【Article】

Evaluating the Effects of a New Vehicle Emission Standard on Urban Air Quality in Jakarta City

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Abstract

This paper describes an initial analysis to evaluate the effects of a new vehicle emission standard "Decree of The State Minister of Environment of Republic Indonesia No 141 Year 2003" on the ambient air quality in Jakarta City. The decree is enacted to reduce emission loads from mobile sources. This new emission standard will be applied step by step: to new type/new model that launched in 2005 from January 2005, to four-stroke motor cycle (current model that still produced since several years before) from July 2006 and to all models from January 2007. Current and future emission loads are estimated with respect to major roads in the center of Jakarta city. It is found that in the long term, implementation of the new vehicle emission standard will significantly reduce emission loads from gasoline-type vehicles. However, the new standard seems not effective to diesel-type vehicles.

Key Words: emission factor, Jakarta City, mobile sources, new emission standard

1. Introduction

In Indonesia, a new emission standard, "Decree of The State Minister of Environment of Republic Indonesia No 141 Year 2003" enacted in 2003, for new types of vehicles put into effect with the start of 2005. This new standard replaced the vehicle emissions standard that was introduced in 1993. There are four underlying causes behind this change: (1) rising public concern about cleaner air, and increased demand for a better life, (2) recent improvement in motor vehicle engine technology, (3) increasing vehicle fleet size, and (4) technical inefficiency of the emission testing adopted since 1993. In line with the standard of EURO II, enforcement of the new emission standard is divided into three phases.

Starting from January 1, 2005, the new standard has been applying to new types and new models that launched in 2005, but for the existing models manufactured in the same year, the previous emission standard is applied. From July 1, 2006, the new standard will be applied to four-stroke motorcycles, and lastly from January 1, 2007, all the existing and new models will be added in the list of emission standards.

In this study, we attempt to evaluate the prospective improvement in urban air quality under the implementation of the new vehicle emission standard. To do so, we use a dynamic model to estimate the reduction of emission loads. The analysis covers the mobile sources along major roads in the central area of Jakarta City.

2. Framework and Research Methodology

Pollution level produced by a vehicle is influenced by a number of factors. Engine technologies and emissions control devices such as catalytic converter are the importance factors. Related to the engine and emission control devices, the maintenance is an important factor. Fuel type and its quality affect level of emissions. As well, emissions level is also influenced by the driving cycles. As cars in heavy traffic have to stop and run repeatedly, the emission levels are clearly higher than the cars in free flow conditions. Factors influencing the emission levels from vehicles are summarized in Figure 1.

Reducing vehicle emissions requires a comprehensive strategy. Generally, a motor vehicle emission control program aims to reduce emissions to a level necessary to achieve improved environmental conditions. To address emissions from mobile sources, an integrated approach is needed. Because some of the measures can only be effective if enforced along with other measures. This is especially true for the imposition of tighter emission standards along with the imposition of stricter standard for cleaner fuels. Strategies shown in Figure 2 are not in sequence order, but should be applied simultaneously.

Imposing tighter vehicle emission standards does not usually result in additional direct cost for governments. Usually, implementation costs fully end in vehicle owners. The majority of the governments in Asia, including Indonesia, have adopted the Euro emission standards for gasoline and diesel vehicles. There are two immediate advantages of this. Firstly, Asian governments can make use of the experiences of the European countries, which have been implementing the Euro emissions standards for a long time. Secondly, use of similar standards across Asia has great advantages for the auto industry.

As newly produced vehicle standards are tightened, standards for vehicles already in use should also be tightened. These standards form the basis for routine vehicle emission inspection carried out as a part

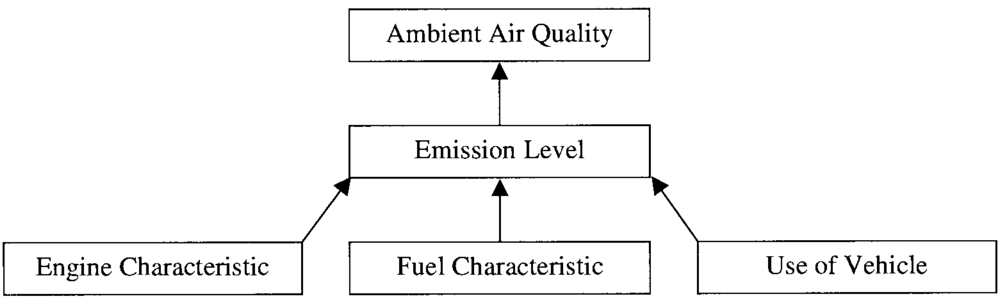

Figure 1. Factors influencing levels of vehicle emissions (ADB, 2003).

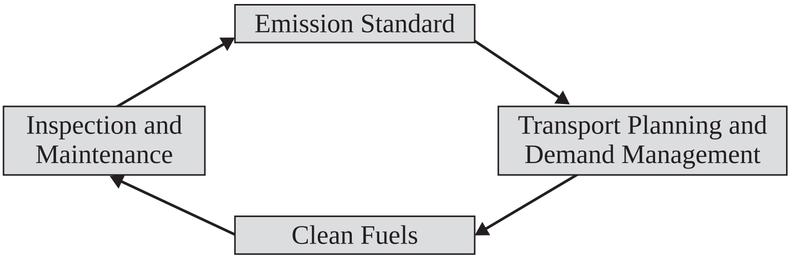

Figure 2. Elements of a comprehensive vehicle pollution control strategy (ADB, 2003).

of the inspection and maintenance (I/M) program. Criteria pollutant which should be regulated for in-use vehicles are Particulate Matter (PM) smoke and Nitrogen Oxides (NO_x) for diesel-fuelled vehicles, Carbon Monoxide (CO), Hydrocarbons (HC), and NO_x for gasoline-fuelled vehicles, and CO, HC and smoke for two and three wheelers.

In this study, we deal with pre-implementation period (before 2005) and full-implementation period (after 2007). Here, future emission loads are estimated based on the following two scenarios:

(a) Scenario I: a case without any policy interventions or an uncontrolled case

(b) Scenario II: a case with interventions by a new emission standard or a controlled case

Target pollutants are NO_x, PM, CO, Sulfur Dioxide (SO_2) and HC. Estimations are conducted with respect to the central area of Jakarta City, which extends of 10 km in the east-west direction and 12 km in the south-north direction. The study area is divided into thirty 2×2 km square grids (see Figure 3).

This study focuses on available secondary data for vehicle population and its compositions. Jakarta City is selected as the case study area because of the availability of necessary data. Secondary data sources for this study include all the data from previous relevant studies, traffic count surveys by governmental agencies for major roads in the case study area, future planning and other future relevant policies by governmental agencies that cover fuel quality improvement, future road development and control of vehicles ownership. This study will be conducted step by step as shown below.

1) To calculate emission load inventory from the existing motor vehicles.
2) To predict future emission loads for each vehicle category. Scenarios for emission calculation depend on the implementation of options for vehicles emissions control strategies (vehicles standard, technology and improvement in fuel consumption).
3) To evaluate the emission reduction by comparing the future emission loads from that in current conditions. The above-mentioned two scenarios are applied, i.e., an uncontrolled case and a controlled case.

Emission load inventory is calculated for the existing mobile sources in reference year (y). Total current emission load from all the sources use the following equations.

