Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 3105 - 3120, 2005

ASSESSMENT OF INTEGRATED ENVIRONMENTAL STRATEGIES FOR METRO MANILA

Karl B. N. VERGEL
Assistant Professor
Department of Civil Engineering/
Transportation and Environment Group
National Center for Transportation Studies
University of the Philippines
Diliman, Quezon City 1101 Philippines
Fax: +63-2-928-8305
Email: karl.vergel@up.edu.ph

Noriel Christopher C. TIGLAO
Assistant Professor
National College of Public Administration and Governance/
Urban and Regional Systems Analysis Group
National Center for Transportation Studies
University of the Philippines
Diliman, Quezon City 1101 Philippines
Fax: +63-2-928-8305
Email: nctiglao@up.edu.ph

Abstract: Studies and government programs are reviewed to develop environmental strategies. BAU scenarios for 2005, 2010 and 2015, implementation of motor vehicle inspection system (MVIS), transportation demand management, replacement of 2-stroke tricycles with 4-stroke tricycles, construction of bike lanes, expansion of railway network, installation of diesel particulate traps (DPTs) for public transport vehicles, use of alternative fuels in public transport and policy combinations are assessed in terms of total PM emissions based on the emission model and aggregate travel demand forecasting models and database of the 1996 Metro Manila Urban Transportation Integration Study. Measures such as the MVIS and introduction of 4-stroke tricycles are the single policies that effected higher reduction in emissions from 11-16 tons/day in 2010 to around 12-16 tons/day in 2015. These are followed by the railway network expansion with reduction of 11 tons/day in 2015 and by the installation of DPTs in public transport vehicles.

Key Words: air quality, emissions inventory, particulate matter, 4-step transport demand model, emissions model, environmental strategies

1. INTRODUCTION

With the deterioration of air quality of Metro Manila that was attributed mostly to PM emissions from transportation in the 1990s, several studies funded by international organizations were conducted to assess the state of the environment and formulate policies to reduce emissions from motor vehicles. These studies have concluded particulate matter, followed to some degree, by carbon monoxide and nitrogen dioxide, are the key air pollutants attributed to motor vehicle traffic. Figure 1 shows the trend of the annual average concentration of total suspended particulates where most observed values exceeded the annual average standard starting in the late 1980s. According to the Philippine Environmental Management Bureau (2003), in recent years, the concentration of fine particulate matter ($PM_{2.5}$) had exceeded the annual guideline value. Sulfur oxides and total organic gases were still within air quality standards. Ambient lead concentration has generally decreased from 1987 up to 2000. Also, more than 70% of the people in Metro Manila are concerned with the effects of motorized vehicle emissions on their health or air pollution in general based on surveys conducted in 2000 (Yai and Vergel, 2002) and 2001 according to the Philippines Environment Monitor 2002 (The World Bank Group, 2002)

The implementation of the Philippine Clean Air Act of 1999 started in 2000 and emission standards were enforced on motor vehicles starting 2003. National government agencies and some local governments have started activities in line with the Clean Air Act. In 2001, partnerships with non-government organizations (NGOs) and the private sector and the academe have been forged to coordinate activities on clean air in the metropolis. With numerous foreign-funded studies and programs of national government organizations related to clean air (environment and natural resources, energy, transportation and communications, and, trade and industry departments and line agencies) and initiatives of local governments and civil society, there had been no study that integrated and coordinated previous studies and government plans and programs. In this study, several project studies and researches and national government programs and plans are reviewed to develop the policy scenarios for environmental assessment.

The objectives of this study are to develop environmental strategies for Metro Manila for the reduction of air pollution and evaluate the effectiveness of the strategies in terms of reduction in particulate matter emissions.

Aside from quantifying PM emissions of policies, baseline emissions of present and future years are also estimated by the study, thus establishing a more accurate emissions inventory from mobile or transportation sources.

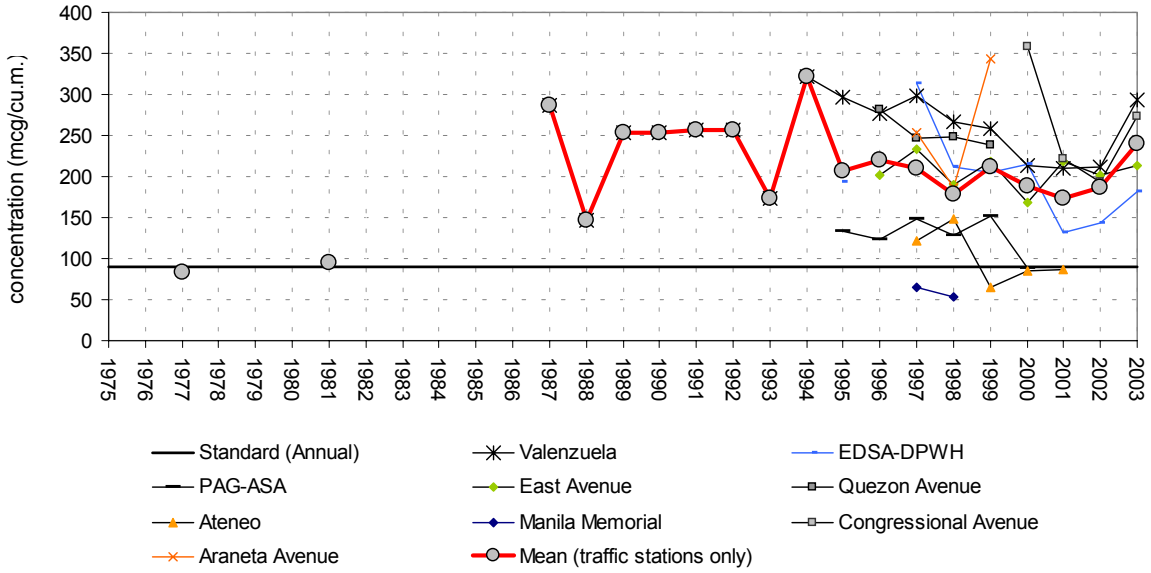

Figure 1. TSP Concentration – Road Traffic-Related Monitoring Stations
Data Sources: Department of Environment and Natural Resources Environmental Management Bureau, Philippines (DENR-EMB), DENR National Capital Region, Philippines (DENR-NCR)

