Economic Valuation of Health Impacts due to Motor Vehicle Emissions: A Case of Metropolitan Jakarta

自動車排気ガスによる健康被害の経済的評価：ジャカルタ都市圏のケーススタディ

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1. Introduction

The Metropolitan Jakarta, as with many other megacities facing a serious problem of air pollution, is now recognized as the third dirtiest air polluted city in the world. The air pollution concentration has increased because of its rapid growth of motor vehicle owner, urbanization and industrialization, as well as economic growth. Moreover, the economic valuation of health impacts usually did not include in an observation because it was categorized as an external cost.

Cifuentes and Lester (1993) analyzed that most studies focused on identifying and quantifying the effects of air pollution, without trying to ascribe a dollar value to them. A few studies assigned monetary values to the effects. Interest in the area has increased rapidly in the 1990s, due to concern about global climate change and using market mechanism to improve environmental quality. Researchers, several groups or institutions have studied the economic value of air pollution in the Jakarta city. World Bank (1997) studied urban air quality assessment, health impacts of air pollution, abatement measures and its action plan for Jakarta in 1990. Their study emphasized the damage to the health of those who are exposed to air pollution. The population exposure was based on measured and calculated concentrations of air pollution through emission inventories and dispersion modeling. JICA-BAPEDAL (1997) monitored ambient air quality and actual emission data of stack gases continuously and by scientifically proven methods applied for the first time in Jakarta-Bekasi-Tangerang-Bekasi (known as Jabotabek area), in order to grasp present air condition, and to prepare an air pollution control strategy until 2010 in consideration of socio-economic condition. This study also included the formulation of more concrete action plan until 2000 by conducting investigation and analyses on the present status of socio-economy, nature and meteorology, air quality, and air pollution sources. Dollaris and Heuberger (2000) discussed air quality in Jakarta and health costs due to air pollution for the year 2000. Small and Kazimi (1995) focused on measuring the costs of regional (tropospheric) air pollution from motor vehicles for Los Angeles in 1992. Their methodology of damage estimation for mortality has been applied to this paper as comparison.

The purpose of this study is to investigate latest urban air pollution status, to estimate the economic valuation of health impacts from motor vehicles emissions for the Metropolitan Jakarta, for the year 2000, 2005, 2010 and 2020, to study the countermeasure and cost-benefit analysis (CBA) of motor vehicle emissions in order to provide the alternatives for reducing emission and improving air quality for Jakarta, and to select the best alternative for decision making based on the timetable of introduction. Hopefully, this result may help the government, public policy makers, researchers to make more rational decisions for the future.

2. Method

As illustrated in Figure 1, GDP per capita was a starting point of study for computing number of vehicle and motor vehicle emissions. GDP current prices were colleted from 1984 to 1999; population was from 1984 to 2000; Consumer Price Index (CPI) was from 1984 to 2000. Finally those values should be converted to GDP constant 1999 price in order to remove number of possible biases which could be happen in measuring economic well-being.

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Number of motor vehicles in future were estimated based on per capita GDP and the number of vehicle per capita. The prediction of future population data in Jakarta from 2000 to 2020 was collected officially from the Department of Population, the Republic of Indonesia. Finally using this relationship, future number of vehicles could be obtained.

Emission for motor vehicles in Jakarta was estimated using a vehicle kilometer traveled (VKT), assuming that the future VKT per car was the same as in 1990. Trends in increasing VKT and emission factor for each model were multiplied to find motor vehicle emissions. Emission factor value referred to a base case scenario of implemented exhaust emission regulation in the future.

Total air quality concentrations in Jakarta area were generally collected from represented air quality monitoring stations. Each emission disperses and transforms chemically to the atmosphere. The share of motor vehicle emissions influenced to total air quality was observed and analyzed referred to previous study. Future ambient pollutions each area in Jakarta was projected through statistical method and mostly based on best assumption since multiple regression analysis could not give decisive answers.

Total health effect estimates were based on dose-effect relationships. Regrettably, all the dose-relationship of air pollutants could not be computed in this research due to the fact that no empirical studies have been carried out so far specifically for other pollutants, except for PM_{10} and Lead. The economic value of health impacts could be calculated by multiplying the number of cases and costs for treatment.

Countermeasures are informed choices among technical and financial options available for achieving pollution reduction and improving air quality in the short-, mid- and long-term in Metropolitan Jakarta.

