ESTIMATION AND MAPPING OF VEHICULAR TRAFFIC-INDUCED NOISE ALONG A. BONIFACIO AVENUE AND SUMULONG HIGHWAY IN MARIKINA CITY

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Abstract: This study is an attempt to estimate the noise level from motor vehicles using mathematical model and present it through a map. The Golmohammadi, et al (2007) equation was used to estimate noise level from motor vehicles wherein four groups of variables were considered: road dimension parameters, traffic flow, vehicle speed and noise emission levels of four groups of vehicles. The predicted noise values from the model were compared with those measured in the field. Predicted average noise emission levels were found to compare favorably with measured values. In general, the measurements and the model results indicated that the highest noise levels were found to occur close to the road. It was also observed that there is a decrease in noise levels as the distance from the road increases. Using the same equation, the noise emission levels along A. Bonifacio Avenue and Sumulong Highway were calculated. The results indicated that the estimated noise emission values were above the Philippine noise standards. The distances from the road of 75 dB, 65 dB and 60 dB noise level were also calculated using the sound propagation equation. The number of buildings, most especially those classified as noise sensitive receptors, were also determined. The estimated noise levels and the number of noise sensitive buildings were presented in a map using ArcView GIS. The mapped results of this study are useful in transport development, traffic management planning and land use planning.

Key Words: Noise level, noise sensitive receptor

1. INTRODUCTION

Transportation has become an integral part of everyone's life. It is one of the contributory factors in the economic growth of an area. Aside from the benefits that we get from transportation, it also brought negative impacts. These impacts are the detrimental effects of traffic to the environment such as air pollution, vibration, accidents, severance, visual intrusion and noise.

Noise is defined as unwanted sounds. It is unwanted because it annoys people, interferes with conversation, disturbs sleep, cause stress, and threatens public health. People exposed to high level of noise for a long period of time may cause temporarily or permanent deafness.

Noise from traffic came from the stream of vehicles operating simultaneously. The noise from the traffic is narrow in one direction and long in the other compared to the distance to the listener, and this is considered as a line source. The sound level spreads out cylindrically, making the sound level same at all points at the same distance from the line. The characteristics of the sound is that the sound level decreases with increasing distance. In a line source, the sound level drops by 3 dB per doubling of distance until ground and air attenuation noticeably affect the level. The unit dB stands for decibel, the unit of measurement of sound.

The government of the Philippines has been aware of detrimental effects of noise as early as 1978. This is manifested by the presence of the „Environment Quality Standards for Noise in General Areas" in that year. The noise standards are set according to land use and period of time. The land use have five categories: (1) AA defined as section or contiguous area which requires quietness, such as an area within 100 meters from school sites, nursery schools, hospitals and special homes for the aged; (2) A defined as a section or contiguous area which is primarily used for residential purposes; (3) B defined as a section or contiguous area which is primarily used for commercial area; (4) C as a section primarily reserved as a light industrial area; and (5) D as a section primarily reserved as a heavy industrial area. The time period is also divided into four intervals, namely (1) Morning which means from 5:00 am to 9:00 am; (2) Daytime which covers the time from 9:00 am to 6:00 pm; (3) Evening which starts at 6:00 pm to 10:00 pm requiring lower noise level than daytime; and (4) Nighttime, 10:00 pm to 5:00 am, sleeping time of the majority of the population. Table 1 shows the noise standard of 1978.

Table 1: Noise Standards in General Areas

Category of Area[1]	Daytime (9am - 6pm)	Morning (5am – 9am) and Evening (6pm – 10pm)	Nighttime (10pm – 5am)
AA	50 dB	45 dB	40 dB
A	55 dB	50 dB	45 dB
B	65 dB	60 dB	55 dB
C	70 dB	65 dB	60 dB
D	75 dB	70 dB	65 dB

Source: Rules & Regulations of the National Pollution Control Commission (1978), Section 78, Table 1. Environment Quality Atandards for Noise in general Areas (maximum allowable noise levels in general areas).

Legend[1]

AA – Section or contiguous area which requires quietness, such as an area within 100 meters from school sites, nursery schools, hospitals and special homes for the aged
A - a section or contiguous area which is primarily used for residential purposes;
B - a section or contiguous area which is primarily used for commercial area;
C - a section primarily reserved as a light industrial area;
D - a section primarily reserved as a heavy industrial area.

The noise standards of 1978 was amended in 1980, the noise level limits were increased by 10 dB in those areas that are directly fronting or facing a road that is 4 or more lanes. This is shown in Table 2

Table 2: Noise Standards in Areas Directly Fronting/Facing 4-Lane Road

Category of Area[1]	Daytime (9am - 6pm)	Morning (5am – 9am) and Evening (6pm – 10pm)	Nighttime (10pm – 5am)
AA	60 dB	55 dB	40 dB
A	65 dB	60 dB	45 dB
B	75 dB	70 dB	55 dB
C	80 dB	75 dB	60 dB
D	85 dB	80 dB	65 dB

Source: NPCC Memorandum Circular No. 002 (May 12, 1980)

The actual noise level in three sites in Metro Manila as measured by Ms. Belinda I. Fajardo for her thesis in 1999 registered noise levels ranging from 75 dB to 89 dB. The noise levels measured exceeded the standard of 75 dB, noise standard for section or contiguous area primarily used for commercial area. The location and noise level recorded are shown in Table 3.