2. POLICY SCENARIO DEVELOPMENT AND ASSUMPTIONS

Policy scenarios were developed based the review of past project studies and researches conducted by different local and international organizations. The scenarios aside from the business-as-usual scenarios can be generally classified into 3 categories based on a framework for selecting instruments (World Bank, 2001): a) reducing vehicle-kilometers, b) reducing fuel used per vehicle kilometer, and c) reducing emissions per unit of fuel used.

2.1 Business-As-Usual Scenarios (BAU)

Transportation demand was forecasted for 2005, 2010 and 2015 using the main transportation network in place in 2005. The transport networks in BAU scenarios in 2005 and 2010 are assumed to be the same. The 2015 BAU scenario assumes that the primary and secondary road network development is based on the Metro Manila Urban Transportation Integration Study (MMUTIS) (Japan International Cooperation Agency or JICA, 1999) Master Plan for roads in 2015.

The BAU scenarios in 2005, 2010 and 2015 assume that the motor vehicle emission standards have already been initially implemented as reflected by the I/M (inspection and maintenance) Scenario of 2005 in the Vehicular Emission Control Planning (VECP) Project Report (Asian Development Bank, 1992). The PM emission factors are reduced by 30% for all vehicles. The implementation of the motor vehicle exhaust emission standards in the Clean Air Act started in January 2003. The scenarios with the corresponding assumptions on transport network, demand and enforced policies are summarized in Table 1.

Table 1. BAU Scenarios

Scenario	Transport Network, Demand and Policy Assumptions
BAU 2005	2005 transportation demand + 2005 transport network + I/M Standards
BAU 2010	2010 transportation demand + 2005 transport network + I/M Standards
BAU 2015	2015 transportation demand + 2005 transport network + primary and secondary road network in 2015 + I/M Standards

2.2 Reducing Vehicle Kilometers

Scenarios under this category generally include increasing private vehicle occupancy, demand restraint and promotion of public transportation. Policies here included demand restraint using administrative instrument such as limitation on vehicle use and increase in the share of public transport through expansion of urban rail network, as summarized in Table 2.

a) Transportation Demand Management (TDM)

According to MMUTIS (JICA, 1999), 22.9% of private car users was affected by the UVVRP (Unified Vehicular Volume Reduction Program), the TDM scheme implemented in Metro Manila. Only those who used public transport and those who shared a ride as alternative modes of transport to private car were considered to affect the private vehicle traffic. The reduction of 11.08%, derived from the 1996 MMUTIS Study, was applied to vehicle-kilometers of private transport modes such as gas car, gas jeepney/utility vehicle and diesel car/utility vehicle in all 98 traffic analysis zones.

b) Expansion of the Metropolitan Railway Network (Rail 2015)

In Metro Manila, there are already 45.3 kilometers of LRT/MRT lines (Line 1, Line 2 and Line 3) as of April 2003 and there also exists a heavy rail line, which is approximately 30 kilometers (Philippine National Railways (PNR) Commuter Line). In the 1996 Metro Manila Urban Transportation Integration Study (JICA, 1999), there is a master plan for the expansion of the railway network through the extension of existing LRT/MRT lines, construction of new LRT/MRT lines and busways, and upgrade of the PNR lines. By 2015, it is planned that there

will be approximately 164.1 kilometers of new MRT/LRT lines and 19.7 kilometers of busways. With the expansion of the railway network, it is expected that more people will shift their transport mode from private vehicles, buses and jeepneys to rail due to a more convenient railway service. The model for demand shift from private cars to public transit was used based on the MMUTIS. The model calculated the probability of shifting as a function of difference in travel time (in minutes) and travel cost (in pesos) of the public mode and private mode of transport. This is expected to reduce the vehicle-kilometers of travel of private cars and road-based public transport.

Table 2. Policy Scenarios for Reducing Vehicle Kilometers

Scenario	Policy and Assumptions
Transportation Demand Management (TDM)	Vehicle-kilometers of private transport modes such as gas car, gas jeepney/utility vehicle and diesel car/utility vehicle were reduced by 11.08% in all 98 traffic analysis zones
Expansion of the Metropolitan Railway Network by 2015 (Rail2015)	Expansion of the metropolitan railway network by 2015 by approximately 164.1 kilometers of new MRT/LRT lines and 19.7 kilometers of busways according to the MMUTIS Master Plan resulting to reduced road-based traffic demand (7.28% in public transport and 14.29% in private transport)

2.3 Reducing Fuel Used Per Vehicle Kilometer

Scenarios under this category generally include improvement of fuel economy, promotion of non-motorized transport and ITS technologies. The policy included in the assessment is on promotion of NMT, as summarized in Table 3.

The Marikina City Government has started to construct exclusive bikeways in 2001. The master plan will involve construction of bikeways on 66 kilometers of roads in the city. With this, it is assumed that there will be a significant increase in the use of bicycles for work trips. The modal share of bicycles and percentage shift from non-cycling modes in Marikina City were estimated for 2004 and 2014 in the Marikina Bikeways Feasibility Study (U.P. National Center for Transportation Studies Foundation Inc., 2000). Only the internal trips were considered in the analysis. The shift in 2004 is assumed to take effect in 2005 while the shift in 2014 is assumed to take effect in 2015. The rates of shift (1.5% in 2005 and 3.5% in 2015) from tricycles to cycling modes were applied as reduction rates of tricycle vehicle-kilometers of 2 zones representing Marikina City. For the scenario of bikeways in Metro Manila, the rates were applied to reduce the tricycle vehicle-kilometers of all the 98 zones.