In order to compare alternative options and to evaluate an economic merit based on the countermeasures, the cost-benefit analysis (CBA) was used. Costs were estimated based on the actual costs borne directly by users (motor vehicle owners) for achieving its pollution reduction. Benefits were computed from reduction of health cost.

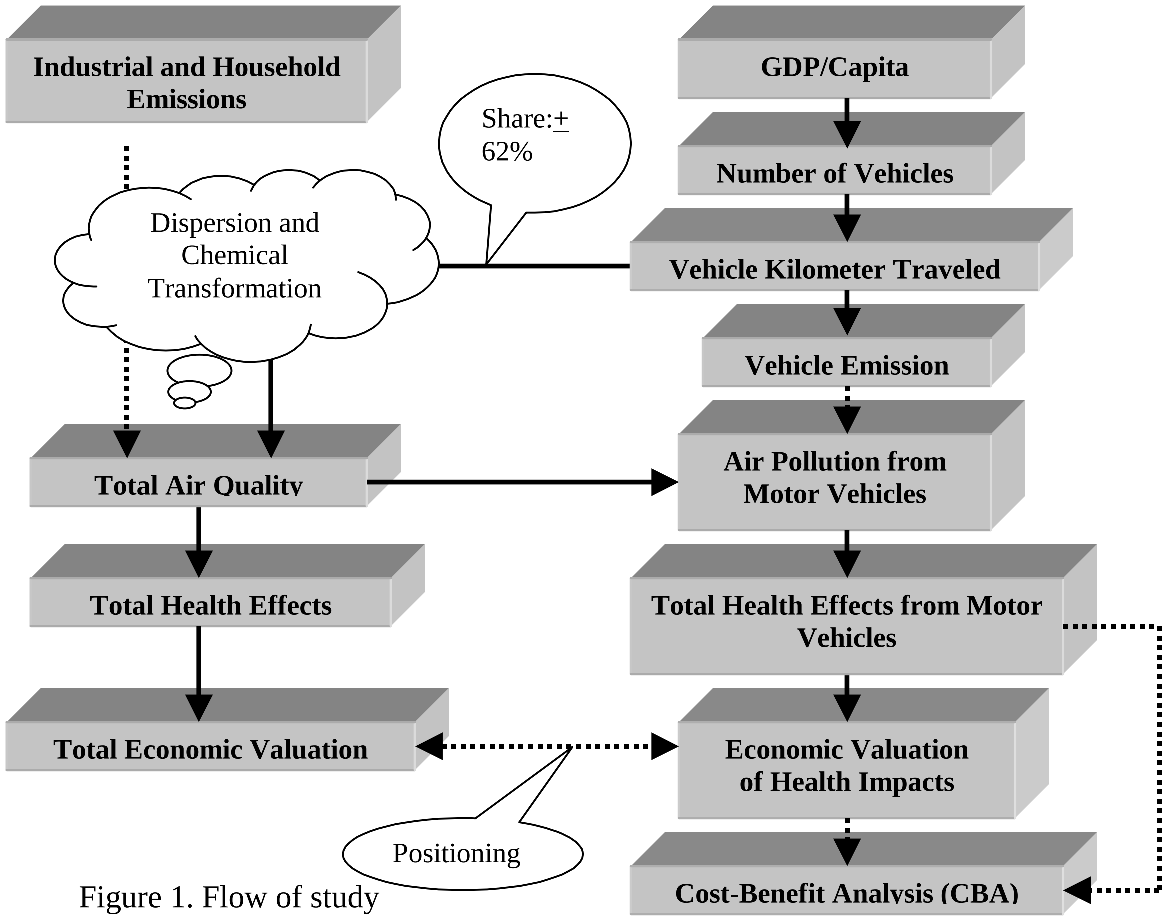

Figure 1. Flow of study

3. Estimation of Health Cost

By multiplying the projection of future VKT values and emission factors, total emission of each pollutant could be found. Scenarios of emission in Jakarta were estimated based on the existing exhaust emission regulation. The final result is shown in Table 1.

Table 1. Total estimated emission in Jakarta (ton/year)

Year	TSP	NOx	CO	HC	SOx	PM10
1990	6,373	31,543	500,635	73,765	3,596	3,632
2000	15,690	74,864	1,216,811	179,567	8,266	8,943
2005	23,559	115,683	1,743,049	256,540	13,073	13,412
2010	28,371	135,556	2,101,436	309,317	15,726	16,152
2020	37,840	185,769	2,807,170	413,251	20,941	21,544

Five methods have been used in order to compare its result. The general description can be seen in Table 2.

