PHILIPPINE ENGINEERING JOURNAL
*PEJ* 2004; **Vol. 25 No. 2**:1–22

# A Study on Roadside Noise Generated by Tricycles

Karl N. Vergel[1*], Frielly T. Cacho[2] and Cheryl Lyne E. Capiz[3]

[1] *Department of Civil Engineering*
*National Center for Transportation Studies*
*University of the Philippines Diliman*
*Quezon City 1101 PHILIPPINES*

[2] *Palace Project*
*SBG Contracting Company*
*1550 P.O. Box Dubai*
*UNITED ARAB EMIRATES*

[3] *Department of Civil Engineering*
*Chulalongkorn University*
*Bangkok, THAILAND*

ABSTRACT

The study is aimed at quantifying the levels of noise contributed by tricycles in the roadside residential environment. Specific objectives include the measurement of roadside noise levels, relating noise levels and road traffic flow characteristics and relating the noise performance of tricycles with loading, speed and road gradient (sloping or level) at on-road conditions, and with type of engine, loading, fuel-oil mix ratio and type of lubricant at simulated loading conditions. Tricycles comprise majority of the traffic passing through the study area. Results from the 24-hour survey of noise levels have shown that all readings exceeded the existing local standards. A multiple linear regression model predicting roadside noise level as a function of the traffic speed and tricycle traffic volume is developed with a relatively high correlation, indicating the significant contribution to noise by tricycles. There is a relationship of on-road noise performance of tricycles with its speed and load and type of road. With respect to noise performance under simulated loading, there is an increase in noise level with increase in speed level.

## 1. INTRODUCTION

Sound is the result of pressure changes in a medium which is usually air. Unpleasant, undesired and unwanted sound is called noise. It is any disturbance to the environment, threat to the quality of lives. Construction works, road works and drilling, trembling sound of jackhammer, horns from automobiles, industrial noise and aircrafts are examples of noise. Such case produces sound that affects all sorts of people, young and old, rich and poor, healthy and sick. Because noise does not result to any obvious and immediate danger to health as polluted water and air,

*Correspondence to: Department of Civil Engineering, Melchor Hall, Quezon City 1101, Philippines
email: karl.vergel@up.edu.ph



*Received June 30, 2005*
*Revised June 22, 2006*
*Accepted July 21, 2006*

public awareness of noise and commitment to noise prevention and reduction has been small (Bugliarello *et al.*, [3]).

Noise has a significant impact on the quality of life. The World Health Organization's (WHO) definition of health includes total physical and mental well-being. Noise can both awaken people and keep them from going to sleep. It can annoy and somehow affect the behavior and performance of an individual because one is deprived of sufficient resting time during nighttime.

Noise pollution is defined as the combination of sounds resulting to noise, thereby producing an annoying and disturbing sound. It is produced by different sources: aircraft noise, noise from railroads, construction noise, noise from vehicles, industrial noise and road traffic noise. Its effects are mainly affected by the duration and level of noise.

Noise has various effects on humans and extreme exposure could result to temporary or permanent hearing loss. It can also interfere with communication, it affects and disturbs sleep, affects individual behavior and performance. The effects of noise are seldom catastrophic, and are often only transitory, but adverse effects can be cumulative with prolonged or repeated exposure. Although it often causes discomfort and sometimes pain, noise does not cause ears to bleed and noise-induced hearing loss usually takes years to develop. Noise-induced hearing loss can indeed impair the quality of life, through a reduction in the ability to hear important sounds and to communicate. Some of the other effects of noise, such as sleep disruption, the masking of speech and television, and the inability to enjoy one's property or leisure time also impair the quality of life. In addition, noise can interfere with the teaching and learning process, disrupt the performance of certain tasks, and increase the incidence of antisocial behavior. There is also some evidence that it can adversely affect general health and well-being in the same manner as chronic stress. (Suter, [17])

The primary contributor to roadside noise is transportation. The noise produced by vehicles may be termed as road traffic noise. In the vehicle, the principal noise source is the power unit and its auxiliaries, transmission system, tires and braking system. This type of noise can be augmented by narrow streets and tall buildings, which produce a "canyon" in which traffic noise reverberates (Suter, [17]).

Transport-generated noise is measured in terms of equivalent sound level or Leq. This metric is A-weighted and accounts for all of the sound energy occurring during a particular period of time (i.e., one minute, one hour, one day, etc.). Leq includes peak sounds as well as "valleys" within a particular time frame. Leq could identify the average noise level over a period of time and can be easily measured with sound equipment. Measurements would therefore be in terms of Leq dB (A). An 'A' weighted scale with a slow response was chosen because it has been universally adopted for measurement of transport noise to compensate human hearing characteristics. This scale simulates the response of the ear at low levels and has been found to correlate well with subjective response to noise

In Metro Manila, people travel mainly by public transport through jeepneys, buses and tricycles. In residential areas, tricycles have been the major mode of transport. A tricycle is a motorcycle attached to a side frame (sidecar), its typical configuration changes into other forms in order to adapt to various road conditions and numbers of passengers to carry. Usually, it can carry 3 to 5 passengers per trip. Tricycles contribute to 2.373 million daily person trips (13.4% of total person trips) made in Metro Manila according to Metro Manila Urban Transportation Integration Study (MMUTIS) in 1996 funded by the Japan International Cooperation Agency (JICA). It is equivalent to 938,000 vehicle trips daily (26.3% of total vehicle trips) with an

 

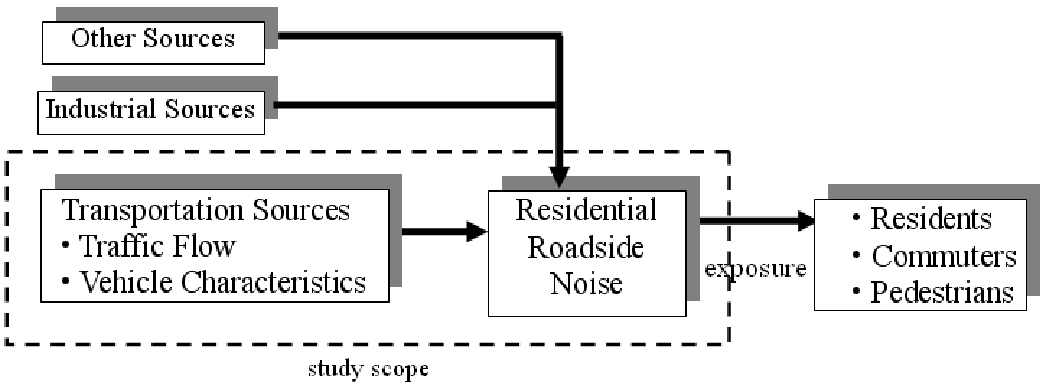


Figure 1. Framework of the Study.

average occupancy of 2.5 persons/tricycle, which is next to the passenger cars/utility vehicles share at 37.3% (JICA, [12]).

The primary aim of the research is to quantify the noise generated by tricycles in residential environments. Specific objectives of the study are the following:

- to determine the variation of levels of noise on a particular roadside residential environment in one day and compare with the existing noise standards;
- to find the relationship of traffic flow characteristics such as the traffic speed and traffic volume of tricycles and the roadside noise level; and,
- to relate the noise performance by tricycles as a function of speed and load of the tricycle during running conditions and the general slope of the road.

