AN INTEGRATED TRANSPORTATION AND AIR QUALITY MANAGEMENT PLAN FOR SURABAYA INDONESIA

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ABSTRACT

This paper presents an 10-20 year estimate of motor vehicle emission and its effects in Surabaya using population a transport statistics and ambient air quality characteristics from 1985-1990. Controlling motor vehicle emissions, reducing number of trips and number of motor vehicle usage are needed to solve the problem. A set of strategies motor vehicles emission reduction and an efficient transportation system in Surabaya are also proposed.

ABSTRAK

Proyeksi populasi, transportasi dan batas kualitas udara di kota Surabaya dilakukan menggunakan data yang ters tahun 19985-1990 untuk memprediksi permasalahan kualitas udara berkaitan dengan transportasi kota dan dampak Jika kecenderungan berlanjut, permasalahan polusi udara CO akan terjadi di tahun 2015 dan NOx telah terjadi di t 1995. Pengontrolan emisi kendaraan bermotor, pengurangan jumlah perjalanan dan jumlah kendaraan berm diperlukan untuk mengatasi permasalahan. Sejumlah usulan diberikan untuk pengurangan emisi kendaraan berm dan peningkatan efisiensi sistem transportasi di Surabaya.

Keywords : air quality, emission factors, projections

I. INTRODUCTION

Surabaya, the second largest city in Indonesia, has a high rate of growth during the past two decades in both population and economic activity. This growth has lead to an increasing number of motor vehicles that lead to congestion and decreasing air quality in the city. This growth is expected to continue and, unless steps are taken, the problems will worsen.

If the motor vehicle growth is same as the last decades, it will create problem in public health, human productivity and social welfare. There is very little data available in Indonesia concerning the health risks from transportation emissions. No comprehensive analysis of the levels of pollution over a period of time and observed consequential increases in pollution related illnesses are reported. However, experiences from other cities, like Jakarta, Mexico and Bangkok [Faiz,1992, UNEP,1992, Hanson,1989] shows that if air pollution exceeds a threshold, it will have health impacts such as viral infection, bronchitis, eye irritation, and lung cancer. It can also cause reduced human productivity and deterioration on building, monument and materials.

The purpose of this paper is to illustrate the air pollution emissions for 10 and 20 planning years and the need for a transportation and air quality policy to main sustainable development in Surabaya. The pollut observed in this study are carbon monoxide (CO) nitrogen oxide (NOx).

II. CITY CHARACTERISTICS

Surabaya is located in the center of the northern coa East Java Province. The topography is mainly flat at a 3-6m above sea level. The tropical climate has identifiable seasons. The dry season generally lasts f May to October, and the wet or rainy season f November up to April. Wind velocity normally ra from 5.6 to 37 km/hours and is relatively con throughout the year. The predominant wind directi easterly. The mean annual rainfall is 1321 mm and average annual temperature is 27.8C.

There are about 2.7 million people now (1998) w total city area of 29,000 hectares and a diameter of ar 20 km. Table 1 shows historical yearly populations economic activity indicator data and their growth available data 1985 to 1990 and the projection fo 1995, 2005 and 2015 planning years. The average a population growth was 2.50% in 1985 to 1990 or 13 in five years while the average annual gross reg domestic product per capita (GRDP) was 9.53%

57.64% in five years. The planning projections are based on the five years growth rates.

Table 1. Population and Economic Activity of Surabaya Historical Data & Projection

Years	Population	GRDP (Rp. 10^6)	Income/cap (Rp. 10^3
1985	2,302,242	1,664,483	629,39
1986	2,360,949	1,715,981	634,56
1987	2,420,233	1,881,035	682,56
1988	2,480,060	2,122,748	756,36
1989	2,541,144	2,390,645	825,85
1990	2,604,187	2,617,013	875,63
1995	2,946,000	4,125,517	1,221,40
2000	3,332,000	6,503,555	1,703,69
2005	4,769,000	10,252,347	2,376,44
2010	4,263,000	16,162,024	3,314,84
2015	4,823,000	25,478,168	4,623,79