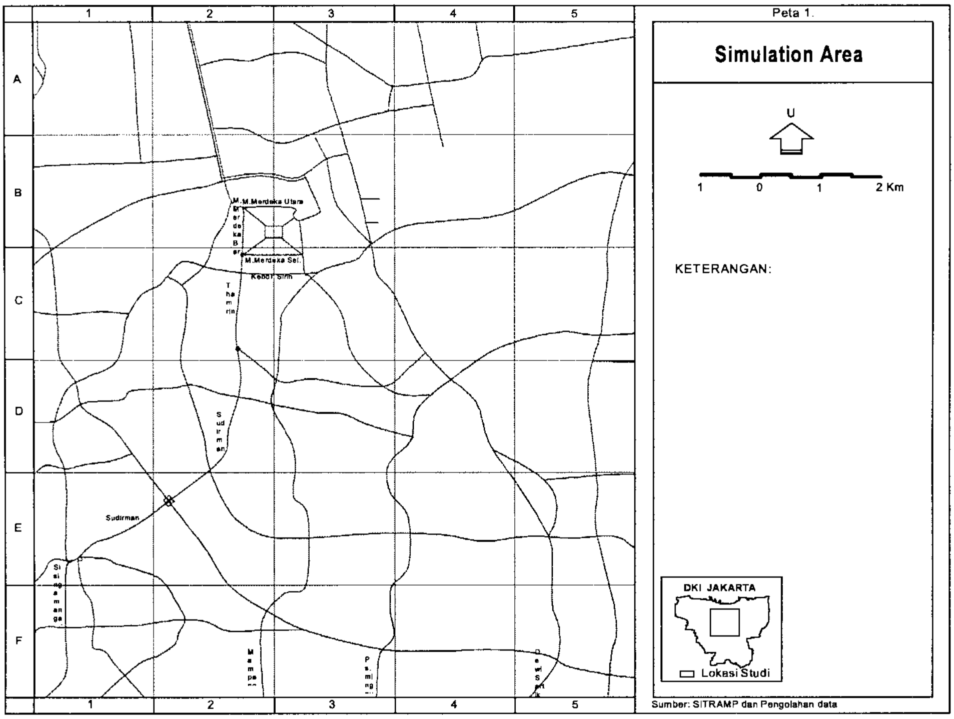

Figure 3. Simulation area and grid system (Nugroho et al., 2004).

$$E_{load} = \text{Vehicle Activity (VKT)} \times \text{Emission Factor} \qquad (1)$$

$$\text{VKT} = \text{Traffic Volume} \times \text{Road Length} \qquad (2)$$

where,

E_{load} : Emission load from all vehicle categories,
Vehicle Activity : Running Kilometre (km/day),
Emission Factor : Emission factor from each vehicle category,
Traffic Volume : Traffic volume of road (veh/day), and
Road Length : Road length in each grid (km).

Equation (2) can be further expressed as follows:

$$\text{VKT}_{c,d,y} = \sum_{i=1}^{n} [\text{Traffic Volume}_{(c,i,d,y)} \times \text{Road Length}_{(i,d,y)}] \qquad (3)$$

where,

c : vehicle category,
i : road segment/major road name which is located in each grid,
d : grid, and
y : reference year

Calculation of current emission loads from mobile source ($E_{M(c),p,d,y}$) in all grids uses the following equations.

$$E_{M(c),p,d,y} = VKT_{c,d,y} \times EF_{c,p,y} \times 10^{-6} \quad (4)$$

$$E_{M(all),p,y} = \sum_{c=1}^{c=7} \sum_{d=1}^{d=30} E_{M(c),p,d,y} \quad (5)$$

where,

$E_{M(c),p,d,y}$: Emission loads from vehicle sources for vehicle category *c*, pollutant *p* in grid *d* and in the year *y* (ton/year),

$E_{M(all),p,y}$: Emission loads from all vehicle sources for all vehicle categories, pollutant *p* in all grids and in the year y (ton/year),

$EF_{c,p,y}$: Emission factor of vehicle category *c*, pollutant *p* and in the year *y* (gram/km),

p : Pollutants index (THC, CO, NO_x, SO_2 and PM_{10}),

c : Vehicles category, and

y : Estimated year index

Estimation of future vehicle kilometer traveled by all the vehicle categories in grid *d* uses the following equation.

$$VKT_{all,d,y} = \sum_{c=1}^{c=7} VKT_{c,d,y} \quad (6)$$

$$VKT_{all,d,t} = VKT_{all,d,y} \times (1 + r_{v,d(g)})^{(t-y)} \quad (7)$$

where,

$VKT_{c,d,y}$: Vehicle kilometer traveled by vehicle category *c* in grid *d* for reference year *y* (km/year),

$VKT_{all,d,y}$: Vehicle kilometer traveled by all vehicle categories in grid *d* for reference year *y* (km/year),

$VKT_{all,d,t}$: Vehicle kilometer traveled by all vehicle categories in grid *d* and future year *t* (km/year), and

$r_{v,d(g)}$: Traffic volume growth rate in grid *d* for all categories.

Emissions factor in the future year t includes the emissions factor for the used vehicle model year before 2005 (based on emissions factor for reference year *y*) and emissions indicated in the Ministry Decree 141/2003 for Euro II Vehicles (model year 2007). Composition of vehicle technology of Euro II and Non-Euro compliance is determined based on vehicle population estimation of Euro II and Non-Euro II vehicles in future year *t*. These fractions will be used to determine vehicle share in major roads for each category in each grid.

3. Data

Secondary data of motor vehicle population in Jakarta area were obtained from the State Police Agency in the Jakarta Region (Metrojaya) from registered motor vehicles database. The jurisdiction area of Metrojaya also covers the neighboring areas, such as Bekasi, Tangerang and Depok. Based on vehicle registration files from 1995 to 2002, total number of registered motor vehicles in 2002 is around 5 million units, which correspond to 20.3% of motor vehicle population in Indonesia. Registered motor vehicles in Jakarta are dominated by motorcycles (58.9%), and passenger cars (28.7%). Detailed information is shown in Figure 4.

Another source of data for vehicle population information in Indonesia is sales records by Gaikindo (Indonesian Association of Automobile) and motorcycle sales records by AISI (Indonesian Association of Motorcycle Producer). Based on the Gaikindo sales records between 1976 and 2003, vehicle sales peaked in 1997 (before economic crisis) with 397,000 units. Vehicle sales in 2003 reached 354,000 units approximately. Based on vehicle sales records of Gaikindo, during 2000-2003 period, annual vehicle sales in Jabotabek reached 34.3%~37.4% of total vehicle sales in Indonesia. On the other hand, according to motorcycle sales records of AISI between 1985 and 2003, motorcycle sales peaked in 2003 with 2.5 million units. Similar to the vehicle sales, motorcycle sales decrease dramatically after the Asian economic crisis, however the sales assume an increasing trend after 2000. In the State Police of Metrojaya services area (Jakarta, Bekasi, Depok and Tangerang) between 1995 and 2003, percentage of motorcycles increased from 51.0% to 58.9%. Percentage of passenger cars in the State Police of Metrojaya area is around 27.2% in 2003 to 30.5% in 2000. Percentages of truck and bus populations tend to decrease since 1995. Shares of bus and truck populations are 10.3% and 10.6% respectively in 1995. However, in 2003, busses and trucks decreased to 5.6% and 8.3%, respectively (see Figure 5)

Vehicle sales based on fuel type in Jabotabek area from 2000 to 2003 are dominated by gasoline vehicles (Gaikindo sales records for Jabotabek). Light duty vehicle category leads the sales record with 92%

