VEHICULAR AIR POLLUTION ABATEMENT STRATEGIES FOR METRO MANILA

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abstract: Increasing motorization trend, aging vehicle fleet, and worsening traffic congestion are among the most significant factors contributing to the severe degradation of air quality in Metro-Manila. Recent studies indicate that Suspended Particulate Materials, Nitrogen Oxides, Lead, and Sulfur are currently the most predominant air pollutants; and, future projections reveal an increasing level of Carbon Monoxide emissions. These pollutants pose dangers to human health, the urban physical environment, and the economy in general. In this paper, the factors affecting vehicular air pollution trends in Metro-Manila were examined and various strategies to control air pollution were recommended.

1. INTRODUCTION

With a current population of approximately 8.9 million, Metro-Manila is expected to become one of the world's megacities by the turn of the century. This phenomenal growth has started to severely strain the existing urban infrastructure and ecology. In particular, the supply and operation of various transport infrastructures cannot cope up with the increasing demand for efficient movement of people and goods. This results in serious traffic congestion which exacerbates the urban air quality problem and causes enormous social welfare and economic losses to society. A critical element in addressing these issues is the development of effective institutional systems which can jointly provide for and manage both transportation and environmental concerns. This paper examines the urban air quality problem in Metro-Manila; reviews current efforts to address this problem; and recommends control strategies appropriate for Metro Manila.

2. SOURCES AND IMPACTS OF AIR POLLUTION

2.1 Sources of Common Air Pollutants

Air pollution is defined as the presence in the outdoor atmosphere of one or more contaminants or combination thereof in such quantities and of such duration as may be or may tend to be injurious to human, plant, or animal life, or property or the conduct of business. Contaminants may include dust, fumes, mist, liquid, smoke, other particulate matter, vapor, gas, odorous substances or any combination thereof.

Sources of air pollution have traditionally been classified as either mobile or stationary. Mobile refers to motor vehicles while stationary refers to industrial sources. In urban areas such as

Metro Manila, the largest fraction of most pollutants come from mobile sources. Motor vehicle-attributed pollutants include Carbon Monoxide, Hydrocarbons, Lead, Nitrogen Oxides, Suspended Particulate Matters, Photo-Chemical Oxidants and Sulfur Dioxide.

2.2 Effects of Air Pollution

The harmful consequences of particulates, lead, carbon monoxide, nitrogen oxide and other air pollutants are well-documented (see e.g., Horowitz, 1982; Faiz, et al, 1990; Mboi, 1995). Particulates can cause breathing difficulties and reduced visibility but more distressingly are known to exacerbate mortality. Furthermore, recent studies indicate that diesel particulates may be carcinogenic. Lead affects the central nervous system, lowers IQ, causes behavioral problems, decreases ability to concentrate, increases the incidence of high blood pressure, and has been found to be carcinogenic in animals and potentially so in humans. Carbon monoxide impairs cardiovascular functions which can result in heart failure, brain damage, impaired perception and asphyxiation. It is also known to contribute to elevated levels of tropospheric ozone. Nitrogen oxides cause eye and nasal irritation, respiratory tract disease, lung damage and decreased pulmonary function. It also reacts with other pollutants to form ozone and other toxic pollutants.

In Metro Manila, the jeepney drivers, bus drivers, traffic policemen and aides, and public transport commuters are the population segments most widely exposed to the harmful effects of air pollution. Among them, the jeepney drivers numbering almost 70,000 have the highest exposure. A recent epidemiological study revealed that jeepney drivers have significantly higher prevalence of chronic respiratory symptoms such as wheezing, shortness of breath, chronic cough and pleghm production; have higher incidence of respiratory illnesses such as chronic obstructive pulmonary disease, pulmonary tuberculosis, and pulmonary illnesses; and, have much higher exposure to carbon monoxide and lead than commuters.

The economic consequences of air pollution are typically measured in terms of monetary values assigned to mortality effects; costs of reducing morbidity; reductions in the value of agricultural crops and vegetation; costs of reducing soiling and material damages; loss in property. The mechanics of these economic valuation task are fraught with difficulties and controversies but nonetheless there is a general consensus that the cost to society due to air pollution is significantly high. Among developed countries, the estimated cost of air pollution ranges from 0.03% to 0.92% of Gross National Product (OECD, 1994).

3. METRO-MANILA AIR QUALITY CONDITION

3.1 The Dominant Role of Motor Vehicles

In the1990 Emissions Inventory undertaken by the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR), it was revealed that mobile sources of emissions account for approximately 78% of total air pollutants. The remaining 22% is attributed to industrial or stationary sources. Figure 1 further shows that except for Sulfur Oxides, mobile sources contributes a bigger percentage of the pollution load with Carbon Dioxide (CO_2) and Total Organic Gases (TOG) at 100% and 98% respectively.