Table 3. Policy Scenarios for Reducing Fuel Used Per Vehicle Kilometer

Scenario	Policy and Assumptions
Construction of Bikeways (BWMK and BWMM)	The rates of shift (1.5% in 2005 and 3.5% in 2015) from tricycle to cycling modes were applied as reduction rates of the tricycle vehicle-kilometers of traffic analysis zones • Marikina (BWMK): applied to zones 74 and 76 only • Metro Manila (BWMM): applied to all 98 zones

2.4 Reducing Emissions Per Unit of Fuel Used

Scenarios under this category generally include improvement of fuel quality, improved

vehicle inspection and maintenance, improvements in conventional diesel technology, clean 2 and 3-wheeler technology, use of alternative fuels and switch to clean diesel.

a) Motor Vehicle Inspection System (MVIS)

The MVIS scenario assumes that the MVIS facilities provided for in the Implementing Rules and Regulation of the Clean Air Act of 1999 are established in Metro Manila. With the MVIS, it was assumed that certain percentages of the vehicle fleet are expected to comply with the emission standards. In Table 4, the category "cars" include gasoline-fed cars, jeepneys/utility vehicles, diesel-fed cars/utility vehicles while the category "jeepneys" means diesel-fed jeepneys, the category "buses" means diesel-fed buses, and the category "trucks" means diesel-fed trucks. The corresponding reductions in the PM emission factors are applied to the shares of the vehicle fleet. The scenarios for the MVIS in 2005, 2010 and 2015 are discussed as MVIS2005, MVIS2010 and MVIS2015 below.

MVIS2005 = + STDS2: In 2005, it was assumed that the STDS2 scenario will be implemented but without the I/M scenario. This means a reduction in PM emission factor by 60% applying the percentages of compliance in the STDS2 scenario.

MVIS2010 = + STDS2 + I/M: In 2010, the 60% reduction in emission factor under the STDS2 scenario was further applied after the 30% reduction of emission factor under the I/M scenario.

MVIS2015 = + STDS3 + I/M: In 2015, the 60% reduction in emission factor under the STDS3 scenario was further applied after the 30% reduction of emission factor under the I/M scenario. The percentage of the vehicle fleet complying with such standards is higher than the STDS2 and all buses are expected to be running on compressed natural gas (CNG) fuel.

b) Switch to 4-Stroke Tricycles or Three-Wheelers (4STC)

This scenario assumes that 2-stroke tricycles, which comprise 95-98% of tricycles in Metro Manila, will be totally replaced with 4-stroke tricycles. Based on the study of Shah and Harshadeep (2001), the PM_{10} emission factor of 4-stroke motorcycles is approximately 1/5 of the emission factor of 2-stroke tricycles and this ratio was applied to all the zones.

c) Diesel Particulate Trap in Public Transport Vehicles (DPTB and DPTBJ)

The current technology of DPT can reduce particulate matter by 30% from diesel exhaust based on the experience in Hong Kong (Eco-Tek Holdings Limited, 2002). This reduction rate was applied to the PM emission factors of buses and jeepneys using the baseline scenario of transportation demand in 2005. The following scenarios were assessed under the installation of the diesel particulate trap for public transport:

DPTB2005: Reduction of PM emission factor of buses by 30%
DPTBJ2005: Reduction of PM emission factors of buses and jeepneys by 30%

d) Compressed Natural Gas for Buses (CNGB)

Based on the plan of the Department of Energy, the following percentages of the bus fleet powered by CNG will be running on specified roads in 2005 and 2010 (Table 4). It was also

estimated that the emission factor of buses will be reduced by 86% if it will be replaced by CNG.

e) Coco-Methyl Ester Blends for Jeepneys (CMEJ)

Based on the plan of the Department of Energy, the following percentages of the utility vehicle fleet fed with diesel-CME blend were estimated for 2005 and 2010 (Table 4). It was also estimated that the emission factor of jeepneys will be reduced by 40% if its fuel will be blended with CME. The reduction in emissions was applied to all zones.

Table 4. Policy Scenarios for Reducing Emissions Per Unit of Fuel Used

Scenario	Policy and Assumptions
Implementation of the Motor Vehicle Inspection System (MVIS)	Reduction of PM emission factors and the corresponding percentages of vehicle types with reduced emission factors MVIS2005 = + STDS2 • Implementation of the STDS2 scenario without the I/M scenario • reduction in PM emission factor by 60% • percent of vehicles: cars=25%, jeepneys=100%, buses=30%, trucks=30% MVIS2010 = + STDS2 + I/M • Implementation of the STDS2 scenario on top of the I/M scenario • Reduction of PM emission factor by 60% after the 30% reduction of emission factor under the I/M scenario • percent of vehicles: cars=25%, jeepneys=100%, buses=30%, trucks=30% MVIS2015 = + STDS3 + I/M • Implementation of the STDS3 scenario on top of the I/M scenario • Reduction of PM emission factor by 60% after the 30% reduction of emission factor under the I/M scenario • percent of vehicles: cars=50%, jeepneys=100%, buses=100%CNG, trucks=40%
Replacement of 2-Stroke with 4-Stroke Motorcycles for Tricycles (4STC)	The PM emission factor of tricycles was reduced to 1/5 of the emission factor of tricycles in the baseline scenario applied to 100% of the tricycles in all zones
Diesel Particulate Trap for Buses and Jeepneys (DPTBJ and DPTB)	Installation of the diesel particulate trap is expected to reduce the PM emission factor of buses and jeepneys by 30% DPTB: reduction of PM emission factor of buses only
Compressed Natural Gas (CNG) for Buses (CNGB)	Reduction of emission factor of buses by 86% if diesel is replaced by CNG • 2005 (Low: 0.88%/High: 1.76% applied to zones passed by C-5. EDSA and SLEX) • 2010 (Low: 11.47%/High: 22.93% applied to zones passed by C-5. EDSA, SLEX and NLEX)
Coco-methyl ester (CME) for Jeepneys (CMEJ)	Reduction of emission factor of jeepneys by 86% if diesel is blended with CME • 2005 (Low: 0.64%/High: 1.27% applied to all zones) • 2010 (Low: 2.0%/High: 4.0% applied to all zones)