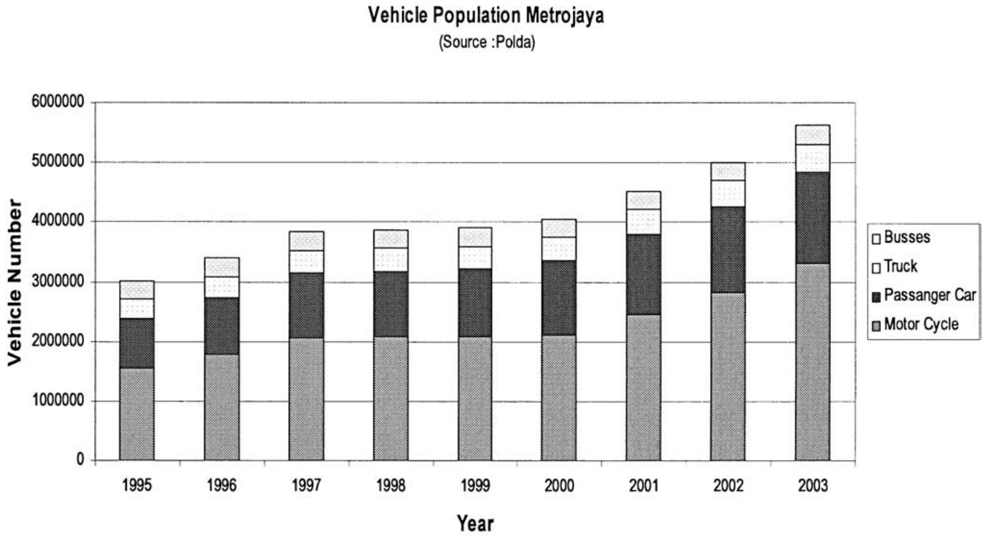

Figure 4. Vehicle registered in State Police Metrojaya.

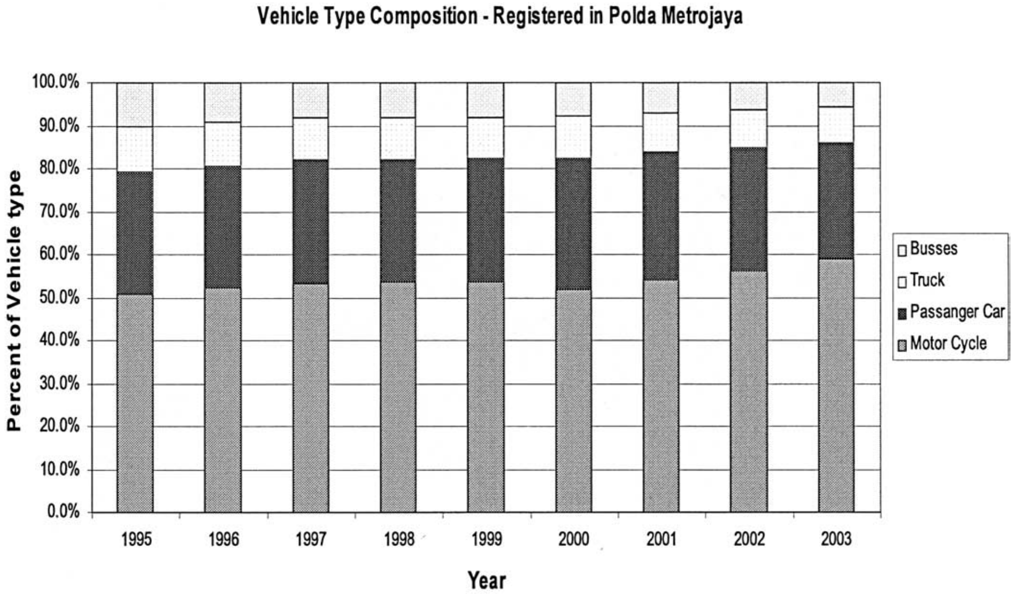

Figure 5. Vehicle composition registered in State Police Metrojaya.

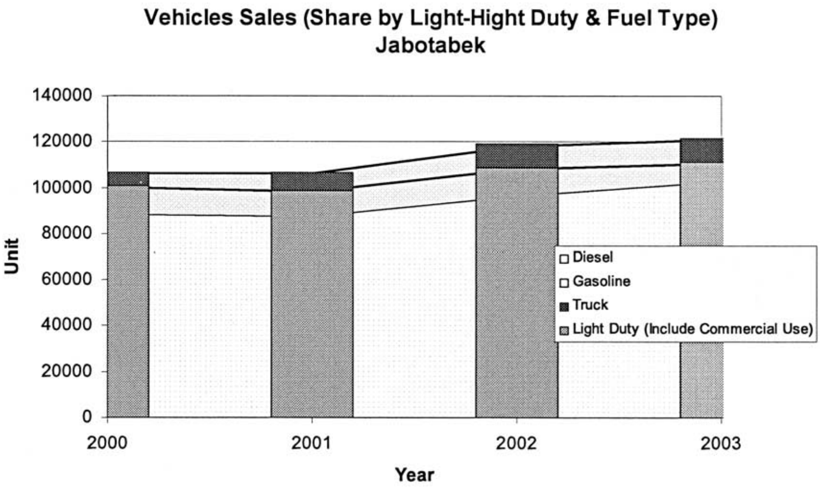

Figure 6. Vehicle share in Jabotabek by fuel and vehicle category (2000-2003).

of total sales and high duty vehicle sales only stays at 8%. According to the motorcycle sales records by AISI between 1990 and 2000, the four-stroke motorcycle ownership increased to 80% of total annual motorcycles sales from 1996 to 2000. As a result, this increase in four-stroke motorcycle ownership, approximately one-to-one ratio of two-stroke and four-stroke motorcycle ownership has changed to one-to-four ratio favoring four-cycle motorcycles (Figures 6 and 7).

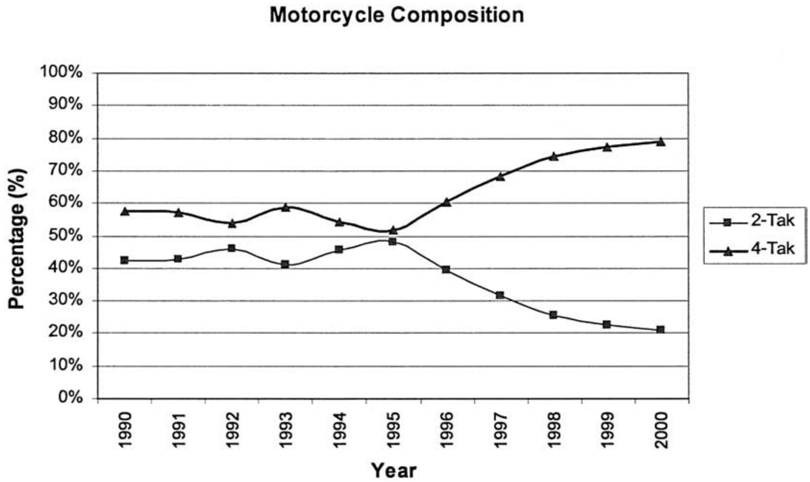

Figure 7. Two-stroke and four-stroke motorcycle composition.