Average growth of population : 2.50% per year or 13.12% per 5 years
Avarage growth of GRDP : 9.53% per year or 57,.64% per 5 years
Average growth of Income per capita : 6.88% per year or 39.49% per 5 years
Source: [BPS, 1991], data compiled & projected by author

III. TRANSPORTATION CHARACTERISTICS

In 1990, the motor vehicle population was 520,631; 69.7% motor cycles (MC), 19.6% light duty vehicles (LDV), and 10.7% heavy duty vehicles (HDV). Light duty vehicles include passenger cars, taxis, and bemos while heavy duty vehicles include goods vehicles such as truck, pick up and bus. The number of motor cycles in Surabaya is quite high compared with other vehicles. The high economic growth of this city will shift some middle income people to the high income group and create a demand for motor vehicles. Table 2 shows the number of motor vehicles from 1985 to 1990 and their growth and the projections for the planning years. The average annual growth of LDV, MC, and HDV is 7.92%, 4.55% and 5.07% or in five years, growth is 46.38%, 24.90% and 28.02% respectively. Assuming that growth of transportation is a function of population and economic growth, then motor vehicle growth will follow this trend. Thus, it is reasonable to project the number of motor vehicles based on a five year historical average growth rates for each classification.

Table 2. Motor Vehicles Population of Surabaya : Historical Data & Projection

Years	LDV		MC		HDV	
	Number	growth/yr	Number	growth/yr	Number	growth/yr
1985	69,629	-	290,650	-	43,740	-
1986	74,143	6.48%	297,801	2.46%	45,152	3.23%
1987	81,578	10.03%	312,421	4.91%	47,694	5.63%
1988	89,597	9.83%	324,833	3.97%	49,682	4.17%
1989	95,765	6.88%	337,447	3.88%	52,044	4.75%
1990	101,860	6.36%	362,800	7.51%	55,971	7.55%
1995	149,000		453,000		72,000	
2000	218,000		566,000		92,000	
2005	319,000		707,000		117,000	
2010	468,000		883,000		150,000	
2015	684,000		1,103,000		193,000	

Average growth of Light Duty Vehicles: 7.92% per year or 46.38% per 5 years
Average growth of Motor Cycle: 4.55% per year or 24.90% per 5 years
Average growth of Heavy Duty Vehicles: 5.07% per year or 28.02% per 5 years
Source: [BPS, 1991] data compiled and projected by author.

There were 39,801 becaks (tricycle) registered in 1990 and the numbers remained constant from 1987 to 1990 because of the government prohibition of additional becaks. A other usual mode is the bicycle. However, there is no recorded data on bicycles in this city.

There is no urban rail transit system in Surabaya. The main public transport inside the city is bus and paratransit such as bemos, microlets and taxis. Table 3 is the record number of buses and ridership and percentage of user from 1987 to 1990. The percentage of people using public transport can be calculated by Equation (1):

$$P = 100.r/(365.s.p.t) \qquad (1)$$

where,

P = percentage of public transport user (%)
r = ridership of public transport (person per years)
s = percentage of population that can doing trip every day (%).
p = number of population of that year (person).
t = average number of trip per person per day.

Table 3. Public Buses & its Usage in Surabaya: Historical Data & Projection

Years	Public Buses		Ridership 10^ 6	Percentage Buses User
	number	growth/yr		
1985	2376	-	-	-
1986	2403	1.14%	-	-
1987	2483	3.33%	120.78	11.39%
1988	2701	8.78%	110.90	10.21%
1989	2799	3.63%	119.58	10.74%
1990	2850	1.82%	123.95	10.87%
1995	3424	3.74%	130.93	10.15%
2000	4100		138.30	9.48%
2005	4900		146.08	8.85%
2010	5900		154.31	8.26%
2015	7100		162.99	7.72%

Avarage growth of public buses: 3.74% per year or 20.15% per 5 years
Source: [BPS, 1991], data compiled and projected by author

The percentage of bus users in Table 3 is based on the assumption that 60% of the population make 2 trips every day. The number of bus riderships per year is only counted in the terminal. It does not include people who ride the bus from outside the terminal. Thus, the percentage of bus users should be much higher than the number in Table 3. From observation in the city, the percentage of bus users can reach 40% of the population.