2.5 Combination of Policies

Table 5 shows the combined policy scenarios assessed in this study. Combination 1 combines all scenarios that can be implemented without too many barriers. The policy combination excluded the railway network development since it is planned to be completed by 2015. It also excluded the switch to 4-stroke tricycles since there had been problems with respect to the readiness of this transport mode to comply with emission standards which were started to be enforced in 2003. By 2010, it is expected that most of the engines of tricycles had been converted to 4-stroke engines with lesser particulate emissions.

Table 5. Combined Policy Scenarios

Scenario	Policy and Assumptions
Combination 1 (Combi 1)	Combination of all scenarios except railways and switch to four-stroke tricycles (2005)
Combination 2 (Combi 2)	Combination of all scenarios except railways (2010)
Combination 3 (Combi 3)	Combination of all scenarios (2015)

3. ESTIMATION OF TRANSPORTATION DEMAND

3.1 Study Area and Zoning

The modeling for the transportation demand covered Metro Manila and towns/cities of the adjoining provinces of Bulacan, Rizal, Cavite and Laguna. The 1996 MMUTIS Study (JICA, 1999) established 265 traffic analysis zones for the 17 cities/towns of Metro Manila and 51 zones for the adjoining towns and cities. These zones were combined to form 98 traffic analysis zones wherein 94 traffic analysis zones were constructed for Metro Manila and 4 other zones corresponding to the 4 adjacent provinces, as shown in Figure 2.

3.2 Socio-economic Characteristics

Transportation demand modelling for the present and the future years requires a database of socio-economic characteristics aggregated to the traffic analysis zones. The following socio-economic characteristics were considered in the modelling:

- population
- employment by residence
- employment by workplace
- school attendance by residence
- school attendance by school
- car ownership

The above data exists for the 265 zones and were derived from the 1996 household interview survey (HIS) of the MMUTIS database. Data were subsequently aggregated for the 98 zones. The socio-economic data is also available in years 2000 and 2010 (forecasted). The zonal socio-economic characteristics were calculated for the years 2002, 2010 and 2015 using a growth rate based on the data in 2000 and 2010 and applying the rate on the 1996 data from the HIS of MMUTIS database. The zonal car ownership was estimated for 2002 using the growth rate based on the 1996 and 2005 data. The zonal car ownership for 2010 and 2015 were estimated using the growth rate based on the 2005 and 2015 forecast data.

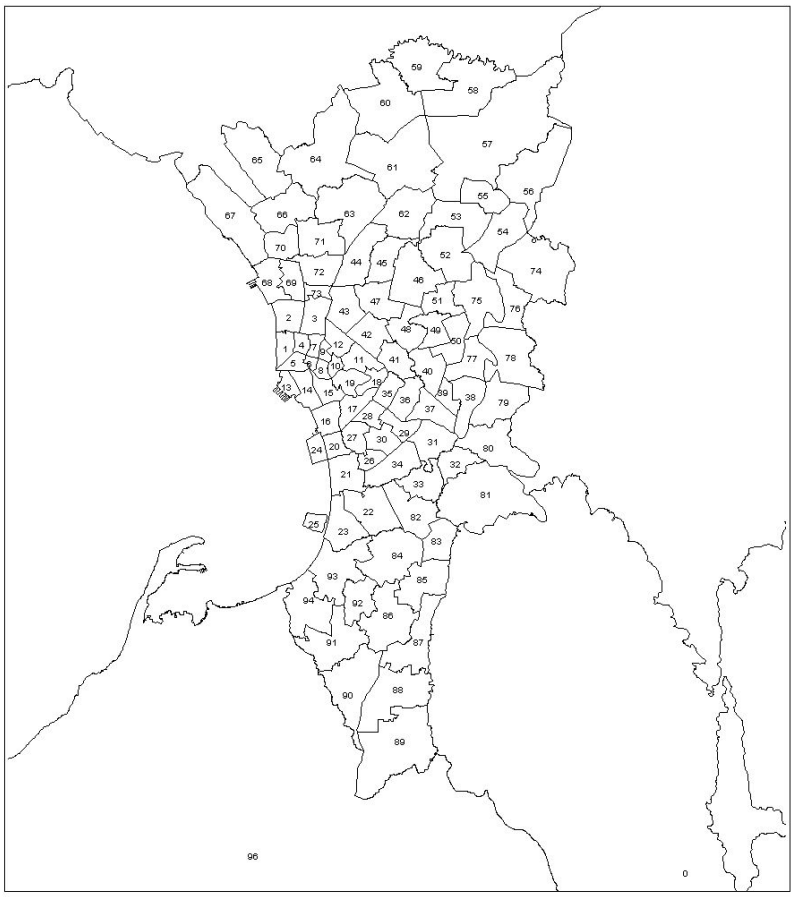

Figure 2. Traffic Analysis Zones (TAZ) of Metro Manila
and Some Towns/Cities of the Adjoining Provinces

3.3 Transportation Network Characteristics

Transportation demand modelling for the present and the future years also requires data on transportation network that consists of roads and public transport lines. The public transport network mainly consists of railway lines and buses and jeepney routes. The study utilized the MMUTIS transportation network built in 1996 and was updated to include the following roads and rail transit lines in 2005:

- Road Network
    - Primary and Secondary Road Network
    - Expressway Network
        - North Luzon Expressway
        - South Luzon Expressway
        - Manila-Cavite Expressway
        - Metro Manila Skyway (Makati-Bicutan)
- Rail-Based Mass Transit Lines
    - LRT Line 1 (Monumento – Baclaran)
    - MRT Line 3 (Monumento – Taft Avenue)
    - LRT Line 2 (Santolan – Recto)

The network consisting nodes and links is encoded in a digital map in JICA STRADA format, as displayed in Figure 3, indicating the transportation network for the BAU scenario in 2005.