Table 2. Five methods of economic valuation of health impacts

No	Method	Remarks
1	World Bank – US Derived	Mortality and mordibity value use US data. Willingness to pay (WTGP) is about US$ 3 Million per statistical life (in 1990 price). WTP and other specific values should be converted by PPP.
2	World Bank - Indonesian Data	Mortality and mordibity value use Indonesian data. Value statistical life (VSL) has been used for mortality. VSL in 1990 was Rp. 23.45 Million.
3	OSTRO	Basically World Bank has adopted from Ostro's paper (1994) to estimated Jakarta, but it was improved by local researcher's paper.
4	WHO	Mainly WHO and OSTRO is similar approach. WHO's figure is higher than OSTRO's figure since WHO study includes short and long-term, but OSTRO is considered only short term.
5	Small & Kazimi	Small & kazimi's paper was applied to Los Angeles, US. WTP value was US$ 4.7 Million (1992 price). This value should be converted by PPP.

Finally, the total health cost of PM10 and Lead from motor vehicles emission in Jakarta are shown in Figure 2 and 3.

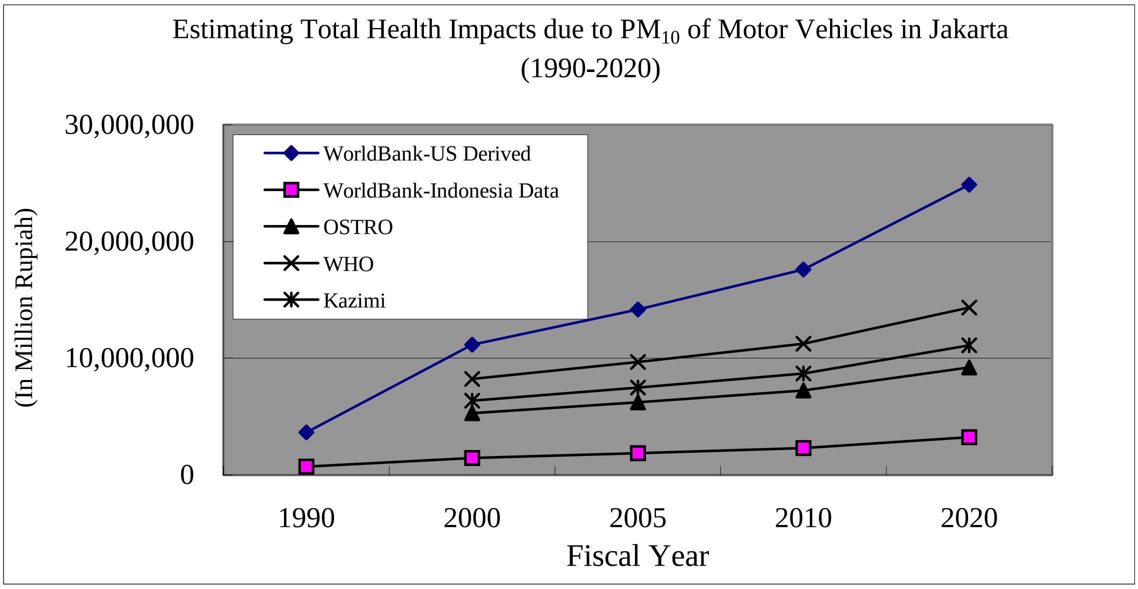

Figure 2. Total health cost from motor vehicle emission

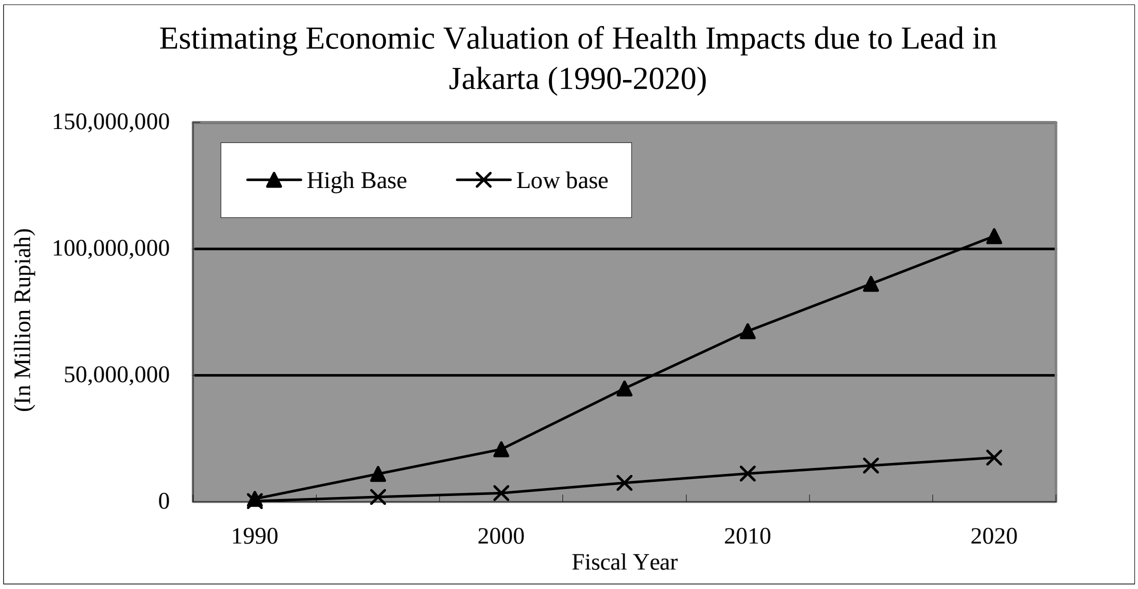

Figure 3. Health cost due to lead

It can be observed from Figure 2 and 3 that the estimated economic value of health impacts due to PM10 and lead increase rapidly comparing with the year 1990. Particle matter is the most dangerous pollutant and perhaps the most complicated. It is heterogeneous mix of solid or liquid compounds, including organic aerosols, sulphates, nitrates and metals, suspending in the atmosphere. Lead, in the form of Tetra Ethyl Lead (TEL), has traditionally been added to gasoline to increase the octane or to increase the resistance of a knocking in an automobile engine before 1985 production. In addition, lead acts as a lubricating agent that protects exhaust valve seats from excessive wear. But lead has major effect such as hypertension, coronary heart disease, and decline of intelligent quotient (IQ) in children (World Bank (1997)). Although many sources account for human exposure, approximately 90% of all lead emission into the atmosphere is due to the use of leaded gasoline (Salkever (1996), Schwartz (1996)). It seems that leaded gasoline should be phased out as soon as possible in order to decrease its health cost in the future.