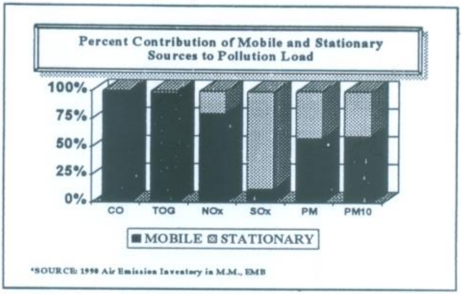

Figure 1. Sources of Air Pollution

3.2 Findings of Previous Monitoring Activities

3.2.1 The 1992 ADB Study

More recently, the Asian Development Bank funded the Vehicle Emission Control Planning Project for Metro Manila in which field surveys on and estimation of motor vehicle emissions were undertaken. Field surveys involved the installation of five monitoring stations along several major road sections throughout Metro Manila. Monitoring activities for every station lasted for between one to seven months. Among the findings were as follows: (a) Particulates, nitrogen oxides and lead are the most serious pollutants in Metro-Manila; (b) Jeepneys, taxicabs and buses which are predominantly diesel-fueled contribute around two-thirds of total particulates; (c) Private vehicles and other gasoline-fueled vehicles are the primary sources of nitrogen oxides, hydrocarbons and carbon monoxide. (ADB, 1992).

Table 1 shows the air pollution exposure levels as monitored compared with the study's proposed Philippine Air Quality Standards. The figures show that particulates and lead concentrations exceed the standards by at least 100%. And to a lesser extent, carbon monoxide and nitrogen dioxide concentrations also exceed the standards.

Table 1. Maximum Air Quality Measurements Compared to Proposed Philippine Guidelines

Pollutant	Tme Average Criterion	Measured Concentrations	Proposed Philippine Guidelines
PM_{10}	2nd High 24-hour (ug/Ncu.m.)	313	150
	Annual Geometric Mean (ug/Ncu.m)	215	60
TSP	2nd High 24-hour (ug/Ncu.m.)	762	230
	Annual Geometric Mean (ug/Ncu.m)	479	90
Lead	3-month Average (ug/Ncu.m.)	3.3	1.5
CO	1-hour (ppm)	20.6	30
	8-hour (ppm)	11.3	9
NO_2	1-hour (ppm)	0.24	0.14
	Annual (ppm)	0.01	0.04
SO_2	24-hour (ppm)	0.04	0.07
	Annual (ppm)	0.02	0.03
Total Oxidant	1-hour (ppm)	<0.01	0.08

Source: Asian Development Bank, 1992

3.2.2 Government Monitoring Activities and Historical Trends

Monitoring activities in Metro Manila started as early as 1971 by the then National Water and Air Pollution Control Commission (NWAPCC). Six stations, primarily traffic oriented, were established to monitor oxidant (ozone), sulfur dioxide, nitrogen dioxide, suspended particulates and lead using mechanized samplers. In 1974, the mechanized equipment was replaced by automatic instruments that made possible the first hourly monitoring of carbon monoxide, total hydrocarbons, total oxidants, oxides of nitrogen, sulfur dioxide and suspended particulates along with some meteorological parameters. (ADB, 1992)

In the early eighties, the then National Pollution Control Commission was forced to stop operating other equipment leaving only TSP, CO and SO_2 as the parameters under study due to lack of spare parts and the high cost of maintenance. By 1983, the remaining equipment began to breakdown leading to the shut down of all monitoring operations before the end of 1985. When monitoring was resumed in 1986, manual samplers had to be utilized for sulfur dioxide and particulates. (EMB, 1990)

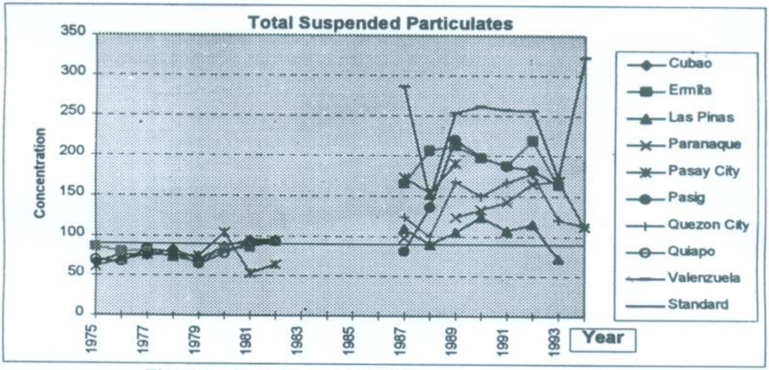

Figure 2. Annual average of 24-hour measurements for TSP.