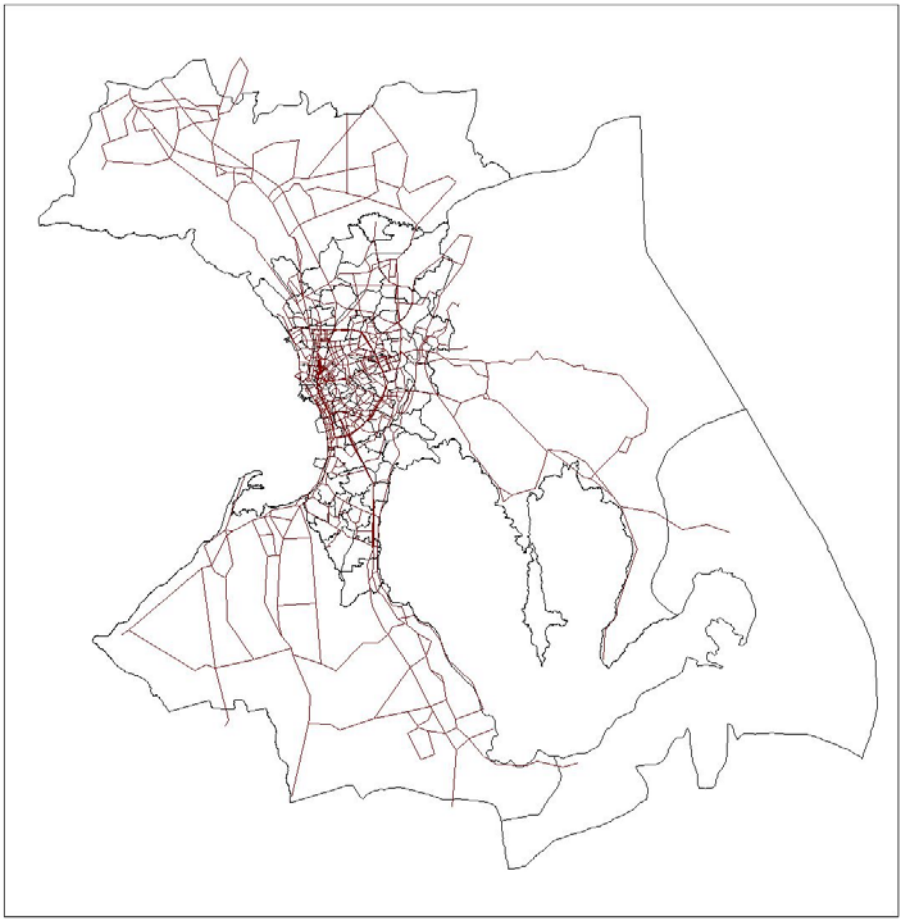

Figure 3. Road and Railway Network for the BAU Scenario (2005)

3.4 Transportation Demand Estimation Method

a) The Four-Step Model

The 4-Step Model was used to estimate transportation demand for the baseline scenarios in 2005, 2010 and 2015, and the railway scenario in 2015. The procedure for demand forecasting used by MMUTIS was adopted by this study. The JICA STRADA (JICA System for Travel Demand Analysis), utilized in the MMUTIS Study, was used to estimate the transportation demand. The zoning system, socio-economic characteristics and transportation network which came from the MMUTIS database, served as inputs to the transportation demand modelling procedure. The 4-Step Model is discussed in the following sub-sections.

b) Trip Generation/Attraction

The trip generation/attraction step calculates the number of person trips are generated from and attracted to each traffic analysis zone. Model functions for trip generation and attraction are estimated with zonal socio-economic attributes calculated in Section 2 as explanatory variables. The trip generation model for Metro Manila is correlated with the variable "employment by workplace". The number of person trips generated from and attracted to each of the 98 zones by private and public modes is estimated.

c) Trip Distribution

The trip distribution step estimates the number of person trips originating from a traffic analysis zone (origin zone) and ending in another traffic analysis zone (destination zone). Trips generated from and attracted to each zone are distributed among the zones generating a 98 by 98 origin-destination (O-D) matrix of person trips. In this step, two matrices (98 by 98) are generated consisting of private and public person trips. According to the MMUTIS (JICA, 1999), the interzonal trip distribution was initially based on the Voorhees-type gravity model which distributes generated traffic in proportion to the share of attracted traffic discounted by interzonal impedance. However, the models did not show satisfactory correlation such that an adjustment factor which is the quotient of actual and theoretical number of trips in 1996 was introduced to distribute trips in the future years.

d) Modal Split

The modal split or mode choice step estimates how many of the person trips for each pair of origin and destination (O-D) zones will use private or public transport modes. However, the procedure for demand forecast in this study has already segregated the public and private trips earlier in the trip generation step.

e) Traffic Assignment

The traffic or trip assignment step identifies the exact routes that will be taken by each of the person trips. It involves assigning traffic to a road network or a transit network. The road and transit network of Metro Manila for the baseline scenario in 2005 is shown earlier in Figure 3. Traffic is assigned to available transit or roadway routes using a mathematical algorithm that determines the amount of traffic as a function of travel time, volume, capacity, or impedance factor. The three common methods are all-or-nothing, diversion and capacity restraint. The highway-type assignment for private and public modes is adopted as the model. The JICA STRADA outputs of the traffic assignment are the following: link vehicle traffic volumes per day, link average traffic speed per day, link volume-to-capacity ratios per day and link trip lengths per day. The traffic volumes were obtained by dividing the number of person trips assigned to each route by the average vehicle occupancy. The vehicle occupancy data were obtained from the MMUTIS database.