The framework, shown in Figure 1, shows the 3 possible sources of noise in residential environments and the effects on people in terms of exposure to roadside noise levels. The scope of the study is on transportation sources where traffic flow and vehicle characteristics are important factors. The study will mainly focus on tricycles passing through residential roads which are observed to contribute mostly to roadside noise levels in a number of residential areas.

## 2. PREVIOUS STUDIES ON TRANSPORTATION-GENERATED NOISE

### *2.1. Studies on Noise Generated by Transportation*

Pamanikabud [15] presented the analysis and simulation of traffic noise model for the super-highway in Bangkok, with considerations on non-typical local traffic vehicles such as tuk-tuk (3-wheeled motorcycle taxi) and motorcycle. Linear models between noise level in Leq and the spot speed of vehicles were developed. The linear relationship between noise level in Leq and speed of vehicle was the most suitable to highway traffic noise data in Bangkok's Vibhawadee-Rangsit Super-Highway in the analysis of reference energy mean emission level (Lo) for each type of vehicle in the Bangkok traffic stream that included motorcycles and tuk-

tuk in additional to the other standard types of vehicle. Results from this study also showed a significant improvement in the forecasting of the super-highway traffic noise in Bangkok by utilizing the reference energy mean emission level (Lo) into the overall highway traffic noise model in comparison to the utilization of Lo as previously given by FHWA with the inclusion of motorcycle and tuk-tuk into the heavy vehicle class. The modified model gave statistically significant results in fitting with the observed traffic noise data on this super-highway in the paired t-test at both 5% and 10% significance levels.

In Metro Manila, the National Center for Transportation Studies of the University of the Philippines (UP-NCTS) conducted noise level measurements in 1997 in major roads such as EDSA, Taft Avenue, Roxas Boulevard, South Superhighway, Quezon Avenue and Quirino Avenue under the Metro Manila Urban Transportation Integration Study Environmental Impact Analysis Study [19]. Roadside noise levels measured at the said stations indicated a worsening level of noise pollution. The highest recorded noise level was 83.9 dBA at EDSA. Noise levels exceeded noise standards in Taft Avenue at all times of the day. Another noise level survey was conducted by UP-NCTS in 2001 at 4 mid-block road sections in Manila, Quezon City and Taguig and an interchange in Makati City [20]. There were more instances of sound levels exceeding the daytime and nighttime standards in R-10 road due to vibrations caused by heavy trucks and trailers which consisted majority of the traffic flow. Measured sound levels at the roadside of Taft Avenue exceeded the national standards at all times. Sound levels at the Ayala Interchange and at C-5 (BCDA) also exceeded the national standards at all times not only at the roadside but as far as 5 meters and 15 meters from the road.

Fajardo [11] conducted field measurements of noise levels simultaneously with noise perception surveys at 3 sites in Metro Manila, namely: Quezon Avenue (near Sto. Domingo Church), Taft Avenue (Pedro Gil) and EDSA (Camp Crame). Findings showed that: a) existing noise levels at survey sites exceeded current standards for the daytime period; b) the level of awareness of road traffic noise as very high at all sites; c) the perceived degree of annoyance to noise varied widely among individuals and with respect to actual noise levels; d) beyond a certain threshold noise level, there was a high variability in individual perceptions to noise; e) the minimum and maximum tolerable noise levels were found to be 25 dB and 80 dB, respectively; f) individuals appear to tolerate a noise level of 80 dB which is higher than the 75 dB standard for the daytime period; and, g) road traffic noise as a problem has reached a point in which the government must initiate actions to alleviate the adverse impacts on individuals.

Yusoff and Karim [25] examined the level of noise pollution due to various modes of transportation, its effect towards the environment and examined some of the control measures that can be adopted to minimize the impact of the noise emitted. Simultaneously, they also conducted a public survey to gauge the existing public attitude and degree of awareness towards contemporary transportation noise pollution problems. From the analysis of measured transportation noise in the Klang Valley, it was clear that most of the residents near the vicinity of the noise sources were constantly exposed to very high levels of noise. Sound pressure level recorded as Lmax was as high as 104.3 dB (A), which can be considered very high, and may cause hazardous health effects under prolonged exposure of residents. As a comparison, the Lmax recorded from previous study by Lee and Sumiani (1994), was: 84 dB (A) for cars, 92 dB (A) for motorcycles, 94 dB (A) for minibuses, 90 dB (A) for long buses and 92 dB (A) for heavy lorries. The values obtained from the studies showed the surrounding noise levels of the selected sites were mostly beyond the recommended level of 55 dB (A) for daytime and 45 dB

 

(A) for nighttime standards for residential areas.

### 2.2. *Noise Standards and Regulations*

Because of their sensitivity to frequency and temporal characteristics of noise, both the Leq (energy-equivalent sound levels) and the Ldn (day/night average equivalent sound levels) have become widely used in environmental noise regulations and criteria. Among U.S. federal agencies using Leq or Ldn are the Environmental Protection Agency, Federal Highway Administation, Department of Housing and Urban Development (HUD), Federal Aviation Adminisration and Department of Defense (Cavanaugh and Tocci, [6]). The guidelines have been devised to achieve the HUD goal for interior noise levels not exceeding an Ldn of 45 dB. HUD is the lead federal agency setting standards for interior and exterior noise for federally-supported housing in the U.S.

In the Philippines, laws and standards on noise were provided by the defunct National Pollution Control Commission (NPCC, [13]) through Presidential Decree No. 1152. Section 5 indicates that community noise standards shall be established considering among others, location, zoning and land use classification, as shown in Table I and Table II. Section 6 states that there shall be established a standard for noise-producing equipment such as construction equipment, transportation equipment, stationary engines, and electrical or electronic equipment and such similar equipment or contrivances. The standard shall set a limit on the acceptable level of noise emitted from given equipment for the protection of public health and welfare, considering among others, the magnitude and condition of use, the degree of noise reduction achievable through the application of best available technology and the cost of compliance. The installation of any noise-producing equipment shall conform to the requirements of Presidential Decree No. 1096 and other applicable laws as well as their implementing rules and regulations. Section 8, Air Quality and Noise Standards, stated that the National Pollution Control Commission in coordination with appropriate government agencies shall be responsible for the enforcement of ambient air quality emission and noise standards, including the monitoring and surveillance of air pollutants, licensing and permitting of air pollution control facilities, and the promulgation of appropriate rules and regulations. Existing air quality emission and noise standards may be revised and/or modified consistent with new development and technology.

With respect to standards on noise performance of vehicles, the Quezon City Council passed an ordinance (Ordinance No. SP-1221, S-2003, page 2-PO2002-50, 56th Regular Session, Quezon City Council, Philippines, [14]) requiring noise pollution testing before the grant of a permit for the operation of any motorized vehicle like the tricycle. The noise level measurement is done by placing the sound level meter at a distance of 3 meters from the exhaust of the tricycle. The noise level should not exceed 90 decibels.