Annual average readings of TSP from four monitoring stations in Metro Manila (Figure 3.2) showed to be between 60 to 100 $\mu g/m^3$ from mid-70's to early eighties. When monitoring resumed, notably higher measurements were recorded but these were partly attributed to the change in sampling method used from the light scattering method using automatic samplers to the gravimetric method using high volume manual samplers (EMB, 1990). An upward trend showed for all stations in 1988 while, except for Valenzuela, a downward trend is noted in 1992. Assuming a certain percentage of error or inaccuracy in measurements and despite trends, the data nevertheless indicate that TSP concentration has risen and is becoming a serious concern in the metropolis (Mage, 1989).

Findings on other pollutants were as follows: (a) SO_2 is a less alarming pollutant in Metro Manila with annual averages from 1987 to 1995 that were way below the 0.03 ppm air quality guideline mark; (b) CO measurements indicate a significant increasing trend; and, (c) NO_2 concentration is way below the guidelines in 1986 and 1987 but trend is not established due to insufficiency of data.

4. FACTORS CONTRIBUTING TO VEHICULAR AIR POLLUTION

4.1 Increasing Motorization Trend

Motor vehicles account for a large portion of the total air pollution load. Vehicle registration on practically all types of vehicles experienced a significant increase in the past ten years. Land Transportation Office data shows that there is a total of 1,055,692 registered vehicles in NCR for the year 1995. This figure is more than twice the total vehicle registration a decade ago. Historical records indicate that vehicle registration dramatically increased after its period of decline during the economic and political crises three years before the EDSA Revolution. As the Philippine economy recovers the statistics indicated an annual average increase of about 8.66% in total vehicle registration, and a significant growth in new vehicle registration which posted an annual average increase of 27.25% from 1986 to present.

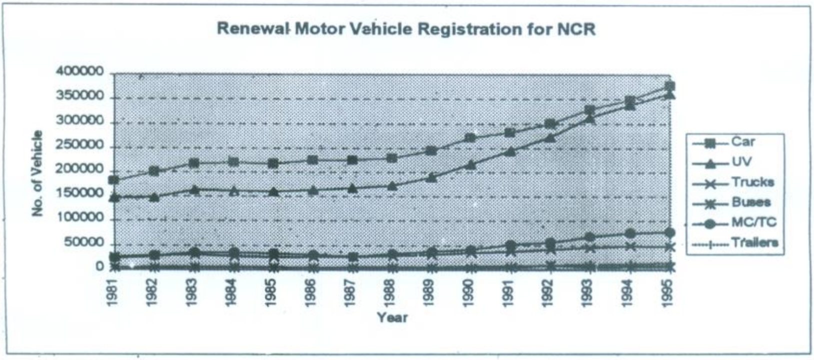

Figure 3

4.2 Increasing Supply of Motor Vehicles

The growth of the automotive industry after its near collapse in 1983 can be attributed to government's effort to revitalize the industry through the Car Development Program (CDP), Commercial Vehicle Development Program (CVDP) and Motorcycle Development Program (MDP) in 1987 and 1988. In 1990, the People's Car Category was added to the CDP and this resulted in an increase from three to eight in the number of participating car manufacturers. Further developments include a) the creation of a third category covering luxury vehicles in

1992; b) the formation of the ASEAN Industrial Joint Venture (AIJV) which allows the exchange of products/components under a preferential tariff scheme in 1994; and more recently c) the issuance of Department of Trade and Industry's Memorandum Order No. 136 in February 1996, which further liberalizes motor vehicle production. This liberalization policy was aimed at making vehicles available and affordable to the greatest number of buyers. All these developments led to an increase in motor vehicle production output to 261,982 units in 1995 as compared to 100,589 units in 1991 representing an average annual increase of 27%.

The 1992 ADB Study estimates that with the continuous increase in vehicle population, assuming no additional control measures will be implemented, total pollutants from vehicles will at least double by the year 2005.

4.3 Engine Performance of Vehicle Fleet

Another factor affecting automotive emission level is the engine performance of the vehicles. This factor is basically influenced by engine wear out and maintenance. Wearing out of vehicle is directly affected by the cumulative engine kilometrage and vehicle age. Worn out and poorly maintained engines become less efficient thus increasing fuel consumption for an equal number of kilometers traveled and consequently increases the emission factors of vehicles.

Many vehicles in Metro Manila appear to be deteriorated with signs of being poorly maintained. Due to the high cost of new vehicles and the absence of an effective vehicle phase out policy, the propensity of owners to decommission aging and deteriorated vehicles is very low. Furthermore, importation of second hand buses and engines, particularly diesel engines used for jeepneys, also contribute to the aging vehicle fleet problem.

Recently, a policy prohibiting the operation of old and dilapidated taxicabs in the roads of Metro Manila was implemented. Despite the policy's success in alleviating the aging taxicab fleet, the policy failed to produce a significant effect on the entire motor vehicle fleet because the owners of these phased-out taxicabs simply converted their vehicle registration from taxicab to private vehicle so most of these phased-out taxicabs are back on the streets of Metro-Manila.