The high and low scenarios for further estimation were also made based on the highest and the lowest value from the five methods of health cost, as shown in Table 3.

Table 3. Health cost per capita based on the high and low scenarios (in Rupiah, 2000 price)

Year	**PM10**		**Lead**	
	High base	**Low Base**	**High Base**	**Low Base**
2000	1,110,000	145,000	2,066,000	342,000
2005	1,304,000	170,000	4,120,000	682,000
2010	1,529,000	200,000	5,856,000	971,000
2020	2,002,000	262,000	8,460,000	1,405,000

The result indicates that the PM_{10} pollutant from motor vehicle emission in Jakarta increases rapidly six times from 3,632 ton/year in 1990 to 21,554 ton/year in 2020. Then, the economic value of health impacts due to PM_{10} of motor vehicles emissions is predicted to be Rp. 150,000 per capita in 2000 to Rp. 260,000 per capita (low base) in 2020, and from Rp. 1 million per capita in 2000 to Rp. 2 million per capita in 2020 (high base). GDP per capita is estimated to be Rp. 16 million in 2000 to Rp. 23 million in 2020. The health cost from total PM_{10} from all sources is Rp. 2.5 million per capita in 2000 to Rp. 4 million per capita (high base) in 2020. That means the health impacts per capita from PM_{10} (high base) were estimated around 17% in comparison with GDP per capita in 2020.

In case of leaded gasoline, its health cost is estimated to be Rp. 300,000 million to Rp. 117, 370 billion (low base), and it increases around one hundred times for the high case from Rp. 1,100 billion in 1990 to Rp. 100,000 billion in 2020 (assuming continual production of leaded gasoline up to 2020). The health cost per capita due to lead is predicted to be Rp.340,000 per capita to Rp. 1.4 million per capita (low base) and from Rp. 2 million per capita to Rp. 8.5 million per capita (high base).

4. Cost Benefit Analysis (CBA)

The basic concepts of CBA are based on the timetable of introduction shown in Figure 4. It can be explained that year 2001 become the starting point for calculation and all values are computed through future value and present value (discount rate) in order to compare and select the best alternative for finding a good decision-making.