Assuming that an average vehicle makes 4 trips per day at approximately 10 km per trip for MC and LDV and 16 km for HDV, then the average distance travel ad per vehicle, VkmT, will be 14,600 and 58,400 km/vehicle per year. Percentage engine type of vehicle which is classified by engine type is shown in Table 4. The data is based on road vehicle registration in 1990.

Tabel 4. Percentage of Diesel and Gasoline Vehicles in Surabaya

Vehicle Class	Engine	Percentage
LDV	diesel	8.82%
	gasoline	91.18%
HDV	diesel	38,46%
	gasoline	61.54%
MC	gasoline	100.00%

Base on 1990 on road data; data compiled by author
Source: IIEC, 1991

IV. MOTOR VEHICLE EMISSION FACTORS AND INVENTORY

No data is available in Indonesia on emission factors, thus CO and NOx emission factors from US vehicles-MOBILE4 (Faiz, 1992) is used in this paper. Table 5 shows the emission factors (gram/km) for new vehicles.

Assume that 20% of all vehicles are new and 60% are 1-5 years and the remaining 20% is more than 5 years. Because there is no data on emission factors for old vehicles, assume that engine 1-5 years old have deterioration factor of 30% and engines more than 5 years have a deterioration factor of 50%. Based on this assumption, the estimate emission should be multiplied by 1.28 (=0.2x1+0.6x1.3+0.2x1.5).

Table 5. Motor Vehicle Emission Factor

Engine type	Vehicle class	Emission control	emission (gram/km) CO	NOx
Gasoline	LDV	uncontroled	40.62	2.14
		non catalyst control	23.8	1.97
		oxidation catalyst	12.98	1.59
		early 3 way catalyst	3.12	0.52
		advance 3 way catalyst	3.14	0.5
	MC	uncontroled	23.8	0.19
		non catalytic control	13.2	0.53
	HDV	uncontroled	143.14	5.71
		moderate control	40.23	3.45
		advance control	8.43	2.64
Diesel	LDV	uncontroled	1.61	1.45
		moderate control	0.98	1.04
		advance control	0.98	0.76
	HDV	uncontroled	8.54	16.79
		moderate control	8.28	11.9
		advance control	6.8	5.01

Source: [Faiz, 1992], compiled from projected US MOBILE IV

The estimate CO and NOx emission for LDV, MC and HDV can be calculated multiplying the number of vehicles in each class by appropiate VkmT and the gram/km CO or NOx emission factors or :

Em = 14,600 x 1.28 x N x e x 10-6 for MC or LDV (2a)

Em = 58,400 x 1.28 x N x e x 10-6 for HDV (2b)

where,

Em = estimate CO or NOx emission of the appropiate classification of vehicles in the appropiate year (tonnes/year)

N = number of vehicles of the appropiate classification of vehicles in the appropiate year (vehicles)

e = NOx or CO emission factor of the appropiate classification of vehicles (gram/km)

Table 6 shows the estimate CO and NOx emission of vehicles base on equation 2a and 2b. Increasing number of vehicles have direct effect on increasing the emission from vehicles. The CO and NOx emission from HDV are more significant than others. Reducing HDV's emission will have greater effect than reducing from other class of vehicles.

Table 6. CO and NOx Motor Vehicle Emission Current Trend Projection in Surabaya (Tonnes/Year)

Years	Carbon Monoxide						
	LDV (000)		MC (000)		HDV (000)		Total (000)
1990	71	11.5%	161	26.3%	382	62.2%	614
1995	104	13.0%	202	25.4%	489	61.6%	795
2000	152	14.7%	252	24.4%	627	60.8%	1.030
2005	222	16.6%	314	23.5%	802	59.9%	1,339
2010	325	18.6%	393	22.5%	1,027	58.9%	1,745
2015	476	20.8%	491	21.5%	1,315	57.6%	2,281
Years	Carbon Monoxide						
	LDV (000)		MC (000)		HDV (000)		Total (000)
1990	4	8.4%	1	2.7%	42	88.8%	47
1995	6	9.5%	2	2.6%	53	87.8%	61
2000	8	10.8%	2	2.5%	68	86.7%	79
2005	12	21.1%	3	2.4%	88	85.4%	102
2010	18	13.6%	3	2.4%	112	84.0%	133
2015	27	15.3%	4	2.3%	143	82.5%	174

Source: compiled and projected by author

V. AMBIENT AIR QUALITY CHARACTERISTICS AND PROJECTIONS

Indonesian ambient air quality standards for CO and NOx are 20 ppm (22.90 mg/m3) in 8 hours and 0.05 ppm (0.09 mg/m3) in 24 hours, respectively. WHO standards are more stringent, 10 mg/m3 in 8 hours and 0.15 mg/m3 in 24 hours for CO and NOx, respectively.