Table 3: Actual Noise Levels in Areas that are Predominantly of Commercial

Philippine Noise Standards (PNS)		Range of Noise Level of Survey Sites		
	Category B	EDSA (outside Camp Crame)	Quezon Ave.	Taft Ave.
Daytime (9:00am – 6:00pm)	75 dB	85 – 89 dB	75 – 79 dB	75 – 79 dB

Source: Fajardo, Belinda I. (1999) A Study on Individual Perceptions of Road Traffic Noise. Thesis Paper. School of Urban and Regional Planning.

From the 2001 Noise Survey report done by the UP-NCTS Foundation, Inc. for the Department of Public Works and Highways, the noise levels exceeded the standard by more than 10 dB on those areas that are near school and hospital. These areas require quietness and are considered AA in the Category of Area in the Philippine Noise Standard. This is shown in Table 4.

Table 4: Actual Noise Levels on Noise-sensitive Areas along Marcos Highways

Philippine Noise Standards (PNS)		Range of Noise Level of Survey Sites	
	Category AA	Marcos Hway (in front of AMA school)	Marcos Hway (in front of Sto. Nino Hospital)
Daytime (9:00am – 6:00pm)	60 dB	85 – 89 dB	75 – 79 dB

Source: UP-NCTS Foundation, Inc (2001) Noise Survey: In connection with the Supplemental Environmental Assessment for the Metro Manila Urban Transport Integration Project (MMURTRIP).

It can be seen that the noise standards are not being followed and enforced. The reasons might be due to the lack of resources and the absence of mechanism and equipment for the monitoring, regulating and assessing.

This study is an attempt to assess the noise level due to traffic and show in a map the extent, level and location of noise problems. The objectives of the study are: (1) to estimate the noise due to road traffic; (2) to compare the estimated noise level with the existing standards; and (3) to show the the extent, level and location of noise problems through a noise contour map. The study area is a road corridor in Marikina City, the A. Bonifacio Avenue and Sumulong Highway which is a primary road. The study used the Geographical Information System (GIS) in the analysis and presentation of traffic noise levels.

2. METHODOLOGY

There are several traffic noise models explored in this study in order to estimate the noise levels along A. Bonifacio Avenue and Sumulong Highway. However, only two (2) models were pursued on the basis of available data that can be used to validate and estimate noise at the study area. One of the noise estimation model explored in the study is the Galloway et al (1969) noise model, the simplest model found that incorporates three fundamental parameters into a liner-logarithmic expressions. These parameters are speed, volume and distance of the receptor from the line source of noise. The equation is shown below:

$$L = 10\log q - 10\log d + 20\log u + 20$$

wherein:

d – distance from the noise source,
u – mean speed of observed traffic (mph), and
q – traffic volume in veh/hr.

To take into account the other factors that influence the level and propagation of traffic noise like the number of heavy vehicles, corrections are then added to the sound level computed from the Galloway et al equation. These corrections are enumerated below.

Add 1 dBA for every 2.5% trucks
Add 5 dBA for rough road
Add 2 dBA for roads that have a gradient of 3% to 5% s 3<G<5,
Minus 10 dBA when inside an establishment with open windows
Minus 20 dBA when inside an establishment with closed windows

Another traffic noise model explored is the Golmohammadi et al (2007) model. The model was developed by Golmohammadi et al for the Iran traffic situation. There are four variables used: noise emission level; road dimensions; traffic flow factor; traffic speed factor. Road dimensions are the road length, road width, road gradient and buildings' height around the road segment. The traffic volume and speed per type of vehicle are used. Traffic flow was also considered, linear in two sides and free flow. This model estimates the equivalent sound level (Leq) at a distance of 3 m from the carriageway edge. The Golmohammadi et al noise model is shown below.

$$L = 54.013 + \Delta N + \Delta V + \Delta D$$

wherein:

N = volume of vehicles

V = speed

$\Delta N = (3.542\log N_{car}) + (0.308\log N_{mini}) + (2.361\log N_{truck}) + (0.173\log N_{MC})$,

$\Delta V = (0.668\log V_{car}) + (0.907\log V_{mini}) + (0.1761\log V_{truck}) + (0.302\log V_{MC})$,

$\Delta D = 0.001L + 0.104W + 0.24H + 0.068S$.

These two models were validated using the data from past studies that have noise level measurements aside from the classified volume count and speed data. The data are from the 2001 Noise Survey done by UP-NCTS Foundations,, Inc. The data on classified traffic volume, speed and road inventory were plugged into the two (2) noise models. The results were compared to the actual noise level measurements. The estimated noise level using Golmohammadi et al and Galloway et al are nearly the same as shown in Table 5. However, Golmohammadi et al model considered more variables and clearly specified the receptor location, 3 meters from the carriageway edge. Thus, Golmohammadi et al model was used in the estimation of noise level of the study corridor.