In the absence of historical data on vehicle phase out, the LTO Motor Vehicle Registration was used to approximate the phase out trend by analyzing the historical difference between the total registration for year *n* and the renewal for the year *n+1*. The difference being positive is considered as the approximate phased out population. A negative difference is interpreted as the case wherein the number of renewal in NCR of vehicles previously registered in the province exceeds the number of the those phased out. Results show that from 1981 to 1994, UV has the lowest annual phase out average with only 2.46% of the total population followed by Cars with 2.85 %, Buses with 5.34%, Trailers with 5.60%. Trucks and MC/TC has a relatively high percentage of annual phase out at 11.22% and 21.24% respectively. Trucks and MC/TC however comprise just a small percent of the entire vehicle population.

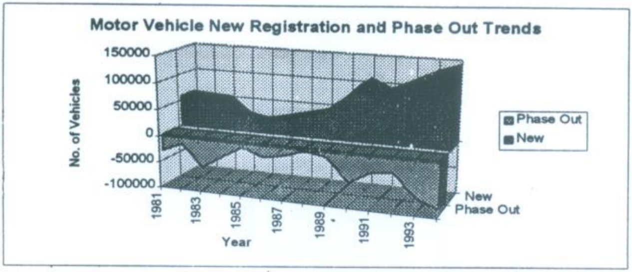

Figure 4

The average phase out for the entire vehicle fleet for the past 14 years is a low 5.36%. A general observation on the phase out trends for all type of vehicles is that phase out is at its lowest between 1985 and 1990 and in an increasing trend starting 1993. The shape of phase out curve is also observed to coincide with the New Registration curve which means that new vehicles are acquired in replacement to the decommissioned ones (Please see Figure 4). New registration however is several times as much as that being phased out.

4.4 Worsening Traffic Congestion

Air pollutant particle volume in automotive gas emissions differs on running speed and idling, acceleration, deceleration and fixed speed travel modes. Emissions of high concentration of CO is produced during idling while large emissions of NO_x is produced during acceleration and deceleration travel modes. In the case of a traffic congestion, the average travel speed is low and vehicle operation involves a high number of idlings, accelerations and decelerations. A free flow condition however yields a high travel speed average and a vehicle operation involving a high number of fixed speed conditions. Generally, CO and NO_x goes with low travel speed and emitted in large amounts during traffic congestion. If the average speed is between 60-80 km/h, exhaust emission volume is very low and tends to increase gradually with higher speeds(NCTS, 1995). Table 2 below shows the concentration of different pollutants for different engines and travel modes.

Table 2. Representative Composition of Exhaust Gases

	Pollutant	Idling	Acceleration	Cruising	Deceleration
Petrol Engines	Carbon Monoxide	69000	29000	27000	39000
	Hydrocarbons	5300	1600	1000	10000
	Nitrogen Oxides	30	1020	650	20
	Aldehydes	30	20	10	290
Diesel Engines	Carbon Monoxide	Trace	1000	Trace	Trace
	Hydrocarbons	400	200	100	300
	Nitrogen Oxides	60	350	240	30
	Aldehydes	10	20	10	30

Source: Pegs and Ramsden

The major transportation problem of Metro Manila is expanding peak period congestion as experienced in most of its major thoroughfares. With the increasing trend in vehicle population outpacing the construction and improvement of roads and other transportation facilities, traffic congestion is now on its worst. This is a fact which daily commuters are not likely to disagree with.

4.5 Motor Vehicle Composition

In air pollution studies, a general classification of vehicles is by the type of the engine, namely the petrol and diesel. Petrol engine emissions primarily include pollutants such as hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and lead and traces of sulfur oxides and particulates in small quantities. Hydrocarbons are largely the result of incomplete combustion of the fuel. Oxides of nitrogen are formed during the condition of high temperature and pressure and high air/fuel ratio while carbon monoxide results from a low air/fuel ratio and an incomplete combustion of carbon contained in the gasoline. Lead content in petrol engine exhaust is in significant proportion to the engine's lead intake. In diesel engines, the principal pollutants being emitted include oxides of nitrogen (NO_x), sulfur oxides (SO_x), particulate matter (PM), and unburned hydrocarbons (HC). Carbon monoxide are also found in small quantities. The NO_x, HC, and most of the particulate emissions from diesels are formed during the combustion process. The sulfur oxides, in contrast, like lead, are derived directly from sulfur in the fuel, hence, can only be controlled by reducing the fuel's sulfur content. (ADB, 1992)

The 1995 NCR Total Motor Vehicle Registration is comprised of 41.5% cars, 39.9% utility vehicles (UV), 10.2% motorcycles/tricycles (MC/TC), 6.0% trucks, 1.6% trailers and 0.8% buses. Each of these vehicle types have their own emission factors depending on engine type, the fuel used and the loading condition. Due to various emission factors, vehicle mix of different percentage distribution will eventually yield a different pollutant load profile.

