	-12	-0.2	2.4	144	0.04
19	71.5	-5	-0.5	2.5	25	0.25
16	71.3	-8	-0.7	5.6	64	0.49
14	71.2	-10	-0.8	8	100	0.64
27	71.2	3	-0.8	-2.4	9	0.64
8	71.1	-16	-0.9	14.4	256	0.81
24	71	0	-1	0	0	1.0
16	71	-8	-1	8	64	1.0
17	71	-7	-1	7	49	1.0
20	70.8	-4	-1.2	4.8	16	1.44
16	70.7	-8	-1.3	10.4	64	1.69
23	70.6	-1	-1.4	1.4	1	1.96
13	70.5	-11	-1.5	16.5	121	2.25
14	70.5	-10	-1.5	15	100	2.25
18	70.3	-6	-1.7	10.2	36	2.89
12	70.2	-12	-1.8	21.6	144	3.24
26	70.2	2	-1.8	-3.6	4	3.24
4	70	-20	-2	40	400	4.0
30	69.8	6	-2.2	-13.2	36	4.84
21	69.2	-3	-2.8	8.4	9	7.84
15	68.7	-9	-3.3	29.7	81	10.89
18	68.7	-6	-3.3	19.8	36	10.89
7	67.7	-17	-4.3	73.1	289	18.49
6	67.6	-18	-4.4	79.2	324	19.36
8	67.5	-16	-4.5	72	256	20.25
14	66.2	-10	-5.8	58	100	33.64
12	66	-12	-6	72	144	36.0
10	65.7	-14	-6.3	88.2	196	39.69
7	65.7	-17	-6.3	107.1	289	39.69
4	65.6	-20	-6.4	128	400	40.96
10	65.3	-14	-6.7	93.8	196	44.89
3	65.1	-21	-6.9	144.9	441	47.61
4	64.3	-20	-7.7	154	400	59.29
9	64.3	-15	-7.7	115.5	225	59.29
6	62.4	-18	-9.6	172.8	324	92.16
6	61.5	-18	-10.5	189	324	110.25
$\Sigma x=$ 2,176	$\Sigma y=$ 6,476.9			$\Sigma(x-\mu_x)(y-\mu_y)=$ 3097.5	$\Sigma(x-\mu_x)^2=$ 15,770	$\Sigma(y-\mu_y)^2=$ 1,128.6

x : traffic density

y : sound pressure level

μ_x: average value of the traffic density computed from all observation points

μ_y: average value of the sound pressure level computed from all observation points

The correlation coefficient **r** between the traffic density and the sound pressure level is obtained from the data (Table 5) as follows:

$r = \Sigma [(x-\mu_x)(y-\mu_y)]/[\Sigma (x-\mu_x)^2 \cdot \Sigma (y-\mu_y)^2]^{1/2}$
$r = (3097.5)/[(15,770)(1,128.6)]^{1/2}$
$r = 0.7342$ (high correlation, marked relationship)

A scatter diagram of the sound pressure level (on the y-axis) and the corresponding traffic density (on the x-axis) at the different locations covered in this study is shown in Figure 1. The trend line, also called the regression line, represents the line of best fit. It graphically shows the correlation between sound pressure level and traffic density, indicating a generally increasing SPL with increasing traffic density.