## 3. RELATIONSHIP OF ROADSIDE NOISE LEVELS AND TRAFFIC FLOW

### 3.1. *Traffic and Roadside Sound Level Survey*

The study area is situated in Maginhawa Street (near Matiwasay Street) in Teachers Village East, Diliman, Quezon City, as shown in Figure 2. Matiwasay Street is closed to traffic. Maginhawa Street passes through three major residential areas in Quezon City: Barangay

 

| Category of Area | Daytime (9AM-6PM) | Morning & Evening (5-9AM&6-10PM) | Nighttime (10PM-5AM) |
|---|---|---|---|
| AA - section or area which requires quietness, such as an area within 100 m. from school sites, nursery schools, hospitals and special homes for the aged | 50dB | 45dB | 40dB |
| A - residential purposes | 55 dB | 50 dB | 45 dB |
| B - commercial area | 65 dB | 60 dB | 55 dB |
| C - light industrial area | 70 dB | 65 dB | 60 dB |
| D - reserved as a heavy industrial area | 75 dB | 70 dB | 65 dB |

Source: Rules and Regulations of the National Pollution Control Commission (NPCC)

Table I. Noise Standards in General Areas

| Category of Area | Daytime | Morning & Evening | Nighttime |
|---|---|---|---|
| AA | 55 dB | 50 dB | 45 dB |
| A | 60 dB | 55 dB | 50 dB |
| B | 70 dB | 65 dB | 60 dB |
| C | 75 dB | 70 dB | 65 dB |
| D | 80 dB | 75 dB | 70 dB |

Source: Rules and Regulations of National Pollution Control Commission

Table II. Noise Standards in Areas Directly Fronting/Facing A Four-Lane Road

UP Village, Barangay Teachers Village East and West and Barangay Sikatuna. Maginhawa St. is classified as a national road with an effective width equivalent to 4 lanes but 2 lanes are mainly being used for traffic. There are 4 tricycle operators and drivers associations (TODAs) operating along Maginhawa St.: Philcoa TODA, UPTV TODA, BSV TODA and Krus na Ligas TODA. These tricycles cover U.P. Village, Teachers Village East and West and transport passengers to C.P. Garcia, Sikatuna Village, Krus na Ligas, Kalayaan Avenue and Maharlika Village (NHA).

As indicated in Figure 2, the source of noise from traffic was assumed to be approximately 0.25 m. above the road surface. The sound level monitoring equipment was set at 10 m. from the centerline of road. The receptor was set at 1.2 m. to 1.5 m. above the ground. The trap length for the spot-speed survey was set at 10 m., represented by 2 markers, with the noise level monitoring equipment located in between the markers.

Traffic flow characteristics, such as traffic volume and traffic speed were measured simultaneous with noise level determination at 10-minute intervals but only during selected peak and off-peak periods in October 3, 2002. Vehicles were classified into jeepneys, medium trucks, trucks, private cars/taxis, motorcycles and tricycles. Traffic monitoring was conducted during nighttime period at 12-2 AM, morning peak hours at 6-9 AM, morning off-peak hours

 

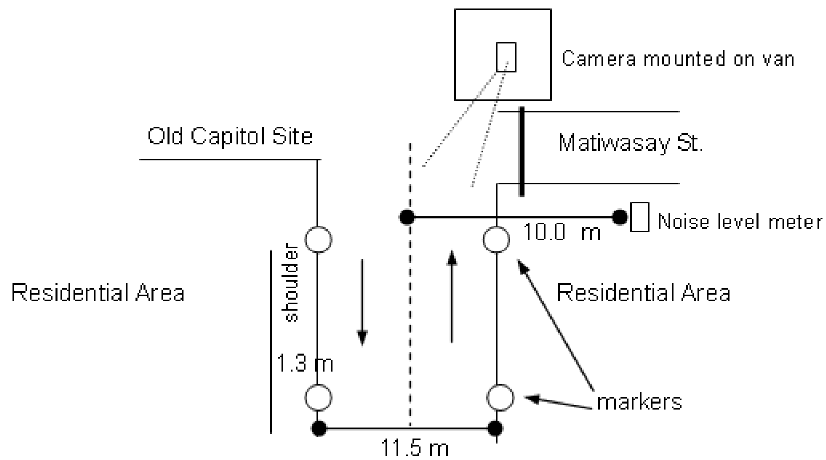


Figure 2. Study Area and Set-Up of Traffic and Sound Level Monitoring Equipment.

Figure 3. UP-NCTS Traffic Flow Monitoring Equipment and Vehicle.

at 11 AM-1 PM, afternoon peak period at 4-7 PM, and an evening period at 10 PM-12 AM. Traffic at the study site was recorded by traffic monitoring equipment with video camera mounted on the vehicle of UP-NCTS, as shown in Figure 3.

Using an Integrating Sound Level Meter (NL-04) as shown in Figure 4, roadside noise level was measured, in terms of Leq dB (A), at 10-minute intervals for 24 hours.

### 3.2. *Traffic Flow Characteristics*

Traffic volume data were encoded at 10-minute intervals. Figure 5 indicates that traffic volume for both directions at Maginhawa Street ranged from 186 to 1,808 veh/hr where minimum traffic volume occurred during the early morning period at 1:00-2:00 AM and the maximum

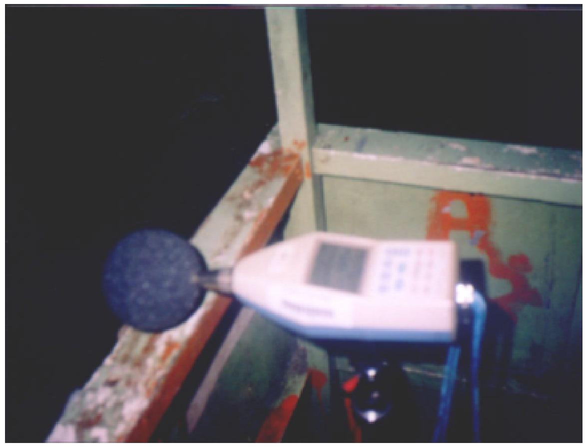

Figure 4. Integrating Sound Level Meter (NL-04).

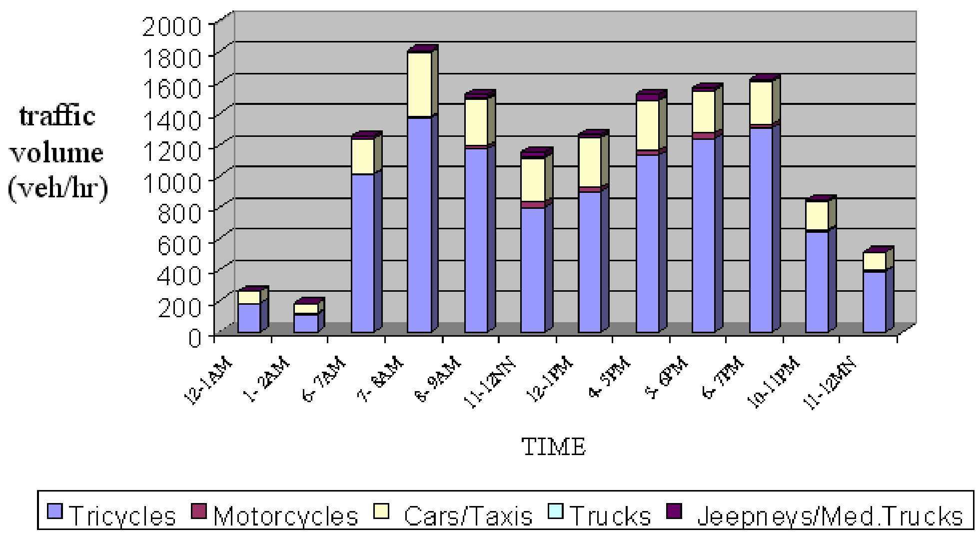


Figure 5. Classified Hourly Traffic Volume At Selected Hours of the Day At Maginhawa Street (Both Directions).

traffic volume occurred during the morning peak period at 7:00-8:00 AM. Traffic flow is predominated by tricycles at most hours of the day where percentage of tricycles in the traffic flow ranged 62-81% during the hours when traffic was monitored.