There is no continuous air quality monitoring in Surabaya. The only monitoring done is for education and research purposes in several days during some years. Using that data, an IIEC study in 1991 showed that the maximum average air pollution in Surabaya from 1980 to 1990 are 6.45 ppm and 0.143 ppm for CO and NOx respectively. These numbers are used as 1990 base year data for projecting ambient air quality.

There is no air quality model for Surabaya city which can relate motor vehicle emission with ambient air quality. Thus, a direct relationship is used for predicting and projecting the ambient air quality. For example, the total CO motor vehicle emission for 1990 and 2015 are 175,000 tonnes/year and 693,000 tonnes/year respectively and the ambient air pollution for 1990 (base year) is 6.45 ppm. The estimated CO ambient air quality in 1995 will be 6.45 x 693,000 / 175,000 = 25.54 ppm or 25.54 / 20 x 100% = 127.71% from standard. This means there will be a CO air pollution problem in 2015. It is necessary to reduce at least 27.71% of 693,000 tonnes/years CO pollution level to achieve ambient air quality standard.

Table 7 shows the projection of current trends for CO and NOx ambient air quality in the planning years and the minimum reduction needed to achieve the ambient air quality standard. Figure 1 and figure 2 show the motor vehicle emission trend according to the control condition. These figures are based on the assumption that there is a constant trend in the number of motor vehicles. If the trend continues, there will be a CO ambient air pollution problem in 2015 and there were NOx ambient air pollution problem in 1995. If the government implements moderate emission control, there will be no CO air quality problem in 2015. However, even if the government will enforce more stringent regulations that all motor vehicles have to have advanced emission control technology, there will still be a NOx air quality problem in 2010. Controlling motor vehicle emissions, reducing number of trips and number of motor vehicle usage are needed to solve the problem. Comprehensive and immediate measures must be taken, especially transportation emission reduction measures, to reduce vehicle emission.

The key institutions to implement this approach are the Trading and Industrial Department and Road Transportation Traffic Agency of Indonesia. The new vehicle emission standard can be included in standard specifications for new vehicles.

2. Inspection and maintenance (I/M) program

The inspection/maintenance program will help to identify old vehicles in which maladjustments or other mechanical problems are causing higher emissions than necessary and control new vehicles which has emission

Table 7. Motor Vehicle Emission & Ambient Air Quality Current Trend Projection

Years	Motor vehicle emission		Ambient Air Quality Characteristics: projected current trend		Ambient Air Quality Characteristics: percentage of standard		Identify problem air pollutants		Reduction motor vehicle emission to achieve the standard			
	CO tonnes/yr	NOx tonnes/yr	CO mg/m^3	NOx mg/m^3	CO	NOx	CO	NOx	CO	NOx	CO tonnes/yr	NOx tonner/yr
1990	614400	47000	-	-	30.3%	98.0%	ok	ok				
1995	794600	60800	9	0.12	39.1%	126.9%	ok	not ok	-	26.9%	-	16,350
2000	1030000	78900	12	0.15	50.7%	164.6%	ok	not ok	-	64.6%	-	50,900
2005	1338600	102500	15	0.20	65.9%	213.8%	ok	not ok	-	113.8%	-	116,600
2010	1744700	133400	20	0.26	85.9%	278.3%	ok	not ok	-	178.3%	-	237,800
2015	2281000	174000	26	0.34	112.3%	363.1%	not ok	not ok	12.3%	263.1%	280,900	457,700

Indonesian ambient air quality standard: CO = 22.90 mg/m3 in 8 hours, Nox = 0.09 mg/m3 in 24 hours
Historical monitoring data [source: IIEC, 1991], based on the maximum value of monitoring from 1980 to 1990 : CO = 6.930 mg/m3, NOx = 0.092 mg/m3.