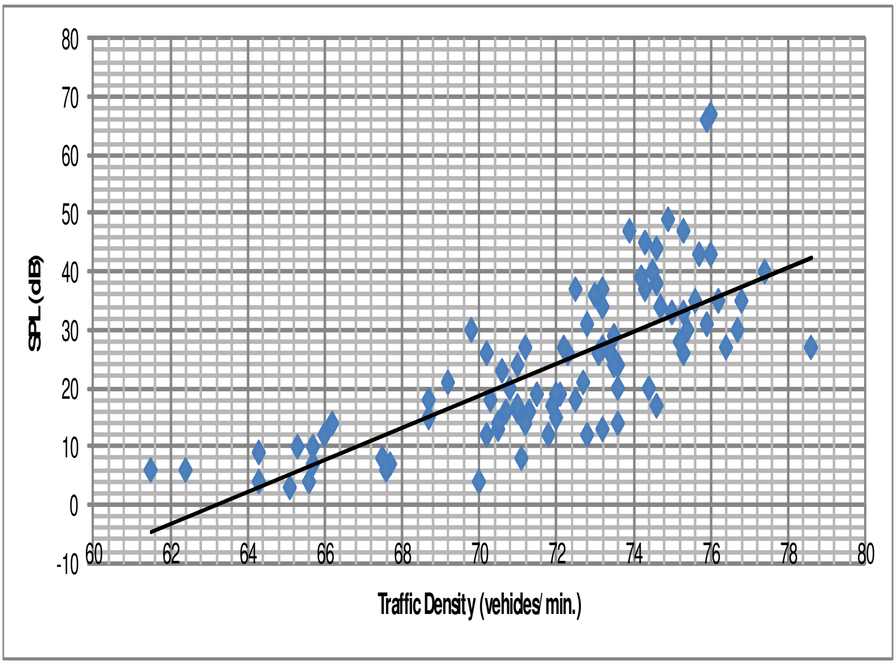

Figure 1. **Scatter Diagram of SPL vs. Traffic Density.**

The frequency distribution of the street noise, with relative amplitude on the y-axis and frequency on the x-axis, are illustrated in graphs (Figures 2 to 8) in the next pages.