Table 5: Actual vs. Estimated Noise Level Using Traffic Noise Models of Golmohammadi et al and Galloway et al

Time	Noise Level (dB) using Golmohammadi, et al Model			Noise Level (dB) using Galloway et al Model		
	Estimated	Actual	deviation	Estimated	Actual	deviation
5:00 - 6:00	73.94	74.90	-0.96	74.86	74.90	-0.04
6:00 - 7:00	74.06	75.60	-1.54	75.85	75.60	0.25
7:00 - 8:00	74.85	75.90	-1.05	77.04	75.90	1.14
8:00 - 9:00	75.00	76.00	-1.00	77.14	76.00	1.14
9:00 - 10:00	75.24	76.80	-1.56	76.81	76.80	0.01
10:00 - 11:00	75.52	75.80	-0.28	77.23	75.80	1.43
11:00 - 12:00	75.63	75.70	-0.07	77.20	75.70	1.50
12:00 - 13:00	75.41	75.80	-0.39	77.13	75.80	1.33
13:00 - 14:00	75.34	75.30	0.04	76.94	75.30	1.64
14:00 - 15:00	74.73	75.10	-0.37	76.37	75.10	1.27
15:00 - 16:00	75.07	75.80	-0.73	76.75	75.80	0.95
16:00 - 17:00	74.77	77.80	-3.03	76.73	77.80	-1.07
17:00 - 18:00	74.91	76.10	-1.19	77.08	76.10	0.98
18:00 - 19:00	74.95	75.60	-0.65	77.45	75.60	1.85
19:00 - 20:00	74.73	74.90	-0.17	77.44	74.90	2.54
20:00 - 21:00	74.97	74.40	0.57	77.36	74.40	2.96

An actual data used in the estimation of the traffic noise levels for the study area is the 2006 actual traffic volume of A. Bonifacio Avenue and Sumulong Highway. For the other variables where data are not available, assumptions were made. Vehicle speed is assumed to be 40 kph for small motorized vehicles (motorcycle, tricycle, private vehicle and PUJ) and 30 kph for big motorized vehicles (bus and truck). The vehicle speed assumption is based on the speed limit specified in Republic Act 4136, also known as Land Transportation and Traffic Code. Lane width is assumed to be 3 meters. The building height used in the calculation is assumed to be 3.5 meters. The road corridor is assumed to be level, having zero gradient.

After calculating the noise level at 3 meters from road edge of A. Bonifacio Avenue and Sumulong Highway, the noise levels at the road centerline of the different road segments were calculated. This is represented by L_w in the sound propagation equation below.

$$L_p = L_W - 10 \times \log_{10}(r) - 8 \quad \text{dB}$$

Since the L_w is now known, and 75 dB, 65 dB or 60 dB can be plugged into the propagation equation as L_p, the distances from the road centerline of each road segment represented as r can be calculated corresponding to 75 dB, 65 dB and 60 dB. The noise levels used (75 dB, 65 dB and 60 dB) were based on the Philippine daytime noise standard: 60 dB limit for noise sensitive area, 65 dB for residential area and 75 dB for the commercial area.

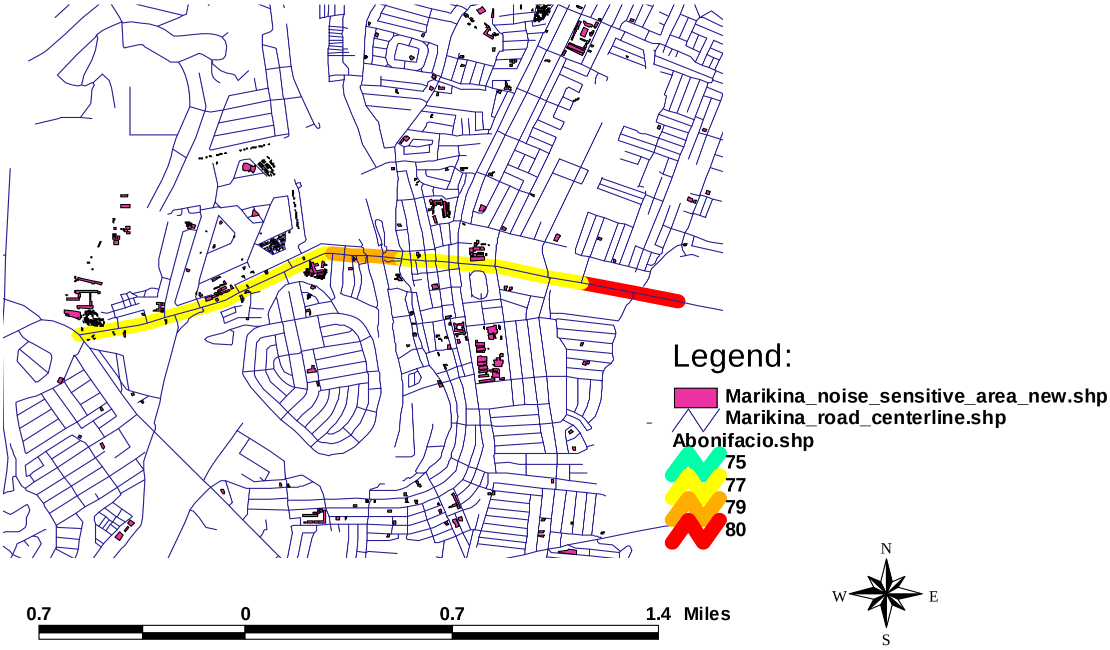
After calculating all the noise level and the corresponding distances from the road centerline, the data were entered into the GIS database. Many GIS features were used like the creation of new themes, buffering and geoprocessing wizard. A new line theme was created composed of the A. Bonifacio Avenue and Sumulong Highway, which is created from the Marikina Road Centerline Map. For the new line theme of the study corridor, the corridor is divided into several road segments. The table corresponding to this theme was edited by adding new fields: Traffic Volume and Noise Level. After which, buffers were created to show how far noise level 75 dB, 65 dB and 60 dB would be able to reach. New theme was created for each buffer zone.