VI. IMPLEMENTATION OF EMISSION REDUCTION MEASURES

The increase in number of motor vehicles has a strong effect on air pollution because the Ministry of Population and Environment (of Indonesia) reports that 75% of the emissions in the urban sector are caused by motor vehicles [IIEC, 1991]. Thus, transportation emission reduction will have a great affect on reducing ambient air pollution.

The transportation emission reduction measures for air quality improvement can be classified into four approaches:

1. more stringent new vehicle emission standards.
2. inspection and maintenance (I/M) program
3. transportation demand management program
4. other emission reduction measures

1. More stringent new vehicle emission standards.

New vehicles, before they are marketed, must have sample emission testing. Vehicle types which do not pass the new vehicle emission standard should be prohibited in the country. Setting more stringent new motor vehicle emission standards will lead to lower emission vehicles and in 10 or 20 years, all old generation vehicles will be replaced with new vehicles which have lower emission.

control equipment. Vehicle equipment will remain in place and operational.

To implement this program, the following measures are suggested :

a. Campaign directed forward existing vehicle improvement and maintenance program, through "on road" control of existing vehicle exhaust
b. Improve the existing yearly inspection of HDVs to include emission inspection.
c. Introduction of fuel conversion kit installations. The government should encourage credit facilities from the private sector for conversion kits, and maintain the wide fuel price differential (for example 50% of gasoline)

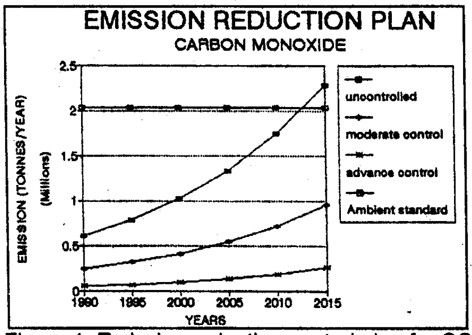

Figure 1. Emission reduction control plan for CO

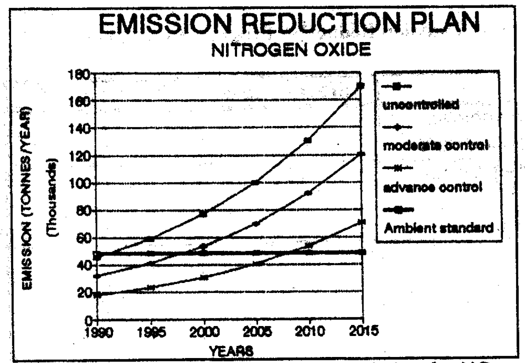

Figure 2. Emission reduction control plan for NOx

Police agency and Road Transportation Traffic Agency are key institution in implementing these measures.

3. Transportation demand management program

The transportation demand management (TDM) program directs to reduce the congestion level in the specific areas for a short term period (10 years). By reducing rush hour traffic by 20% and assuming that 30% of traffic come out during this period, LDV emission will be reduced by approximately 6%.

Assuming that in particular year the number of person-trips are constant, shifting car users to public transit users will reduce the number of cars. Decreasing the number of cars will reduce traffic congestion and LDV's emission. Table 8 shows the emission reduction of CO and NOx by shifting all car users to public transit user.

The TDM program can be classified into 5 category:

Table 8. Public Transit Emission Reduction

Public transit	Capacity (pax/hr-line)[1]	equivalent reducing car trip/day	emission reduction (tonnes/years)	
			CO	NOx
Bus mix traffic	10,000	2083	308900	16300
reserved lane	15,000	3125	463300	24400
exclusive lane	30,000	6250	926600	48800
LRT	36,000	7500	1112000	58600
MRT	70,000	14583	2162200	113900

Asumption: car occupancy 2 pax/car; 1 car travel 10 km/trip; 4 ruch hour, 12 busy hour (50% usage); all car user shift to public transport

[1]data source: [Armstrong-wright, 1986]

a. Public transit incentives, such as bus priority lanes, fare subsidy, and optimized for service demand. The purpose is to encourage people to use public transit instead of car or motor cycle.
b. Vehicle use restrictions, such as road pricing measures, travel zone restrictions, vehicle use/ schedule restrictions, and vehicle ownership restrictions
c. Trip reduction, such as ridership matching, HOV lanes, Parking charges/control, and employer trip reduction.
d. Encouraging usage of more energy efficient modes of transport such as bicycle, becak, and walking incentives.
e. Land use planning that minimize long work related trips between home and the work place such as develop more satellite cities, new town, planned neigbourhoods, and zoning & building codes [Birk & Zegas,1993, Tanaboriboon,1992].