3.5 Additional Procedures for Estimation of Transportation Demand

a) Estimation of Transportation Demand for Tricycles

The transportation demand of the local three-wheelers (a public transport mode in residential areas) called the “tricycles” was estimated separately in 2005, 2010 and 2015 and then the demand was added to the transportation demand which was earlier estimated for private and public trips. The tricycle demand was estimated separately since the outputs of the travel demand analysis software are in terms of private and public traffic volumes which did not include the tricycle mode.

b) Application Program to Aggregate Transportation Demand From Links to Zone

The main outputs of the transportation demand analysis software are daily link-level traffic flows and average traffic speeds. An application program was developed to aggregate the

outputs from links to the traffic analysis zones. The program first identified which traffic analysis zone a specific link belongs. After identifying zone membership, aggregation was done for traffic volumes and average traffic speeds to produce zone-level traffic volumes and average speeds per day.

c) Calculation of Vehicle-Kilometers and Assumptions

The daily vehicle-kilometers for the zones were calculated by multiplying traffic volumes with the length of the road links. The calculations yielded the private and public vehicle-kilometers per day for each zone. It is necessary to further classify the vehicle-kilometers in terms of vehicle types as input to the calculation of vehicle emissions. The composition of public transport vehicles was assumed to be uniform in all zones and the estimates were based on the share of the vehicle kilometers of each type, as shown in Table 6. The share in percent was multiplied by the total vehicle-kilometers of public trips to get the total vehicle-kilometers of each public transport vehicle type for each zone. Since the tricycle demand was estimated separately, it was not necessary to get its share of vehicle-kilometers of the public transport trips. For private vehicle trips, the shares from vehicle registration data of the Land Transportation Office of the Philippines in 2001 (Table 7) were multiplied to the private vehicle kilometers to get the share of vehicle-kilometers of each private vehicle type per zone.

Table 6. Share of Present Travel Distance of Buses and Jeepneys

	Vehicle Trips	Average Trip Length	Veh-Km	Share of Veh-Km
Bus	57,000	13.0	741,000	31.5%
Jeepney	460,000	3.5	1,610,000	68.5%

Source: JICA (1999) MMUTIS Technical Report No. 10:
Traffic Environmental Study, Air and Noise Pollution in Metro Manila

Table 7. Share of Private Modes

Cars (Gas)	Utility Vehicles (Gas)	Utility Vehicles (Diesel)	Trucks (Diesel)
41.9%	21.7%	30.4%	6.0%

Source: Land Transportation Office (LTO), Philippines

3.6 Estimates of Vehicle-Kilometers

The total vehicle-kilometers per day by mode for all the 98 zones of Metro Manila and the adjoining provinces for BAU 2005, 2010, 2015 and the Railway 2015 scenarios are shown in Table 8. The transportation demand where the railway network would be in place by 2015 under the MMUTIS Master Plan would just reduce the vehicle-kilometers of road-based modes especially the private transport mode back to the 2005 level. Without improvements in road and rail network, the road-based transport demand was forecasted to increase to more than 80 million veh-km in 2005 and 2015.

Table 8. Transportation Demand by Mode

Scenario	Vehicle-Kilometers Per Day				Average Speed (km/h)
	public	private	tricycle	total	
BAU2005	12,249,488	52,697,058	8,568,184	73,514,730	27.3
BAU2010	15,978,812	57,182,985		81,729,981	25.8
BAU2015	15,978,812	59,699,820		84,246,816	25.4
Rail 2015	14,191,353	51,167,782		73,927,319	27.8

4. ESTIMATION OF PM EMISSIONS FROM TRANSPORTATION

4.1 Local Vehicle Emission Factors

Table 9 shows the PM (particulate matter) emission factors for the 6 vehicle-fuel types according to traffic speed. The study adopted the locally developed emission factors of the 1992 VECP Project (ADB, 1992) as emission factors at the 20 kph speed level and patterned the variation after the speed-specific and vehicle-specific emission factors provided by the MMUTIS Technical Report No. 10 (JICA, 1999). One of the outputs of the 4-step travel demand forecasting model estimated in JICA STRADA is the average speed of each zone. When the average speed is known, the emission factor for each vehicle-fuel type is taken from Table 9 as a function of traffic speed.

Table 9. PM Emission Factors (g/veh-km) – Derived from the 1992 VECP Project and 1996 MMUTIS Emission Factors

Fuel Type	Vehicle Type	Idling	~10 km/h	10-20 km/h	20 km/h~
Gasoline	Car	0.15	0.12	0.10	0.10
	Jeepney	0.17	0.14	0.13	0.12
	Tricycle (2-stroke)	2.05	2.01	2.00	2.02
Diesel	Car	1.73	2.03	0.90	0.90
	Jeepney	1.59	1.89	0.99	0.90
	Bus	1.60	2.40	1.60	0.90

4.2 Method for Estimation of PM Emissions

The daily PM emissions for each traffic analysis zone were calculated as follows (Eq. 1):

$$PM = \sum_{i=1}^{6} d_i \times EFexhaust_i(v) + \sum_{i=1}^{6} T_s \times d_i \times EFidle_i \quad (1)$$

where: PM = PM emissions per traffic analysis zone (g)
d_i = travel distance of vehicle type i (veh-km) per zone
v = average travel speed per zone (km/h)
$EFexhaust_i$ (v) = exhaust emission factor of vehicle type i as a function of travel speed (g/veh-km)
T_s = idle or stopping time (min/veh-km) per zone
$EFidle_i$ = idle emission factor of vehicle type i (g/min)

