The Development Model of the Policy Alternatives in Controlling Air Pollution in the Jakarta Province, Indonesia

Sri Listyarini and Lina Warlina

***Abstract*—The regulations issued by the Jakarta Provincial Government in order to maintain the perceived air quality have not functioned effectively. It is predicted the negative impacts of air pollution, with the huge of the money value. Therefore, it is necessary to conduct research to build an alternative policy that is expected to function effectively to reduce air pollution in Jakarta. Alternative policies was developed by the method of multi-criteria decision analysis (MCDA) with the software PRIME (Preference ratios in multiattribute evaluation) model is expected to control the environmental pollution, especially air pollution. The outcome from the MCDA model is the anticipation of a policy with an environmentally driven rather than economically driven approach as the developmental basis. The research recommends reducing emission of air pollution by combining command and control (CAC) policies with economic instrument (EI) policies and do-it-yourself (DIY) policies. Additionally, all stakeholders must have access to the academic policy development in order to improve their concerns and commitments.**

***Index Terms*—Air pollution, command and control (CAC), do-it-yourself (DIY), economic instruments (EI), multi-criteria decision analysis (MCDA).**

I. Introduction

Study conducted by Syahril *et al.* [1] regarding air quality Jakarta showed that air pollution emissions in 1995 until the year 1998 continued to increase. The study also predicted that the increase in emissions of air pollution gases will still continue to occur until the year 2015. The Jakarta provincial government has developed various policies to maintain the quality of air, such as:

1) Jakarta Governor Decree No. 670 of 2000 on the Quality Standard Setting Emission for Static Sources in Jakarta Province that establish implementation emission standard for SO_2 and NO_2 gases and TSP (Total Suspended Particulate) for a variety of industries.
2) Jakarta Governor Decree No. 1041 of 2000 on the Air Quality Standard for Motor Vehicle Emissions in Jakarta province that establish the law enforcement for emission gases standard emitted by various types of vehicles.
3) Jakarta Governor Decree No. 551 of 2001 on Stipulation of Ambient Air Quality Standard and Standard Noise Level in Jakarta Province that set the ambient quality standard implementation for various gases at various measurements, including gases SO_2 and NO_2, and TSP.
4) Jakarta Provincial Regulations No. 2 of 2005 on the Air Pollution Control that aims to control sources of air pollutants, thus achieved the air quality that meets the requirements of human health and other living things.

The regulations issued by the Jakarta Provincial Government in order to maintain the perceived air quality have not functioned effectively. This can be seen from the many press articles about the Air Pollution problems in Jakarta, like for instance the Jakarta Globe article about "Jakarta's Air Quality Takes a Toxic Turn for The Worse" and the Jakarta Post article about "Air pollution in city reaches alarming level" [2]. Research by Ostro, 1994 [3] in Jakarta claimed that the emission of air pollutant causing environmental degradation in the form of the resident sick even to death. Study by Listyarini, 2015 [4] predict the health value that have to be paid by the Jakarta residents due to air pollution.

Environmental pollution can be solved by improving technology and policy implementation. According Robert, 2004 [5] environmental policy can be based on the market (economic instruments = EI) or a command and control (CAC) or a persuasive form of self set (do-it-yourself = DIY). In the other way, Potdar, Unnikrishnan, and Singh [6] said that a kind of environmental policy can be in the form of direct regulation (command-and-control), market-based instruments (economic instruments), and soft instruments (voluntary approaches). The development of environmental policy must be implemented by considering the various aspects or criteria. That is why it is necessary to conduct research to build the policy alternatives that is expected to function effectively to reduce air pollution in Jakarta. Policy alternatives developed by the method of multi-criteria decision analysis (MCDA) with the software PRIME (Preference ratios in multiattribute evaluation). The model developed is expected to control environmental pollution, especially air pollution.

II. Materials and Methods

This study was conducted in 2015, and the data used were obtained from Jakarta in Figures 2014 book [7], which contains data of 2013 and earlier. The data are processed through the Focused Group Discussion (FGD) involving environmental experts which then quantified, to develop a policy alternative model using PRIME software.