Transportation department of City government with Police agency and Road Transportation Traffic Agency are key element to implement these measures.

4. Other emission reduction measures

a. Introduce and campaign CNG for public transport improvement program.
b. Limit growth of LDVs and MC by reducing quota import.
c. Provide the additional transportation demand as the city expands by intensive development of public transit option such as improved bus service and develop urban rail transit facilities.
d. Other policies which have no relation with transportation also can be used to reduce air pollution such as plantation, improve telecommunication, monitoring air pollution, environmental standard for industry, and information for public awareness.

To make an effective transportation emission reduction measure, several measures are recommended:

1. Intensive monitoring of air quality (air level and ground level) in several places should be done so that priority areas can be pinpointed in order to apply transportation demand management measures in these areas.
2. Introduce & promote the lead free gasoline and intensive campaign for cheaper prices than leaded fuel, by using tax subsidy change mechanisms, including differentials to the proposed local fuel taxes. There is no unleaded gasoline in Indonesia until now therefore this condition makes it difficult to introduce catalytic converters because acummulation of lead could destroy the conversion kit installations.
3. Public participation to solve the air pollution problem is needed.

Table 9 shows effectiveness and priority of these measures in Surabaya. The effective measures will reduce a lot of emissions with small cost. Some measures which should be done before the others will have more priority, and some measures need a lot of budget and time to implement it.

Table 9. Implementation Transportation & Air Quality Emission Reduction Program in Surabaya

Category	Measures	Effectiveness	Priority
Vehicle emission standard	introduce standard of emission new vehicles	1	A
	more stringent new vehicle emissionstandard	1	B
I/M program	campaign inspection & maintenance program	2	A
	improvement of HDV inspection	1	A
	introduce fuel conversion kit instalations	2	B
Transportation Demand Management	Public Transit Incentives:		
	Bus Priority Lanes	3	A
	Fare Subsidy	3	B
	Optimized for Service Demand	1	A
	Vehicle Use Restrictions:		
	Road Pricing Measures	4	C
	Travel Zone Restrictions	3	A
	Vehicle Use/Schedule Restrictions	4	B
	Vehicle Ownership Restrictions	2	B
	Trip Reduction:		
	Rideshare Matching	4	B
	HOV Lanes	4	C
	Parking Charges	2	A
	Telecommuting	2	B
	Employer Trip Reduction	1	A
	Becak/Bicycling/Walking Incentives	1	A
	Land Use Measures:		
	satelite town	1	C
	new town	1	C
	planned neighbourhoods	1	B
	zoning & building code	2	B
Other	introduce & campaign CNG bus	3	B
	introduce electric rail transit	1	C
	Plantation (green city program)	1	A
	continuous monitoring air quality	1	A
	introduce lead free gasoline	1	A
	unlead gasoline subsidy	1	B
	public awareness program	1	A

Key of Priority :
A = implement as soon as possible (short term)
B = implement before 2005 (medium term)
C = implement before 2015 (long term)

Key of efectiveness :
1 = most effective
2 = significant effective
3 = moderate effective
4 = uncertain, but expected small

VII. CONCLUSION

High growth rate in both population and economic activity has resulted in the increase of the number of motor vehicles which has lead to congestion and decreasing air quality in Surabaya. By projecting CO and NOx emission from motor vehicles, ambient air quality in 10 and 20 planning years are estimated and it can be concluded that, transportation and air quality policy are needed to maintain the sustainable development of Surabaya. Controlling motor vehicle emissions, reducing number of trips and number of motor vehicle usage are needed to solve the problem. Comprehensive and immediate measures must be taken, especially transportation emission reduction measures, to reduce vehicle emission.

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