To estimate future vehicle population in Jakarta area, we employed growth rates based on the State Police of Metrojaya data for each vehicle category (see Table 1). An important step in this study is to estimate the percentage of the vehicles that comply with the EURO II standards. As noted above, the Ministry Decree 141/2003 only applies to a limited number of vehicle categories in 2005, but it will cover all vehicle categories (e.g., passenger car, truck and bus) with the start of the full-implementation in 2007. For the small-sized vehicles, the decree applies to four-stroke current motorcycles starting from July 2006. Considering the previous trend in vehicle sales supplied by both Gaikindo and AISI, we assume that the sales of new types of vehicle will stay at 15% of total new vehicles sales between 2005 and 2007. We further assume only 15% of new vehicles sales during period 2005 to 2007 that comply with the EURO II standards. All vehicles in Indonesia after 2007 must comply with EURO II standards. According to this, future vehicles population and composition are estimated in Figures 8 to 12.

Table 1. Vehicles growth rate in Jabotabek area.

	State Police-Metro *	Gaikindo **	AISI ***
All (Incl MC)	7.6%		
Veh (Excl MC)	5.8%	4.6%	
MC	9.2%		NA
Pass Car	7.9%	3.4%	
Truck	5.5%	21.43%	
Busses	0.1%	19.17%	

Note: * :Vehicle registered 1995-2002, truck category includes pick-up, box, and truck.
** :Vehicle sales record 2000-2003
(Truck: Light truck, truck and heavy truck; Pick-up including light duty vehicle)
*** : Last year sales record (2003)
NA : Not available

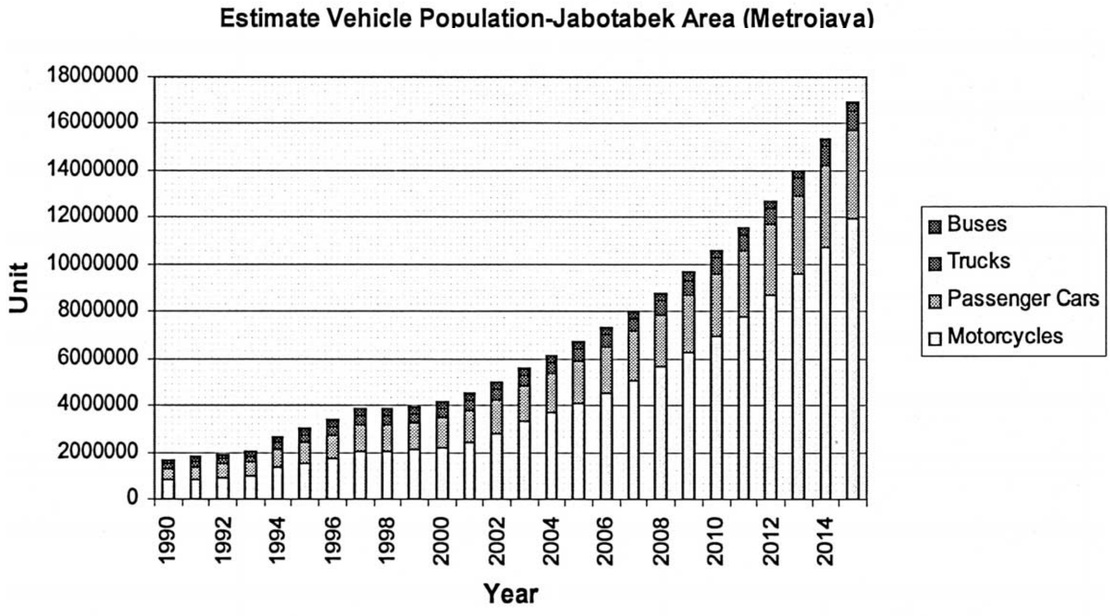

Figure 8. Estimation of vehicle population in Jabotabek.

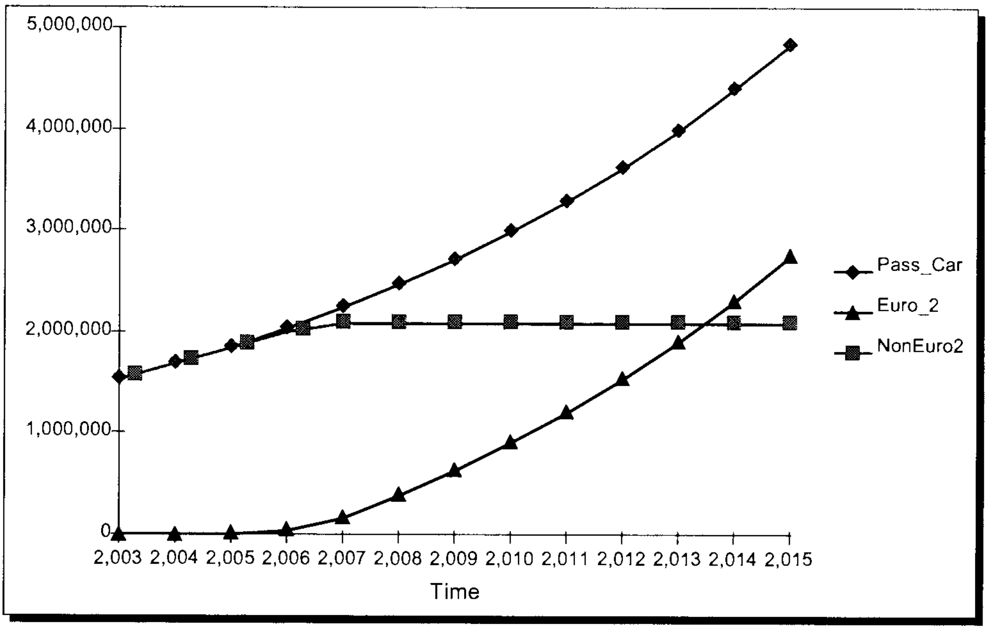

Figure 9. Estimation of passenger car population in Jabotabek.

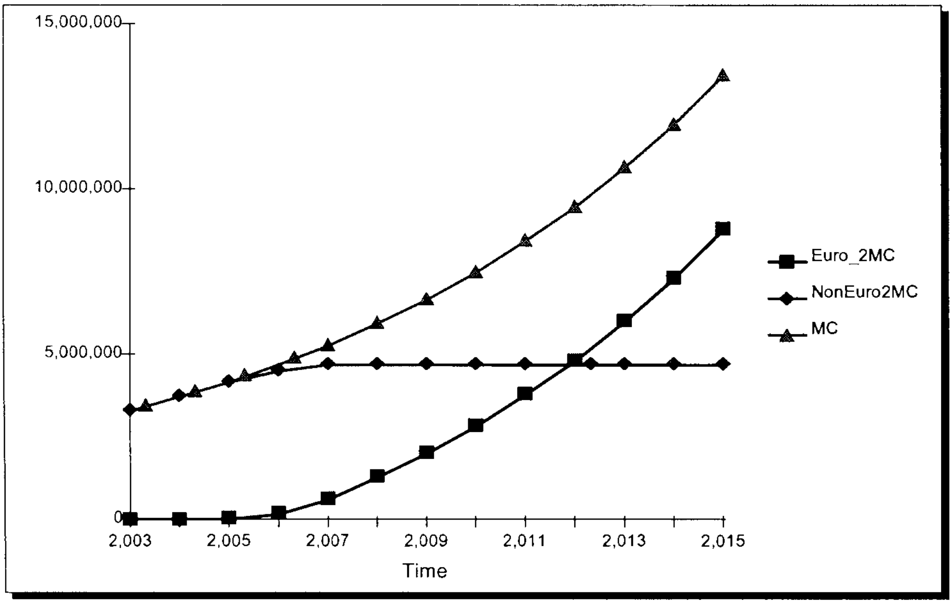

Figure 10. Estimation of motorcycle population in Jabotabek.