According to Belton and Stewart, 2002 [8] criteria or standards are tools for consideration. In the context of

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decision-making, the criteria can indirectly express standards in selecting an alternative order. So the decision-making through multi-criteria decision analysis (MCDA) is the selection of the best alternative by considering each criterion of the alternatives available.

1) In this study a multi-criteria decision analysis performed and the result is an order of priority recommended scenario to be implemented. According to Triantaphyllou and Sánchez, 1997 [9] in short order the development of MCDA techniques include 3 stages:
   Determine the alternatives and the relevant criteria. In this study the alternatives and the criteria are determined based on the results of the expert focus group discussion and literature review.
2) Give the relative weights of each criterion on the impact of each alternative.
3) Process a quantitative value to determine the order of each alternative.

Gustafsson, Salo and Gustafsson [10] mention that processing results from the consideration of each criteria and alternatives in the PRIME software include:

1) Value interval for each alternative,
2) Weight interval for each attribute,
3) Matrix dominance, and
4) Decision rule for comparing between alternatives, there are 4 rules which can be used to provide a decision recommendation, namely:
   - Maximax: alternatives that have the greatest possible value
   - Maximin: alternative with smallest possible value
   - Minimax regret: alternative that has the smallest PLV (possible loss value)
   - Central value: alternative that has the largest median interval value

III. Results and Discussion

The first phase of this research is to determine the criteria and sub-criteria that are considered to affect the policy alternatives. In this study the criteria that are taken are environmental, social, and economic. While the sub-criteria taken from a variety of variables derived from expert judgment and literature review. Criteria and sub-criteria are input in the PRIME software in the form of a value tree, see Fig. 1.

The next step of the research is to determine the base scenario of development and to provide a value or weighting of each sub-criteria. Base scenario was developed based on the development implications of environmental, social, and economic policy on air pollution that will be applied, namely:

1) Development is taking place as usual (business as usual), or
2) Development is based on environment (environmental driven), or
3) Development is based on economic (economic driven).

The weight given to the business as usual scenario is calculated based on data in Jakarta in Figures 2014 book [7], except for the number of people die prematurely and the sick are calculated based on the mathematical formula (1) through (4). Health value is calculated by multiplying the number of dying prematurely by VOSL (Value of Statistical Life) plus the number of sick people multiplied by the cost of health care, 180 US $, that is calculated from [11]. VOSL mention by Susandi [12] is US$144.000. Weighting process performed on the window 'Alternative' in the PRIME software, as can be seen in Fig. 2.

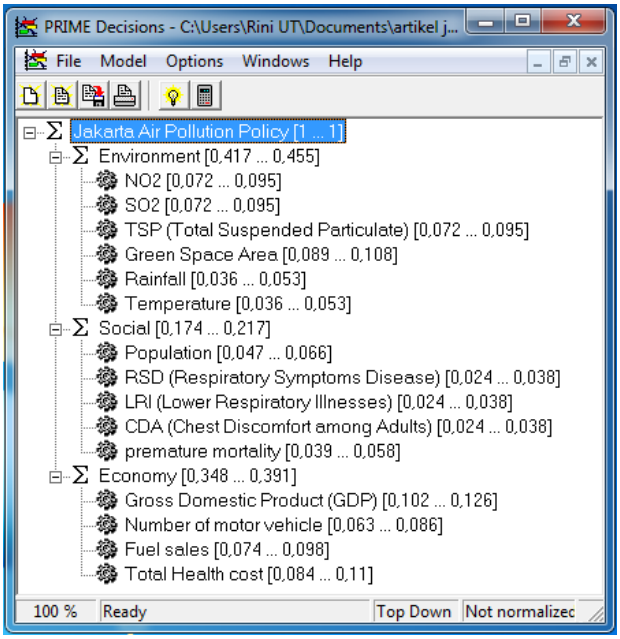

Fig. 1. Value tree to identify the criteria and sub-criteria.