Additional theme was also created to signify the noise sensitive buildings within Marikina City. Noise sensitive buildings are schools, churches, clinic and hospitals. Another theme created is the 100m buffer zone with the road centerline of the study corridor as the center. The themes with the buffer zones were used to intersect with the noise sensitive buildings to get the number of noise sensitive buildings within each of the buffer zones. The total number of buildings within each of the buffer zones was determined using the geoprocessing wizard tool.

3. RESULTS OF THE ANALYSIS

The road corridor under study, A. Bonifacio Avenue to Sumulong Highway, is a 4-lane road and the area around is mostly of commercial and residential uses. The study period is from 9:00 am to 6:00 pm, the daytime in the guideline of the Philippine Noise Standards. The noise standards are then 65 dB and 75 dB for residential (Category A) and commercial (Category B) purposes, respectively.

The noise levels generated by traffic on the road corridor A. Bonifacio Avenue to Sumulong Highway is estimated using the traffic noise model developed by Golmohammadi, et.al. The obtained values are the noise level at 3 meters from the edge of the carriageway. The noise level estimated ranges from 75 to 80 dB. These levels exceed the noise standard for residential and commercial type of land use. These noise levels are shown in Figure



1.

Figure 1. Noise Level at 3 Meters from Road Edge of
A. Bonifacio Avenue and Sumulong Highway

The noise standard for commercial type of land use is 75 dB. The scope of 75 dB is done by using the buffering tool in GIS and this is shown in Figure 2. The distance of the 75 dB mark ranges from 2 to 22 meters away from the carriageway edge. By using the intersect tool of geoprocessing wizard, the total number of buildings within the 75 dB mark was determined. There are a total of 278 buildings within the 75 dB mark. Around 50% of the buildings within the 75 dB mark are utilized for residential purpose, 46% are composed of commercial establishments and offices, and the remaining 4% are noise sensitive buildings. On the basis of the noise standards guidelines of the country, the total noise level exceeds the allowable limit for residential and commercial in the area.

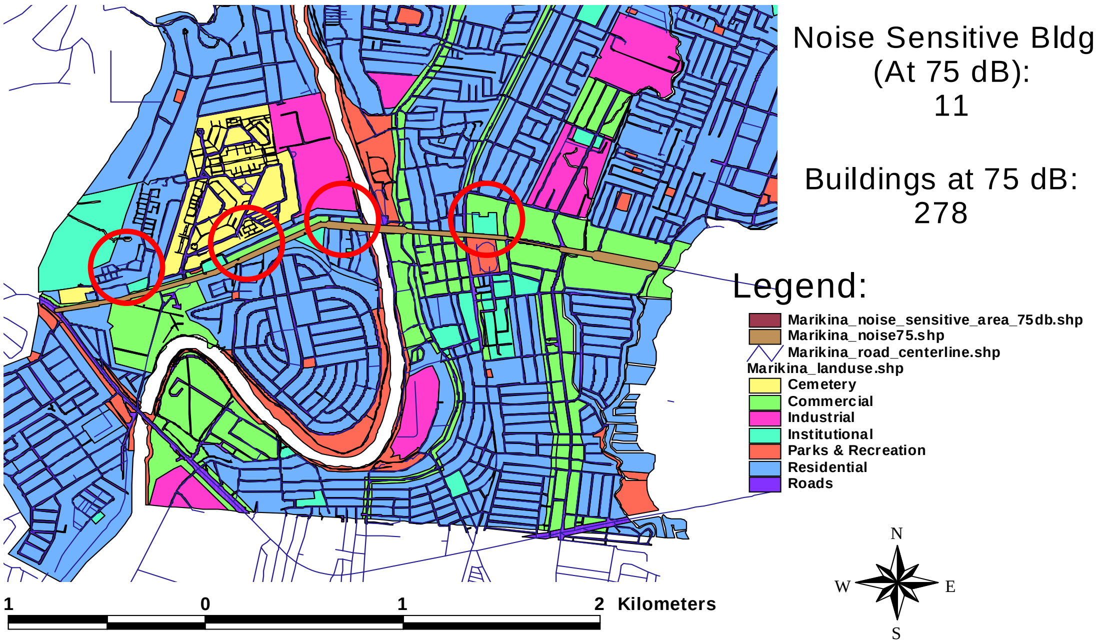


Figure 2. Distance from Road Centerline - 75 dB Noise Level

The noise standard for residential purpose during daytime is 65 dB. Thus, the edge of 65 dB noise level is also calculated from road centerline of A. Bonifacio Avenue and Sumulong Highway. The 65 dB buffer mark is about 74 to 279 meters away from the carriageway edge and is shown in Figure 3. The number of noise sensitive buildings within the 65dB mark is around 381 and the total number of buildings covered is 3,037. Around 63% of all the buildings within this mark are being used for residential purpose. Approximately 13% belong to the noise sensitive category, which has a 60 dB noise level limit as indicated by the noise standard. Most of the noise sensitive buildings are near A. Bonifacio Avenue as indicated by the red circles. There are three (3) areas along A. Bonifacio Avenue and one (1) area in Sumulong Highway wherein the noise sensitive buildings are concentrated.