The stopping or idle time per zone was obtained from the "Two-Fluid Model" developed for Metro Manila by MMUTIS (JICA, 1999). Using the output of travel demand estimation, which is the travel time (min/km) in each zone, the stopping time is calculated using the equation of the Two-Fluid Model as shown below (Eq. 2):

$$T_s = T - T_m^{\frac{1}{n+1}} T^{\frac{n}{n+1}} \quad (2)$$

where: T_s = stopping time per unit distance (min/km)
T = trip time per unit distance (min/km)
T_m = average minimum trip time per unit distance = 1.966 min/km for Metro Manila
n = 1.889 for Metro Manila

4.3 PM Emissions of Policy Scenarios

Table 10 and Table 11 show the magnitudes of the total daily PM emissions for each policy scenario for 2005, 2010 and 2015. A policy introduced in 2005 or in 2010 is assumed to still have an effect in future years thereby contributing to emissions reduction in those years. The total PM emissions in 2005 ranged from 48 tons/day for the BAU scenario down to 36 tons/day emitted from the Combi 1 policy. For 2010, emissions ranged from 58 tons/day for the BAU scenario down to 46 tons/day from the MVIS and 4STC scenario and to 30-42 tons/day in the combined policy scenarios. For 2015, emissions ranged from 60 tons/day for the BAU down to 44 tons/day for the MVIS scenario and 21 tons/day for the combined policy scenario.

Table 10. PM Emissions for Each Policy Scenario, in tons/day (1)

Year	BAU	MVIS	TDM	4STC	BWMK	BWMM	Rail 2015
2005	48.419	42.966	46.661		48.414	48.203	
2010	58.236	46.636	56.072	46.152	58.230	58.009	
2015	60.910	44.205	58.573	48.684	60.897	60.154	49.807

Table 11. PM Emissions for Each Policy Scenario, in tons/day (2)

Year	DPTBJ	DPTB	CNGB	CMEJ	Combi 1	Combi 2	Combi 3
2005	45.217	47.381	48.358	48.343	36.433		
2010	53.637	56.728	57.762	58.004	42.158	30.255	
2015	56.184	59.355	60.401	60.647	43.592	31.971	21.17885

Table 12 and Table 13 show the reduction in total daily PM emissions for each policy scenario for 2005, 2010 and 2015 based on the difference between the PM emission of the policy scenario and the PM emission of the BAU scenario for the year. Figure 5 shows the graph of emissions reduction for all the policy scenarios from 2005 to 2015 where emissions reduction values in between years 2005 and 2010 and in between years 2010 and 2015 were estimated using interpolated vehicle-kilometers.

Table 12. PM Emissions Reduction for Each Policy Scenario, in tons/day (1)

Year	MVIS	TDM	4STC	BWMK	BWMM	Rail 2015
2005	-5.453	-1.759		-0.005	-0.217	
2010	-11.600	-2.164	-12.084	-0.005	-0.227	
2015	-16.704	-2.337	-12.226	-0.013	-0.756	-11.103

Table 13. PM Emissions Reduction for Each Policy Scenario, in tons/day (2)

Year	DPTBJ	DPTB	CNGB	CMEJ	Combi 1	Combi 2	Combi 3
2005	-3.203	-1.039	-0.062	-0.077	-11.987		
2010	-4.599	-1.507	-0.473	-0.232	-16.078	-27.980	
2015	-4.726	-1.555	-0.508	-0.263	-17.318	-28.939	-39.731

Measures such as the motor vehicle inspection system (MVIS) and introduction of 4-stroke tricycles are the single policies that resulted to higher reduction in emissions from 11-12 tons/day in 2010 to around 12-16 tons/day in 2015. These are followed by the completion of the railway network where it had reduced the emissions by 11 tons/day in 2015 and by the installation of DPTs in buses and jeepneys that reduced emissions by 4.6 tons/day in 2010 and

4.7 tons/day in 2015. The MVIS policy is relatively low-cost compared to implementation of clean vehicle standards and improvement of diesel fuel quality as estimated in the URBAIR study (World Bank, 1997). It was also found to be the most effective policy in the JSPS study based on the results of transportation and environment simulation system for the Makati CBD (Vergel and Yai, 2002). The policy of switching to 4-stroke tricycles (4STC) contributed to significant reduction in PM emissions of around 12 tons/day that contributed to 42-43% of PM emission reduction in 2010 and 2015 if all policies (except rail) are implemented. This is similar to the trend in Bangkok where the annual PM emissions decreased by approximately 40% from an almost 100% 2-stroke motorcycle population in 1989 to an almost 100% 4-stroke motorcycle population in 2019 as shown in the workshop presentation of Shah and Harshadeep (2001). The low PM emission reduction of the bikeways network policy can be attributed to the low percentage of trips shifting from motorized transport to bicycles. The similar low PM emission reduction of the use of alternative fuels such as CNG for buses and CME blends in diesel for jeepneys is due to the low percentage of buses and jeepneys running on alternative fuels based on the projections of the government (1,500 buses and 13,000 jeepneys in 2013).

5. CONCLUSIONS

Environmental strategies are developed for Metro Manila based on review of past studies that included projects and researches on air quality, and government programs and plans. BAU scenarios for 2005, 2010 and 2015, implementation of MVIS, TDM, switch to 4-stroke tricycles, construction of bikeways, expansion of railway network, installation of DPTs in jeepneys and buses, use of CNG for buses and CME-diesel blend for jeepneys as well as the policy combinations are assessed in terms of total PM emissions in metric tons/day calculated by the 4-step travel demand estimation models, emission model and transportation database of the 1996 Metro Manila Urban Transportation Integration Study. Measures such as the MVIS and switch to 4-stroke tricycles are the single policies that resulted to higher reduction in emissions from 11-16 tons/day in 2010 to around 12-16 tons/day in 2015. These are followed by the railway network expansion with reduction of 11 tons/day in 2015 and by the installation of DPTs in public transport vehicles. In earlier studies, the MVIS policy was found to be effective and relatively inexpensive to implement, and the switch to 4-stroke three-wheelers was also significant in reducing PM emissions from transportation.