Around 40 samples of vehicle speeds were taken for every 10 minutes during the selected time periods of the traffic flow and speed survey. Spot speeds ranged 17-26 km/h as shown in Figure 6. The speed-flow relationship is shown in Figure 7 consisting of 10-minute speed-volume data. It can be seen that traffic speed does not vary significantly compared with the

 

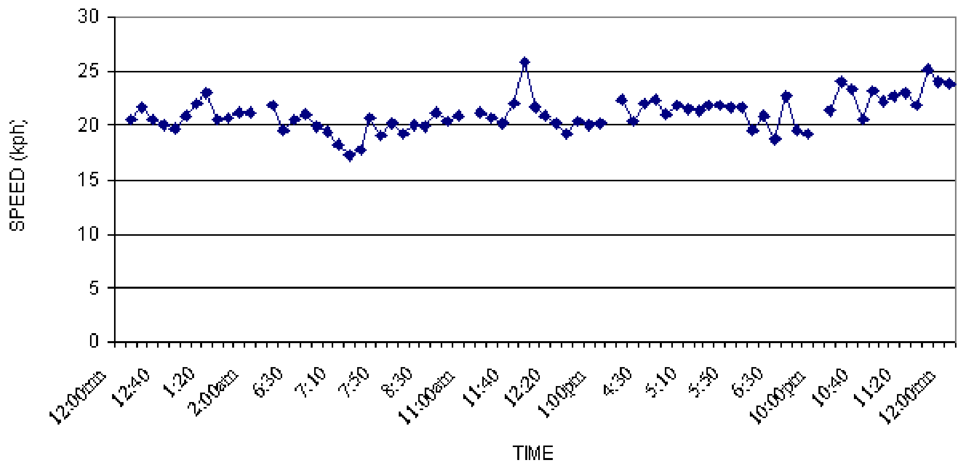


Figure 6. Variation of Average Traffic Speed by Time of Day of Maginhawa Street.

expanded hourly traffic volume and most points fall in the free-flow portion of the speed-flow curve.

### *3.3. Roadside Noise Levels and Comparison With Standards*

Noise level was measured at 10 minute-intervals for 24 hours to assess if noise levels satisfy the existing standards. The straight lines in Figure 8 indicate the noise standards for residential areas (category A) fronting 4-lane roads, shown in Table II. It can be seen in Figure 8 that the measured roadside noise levels exceeded the noise standards at all times of the day. The average noise level was highest for the evening period (6-10 PM) at 78.2 dB followed by the morning period (10 PM-5 AM) at 76.8 dB, exceeding the standards by more than 20 dB, indicating the seriousness of noise levels generated by vehicular traffic in residential roads such as Maginhawa Street where there is a high percentage of tricycles in the traffic flow.

### *3.4. Relationship Between Roadside Noise Levels and Traffic Flow Characteristics*

Figure 9 and Figure 10 show directly proportional relationship between roadside noise level and traffic volume and, noise level and tricycle traffic volume, respectively, at 10-minute intervals. The graphs indicate the strong influence of tricycles on measured roadside noise levels.

A multiple linear regression model of noise level was developed as a function of traffic speed and tricycle traffic volume. Total traffic volume was highly correlated with tricycle volume where the latter was used in the regression due to higher correlation with roadside noise level and predominance in road traffic. Data consisted of 72 samples of roadside noise level (Leq in dBA) measured every 10 minutes, traffic speed (km/h) averaged every 10 minutes and tricycle volume (veh/10 min.) during the selected hours of the day. Table III shows the results of the regression model where roadside noise level is linearly related with traffic speed and tricycle traffic volume with a high correlation ($r^2 = 0.8368$).

 

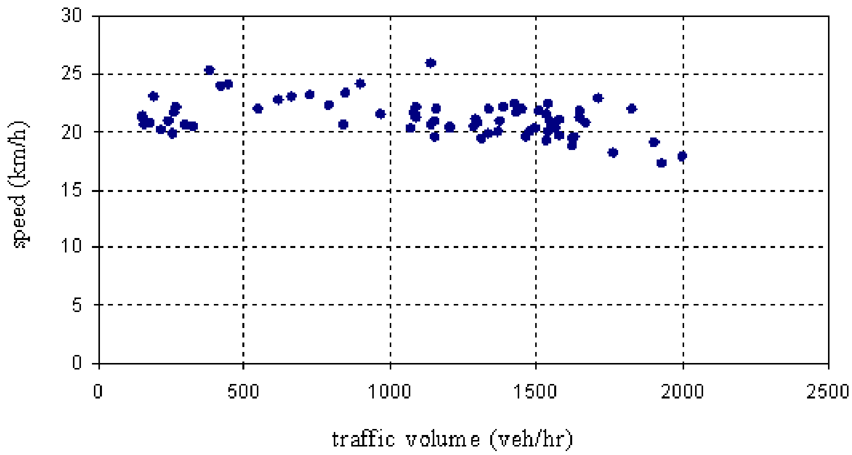


Figure 7. Speed-Flow Relationship of Maginhawa Street.

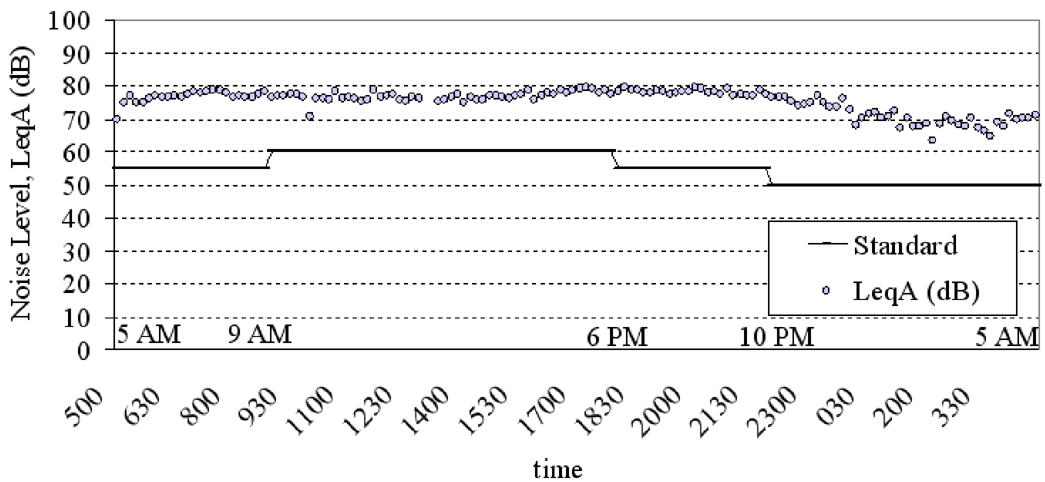


Figure 8. Roadside Noise Level (Maginhawa Street) by Time of Day and Noise Standard.