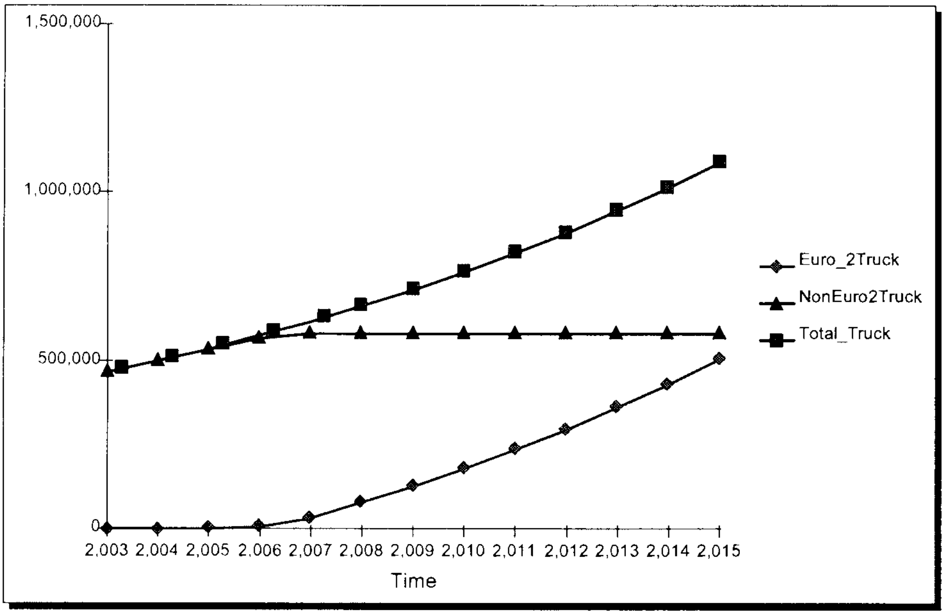

Figure 11. Estimation of truck population in Jabotabek.

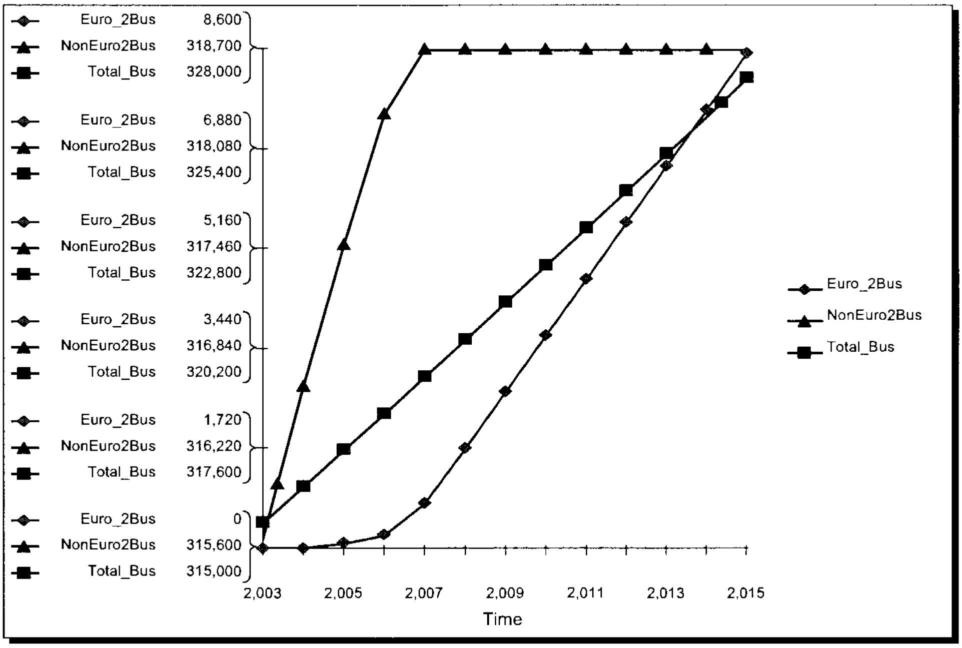

Figure 12. Estimation of bus population in Jabotabek.

Results of a large-scale person-trip survey, called SITRAMP, conducted by Japan International Cooperation Agency (JICA), indicate that the highest traffic in Jabotabek area is detected in the areas associated with high economic activity on the north-south axis between Jakarta and Bogor. This is followed by the east-west axis between Bekasi and Tangerang. The heaviest traffic volume is detected in the CBD area of Jakarta City along 'Jalan Sudirman' with 215,000 vehicles per day (JICA, 2001). Data on traffic volumes and vehicle compositions for several major roads in case study area are compiled from traffic counts conducted by the Local Transportation Agency (DISHUB, 2001). Traffic counts were conducted on weekdays in the peak hours of the morning, the noon and the afternoon. For the counts by the local transportation agency, vehicles were classified into eight categories: (1) Bajaj, Bemo and Toyoko; (2) sedan, jeep, and taxi etc.; (3) Mikrolet, APK, APB and KWK; (4) light truck and minibus; (5) bus; (6) pick-up, and small truck; (7) heavy truck and container; and (8) motorcycle. In this study, we further classify the "Bajaj-Bemo-Toyoko" and the "motorcycle" as a group under the "2/3 wheelers", the "sedan, jeep, and taxi etc." as "private passenger cars", the "mikrolet, APK, APB and KWK" as "commercial-passenger cars". Based on traffic count data collected by the local transportation agency, private passenger cars and motorcycles were dominantly observed in several major roads in Jakarta City (see Figures 13 and 14).

To calculate the emission factors, in this study we use two emission factor categories: (1) current vehicles and (2) new vehicles to represent vehicles that comply with EURO II standards (see Table 2). Calculation of emission loads from each vehicle category used different emission factors. Based on the traffic count data, vehicles were divided into seven categories: (1) motorcycles, (2) private passenger car, (3) commercial passenger Car, (4) light truck and minibus, (5) buss, (6) pick-up, and (7) truck and heavy truck.

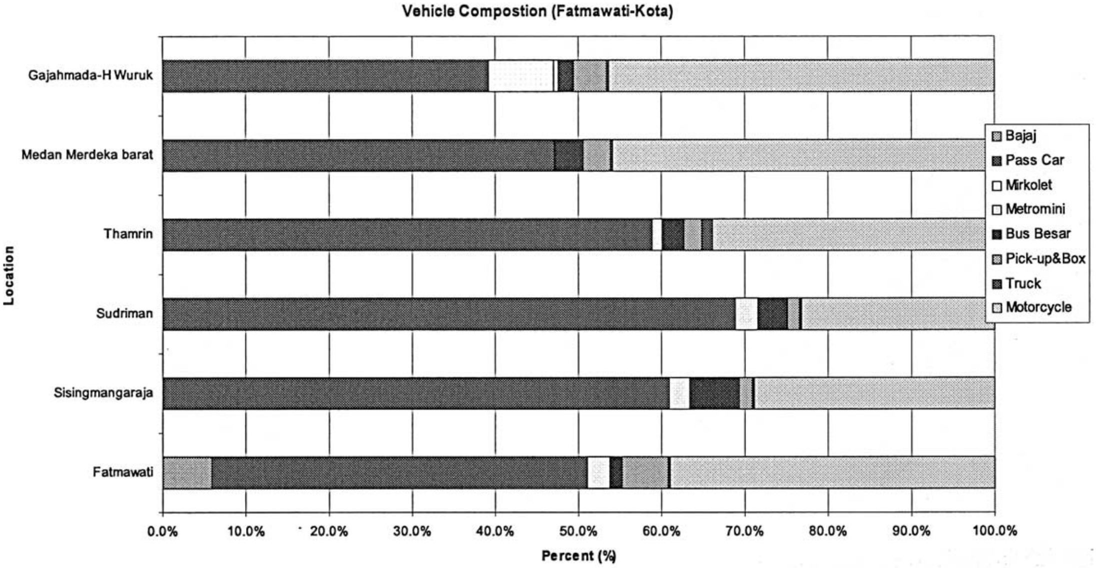

Figure 13. Vehicle composition Fatmawati-Kota (DISHUB, 2001).