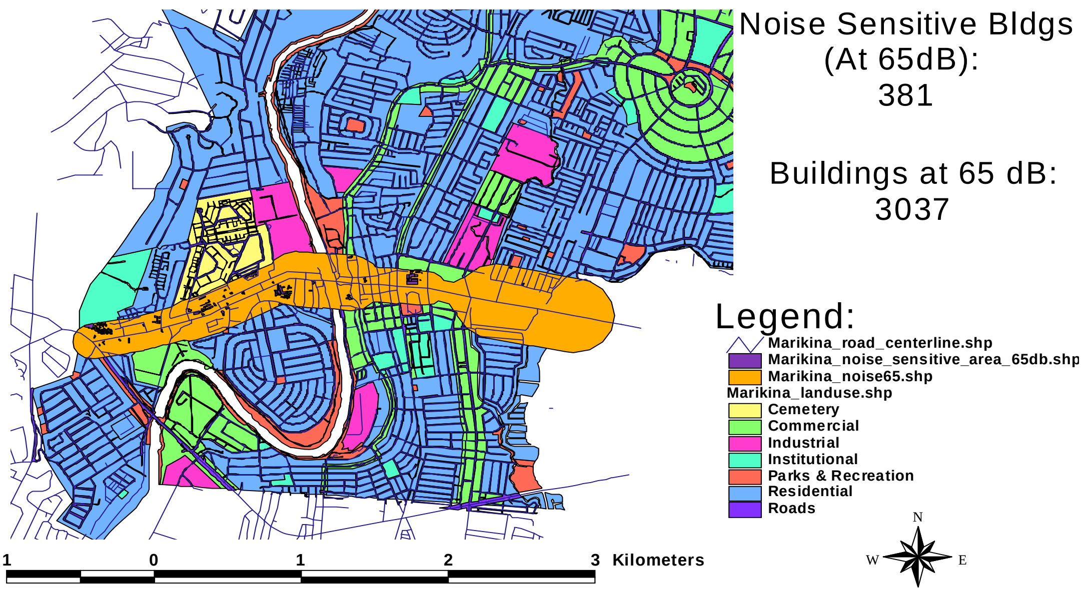


Figure 3. Distance from Road Centerline - 65 dB Noise Level

The Philippine noise standard during daytime for noise sensitive areas or for AA category of area is 60 dB. Thus, the distance from road centerline of 60 dB is computed using the propagation equation for all the road segments of A. Bonifacio Avenue and Sumulong Highway. The computed values for each road segment are utilized in creating the buffer zone for the entire study area. The resulting map is shown in Figure 4. Almost ten (10) thousand buildings are within the 60 dB mark. There are around 614 noise sensitive buildings or 6.4 % of all the buildings are within the 60 dB buffer zone. Around 80% of all the buildings, on the other hand, are being utilized for residential purpose.