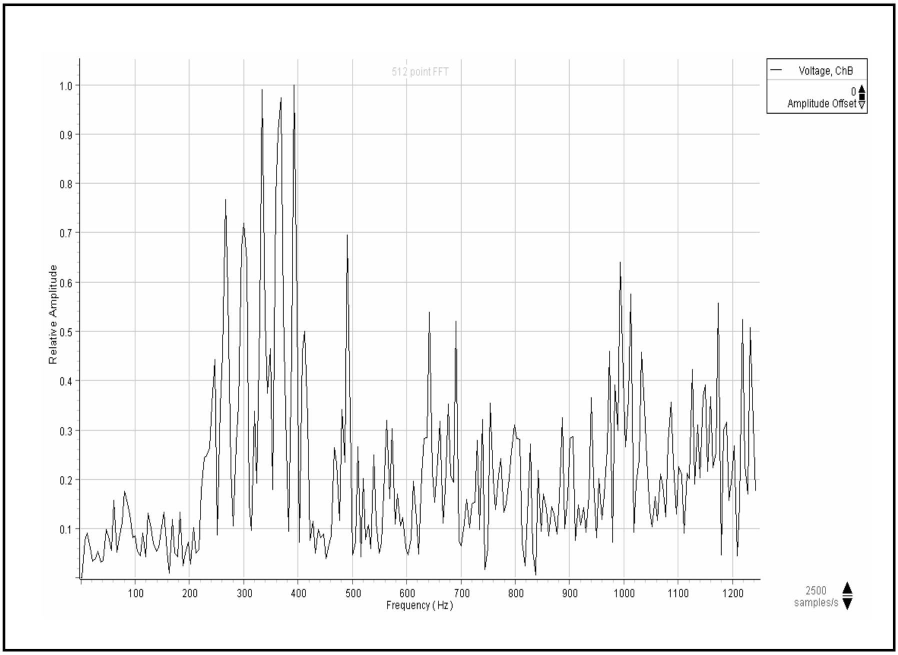

Figure 2. **Sample Frequency Distribution 1.**

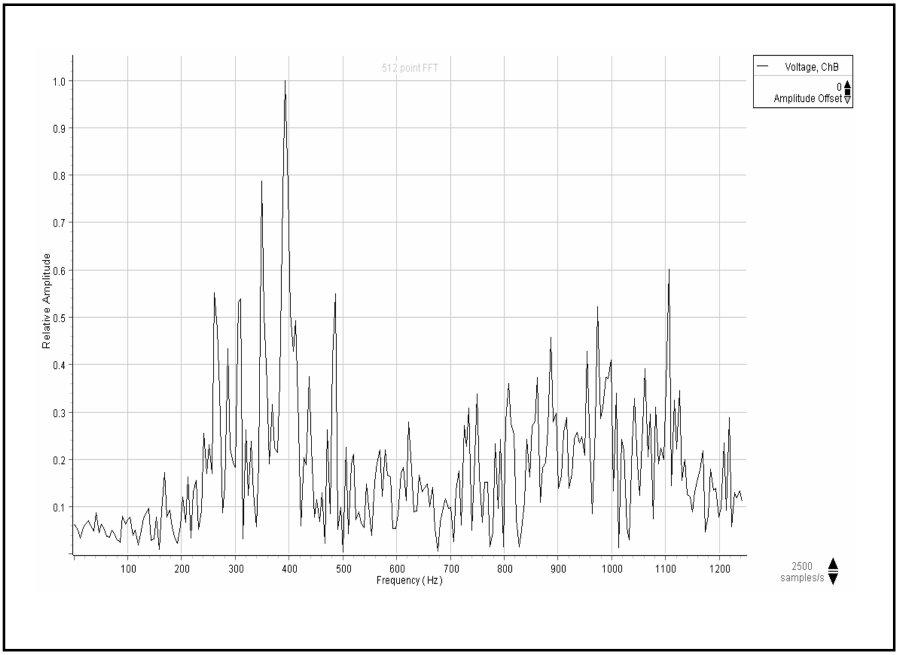

Figure 3. **Sample Frequency Distribution 2.**

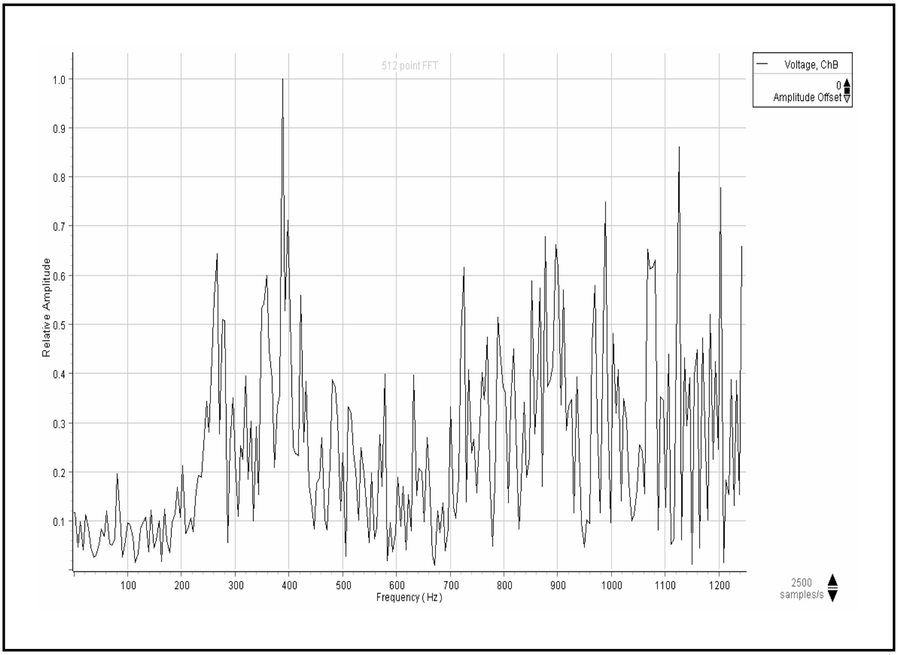

Figure 4. **Sample Frequency Distribution 3.**

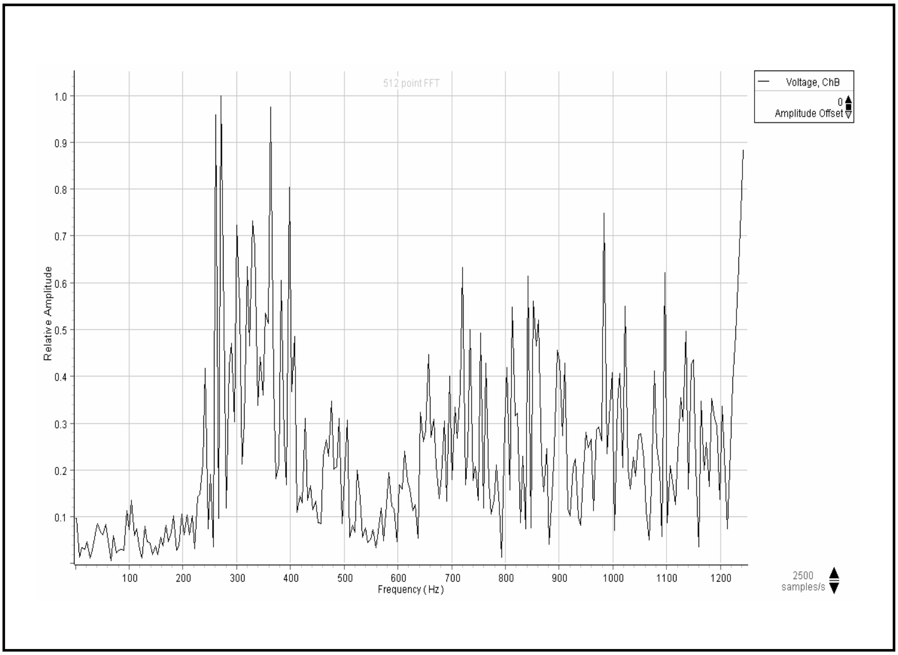

Figure 5. **Sample Frequency Distribution 4.**

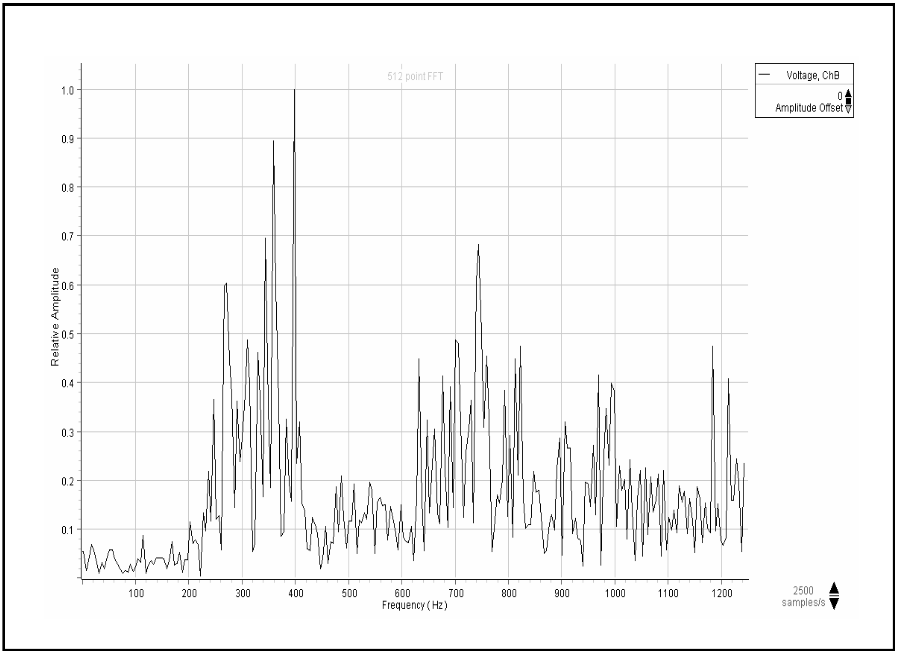

Figure 6. **Sample Frequency Distribution 5.**

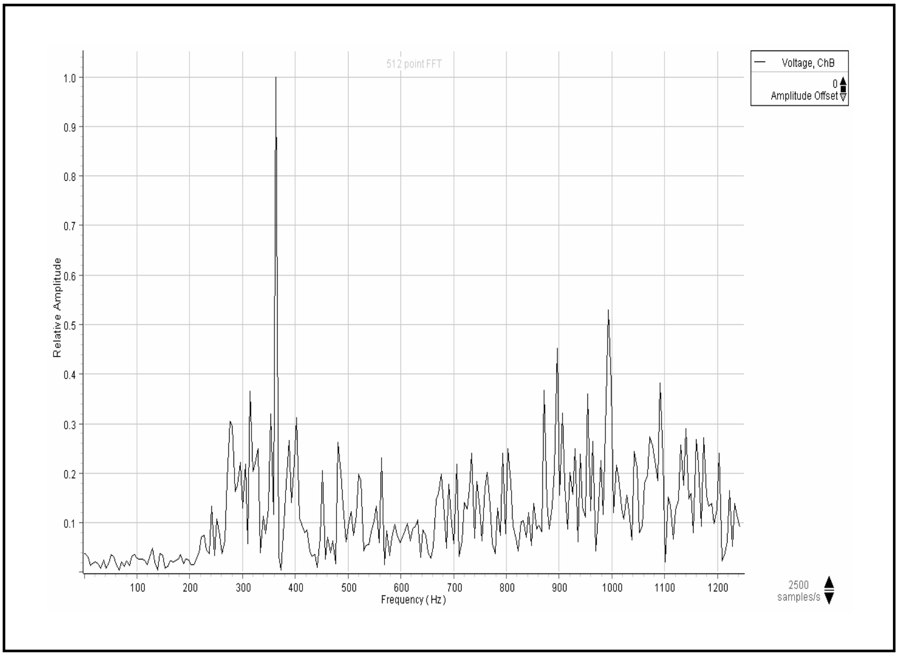

Figure 7. **Sample Frequency Distribution 6.**

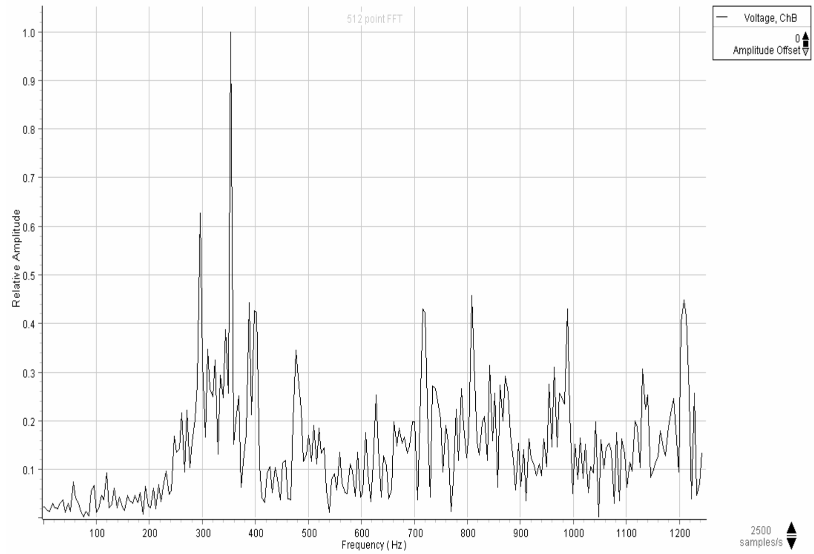

Figure 8. **Sample Frequency Distribution 7.**

LIMITATIONS OF THE STUDY

At the time that data in this study were taken, many of the main and side streets of the city were undergoing repair. However, as mentioned earlier, measurements of the SPL were taken at locations far enough from road repair sites, so that whatever noise was measured was mainly due to motorized vehicle traffic. Because of the road repairs and constructions, there was rerouting of traffic, as well as new and temporary rules on the direction of traffic flow, like making some streets one-way streets. The results of the study, therefore, reflect these limitations. Traffic density is not expected to be the same in certain roads during and after the road repairs and constructions. However, the correlation between street noise and traffic density holds as well as the effects of the location layout (roads, buildings, trees, open spaces) on the noise level.