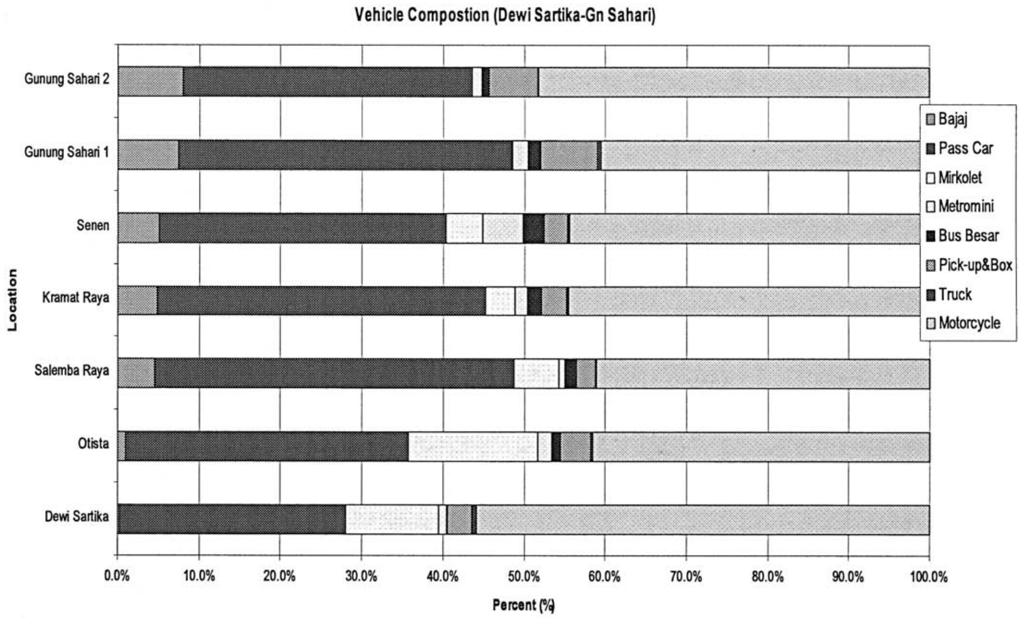

Figure 14. Vehicle composition Dewi Sartika-Gn Sahari (DISHUB, 2001).

Table 2. Emission factors.

a: Emission factors for uncontrolled vehicles (Non-Euro II)

Vehicle Category	Vehicle: Uncontrolled Before 2001*-Gasoline					Vehicle: Uncontrolled Before 2001*-Diesel				
	THC	CO	NO_x	PM_{10}	SO_2	THC	CO	NO_x	PM_{10}	SO_2
MC	12.11	34.51	0.404	0.205	0.015	—	—	—	—	—
PC-Private	8.375	59.546	2.138	0.081	0.031	1.253	2.414	1.148	0.435	0.538
PC-Commercial	8.375	59.546	2.138	0.081	0.031	1.253	2.414	1.148	0.435	0.538
Light Truck & Minibus	—	—	—	—	—	1.082	1.929	1.707	0.559	0.676
Busses	—	—	—	—	—	2.145	10.284	14.52	1.243	1.945
Pick-up	8.375	59.546	2.138	0.081	0.031	1.253	2.414	1.148	0.435	0.538
Truck& Heavy Truck	—	—	—	—	—	2.145	10.284	14.52	1.243	1.945

Source: JICA (1997), and Syahril et al. (2002)

b: Emission factors for controlled vehicles (Euro II)

Vehicle Category	MOE Decree 141/2003-Gasoline					MOE Decree 141/2003-Diesel				
	THC	CO	NO_x	PM_{10}	SO_2	THC	CO	NO_x	PM_{10}	SO_2
MC	1.2	5.5	0.3	0.205	0.008	—	—	—	—	—
PC-Private	0.45	2.2	0.05	0.012	0.012	0.63	1	0.07	0.08	0.012
PC-Commercial	0.45	2.2	0.05	0.012	0.012	0.63	1	0.07	0.08	0.012
Light Truck & Mini bus	—	—	—	—	—	0.63	1	0.07	0.08	0.085
Busses	—	—	—	—	—	0.438	7.703	2.811	0.298	0.246
Pick-up	0.45	2.2	0.05	0.012	0.012	0.63	1	0.07	0.08	0.012
Truck& Heavy Truck	—	—	—	—	—	0.438	7.703	2.811	0.298	0.246

Source: MOE (2003)

4. Emissions Loads

As noted above, the simulation area extends 10km on the east-west direction and 12km on the north-south direction. We divided the simulation area into thirty 2km × 2km square grids. In the simulation, only major road network is used (Figure 3).

In 2000, the estimated emission loads from the traffic on the major roads in the case study area is about 40,500 tons of Total Hydrocarbon (THC), 204,000 tons of Carbon Monoxide (CO), 6,400 ton/year for Nitrogen Oxide (NOx), 700 tons of Particulate Matter less than 10 micron (PM_{10}) and 300 tons of Sulfur Dioxide (SO_2). Private passenger cars are responsible for more than 50% of emission loads of THC, CO, NO_X and SO_2. Also private passenger car together with motorcycle group contribute more

Table 3. Emission loads and running kilometers of major roads in 2000.

Vehicle Category	Emissions (ton/year)					RK km/year
	THC	CO	NO_x	PM_{10}	SO_2	
MC	19,198.9	54,711.3	640.5	325.0	23.8	1,585,376,424.5
PC-Private	19,780.6	139,232.4	5,229.1	282.9	188.8	2,546,124,331.0
PC-Commercial	604.8	4,299.9	154.4	5.8	2.2	72,212,194.8
Light Truck & Minibus	105.6	203.4	96.7	36.6	45.3	84,237,945.2
Busses	99.5	191.6	91.1	34.5	42.7	79,372,390.0
Pick-up	820.0	5,641.0	233.4	20.2	18.6	122,646,527.7
Truck& Heavy Truck	46.1	88.7	42.2	16.0	19.8	36,755,195.7
Total Emissions	40,655.3	204,368.4	6,487.4	721.2	341.2	4,526,725,009.0

Source: Calculation

than 80% of the total emission loads of THC, CO, NO_x and PM_{10} and about 40% of the total emission loads of PM_{10}. Heavy-duty vehicles are responsible for most of the SO_2 emissions. The estimated emissions of all pollutants (THC, CO, NOx, PM_{10} and SO_2) and running kilometers are given in Table 3 and Figures 15 to 20.