Based on the vehicles emission factors, strategies controlling a particular pollutant can be designed. Control measure to reduce hydrocarbon should primarily focus on motorcycles with the highest emission factor despite its small engine and the rest of the gasoline-fueled vehicles. Strategies to control sulfur oxides and particulate matter should focus on buses, trucks, jeepney and rest of the diesel-fueled utility vehicles. Strategies to control carbon monoxide and lead, on the other hand, should focus on cars, motorcycles and gasoline-fueled utility vehicles. Though emission factors on NO_x of gasoline-fueled engine of the same size is twice greater than its diesel counterpart, focus should be given also to buses, despite being diesel-engined, for having the highest NO_x emission factor because of its engine size.

Cars, motorcycles and gasoline about 45.7% of the utility vehicles are petrol engined while buses, trucks, trailers and about 54.3% of the utility vehicles are primarily diesel engined. The entire 1994 vehicle population is comprised of 69% gasoline and 31% diesel engined.

Diesel-engined vehicles, despite being fewer than gasoline, remains to be a significant contributor of most of the pollutants and the main culprit for the vehicle-borne particulates being the most critical pollutant that degrades the air quality of the metropolis. This is primarily because diesel-engined vehicles are mostly those in the public transport/goods movement industry, thus, generating a longer vehicle-kilometer traveled far beyond that of average private cars. An ADB Vehicle fleet and Kilometrage Inventory for 1990 shows that although cars, gasoline-fueled utility vehicles, motorcycles and tricycles constitute a large majority at 73% of total vehicles registered, it generated only 50% of the total annual kilometrage. On the other hand, taxicabs, jeepneys, trucks, buses and diesel-fueled utility vehicles, which comprise mainly the public transport and commercial vehicle fleet in the metropolis, account for 27% of total vehicles registered and 50% of the total annual kilometrage.

Ironically, despite diesel-engined vehicles being a primary source of critical pollutants in the metropolis, the government, through its fuel pricing scheme and the second-hand vehicle importation policy had been encouraging the use of diesel, often second hand, over the gasoline. The considerably cheaper amount of diesel fuel plus the more affordable bargain on second-hand diesel engines creates a general preference to the use of diesel vehicles particularly the public transport, cargo and utility vehicles.

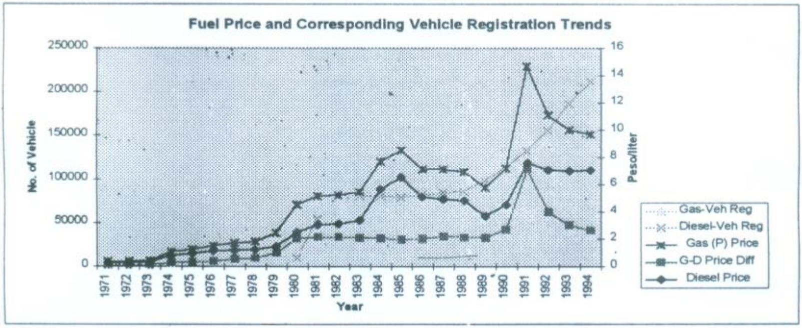

Figure 5

Historical data shows (Please see Figure 5) that a trend wherein diesel outpaces the growth rate of gasoline (1981-1985 and 1991-1994) were triggered by an increase in the difference between the gasoline and diesel fuel prices(1980 and 1991): Figure 5 further shows that a relatively stable difference following the increase in difference (1981 to 1989) tends to equalize the diesel and gasoline vehicle registration growth rates (1988-1990). The biggest difference between gasoline and diesel fuel prices occurred as an effect of the 1990 Gulf War. Furthermore, the significant increase of cars for the past decade have caused an extreme congestion problem subsequently increasing the emission levels of diesel-engined vehicles idling in traffic jams.

5. PAST AND PRESENT EFFORTS AT ADDRESSING THE AIR POLLUTION PROBLEM

5.1 General Background

There are mainly four agencies of government with responsibilities related to motor vehicle emission control, namely: Department of Environment and Natural Resources (DENR), Department of Transportation and Communications (DOTC), Philippine National Police (PNP), and Metro Manila Development Authority (MMDA). The DENR is the lead agency and has primary responsibility to prevent, control and abate motor vehicle pollution. All four agencies have their own units dealing with apprehension and/or law enforcement functions. The DOTC's role is to coordinate and cooperate with the DENR, PNP and MMDA in the enforcement of laws, rules and regulations.

More recently, the ongoing effort towards devolution of certain functions from the national to local government as mandated under the Local Government Code, also known as Republic Act 7160, resulted in having the local government participate in enforcement activities, and share with the DENR the primary responsibility of environmental management of their localities.