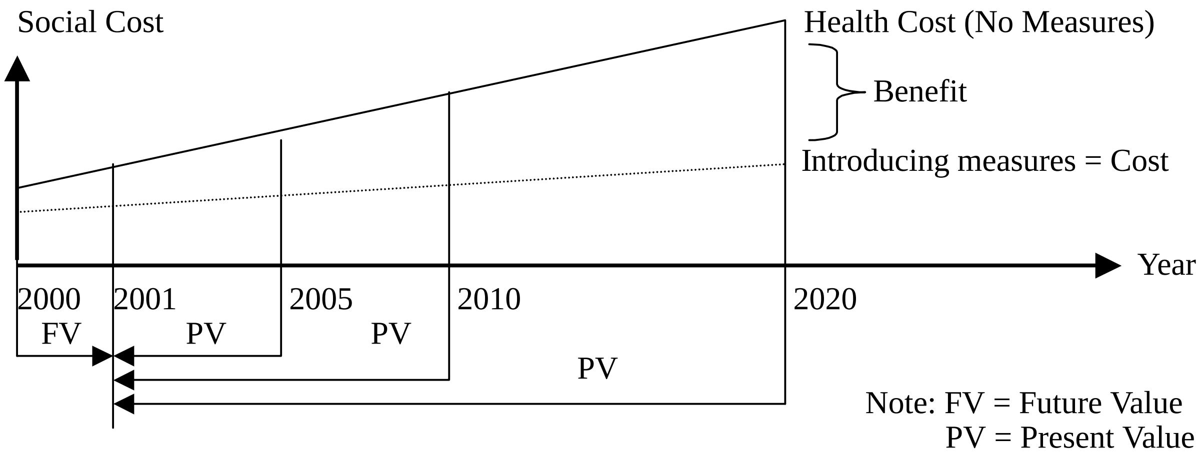

Figure 4. Basic concepts of CBA based on timetable of introduction

Based on the CBA result in Table 4, it is found that introducing unleaded gasoline, inspection maintenance program and installing catalytic converter have the highest value. That means that those countermeasures are efficient and better for introducing in advance.

Table 4. CBA result based on timetable of introduction (discount rate = 5%)

Countermeasures	2001	2005	2010	2020
Introducing Unleaded Gasoline △1	←		6,955-43,211 21-123	
Inspection Maintenance Program △3	931-1,510 22-25			
Switching to Gaseous Fuel	-2,234-(-1,323) 0.5-0.7			
Introduction of New Emission Regulation	11-92 7-56			
Improving Diesel Fuel Quality	-44-364 1-5			
Install Catalytic Converter △2	-1,723-3,115 0.3-2.3		← Net Benefit ← Cost/Benefit Ratio	

Note: △ = the highest value

In case of introducing unleaded gasoline, it is recommended to start in 2001 (or as soon as possible) since the cost of health impacts from lead could be minimized. Catalytic converter is also proposed to adjust its introduction to the year that all fuels sold in Indonesia would become lead-free, since catalytic converter could not work efficiently for leaded gasoline.

The CBA method in this research has been used to provide a methodological advance by computing the long-term costs and benefits for providing a more realistic and efficient method. In considering that we are faced directly with its impact to human health, however, one possible explanation is that a pure health approach should be most important to reconsider. It means that countermeasures would become most effective when all efforts for reducing emission and improving air quality could be done as soon as possible. Clearly, the CBA technique has promise as a tool for projects evaluation, but it could not be applied 100% to economic valuation of health impacts, which is based on the assumption of correlation between air pollution exposures and adverse health outcomes found by epidemiological studies.

5. Conclusion

Air pollution from motor vehicle emission has significant effect on health benefits. This research attempts to estimate economic value of health impacts due to motor vehicle emissions by using the assumption of correlation between air pollution exposures and adverse health outcomes found by epidemiological studies. It the end, countermeasures are provided and studied by using the cost-benefit analysis (CBA) in order to select the best alternative for decision-making based on the timetable of introduction. It was originally assumed that the health costs from air pollution have been underestimated compared to other health effects. But the result of this research shows totally different. One possible conclusion is that deteriorating air quality in Jakarta is mainly because of economic expansion, rise in population, increasing growth of motor vehicles and increasing industrial emissions.

Currently existing scientific literatures for the economical valuation of health impacts are focusing on PM_{10} and Lead. It seems that real total health costs could become higher than expectation since other pollutants have also significant relations linking with mortality and morbidity value.

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