To estimate the future emissions, we assume the following scenarios:

1) Estimated shares of vehicle population, which complies with EURO II standards, are given in Figures 21 to 24.
2) Composition of the used vehicles in the major roads with and without EURO II standards refers to the share of vehicle population as shown in Figures 21 to 24.
3) Future traffic volume: Data on traffic volumes for 2000 were compiled from traffic counts by the local transportation agency (DISHUB, 2001). Traffic volume for each major road in each grid is estimated by using equation (7). Traffic in the center of Jakarta City showed a stable growth rate over the past decade. From 1988 to present, traffic on the eastern area of the case study location has increased approximately six percent per year. On the other hand, the south and west segments of case study area have increased two percent per year (JICA, 2001). However, increase of sixteen-hour traffic (excluding motorcycles) on southern and western areas are lower than the eastern segment of case study area, this is mostly due to the tiny increases of traffic to/from the southern Jakarta.

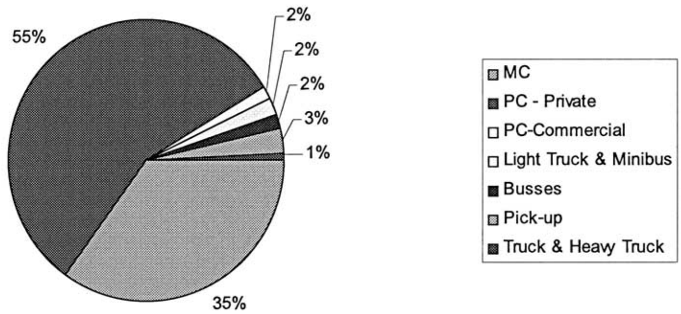

Figure 15. Running kilometer(km/year) share (2000).

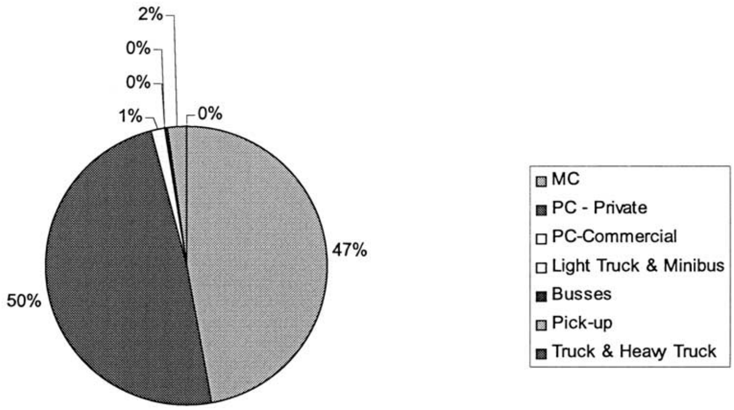

Figure 16. THC emission load share (2000).

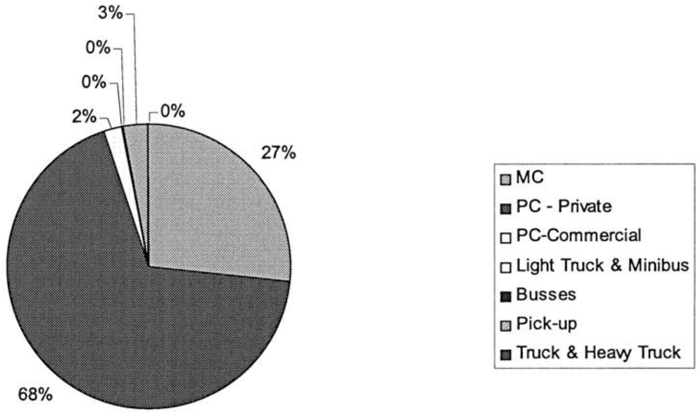

Figure 17. CO emission load share (2000).

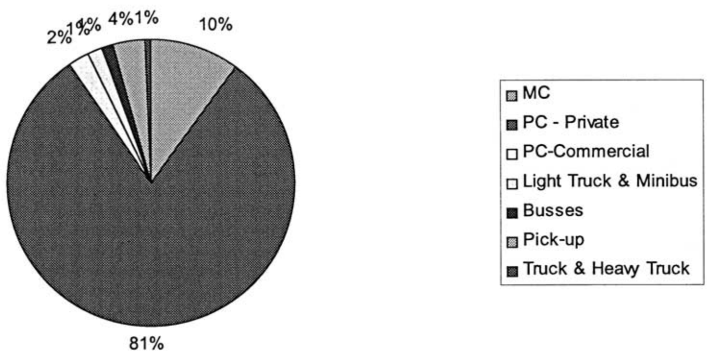

Figure 18. NO_x emission load share (2000).

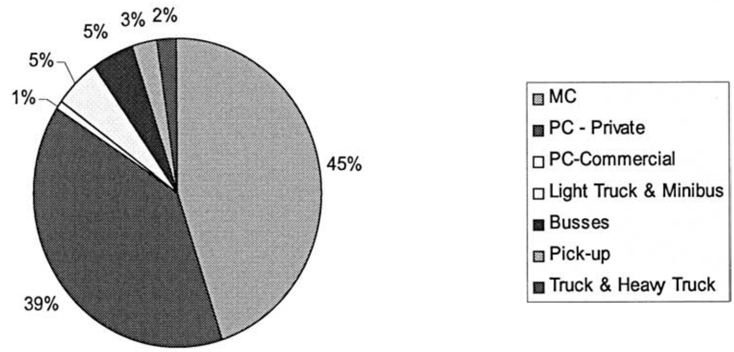

Figure 19. PM_{10} emission load share (2000).

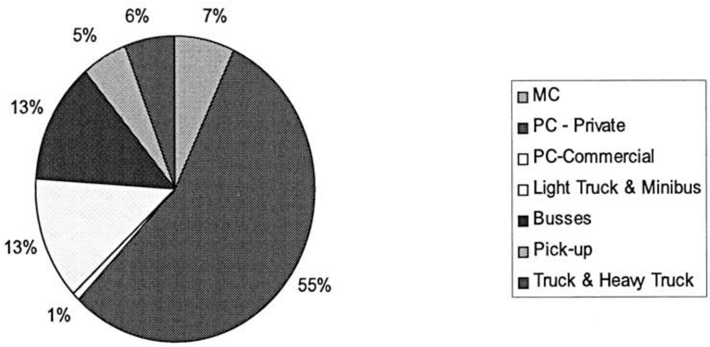

Figure 20. SO_2 emission load share (2000).

Time	Fraksi_Total_PC_Euro_2	Fraksi_Total_PC_Non_Euro_2
2,003	0.00	1.00
2,004	0.00	1.00
2,005	0.00701	0.993
2,006	0.0201	0.98
2,007	0.0717	0.928
2,008	0.157	0.843
2,009	0.234	0.766
2,010	0.304	0.696
2,011	0.367	0.633
2,012	0.425	0.575
2,013	0.478	0.522
2,014	0.525	0.475
2,015	0.569	0.431

Figure 21. Fraction of Euro II and Non Euro II for passenger cars (PC).

Time	Fraksi_Total_MC_Euro_2	Fraksi_Total_MC_Non_Euro_2
2,003	0.00	1.00
2,004	0.00	1.00
2,005	0.00849	0.992
2,006	0.0399	0.96
2,007	0.115	0.885
2,008	0.213	0.787
2,009	0.299	0.701
2,010	0.377	0.623
2,011	0.445	0.555
2,012	0.506	0.494
2,013	0.561	0.439
2,014	0.609	0.391
2,015	0.652	0.348

Figure 22. Fraction of Euro II and Non Euro II for motor cycles (MC).