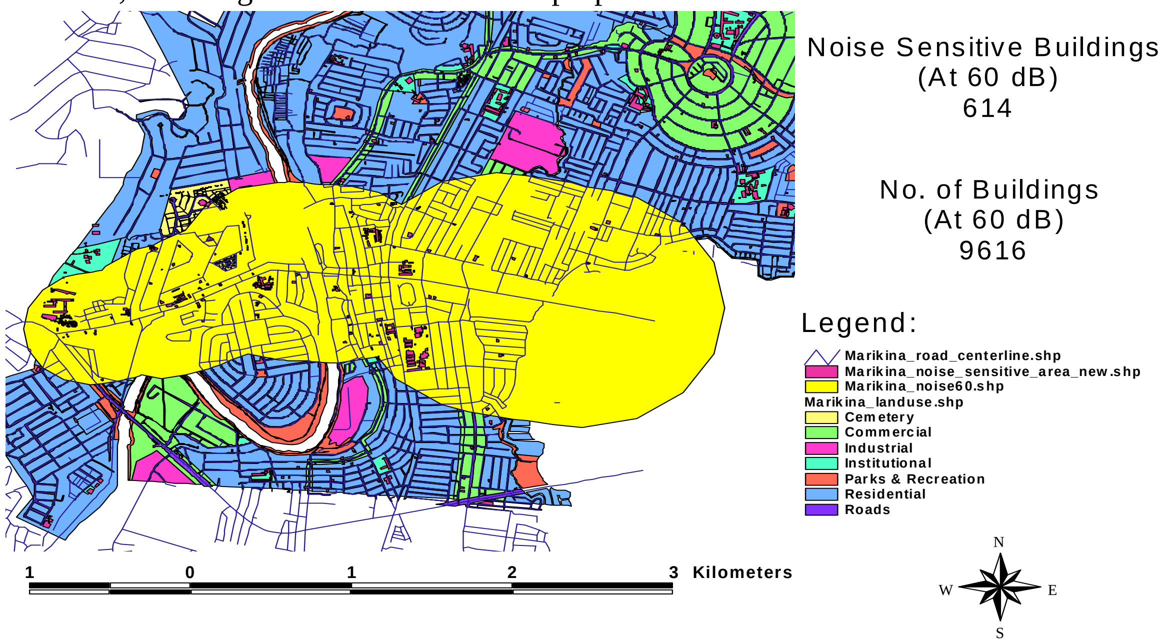


Figure 4. Distance from Road Centerline - 60 dB Noise Level

The buffer zone of distances from road centerline of noise level at 75 dB, 65 dB and 60 dB are also presented in a single map, as shown in Figure 5. The extent of noise level decreases from Sumulong Highway (right side) to A. Bonifacio Avenue (left side). This is because the traffic volume decreased and traffic volume is a major contributor to noise as evidence in the equation being used. Figure 6 shows the vehicular volume decreasing from Sumulong Highway to A. Bonifacio Avenue. This occurs since there are public utility vehicle routes (Figure 7), which cuts across the study area and leading to other cities or municipalities nearby, thus, decreasing the through traffic volume from Sumulong Highway to A. Bonifacio Avenue.

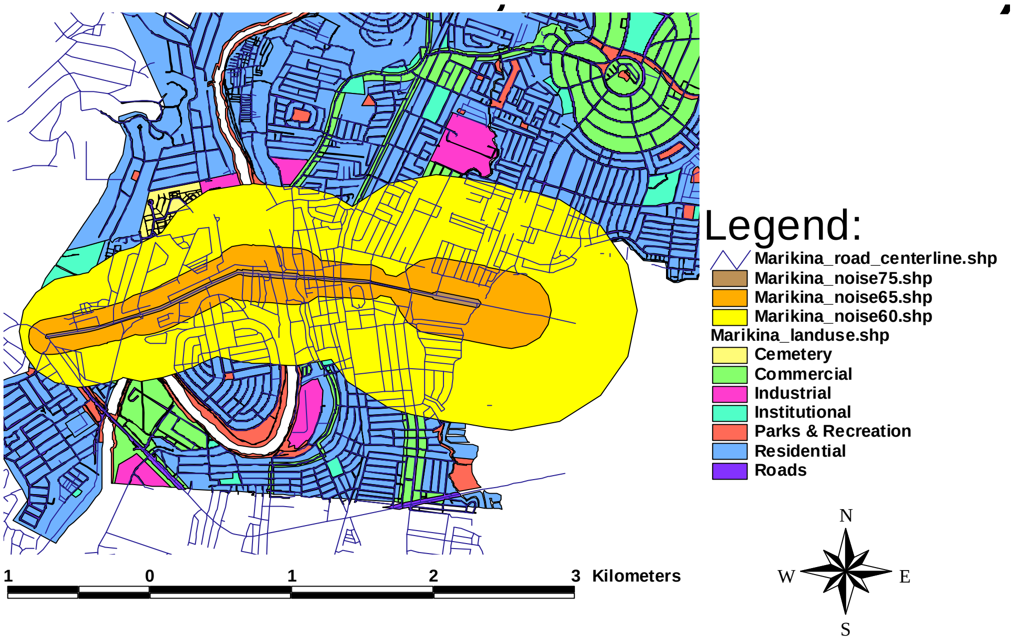


Figure 5. Distance from Road Centerline
(Noise Level 75 dB, 65 dB and 60 dB)

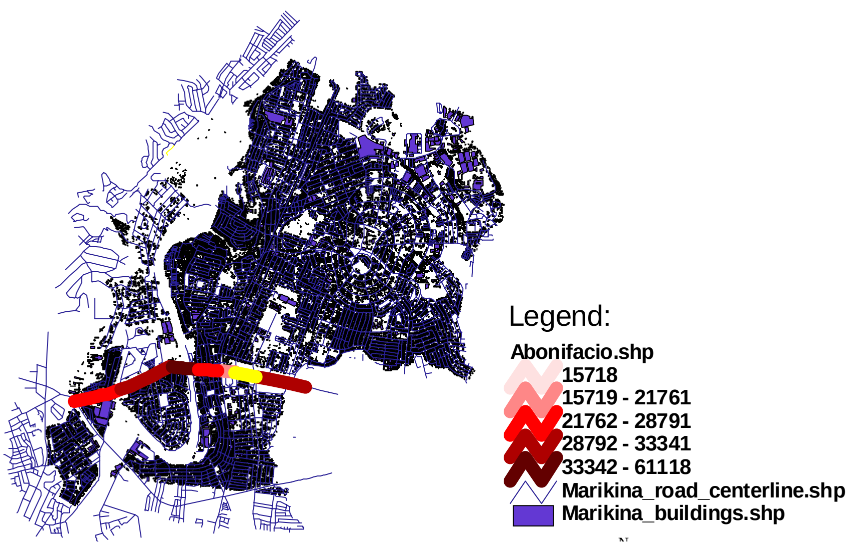


Figure 6. Traffic Volume Along A. Bonifacio and Sumulong Highway (2006)