5.2 Environmental Legislation

Environmental legislation in the Philippines was initiated in 1964 with the passing of Republic Act No. 3931 entitled Pollution Control Law. This law created the National Water and Air Pollution Control Commission which subsequently issued a rule to limit exhaust emission to a certain level using a measure of the degree of blackness of emissions known as Ringelmann number.

In the early seventies, when former President Ferdinand Marcos declared martial law in the Philippines, Presidential Decree 984 was issued to create the National Pollution Control Commission (NPCC), followed by the issuance of Presidential Decree 1152, also known as the Philippine Environment Code, which designated the Land Transportation Commission (LTC) as the agency responsible for enforcement of motor-vehicle emission rules and regulations.

In 1977, a major revision of the Philippine Environment Code was completed with the issuance of Presidential Decree 1181 which: (a) transferred enforcement powers from the LTC to the NPCC; (b) designated LTC and other transport-related agencies with the responsibility to support NPCC's enforcement functions; (c) gave NPCC vast powers to set emission standards for all types of motor vehicles; develop regulations for the sale, distribution, and registration of motor vehicles; set specifications for motor fuels; set deadlines for compliance; and issue certificates of compliance (ADB, 1992).

In the mid-1980's, after the EDSA People Power Movement toppled the Marcos dictatorship and President Corazon Aquino was sworn into office, Executive Order 192 was issued to abolish the NPCC and transfer its powers and functions to the Department of Environment and Natural Resources.

5.3 Pollution Abatement Programs

Previous efforts at air pollution abatement were focused mainly in controlling particulate emissions from diesel-fueled motor vehicles. As part of the issuance of PD 1181, the Anti-Smoke Belching Program was launched in 1977. Under this program, the DENR Apprehension Teams make on the road spot checks of suspected violators using a Ringelmann Chart. Those failing the test are sent to the Motor Vehicle Pollution Control Center for further testing using the Hartridge Smoke Test. Fines ranging from P200 to P1000 are levied to violators, and vehicles are grounded until the necessary repairs are undertaken and then sent back for retesting until a Certificate of Compliance is issued. Experience showed that many vehicles are not returned for retesting. For such cases, a subpoena is issued and referred to the Land Transportation Office for revocation of franchise and/or registration. Newly manufactured vehicles are also required to meet emission standards but due to lack of facilities for emission testing these standards are not strictly enforced (ADB, 1992).

While the government has recognized the importance of controlling motor vehicle air pollution as early as the mid-1960's, it is only recently that the public and the government have seriously considered air pollution as a critical health and environmental issue. It is widely believed that there exists an urgent need to: (a) formulate a comprehensive strategy to address the air pollution problem; and, (b) undertake significant legislative and institutional reforms to strengthen the government's ability to effectively implement pollution abatement programs and manage urban air quality.

With respect to pollution abatement programs, there is a need to expand the coverage to include not only particulate materials but also other pollutants such as carbon monoxide, hydrocarbons, nitrogen oxides, sulfur and lead. PD 1181 needs to be revised to include reasonable emission standards and compliance targets for all these mentioned pollutants.

As with any other concerns of government, the environmental pollution control sector is faced with an all too familiar host of problems, namely: (a) lack of well-defined and coherent metropolitan development strategy; (b) institutional fragmentation and ineffective coordination; (c) inadequate financial support to carry out its mandate; (d) lack of personnel adequately trained in vehicular air pollution control; (e) low level of public awareness of pollution laws and regulations; (f) complex legal and political implications of environmental actions due to overlapping functions and jurisdictions among governmental agencies and conflicting policies, laws and regulations; and, (g) lack of political will.

The most recent proposals to address the above issues were as follows: (a) mandatory inspection and maintenance program for all vehicles; (b) tighter emission standards for motorcycles; (c) program to reduce lead and sulfur in fuels; (d) encourage engine conversion from diesel to gasoline fueled engines through equalization of price of the two fuels; (e) application of modern emission controls to new gasoline vehicles; and, (f) installation of particulate filters on diesel buses (ADB, 1992).

6. MEASURES TO CONTROL MOTOR VEHICLE EMISSIONS

There have been numerous measures aimed at controlling motor vehicle emissions described in the literature (see e.g., Zegras, et al, 1995; Crawford and Smith, 1995; Hall, 1995; Michaelis, 1995; Birk and Zegras, 1993; Bernstein, 1993; Faiz, et al, 1990; and, Horowitz, 1982). These measures may be classified into four categories which define the general strategies for dealing with the motor vehicle emission problem, namely: (a) use cleaner fuels; (b) use cleaner vehicles; (c) improve traffic flow; and, (d) reduce travel demand.