| | Beta | St.Err. | B | Std.Err. | $t(69)$ | $p$-level |
|---|---|---|---|---|---|---|
| intercept | | | 59.42275 | 2.279176 | 26.07204 | 0.000000 |
| traffic speed(km/h) | 0.258506 | 0.052552 | 0.49721 | 0.101078 | 4.91905 | 0.000006 |
| tricycle volume(veh/10min.) | 0.980757 | 0.052552 | 0.04221 | 0.002262 | 18.66260 | 0.000000 |

Table III. Multiple Linear Regression of Roadside Noise Level Against Traffic Speed and Tricycle Volume

 

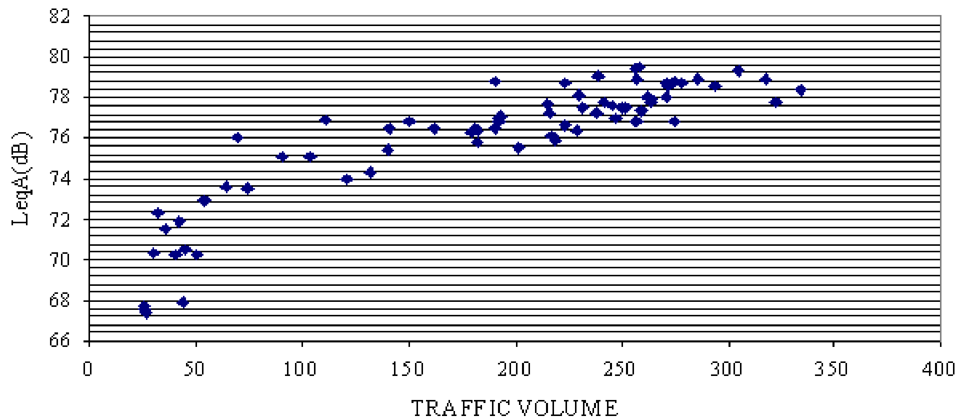


Figure 9. Relationship Between Roadside Noise Level and Traffic Volume.

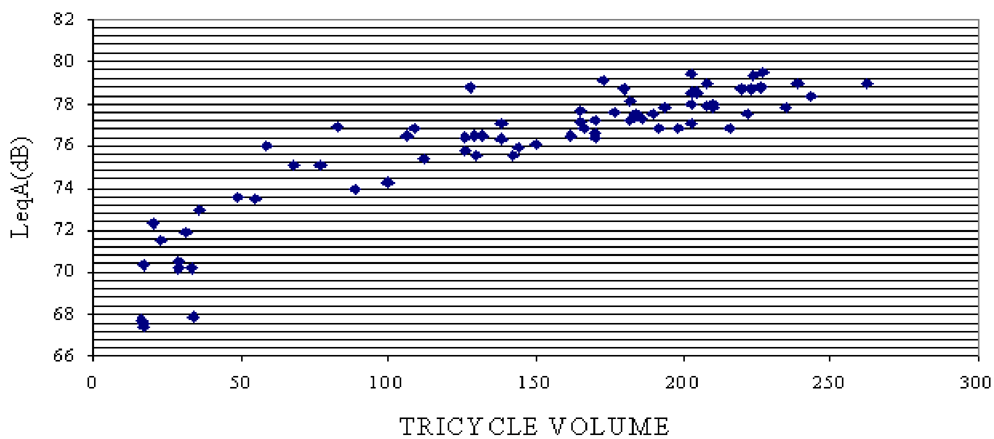


Figure 10. Relationship Between Roadside Noise Level and Tricycle Traffic Volume.

The magnitude of the intercept, which is approximately 59.4 dBA, corresponds to the noise level when there are no tricycles in the traffic stream. This is close to ambient noise levels in residential areas with some vehicle traffic. Recent monitoring at roadside locations inside residential areas with very low traffic levels yielded noise levels of 51-53 dBA.

## 4. RELATIONSHIP BETWEEN TRICYCLE NOISE PERFORMANCE AND OPERATING CHARACTERISTICS

The integrating sound level meter (NL-04 Type 2) was also used in measuring the noise

 

| Load | Mass(kg) |
| --- | --- |
| Driver | 60 |
| Sound Level Meter | 1 |
| 2 Surveyors | 100 |
| 1st Passenger | 50 |
| 2nd Passenger | 55 |
| 3rd Passenger | 45 |

Table IV. Mass of Loads on the Tricycle

| Load | Mass(kg) |
| --- | --- |
| Load 1: driver + instrument + 2 surveyors | 161 |
| Load 2: Load 1 + 1st passenger | 211 |
| Load 3: Load 2 + 2nd passenger | 266 |
| Load 4: Load 3 + 3rd passenger | 310 |

Table V. Loadings on the Tricycle for the On-Road Noise Performance Test

performance of in-use tricycles. Noise performance of exhaust systems of in-use tricycles at on-road running conditions and of new motorcycles in the laboratory under simulated tricycle loading on a chassis dynamometer were assessed in terms of noise level measurements near the exhaust system. The noise performance of tricycles is measured and is related to loading, speed and gradient at on-road conditions and related to type of engine, loading, fuel-oil mix ratio and type of lubricant at simulated loading conditions on the chassis dynamometer.

### *4.1. On-Road Noise Performance of In-Use Tricycles*

*4.1.1. Noise Level Measurement Procedures (On-Road Conditions)* Measurement was done with the instrument held by hand tilted at an angle inside the tricycle's sidecar next to the tricycle driver (Figure 11 and Figure 12). Road segments for the noise performance of tricycles at on-road conditions were chosen such that sound coming from other sources was minimal. The road surface was concrete grade for noise measurements on level ground (University Avenue in Figure 13) and asphalt grade for sloping ground (Matahimik Street, UP Village in Figure 14). The tricycle was then driven to run at almost constant speed at a time at different speed levels. There were 6 speed levels starting at 20 km/h to 45 km/h at 5-km/h intervals for measurements of noise on level ground. The speed levels set on the inclined road were from 20 km/h to 40 km/h only. The measurement interval was at 10 seconds. Five readings were taken for each speed and load condition. The details of the load calculation are shown in Table IV. For each speed, there were 4 load conditions from 161 kg. to 310 kg. (excluding the mass of the tricycle vehicle), as shown in Table V.

*4.1.2. Relationship of On-Road Noise Performance, Load and Speed of Tricycles* For the noise performance of tricycles at on-road running conditions at level roads, it can be seen from Figure 15 that the noise level increases from 6.6 to 8.6 dBA as the running speed increased from 20 to 45 km/h. An increase in the noise levels is also evident (about 2.2 to 4.6 dBA) for an increase in the load of the tricycle from 2 passengers up to 5 passengers for the same running

 

Figure 11. Tricycle Used in the On-Road Survey.

Figure 12. Instrument Set-Up at On Road Running Conditions.

Figure 13. Noise Level Measurements in Level Ground (University Avenue).

 

Figure 14. Noise Level Measurement in Sloping Ground (Matahimik St., UP Village).