6. RECOMMENDATIONS

There had been many studies conducted on air quality since the early 1990s with policy proposals for the reduction of vehicle emissions. A number of these policies have already been implemented but assessment of the impacts on emissions reduction and the corresponding validation with ambient pollutant concentration data had been scarce. In order to more accurately evaluate the effectiveness of policies for vehicle emission reduction, the regular Metro Manila emissions inventories especially from transportation sources being conducted by the Environmental Management Bureau (EMB) of the Philippines can be improved and refined with the results of this study. The EMB had started to conduct emissions inventory that also covered mobile sources in 1987 and 1990 based on macroscopic parameters such as the number of registered vehicles, annual vehicle-kilometers per vehicle and exhaust emission factors.

There is also a need to develop the emission factors for a wide range of vehicle and operating characteristics to improve the accuracy of the emissions calculations. It is also recommended that the database of vehicles in the country be improved in order to have basic vehicle fleet data such as annual mileage and engine age. Emission factors and vehicle fleet data are vital inputs to macroscopic as well as microscopic emission models.

For policies that could not be modeled by the preceding macroscopic emissions inventory, micro-scale models such as the transportation and environment simulation model developed for the Makati CBD by the JSPS Manila Project is recommended to be expanded and improved for application to larger transportation networks in Metro Manila and adjoining provinces. Refinement of these macroscopic and microscopic models through comparison of calculated emissions and validation through ambient concentration of pollutants would also be necessary.

ACKNOWLEDGMENTS

Acknowledgment is given to the National Center for Transportation Studies of the University of the Philippines Diliman (UP-NCTS) for the use of the transportation database and models of the Metro Manila Urban Transportation Integration Study (MMUTIS) and also to the IES (Integrated Environmental Strategies) Philippines Project Team at the Manila Observatory led by Fr. Dan Mcnamara, S.J., Dr. Ronald Subida, Dr. Emman Anglo, Ms. Flordeliza Andres, Dr. Desiree Narvaez and Ms. Mei Velas.

REFERENCES

Asian Development Bank (1992) Final Report for Vehicle Emission Control Planning in Metro Manila, July, ADB T.A. No. 1414-PHI.

Asian Development Bank (2003) RETA 5937: Action Plans for Reducing Vehicle Emissions [online]. Available from: http://www.adb.org/Vehicle-Emissions/reta5937.asp

Eco-Tek Holdings, Limited (2002) Products and Services: Air Pollution, Eco-Trap (Diesel Particulate Trap).

Environmental Management Bureau (1993) Air Pollution Emission Inventory for Metro Manila 1990.

Environmental Management Bureau (2003). 2002 National Air Quality Status Report.

Japan International Cooperation Agency (1999) MMUTIS: Metro Manila Urban Transportation Integration Study Appendices. March 1999.

Japan International Cooperation Agency (1999) Metro Manila Urban Transportation Integration Study Technical Report No. 10: Traffic Environmental Study, Air and Noise Pollution in Metro Manila. March 1999.

Japan International Cooperation Agency (1999) Metro Manila Urban Transportation Integration Study: Final Report, May.

Land Transportation Office, Philippines (2002) Number of Motor Vehicles Registered, By Region, By Type of Motor Vehicle and Type of Fuel Used (unpublished).

Mariño, A. (2001) ASEAN-NZ Natural Gas Utilization for Transport Program Philippines Experience, the 6th ASEAN Science and Technology Week, Brunei Darussalam, 17-20 September.

Masami Kojima, Carter Brandon, and Jitendra Shah (2000) Improving Urban Air Quality in South Asia by Reducing Emissions from Two-Stroke Engine Vehicles, December, The World Bank [online]. Available from: http://www.worldbank.org/ html/fpd/esmap/ publication/airquality.html.

Philippine Council for Industry and Energy Research and Development and the U.P. National Center for Transportation Studies (2004) Standards Development for Local Motorcycle/Tricycle Sector-Final Report.

Shah, J. and Harshadeep, N. (2001) Urban Pollution from Two Stroke Engine Vehicles in Asia: Technical and Policy Options, Regional Workshop on Reduction of Emissions from 2-3 Wheelers, Hanoi, Vietnam. Manila [online]. Available from: http://www.adb.org/ Documents/Events/2001/RETA5937/Hanoi/documents/ 20_Shah. pdf.

The World Bank (1997) **Urban Air Quality Management Strategy in Asia: Metro Manila Report** (World Bank Technical Report No. 380), edited by Jitendrah J .Shah and Tanvi Nagpal, December, International Bank for Reconstruction and Development/The World Bank, Washington, D.C., United States

The World Bank (2001) Vehicular Air Pollution: Setting Priorities, Evaluation of Transport-related Policy Instruments, South Asia Urban Air Quality Management Briefing Note No. 1, International Bank for Reconstruction and Development/The World Bank, Washington, D.C., United States.

The World Bank Group (2002) Philippines Environment Monitor 2002.

The Manila Observatory and the United States Agency for International Development (2004) Integrated Environmental Strategies (IES) Philippines, Draft Final Report.

U.P. National Center for Transportation Studies Foundation, Inc. (2000) Marikina City Bikeways Feasibility Study-Final Report.

Yai, T. and Vergel, K. (2002) Outline of microscopic traffic simulation. In: **Metro Manila: Towards A Sustainable Future-Impact Analysis of Metropolitan Policies for Development and Environmental Conservation** (T. Ohmachi and E. R. Roman, eds.), pp. 135-148. Japan Society for the Promotion of Science and the University of the Philippines Press, Manila.