Time	Fraksi_Total_Truck_Euro_2	Fraksi_Total_Truck_Non_Euro_2
2,003	0.00	1.00
2,004	0.00	1.00
2,005	0.00522	0.995
2,006	0.0151	0.985
2,007	0.054	0.946
2,008	0.119	0.881
2,009	0.179	0.821
2,010	0.235	0.765
2,011	0.288	0.712
2,012	0.336	0.664
2,013	0.382	0.618
2,014	0.424	0.576
2,015	0.464	0.536

Figure 23. Fraction of Euro II and Non Euro II for PC for trucks.

Time	raksi_Total_Busses_Euro_2	Fraksi_Total_Busses_Non_Euro_2
2,003	0.00	1.00
2,004	0.00	1.00
2,005	0.000225	1.00
2,006	0.000673	0.999
2,007	0.00239	0.998
2,008	0.00538	0.995
2,009	0.00836	0.992
2,010	0.0113	0.989
2,011	0.0143	0.986
2,012	0.0172	0.983
2,013	0.0202	0.98
2,014	0.0231	0.977
2,015	0.0261	0.974

Figure 24. Fraction of Euro II and Non Euro II for buses.

For future road network, we assume no change in the present composition of the major road network in the simulation area. Estimations of the future emissions are based on several assumptions:

(a) General vehicle composition on the roads in simulation area is stable over time.

(b) Light and heavy-duty vehicle composition in the vehicle population remains stable during the simulation period.

(c) Vehicle composition by fuel type is assumed equal to the current values and does not change during the simulation period.

(d) Between 2005-2007, the new vehicle share in the population, which complies with EURO II standards, is assumed to be 15% (this value is obtained from a reliable expert of car manufactures market leader in Indonesia); starting from 2007, we assume that all new vehicles comply with EURO II standards.

(e) We do not consider the traffic flow.

(f) We assume that fuel quality complies with EURO II standards.

(g) Emission factors used for estimating EURO II vehicle emissions loads are assumed equal to the values specified in the Ministry Decree 141/2003. On the other hand, we use different emission factors for current vehicles, which are supplied in Table 2.

We estimated the future emissions from vehicle sources based on the two scenarios. Estimation is carried out for the "uncontrolled" condition that means there is no policy interventions related to the implementation of Euro II standards and for the "control" condition where policy interventions by new regulations implemented with the schedule given above.

Based on the simulation results, emission loads under the "uncontrolled" condition will automatically increase for all the pollutants when compared with emission loads in 2000. However, the "control" situation reduces the emissions in 2015 for THC and CO when compared with emissions in 2000. Other pollutants (NOx, PM_{10} and SO_2) also increase significantly when compared to the levels in 2000. In the "control" scenario, emission loads will be reduced for both 2010 and 2015. The highest potential reduction is 30.9% from the "uncontrolled" to "controlled" conditions for THC parameter in 2010 (see Figure 25). In 2015, the highest potential reduction is 55.6% from the "uncontrolled" to "controlled" conditions

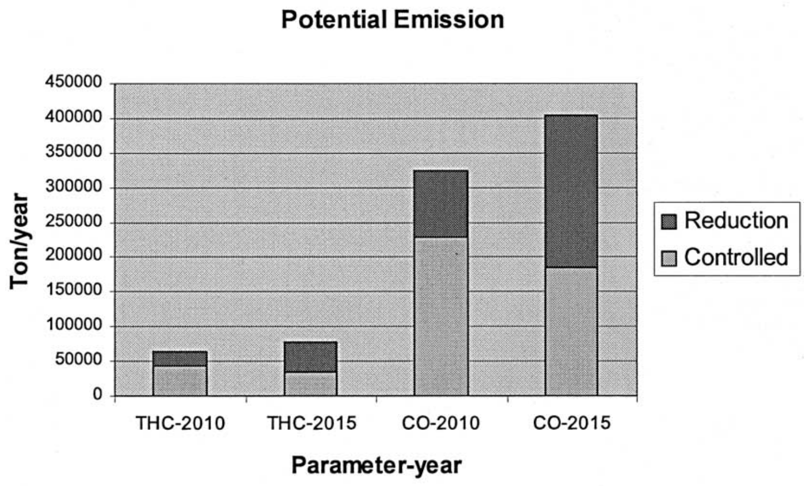

Figure 25. Potential emission reduction for parameter THC and CO.

for THC parameter. Based on the simulation results given in Table 4, in the long-term period (10 year), implementation of EURO II standards reduces emission loads significantly for THC (55.6%), CO (54.4%) and NO_x (43.6%). On the other hand, changing “uncontrolled” condition to “controlled” condition has no significant effect on the reduction of emissions of PM_{10} and SO_2 (see Figure 26).

These results might be caused by the dominant shares of passenger cars and motorcycles. High values of growth rate for passenger cars and motorcycles in Jabotabek areas will speed up composition shares of vehicles that comply with EURO II standards. In 2015, shares of motorcyles and passenger cars that comply with Euro II standards are higher than the shares of motorcycles and passenger cars that do not meet Euro II standards. This might have a significant effect on emission reduction from mobile sources.

Table 4. Future emission loads from automobiles sources.

Parameter	Emissions (ton/year)					Reduction	
	2000	2010		2015		2010	2015
		Uncontrolled	Controlled	Uncontrolled	Controlled		
THC	40,932	63,284	43,731	77,467	34,414	30.9%	55.6%
CO	202,960	324,151	227,963	403,464	83,955	29.7%	54.4%
NOx	6,925	12,742	9,830	15,818	8,925	22.9%	43.6%
PM_{10}	746	1,287	1,133	1,591	1,230	12.0%	22.7%
SO_2	391	820	682	1,018	695	16.7%	31.7%

Source: Calculation

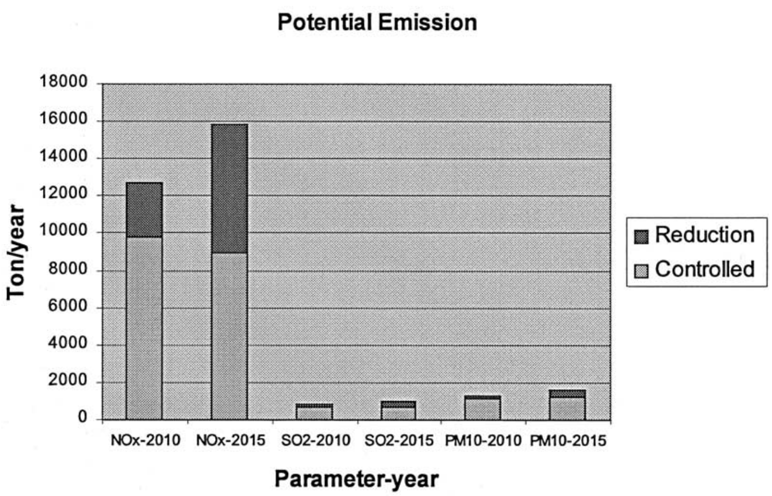

Figure 26. Potential emission reduction for parameter NO_x, PM_{10} and SO_2.

5. Conclusion and Future Research Issues

It is empirically confirmed that emission reduction policy by new vehicle emission standard regulation reduces emission loads from automobiles source significantly (THC 55.6%; CO 54.4% and NO_x 43.6%) in the long term. On the other hand, reduction of the emission loads of PM_{10} and SO_2 are lower (PM_{10} 22.7% and SO_2 31.7%).

To improve emission model estimation for Jakarta City, next research steps are needed: traffic assignment based on some sophisticated transportation assignment models, improvement of vehicle data (vehicle age, composition by technology and engine size), improvement of emission factors by considering vehicle age distribution, deterioration rate and meteorological data for Jakarta City.

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