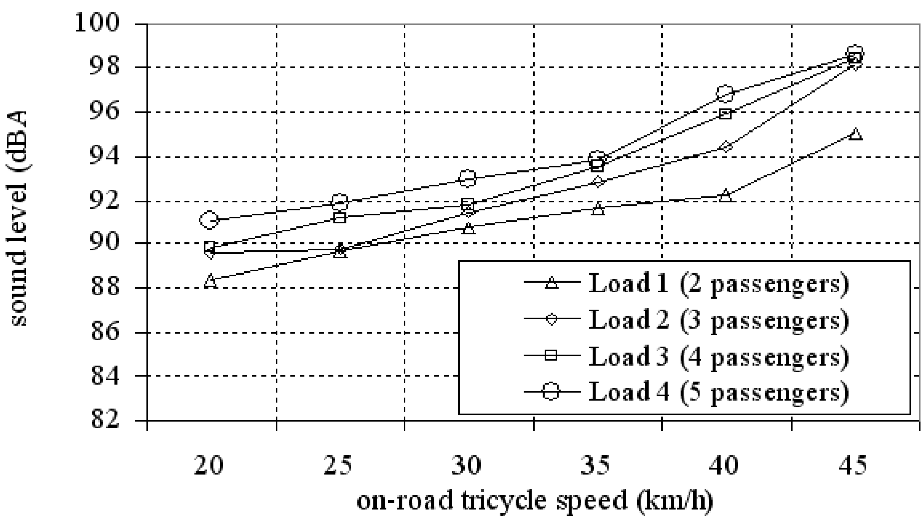


Figure 15. Variation of On-Road Noise Performance, Speed and Load of Tricycles (Level Road Segment).

speed. The measured noise levels from tricycles increased for sloping roads (Figure 16). From a range of 88.4 to 98.6 dBA measured while running on the level road, the noise levels increased to a range of 91.2 to 99.6 dBA for the road sloping upwards. The measured noise levels for the 45-kph level were quite near to the in-use motor vehicle exhaust system noise performance standards (Washington Administrative Code or WAC 173-62) of Washington State [24] in the United States which provided for a maximum of 99 dBA at 0.5 meter away from exhaust of motorcycles. A noise level of 90 dBA is already very annoying and can cause hearing damage if exposed to for 8 hours. This has implications especially for tricycle drivers who are continuously exposed to high noise levels.

 

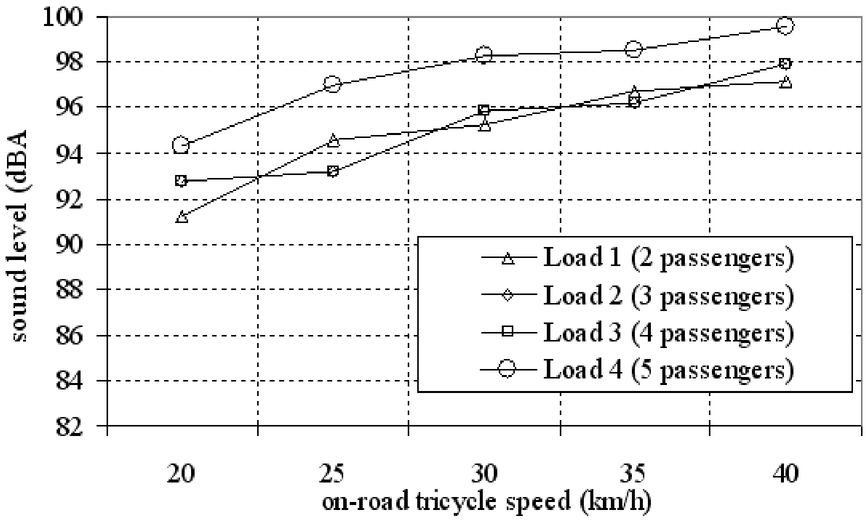


Figure 16. Variation of On-Road Noise Performance, Speed and Load of Tricycles (Road Segment, Sloping Upwards).

*4.2. Noise Performance of Tricycles Under Simulated Loading on Chassis Dynamometer*

*4.2.1. Setting Up of Tricycles for Engine and Noise Performance Tests* The noise performance of tricycles under simulated loading on a chassis dynamometer was assessed through noise level measurements conducted simultaneously with the emissions and engine performance testing of motorcycles acquired in the research project "Standards Development for Local Motorcycle/Tricycle Sector" of the University of the Philippines National Center for Transportation Studies Foundation Inc. (UPNCTSFI) funded by the Philippine Council for Industry and Energy Research and Development (DOST-PCIERD). The tests were conducted at the Department of Mechanical Engineering Laboratory in the University of the Philippines. A chassis dynamometer is an equipment that can simulate a road in which a vehicle is driven. It measures power from the engine through the wheels. The vehicle is parked on rollers which the vehicle then turns and the corresponding output in terms of engine performance measurements such as power and torque are measured.

The research project acquired 3 new units of 2-stroke motorcycles (Model B) and 1 unit of 4-stroke motorcycle (Model D). Based on the tricycle driver survey, Model B and Model D, respectively, are the major 2-stroke and 4-stroke motorcycles used as tricycles in Metro Manila. Premium gasoline and a mineral-based 2T oil (JASO FB grade) were premixed in labeled containers prior to the conduct of the engine performance and noise performance tests. The premixes with the mineral-based lubricant consisted of following fuel-oil ratios (2T oil: gasoline ratio): a) 1:20 (1 part of 2T oil in 20 parts of gasoline) and b) 1:40 (1 part of 2T oil in 20 parts of gasoline). A plant-based lubricant, CME (cocomethyl ester) 2T oil was also premixed with premium gasoline at 1:20 ratio. Table VI shows the outline of the engine tests conducted in the research project.

 

| Test Motorcycle | Engine Type | Displacement | Fuel-Oil Mix Ratio | Lubricant |
|---|---|---|---|---|
| Model B Red | 2-stroke | 125 cc | 1:20 | mineral-based 2T |
| Model B Blue | 2-stroke | 125 cc | 1:40 | mineral-based 2T |
| Model B Black | 2-stroke | 125 cc | 1:20 | CME-based 2T |
| Model D | 4-stroke | 155 cc | fuel only (no premix) | |

Table VI. Test Motorcycles and Fuel-Oil Mix Ratios Used in the Engine Tests

| Component of Load | Load (Half Load) | Load (Full Load) |
|---|---|---|
| Motorcycle | 126 kg | 126 kg |
| Sidecar + Driver's Side Roof | 130 kg | 130 kg |
| Driver (Average Weight of Person=60 kg) | 60 kg | 60 kg |
| 3 Passengers (Average Weight of Person=60 kg) | 120 kg | |
| 5 Passengers (Average Weight of Person=60 kg) | | 300 kg |
| Baggage | 10 kg | 10 kg |
| Allowance | 10 kg | 10 kg |
| Total (Load) | 456 kg | 636 kg |

Table VII. Estimation of Load of Vehicle, Passengers and Baggage

*4.2.2. Estimation of Load for Simulation of Tricycle Loading* Since the chassis dynamometer set-up is for motorcycles, there is a need to simulate loading of the tricycle vehicle in addition to other loads such as passengers and baggage. The components of road load power are drag, rolling resistance and load. The load consists of the vehicle mass including sidecar and accessories and the additional mass due to passengers and baggage. The load estimates for the full and the half load are shown in Table VII. The difference between the half and the full load is in terms of the number of passengers of the tricycle. The engine performance testing component of the tricycle standards research project (UPNCTSFI and DOST-PCIERD, [21]) estimated the road load power, $P_r$, in kW, for the half and full load conditions, to be as follows (Equation 1):

$$P_t = \left[2.73 C_R M_v + 0.0126 C_D A_v S_v^2\right] S_v \tag{1}$$

where $C_R$ =coefficient of rolling resistance (assumed to be 0.012)
$M_v$ = mass of vehicle and load (kg)
$C_D$ = drag coefficient (assumed to be 0.3)
$A_v$ = frontal area of the vehicle (m$^2$)
$S_v$ = vehicle speed (km/h)

Values of the road load power ranged from 0.782 kW at 30 km/h to 1.984 kW at 50 km/h for the full load condition and from 0.664 kW at 30 km/h to 1.787 kW at 50 km/h for the half load condition.