Also, no attempts were made to classify and count particular kinds of motorized vehicles passing the streets that consisted of a mix of cars, jeeps, tricycles, motorcycles, vans, trucks, and other such means of transport. The measuring instrument made no distinction as to the source of noise and only measured the average of the mix of sounds coming from the vehicles. It is expected that heavy trucks would produce greater noise and cars, quieter noise.

Although it is known that sound pressure level is also affected by construction layout, there is not enough data that can be obtained to make it possible to express the relationship in the form of an equation for the Dumaguete-type street noise. Variables in construction layout such as width of the streets, type and rise of buildings, presence of trees and their relative locations, and presence of open spaces vary from place to place in the city, except the rise of buildings that are practically the same—two storeys. It is thus not possible to keep the other variables constant while investigating the influence of one variable on the measured SPL. Also, the effect of building height on the SPL could not be reckoned because practically all buildings on the roadsides of Dumaguete City are only two-storey high except for a few. However, it is evident that for about the same number of vehicles in locations where buildings are standing on the sides of the street, the SPL is higher for the narrower roads than the wider ones. Also evident is the contribution of open spaces and trees to the absorption of sound, rendering the SPL lower.

The data obtained refer to the particular situations and conditions present in the locations, i.e., Dumaguete-type street noise and the findings and conclusions based on the results of the study are to be taken with these limitations in mind.

IMPLICATIONS AND RECOMMENDATIONS

The results of the study are consistent with what the theory predicts. For Dumaguete City streets, the results indicate that street noise is dependent on traffic density, construction layout of buildings and roads, and the presence of sound absorbers in the area. Thus, if traffic noise is to be kept at a level that is tolerable and safe to residents living nearby, attention must be given to the influencing factors earlier mentioned. As the city keeps growing and more vehicles are expected to ply the streets, the local government must enforce the use of efficient vehicle mufflers, so that the sound produced will be of lower levels. Also, new roads to be constructed must be wide enough to ensure continuous and efficient flow of traffic. Trees planted along these roads help abate the noise by absorbing it as well as the carbon dioxide emitted by vehicles. Trees, therefore, beautify, lower noise levels, absorb harmful carbon dioxide, and give us oxygen—important reasons why trees should not be cut but instead, grown. It would be worthwhile to consider in urban planning ways by which noise pollution can be minimized in our streets.

NOTES

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