6.1 Use Cleaner Fuels

In most developing countries, lead content in gasoline and sulfur content in diesel fuel are much higher compared with those in developed countries. Hence, dramatic reductions in particulate lead and sulfur emissions can be gained within existing vehicle technology using conventional fuels (World Bank, 1996). The use of unleaded gasoline and low-sulfur diesel can be promoted through differential taxation for leaded and unleaded gasoline in favor of the latter, fuel price surcharges based on lead content of gasoline and sulfur content of diesel fuel, lower taxes on cleaner fuels, tax deductions to retrofit vehicles with emission control devices, provision of infrastructure to distribute cleaner fuels, and imposition of stricter vehicle emission standards coupled with effective implementation of on-road inspection and maintenance (I/M) programs (Faiz, et al, 1990).

In developed countries where unleaded gasoline and low-sulfur diesel are already widely-used, attention has focused on investigating the technical and economic feasibility of using alternative fuels such as reformulated gasoline and diesel, methanol, ethanol, vegetable oils, compressed natural gas, liquefied petroleum gas and synthetic liquid fuels . Recent studies indicate that alternative fuels which yield the highest reduction in emissions are also the most expensive. Furthermore, while alternative fuels may reduce emissions of volatile organic compounds and carbon monoxide, the emission of other pollutants such as nitrogen oxides and sulfur dioxide may increase (Michaelis, 1995). Research and development efforts on alternative fuels are ongoing as this strategy offers a very promising approach to reducing motor vehicle emissions.

6.2 Use Cleaner Vehicles

This strategy covers a range of measures such as the following: (a) use of exhaust treatment devices such as catalysts and traps; (b) retrofitting of on-the-road vehicles with emission control devices; (c) promoting the use of less polluting conventional transport such as electric-powered rail transit systems and non-motorized travel modes; (d) phasing out of aging and deteriorated vehicles which emit higher levels of pollutants; and, (e) development and use of electric cars and buses.

In the context of developing countries, the most significant issues typically involve the continued operation of old and dilapidated vehicles, and the local production and importation of second-hand trucks and buses which are particularly polluting. Furthermore, there is an increasing trend towards using motorcycle powered by two-stroke engines which are up to ten times more polluting than modern four-stroke engines (World Bank, 1996). Therefore, measures aimed at modernizing the aging vehicle fleet, discouraging imports and local production of substandard vehicles, and arresting the growth in motorcycle usage would significantly reduce motor vehicle emissions.

6.3 Improve Traffic Flow

Measures to improve traffic flow in terms of increased travel speed, less vehicle idling, and decreased accelerations and decelerations would serve to reduce carbon monoxide and hydrocarbon emissions. Examples of such measures include: (a) widening of roadways and intersections; (b) on-street parking prohibitions; (c) synchronization of traffic signal operations; (d) implementation of one-way street systems; (e) installation of reversible lanes; (f) turning movement prohibitions; (g) designation of exclusive lanes for buses and other high-occupancy vehicles; and, (h) designation of truck routes. These measures are basically traffic engineering techniques geared towards maximizing the utilization of existing transport supply and typically known as Transportation System Management (TSM) measures.

In most developing countries, the existing transport infrastructure and services are heavily congested because transport supply simply could not keep pace with increasing travel demand. Consequently, the task of improving traffic flow within very limited transport capacity is even more daunting. Furthermore, there is a pressing need to build more roads and expand public transport capacity up to a level that is economically and environmentally sustainable. Most large cities in the developing world are already experiencing severe traffic congestion which exacerbate the air pollution problem, and building additional transport infrastructure is necessary to alleviate but may not necessarily relieve traffic congestion.

6.4 Reduce Travel Demand

It is now widely believed that the worsening traffic congestion problem in cities cannot be solved by simply continually building additional transport capacity and that the demand for travel has to be reduced using transportation demand management (TDM) measures. A variety of TDM measures have been formulated and implemented worldwide. Some examples of these measures are shown Table 3.

In Metro-Manila, there have been very limited applications of TDM measures. Many measures have been considered in the past but only the truck ban and private vehicle traffic restriction, known as the Odd-Even Scheme, have been vigorously implemented. Taxes, license fees, toll fees, parking fees, and the like are currently imposed but mainly for revenue generation rather than for travel demand management.

Table 3. Examples of Transportation Demand Management Measures

General TDM Strategy	Specific TDM Measures
Control Land Use and Development Patterns	Transit-Oriented Development Mixed-Use Development Land Development Impact Fees
Restrain Vehicle Ownership	Vehicle Quota Systems Registration and License Fees Purchase Tax
Restrain Vehicle Usage: Physical Restraints	 Traffic Restriction by Vehicle Type (e.g., truck bans, Odd-Even Scheme, Calendar End Day Scheme, Traffic Cells, etc.)
Pricing Restraints	Parking Restrictions Gasoline Tax Road Congestion Pricing (e.g., Singapore's Area Licensing Scheme) Parking Fees Road Tolls Carbon Tax
Promote Use of High Occupancy Modes	Public Transport Service Improvements Traffic Priority for Public Transport HOV Lanes Park and Ride Facilities Carpooling Reduced Transit Fares
Encourage Flexible Activity Schedule	Flexible Work Schedule Staggered Work Hours Telecommuting
Promote Non-Motorized Transport	Bicycle Lanes Pedestrian Zones