Table VIII shows the 6 sets of engine and noise performance tests which are combinations of two loading conditions and 3 steady-state speeds. All the 4 test motorcycles have undergone the 6 tests.

 

| | 30 kph | 40 kph | 40 kph |
|---|---|---|---|
| Half Load | √ | √ | √ |
| Full Load | √ | √ | √ |

Table VIII. Loading Conditions and Steady-State Speeds for Chassis Dynamometer Tests

*4.2.3. Noise Performance Test Procedure of Tricycles Under Simulated Loading* The procedures for measuring the noise levels of tricycles on the laboratory chassis dynamometer were adopted from the in-use motor vehicle exhaust system noise performance standards and sound level measurement procedures of the Department of Ecology, Washington State [9] in the United States. However, due to limitations of the dynamometer set-up, some parts of the procedures were modified. One such modification was that of the test site. Noise level measurements were performed inside a building that housed the chassis dynamometer. The sound level meter was not placed at the same axis as that of the exhaust in order to avoid the deposits of unburned oil and other particulates on the sound level meter. The following are the procedures followed during the test.

a) The calibration of the sound level meter was performed before and after measurements were made. Only the electrical calibration was done. The electrical circuits of the unit were calibrated using the built-in oscillator.
b) Meteorological conditions were observed during measurements to determine whether or not to continue. Precipitation affects the readings of the instrument. The batteries and the microphone are the most temperature-sensitive elements of the measurement system. As the temperature rises, the life of the batteries decreases.
c) An initial inspection of the vehicle was conducted to determine if defects in the exhaust system such as pinched outlets and holes and rust exist. There were no problems in the exhaust system because the vehicles were brand new.
d) The sound level meter was mounted on a tripod with its microphone placed at the same height as the center of the exhaust outlet. It was positioned with its longitudinal axis parallel to the ground, 0.5 meter from the edge of the exhaust and oriented at 45°from the axis of the exhaust (See Figure 17).
e) Noise measurements were taken for constant speed and constant loading. Measurement time was set to 10 seconds. There were 3 speed settings: 30 kph to 50 kph with 10-kph intervals. For each speed, there were two load conditions: half load and full load. Eight data points were gathered for each case, except in that of the half and full load at 30 kph of the Model B Blue (1:40) test motorcycle.

*4.2.4. Relationship of Tricycle Noise Performance, Engine Type, Type of Lubricant and Fuel-Oil Mix Ratio Under Simulated Loading on Chassis Dynamometer* Figure 18 and Figure 19 show the direct linear relationship of noise level with speed of the test motorcycles at full and half loads, respectively, on the chassis dynamometer. However, it can also be observed that the noise level did not always increase with the increase in load and there has been a relatively small difference between the measured noise levels for the half load and full load. This is due to the similarity in engine speed (rpm) settings of the half load and full load on the dynamometer which is different from on-road conditions where the engine speed could be increased by the

 

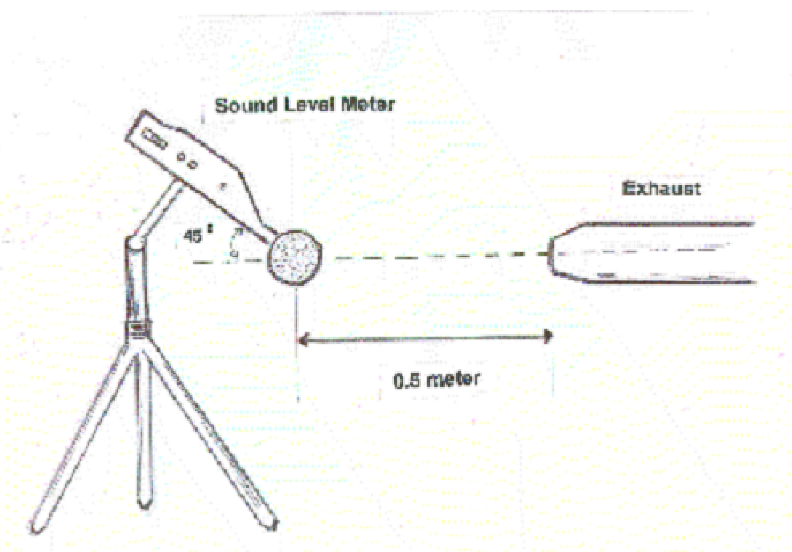


Figure 17. Noise Performance Test Set-up.

driver for higher loads. According to Schroeder *et al.* [16], noise level depends more on the engine speed than on the throttle position which is also very dependent on driver behavior.

The noise level of tricycle with 4-stroke engine was consistently higher than the 2-stroke engines at full and half loads at the 50-km/h speed level and consistently lower at the 30-km/hr speed level. This finding is an important input in the setting up of speed limits for roads especially in residential areas.

## 5. CONCLUSIONS AND RECOMMENDATIONS

### *5.1. Conclusions*

Measured roadside noise levels at a residential area with high tricycle traffic exceeded the local noise standards at all times of the day. Roadside noise levels are correlated to the proportion and speed of tricycles in the road traffic flow. It is also concluded that through regression modeling, the roadside noise level is a function of traffic volume of tricycles and their traffic speed. This indicates that high noise levels in residential areas are attributed to tricycles which serve as the main transport mode in these areas.

On-road noise performance of tricycles is related to its speed and load and the type of road. It increases with the increase in tricycle speed and increase in load. The slope of the road also affects the noise level. With respect to noise performance under simulated loading, there is an increase in noise level at increase in speed level.

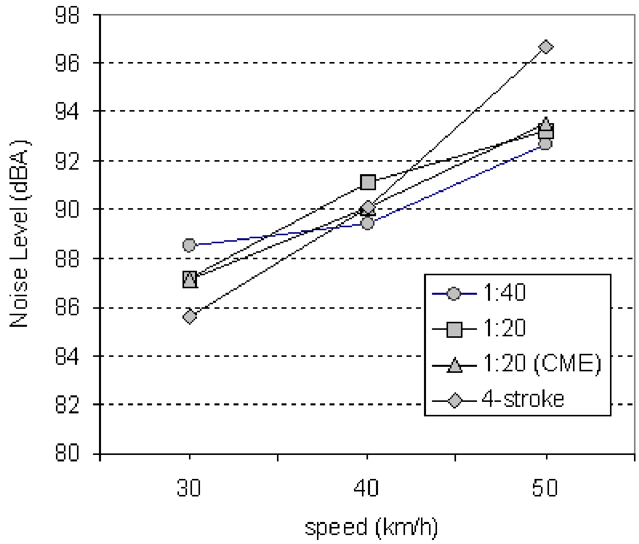


Figure 18. Variation of Noise Level with Fuel-Oil Mixture and Engine Type (Full Load).