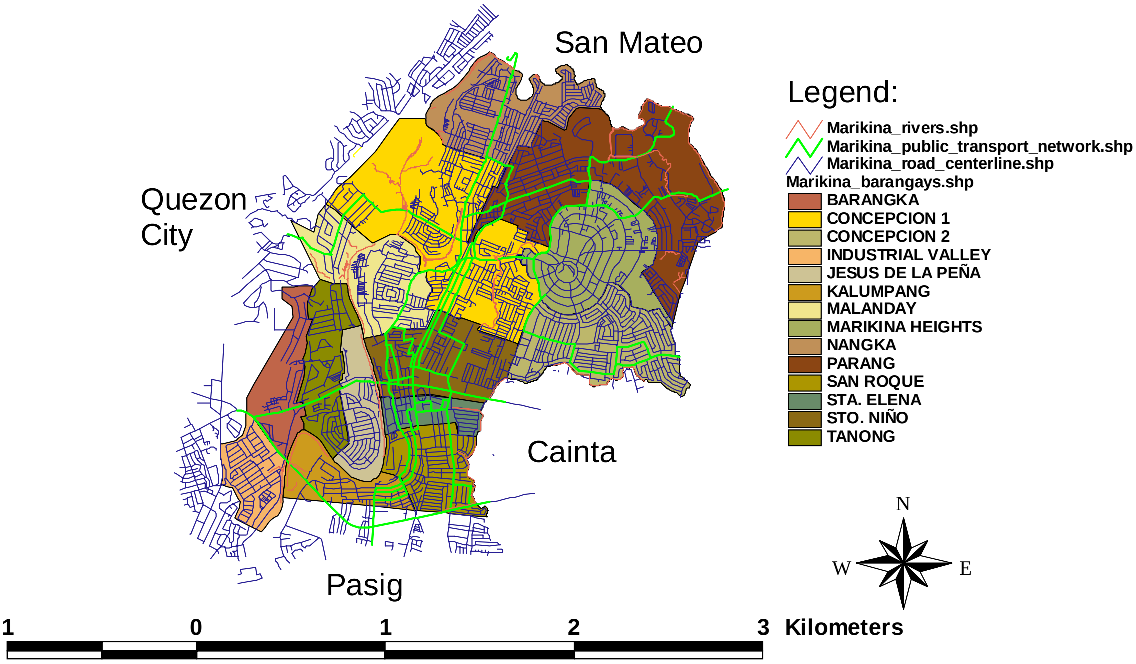


Figure 7. Public Utility Jeepney Routes in Marikina City

Based on noise standards, the noise sensitive buildings should be located 100 meters away from the road. Thus, a buffer zone was created for A. Bonifacio Avenue and Sumulong Highway. The green polygon in Figure 8 is the 100 meters buffer zone. The total number of buildings within the buffer zone is 1,965 with 267 or approximately 14% noise sensitive buildings within the buffer zone. Mitigating measures should be adopted in order to comply with the existing noise standards.

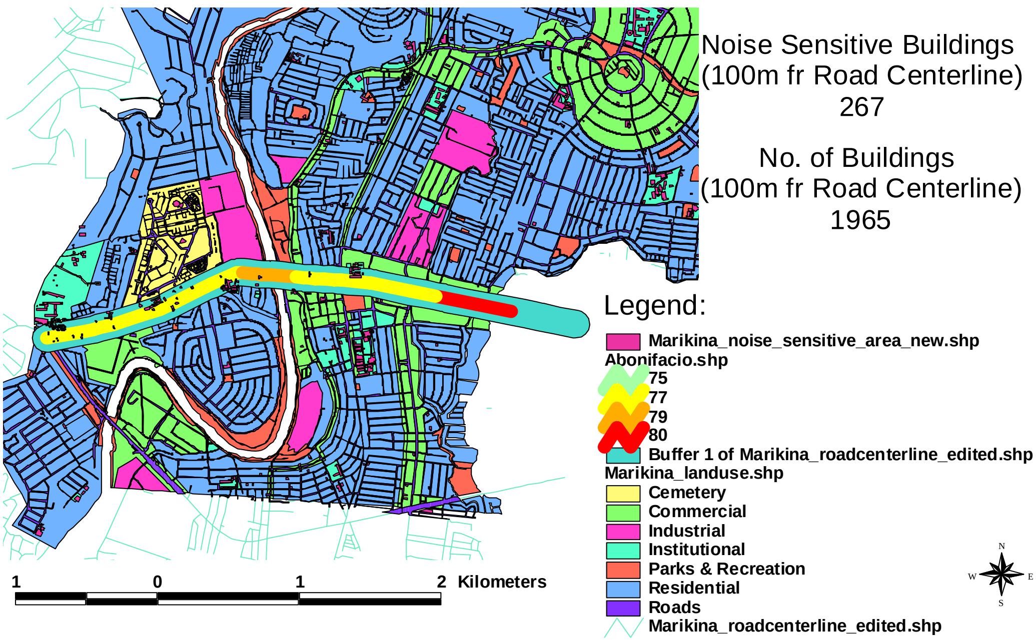


Figure 8. Buffer Zone at 100 meters from the Road Centerline

4. CONCLUSIONS AND RECOMMENDATIONS

The noise generated by traffic on A. Bonifacio Avenue and Sumulong Highway propagates outward the carriageway. At 75 dB, the level of sound that propagated from the traffic on A. Bonifacio Avenue and Sumulong Highway can reach as far as 22 meters away from the carriageway edge. 75 dB is the noise standard for commercial type of land use. There are a total of 278 buildings within the 75 dB mark. Around 50% of the buildings are utilized for residential purpose, 46% are composed of commercial establishments and offices, and the remaining 4% are noise sensitive buildings. All these buildings are experiencing noise level above the allowable limit for land uses of residential and commercial.