7. BRIDGING THE GAP

In the preceding sections, the current programs of government to manage air quality in Metro-Manila and various strategies known worldwide for controlling air pollution were reviewed. From this review, we derive the following key conclusions and recommendations:

7.1 Air Pollution as a Serious Metropolitan Concern

The magnitude of particulate, nitrogen oxide and lead pollutants are already at alarming levels affecting mainly the public transport users, jeepney and bus drivers, pedestrians, and traffic policemen. Furthermore, the prevailing rapid increase in motorization is expected to worsen the level of carbon monoxide, hydrocarbon, and lead emissions. These air pollutants pose serious threats to the health condition of the urban population, and impose economic costs to society in general.

While the government has recognized the importance of maintaining environmental quality as early as the mid-1960's, it was only recently that serious attention has been given to the urban air pollution problem. There is a need to further boost current efforts toward improving air quality in Metro-Manila.

7.2 Wide Range of Available Air Pollution Abatement Strategies

Lessons may be learned from the experiences of developed countries over the past couple of decades in dealing with urban air pollution problems. Among the various strategies discussed in the earlier section, the ones most appropriate for Metro-Manila include Transportation Demand Management (TDM) and Transportation System Management (TSM) measures, and pricing and other policies in favor of cleaner fuels and vehicles. In most situations, TDM and TSM measures will not only mitigate the air pollution problem but also alleviate road traffic congestion. The use of cleaner fuels can be promoted by raising the price of leaded gasoline and high-sulfur diesel through the imposition of environmental taxes.

The promotion of cleaner vehicles can best be done by focusing on policies which serve to hasten the phasing-out of old vehicles. Setting of emission standards and implementing motor vehicle inspection and maintenance schemes would not be sufficient considering that a large proportion of the vehicle population are gross polluters; and, with the high cost of acquiring new vehicles, the propensity to hold on to aging vehicles is also high. Therefore, it is necessary to raise the cost of keeping an aging vehicle to a level that is higher than the price of acquiring a new replacement vehicle.

7.3 Institutional Strengthening as the Next Step Forward

A critical step in addressing the serious air pollution problem in Metro-Manila is to strengthen the institutional aspects of urban air quality management at the metropolitan level. These aspects include the following: (a) integration of transportation and environmental plans and policies; (b) enhancement of vertical and horizontal coordination among relevant agencies; (c) development of local manpower capability for environmental management; and, (d) mobilization of the private sector.

Traditionally, transportation and environmental concerns are under the jurisdiction of separate agencies of government at the national level. Since the officials and staff of these agencies are typically specialists only in their respective fields, sometimes their plans and policies are either in conflict with each other or are not coordinated when implemented. Ideally, air quality concerns should become an integral part of transportation planning. Therefore, the formulation of policies and plans related to transportation and air quality should not be done separately. To enable joint planning for transportation and air quality, there is a need to enhance mutual understanding and communication among transportation and environmental planners.

At the operational level, the management and implementation of transportation and air quality programs are typically handled by various local, metropolitan and national agencies. Therefore, it is necessary to achieve effective vertical and horizontal coordination amongst them. In Metro-Manila, this coordination process is handled through the creation of the Metro-Manila Development Authority (MMDA). While the MMDA has the legal mandate to coordinate plans, such task is extremely difficult to carry on due to the MMDA's highly politicized character. Furthermore, the MMDA is saddled with inadequate financial, managerial and technical resources for air quality management.

As part of the effort to devolve several functions from the national to the local government, a huge demand has been created for training local government personnel on their new responsibilities. This is true even for Metro-Manila which has greater access to specialists and experts of national governmental agencies. Local governments in other metropolitan areas outside Metro-Manila where air pollution is also becoming a serious concern face even more serious problems with respect to inadequate technical and managerial expertise in environmental management in general and air quality management in particular. There is a need to develop training programs on transportation and air quality management specifically geared towards building the capabilities of local personnel in growing metropolitan areas nationwide.

The role of the private sector (i.e., individual citizens, business community and constituency groups) in air quality management is very significant because individual travel behavior is a major factor affecting the level of motor vehicle emissions. Furthermore, the success of TDM measures designed to control air pollution depends on the behavioral responses of motorists and public transport commuters. Their behavior is determined to a large extent by their perceptions, expectations and value judgments with respect to mobility, accessibility and air quality choices. Hence, it is necessary to draw the support and participation of the private sector in the management of urban air quality. This can be done through the creation of formal organizational structures (e.g., NGO's, transportation and environmental management associations, etc.) or informal networks of individuals and organizations which may be utilized or consulted with when developing and implementing transportation and air quality programs.

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