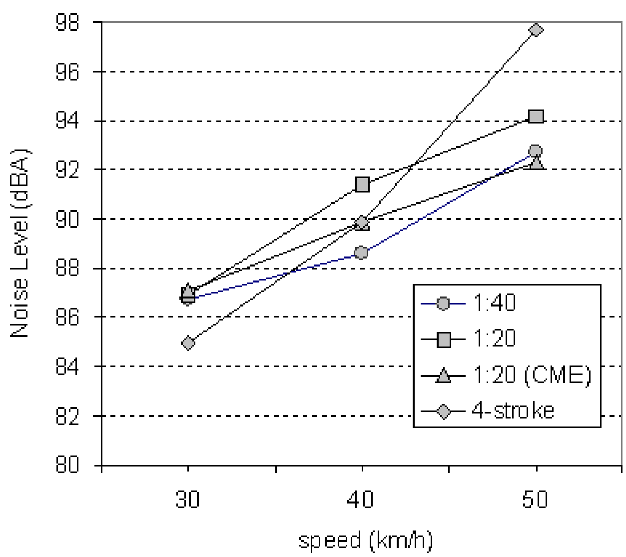


Figure 19. Variation of Noise Level with Fuel-Oil Mixture and Engine Type (Half Load).

### *5.2. Recommendations*

Since tricycles are found to be major contributors of noise, the number of tricycles may be controlled and speed limits may be enforced in residential areas to reduce ambient roadside noise levels. The setting of the speed limit at 30 km/h is expected to effect significant reduction in noise levels since noise emitted is lower at lower speeds and the noise emitted from tricycles with 4-stroke engines is even lower. In the next few years, the ratio of 4-stroke powered tricycles is expected to increase.

From the on-road noise level survey, the speed corresponding to a noise level of about 90 dBA is 25 km/h for the Load 1 and Load 2 conditions (3-4 passengers including the driver). In order to control the noise generated by tricycles, speed limits can be enforced when the load on the tricycle is increased. Stricter speed limits can also be imposed at non-level roads.

With respect to method of measurement under simulated loading, more accurate results may be obtained if noise level measurements were taken in open areas, free of large sound-reflecting surfaces. Noise level measurements may be taken for a wider range of speed and at smaller speed intervals. More measurements may be taken for roads of different gradients.

## ACKNOWLEDGEMENTS

The authors would like to acknowledge the Philippine Council for Industry and Energy Research and Development of the Philippine Department of Science and Technology (DOST-PCIERD) for the funding of the research. The section on noise level measurement is one part of the DOST-PCIERD-funded research project entitled "Standards Development for Local Motorcycle/Tricycle Sector". Acknowledgment is also given to the Technical Working Group of the Standards Development for Local Motorcycle/Tricycle Sector, cooperating agencies such as the Filcar Foundation Inc., Philippine Department of Energy, College of Engineering of the University of the Philippines (specifically the Department of Mechanical Engineering and Department of Industrial Engineering and Operations Research) and the supporting students and staff who were affiliated to the National Center for Transportation Studies of the University of the Philippines during the research project period (April 2002-December 2003) and contributed to this research.

## REFERENCES

1. Benitez, J.V. (2001) Relationship of Traffic Flow Characteristics and Roadside Suspended Particulate Matter (SPM) Emissions in Metro Manila, NCTS
2. Bies, D., Engineering Noise Control (Theory and Practice) (1996), 2nd Edition, E & FN Spon, London.
3. Bugliarello, G. *et al.*(1975) The Impact of Noise Pollution: A Socio-Technological Introduction.
4. Cacho, F. (2002) Study on the Contribution of Tricycles on Noise in Residential Environments, Undergraduate Research Thesis, Department of Civil Engineering, College of Engineering, University of the Philippines Diliman.
5. Capiz, C. L. (2003) A Study on Noise Levels Generated by Tricycles, Undergraduate Research Thesis, Department of Civil Engineering, College of Engineering, University of the Philippines Diliman.
6. Cavanaugh , W.J., Tocci, G.C. (1998) Environmental Noise- Invisible Pollutant, Vol. 1, No. 1, USC Institute of Public Affairs.
7. Davis, M., and Cornwell, D. (1998) Introduction to Environmental Engineering, 3rd Ed., McGraw-Hill.
8. Department of Environment and Natural Resources and Environment Management Bureau (1999) RA 8749: The Philippine Clean Air Act, Implementing Rules and Regulations.
9. Department of Ecology, Washington State, United States (1994) Sound Level Measurement Procedures, Chapter 173-58 WAC, http://www.ecy.wa.gov/pubs/wac17358.pdf.

 

10. Environmental Management Bureau of the Department of Environment and National Resources (EMB-DENR) (2001), RA 8749: Philippine Clean Air Act and its Implementing Rules and Regulations, DENR-Public Affairs Office, Dec. 2001.
11. Fajardo, B. (1999) A Study on Individual Perceptions of Road Traffic, M.A. Urban and Regional Planning (Transportation Planning) Thesis, School of Urban and Regional Planning, University of the Philippines Diliman.
12. Japan International Cooperation Agency (JICA), DOTC, MMDA, DPWH, NEDA, and NCTS (1998) Metro Manila's Transportation and Traffic Situation, MMUTIS Study Team, Manila, 1998.
13. NPCC Memorandum Circular No. 002 (May 12, 1980), Amendments to Noise Control Regulations of the NPCC Rules and Regulations of 1978
14. Ordinance No. SP-1221, S-2003, page 2-PO2002-50, 56th Regular Session, Quezon City Council, Philippines.
15. Pamanikabud, P. (1997). Super-Highway Traffic Noise Simulating Model with Consideration of Local Traffic Vehicles, Journal of the Eastern Asia Society for Transportation Studies, Vol. 2, No. 6, 2031-2038.
16. Schroeder, F. *et al.*(1999) Motorcycle Noise Emissions in Real Traffic Situations, EAEC European Automotive Congress, Barcelona. http://www.tu-darmstadt.de/fzd/deutsch/abstracts/sr_eaec99.pdf
17. Suter, A.H. (1991) Administrative Conference of the United States Noise and Its Effects, http://www.nonoise.org/library/suter/suter.htm
18. TRD-NCTS (1998) Traffic Noise Levels at Selected Points in Metro Manila, TSSP Journal 2, July 1998.
19. University of the Philippines National Center for Transportation Studies (1997) Metro Manila Urban Transportation Integration Study (MMUTIS) Environmental Impact Study, 6 May 1997.
20. University of the Philippines National Center for Transportation Studies Foundation Inc. (2001) Supplemental Air and Noise Pollution Survey, Impact Study on JBIC's Transportation Projects in Metro Manila.
21. University of the Philippines National Center for Transportation Studies Foundation Inc. (UP-NCTSFI) and the Philippine Council for Industry and Energy Research and Development (DOST-PCIERD) (2004) Standards Development for Local Motorcycle/Tricycle Sector, Final Report
22. U.P. Transport Training Center (1983) Course Notes on Transportation and Traffic Technology.
23. White, R.G., Walker, J.G. (1982) Road Vehicle Noise (Noise and Vibration).
24. Washington State Legislature (2005) Chapter 173-62 WAC, Motor Vehicle Noise Performance Standards, http://www.leg.wa.gov/WAC/.
25. Yusoff, S. and Karim, M. R. (1997) Study on Characteristics of Transportation Noise Sources in Klang Valley, Malaysia, Journal of the Eastern Asia Society for Transportation Studies, Vol. 2, No. 6, 2053-2069.

 