The noise standard for residential purpose during daytime is 65 dB. The 65 dB buffer mark is about 74 to 279 meters away from the carriageway edge. Approximately 13% and 63% of the buildings belong are of noise sensitive and residential use respectively. This means that 76% or 2,300 buildings are experiencing noise level over the noise standards.

For the 60 dB limit, there are almost ten (10) thousand buildings experiencing noise level of 60 dB or above. There are around 614 noise sensitive buildings or 6.4 % of all the buildings are within the 60 dB buffer zone. Around 80% of all the buildings, on the other hand, are being utilized for residential purpose. The 60 dB noise level reach is at least 247 meters away from the carriageway edge of the study corridor. At this distance, many factors have to be considered to correct the noise level. The major source of noise seen are those traffic on the parallel roads rather than the A. Bonifacio Avenue and Sumulong Highway since there are many objects that blocks the path of the sound from A. Bonifacio Avenue and Sumulong Highway.

Based on the Philippine noise standards, the noise sensitive buildings should be located 100 meters away from the road. Thus, a buffer zone was created for A. Bonifacio Avenue and Sumulong Highway. The total number of buildings within the buffer zone is 1,965 with 267 or approximately 14% are noise sensitive buildings.

The decrease in vehicular volume leads to a decrease in noise level and extent. This is the pattern seen from Sumulong Highway to A. Bonifacio Avenue.

The results enumerated above tell us that noise levels from traffic are way above the Philippine noise standards. Many buildings are experiencing noise level above the noise limit set for their use.

The recommendations are divided into two parts. The first part is recommendations on the improvement of the study, and the second part is on policy and regulation.

The recommendations for the improvement of the study are:

- Develop a traffic noise model for the Philippine setting to incorporate the uniqueness of the traffic situation in the country. One unique component of the country's traffic is the presence of public utility jeepneys.

- Develop noise attenuation table of the different materials and dimensions of objects that are on the path of traffic noise (i.e. walls made of hollow blocks).
- Improve the presentation on map by incorporating and showing the noise reduction due to presence of objects on the path of the noise propagation.
- Use actual data rather than assuming too many variables. It is suggested that speed survey and basic road inventory be incorporated in surveys of classified volume count. Do noise survey if resources permit.
- Include in building database, the building height in a format that is GIS compatible.

For the recommendation on policy and regulation:

- Include a section dedicated to noise pollution in Traffic Impact Assessment (TIA) and Environmental Impact Assessment (EIA). TIA and EIA are being done on proposed development. The mitigating measures can then be incorporated in the early part of the planning process, maybe on the design of the infrastructures. This is being proactive rather than reactive.
- Specify the traffic noise models and procedures in measuring traffic noise. This will bring less conflict between the developer and evaluator.
- Review the Philippine Noise Standards. The existing noise standards were set 25 years ago and many pertinent data were left off like the noise index to be used. Two common indexes that are being used in noise standards are equivalent sound level (Leq) and the level that is exceeded 10% of the time (L_{10}). The implementing rules and regulations should also be developed to provide principle and framework to enable the consistent management of road traffic noise
- Develop noise standards for different types of vehicles (i.e. engine sound, exhaust). This can encourage the vehicle manufacturers to design vehicles that generate less noise. This can encourage motorist to maintain their vehicles else vehicle registration will be not be renewed.
- Consider the noise level that will be generated by road traffic in the preparation of Land Use Plan. So that buffer zones and noise sensitive areas can be appropriately placed.
- Do regular monitoring of noise level to recommend appropriate mitigating measures. The measures can be financed by the government, motorists and/or developer/owner of the establishments. Noise mitigating measures are
  - Resurfacing pavements with noise-absorptive materials that can have 1 to 5 dBA reduction.
  - Erection of noise barriers that can have a 10 to 30 dBA reduction
  - Insulations of the buildings that can have up to 37 dBA reduction
  - Vegetation of 50 meter deep can reduce 3 dbA
  - Redesign of the establishments. Locating the commercial part of the establishment on the side facing the road
  - Traffic management that regulates the use of vehicle, promoting better traffic flow, speed limit and rerouting heavy vehicles. It is estimated that 2 to 5 dB reduction can be achieved
  - Relocation of the road or the establishment. Increase the distance of the buildings from the carriageway. Noise level decrease by 3 db for each doubling of distance from the source.

The solutions to address road traffic noise are not often found in a single program but rely on combinations of programs. For the study corridor, relocation of the establishments or the road is out of the question. The possible measure to experience an immediate drop of about 30 dB on the area around the study corridor are the construction of noise barrier or/and sound insulation of the buildings especially those that are noise sensitive. Traffic management is also recommended to promote better traffic flow. However, there are factors that should be looked up before deciding in the implementation, like the material for the noise barrier, durability, maintenance, cost, aesthetic and public acceptability of the measures.

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