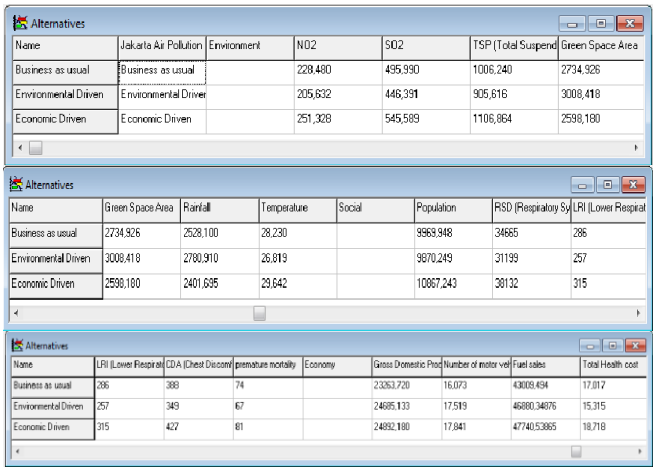

Fig. 2. Matrix of scenarios that include weighting each sub-criteria.

Ostro [3] and Syahril, Resosudarmo and Tomo [13] give these mathematical equations:

1) Premature mortality

$$NP(t)=0{,}002*\left[\frac{SO_2(t)-SO_2st}{SO_2st}\right]*P(t)*CM(t) \quad for\, SO_2(t)>SO_2st \tag{1}$$

where:

NP(t): number of population who die prematurely caused by SO2 gas air pollution in year t

SO2(t): SO2 gas ambient concentration (µg/m3) in year t

SO2st: SO2 ambient concentration standard

P(t): the amount of population in year t

CM(t): mortality rate = 0,0035 (BPS, Bappenas, and UNFPA Indonesia, 2005 [14])

2) LRI (lower respiratory illnesses) in children

$$NLRI(t)=0{,}0001*\left\lfloor\frac{SO_2(t)-SO_2st}{SO_2st}\right\rfloor*\Pr C(t)*P(t)\ for\ SO_2(t)>SO_2st \quad (2)$$

where:

NLRI(t): number of population who has LRI desease by the year t

PrC(t): percentage or proportion of children under 14 years = 26,9% [14].

3) CDA (chest discomfort among adults)

$$NCDA(t)=0{,}00005*\left\lfloor\frac{SO_2(t)-SO_2st}{SO_2st}\right\rfloor*\Pr A(t)*P(t)\ for\ SO_2(t)>SO_2st \quad (3)$$

where:

NCDA(t): number of population who has CDA desease by the year t

PrA(t): percentage or proportion of adult = 73,1% [14].

4) RSD (respiratory symptoms disease)

$$NRSD(t)=6{,}02*\left\lfloor\frac{NO_2(t)-NO_2st}{NO_2st}\right\rfloor*\Pr A(t)*P(t)/1877{,}55 \quad (4)$$

where:

NRSD(t): number of residents who have RSD in year-t

NO2(t): concentration of NO2 gas (ppm) in year-t

NO2st: standard concentration of NO2 gas per year

PrA(t): percentage of adult in year-t. Based on data from [14],

P(t): number of Jakarta population in year-t

1877,55: convertion factor of concentration of NO2 from ppm to μg/m^3

Weigh on business as usual scenario for each sub-criterion used as a reference for weighting the same sub-criteria for environmental driven and economic driven scenarios. Weighting process to environmental driven and economic driven scenarios are based on the results of experts discussion forum.

The third stage is to provide a comparison of each sub-criteria on the same criteria and compare each criterion, in the form of score and weight assessment and holistic assessment comparison on the window 'preference information', see Fig. 3.

The results of this research are 4 (four) windows, namely: Value intervals, Weights, Matrix Dominance, and Decision Rules. The first result of this research is the value intervals (see Fig. 4). Value interval results showed that the alternative development based on environmental driven scenario has a higher value than the 2 other development base scenario. It should be considered for the development policy of a principled on environmental rules.

The second output of this research is a matrix weights, see Fig. 5. The results showed that the highest values found in the environmental criteria, economic criteria next, followed by social criteria as the last priority criteria. Here can be seen that to implement sustainable development ideally we should take environmental factors as a priority than economic factors.

Matrix Dominance which is the third output of this research can be seen in Fig. 6. Red dots on the matrix dominance states that the alternative to the line is dominated by the alternative in the column. While green dots indicate the opposite, that is an alternative to the column is dominated by the alternatives on the line. Gray dots indicate diagonal matrix that does not state domination.

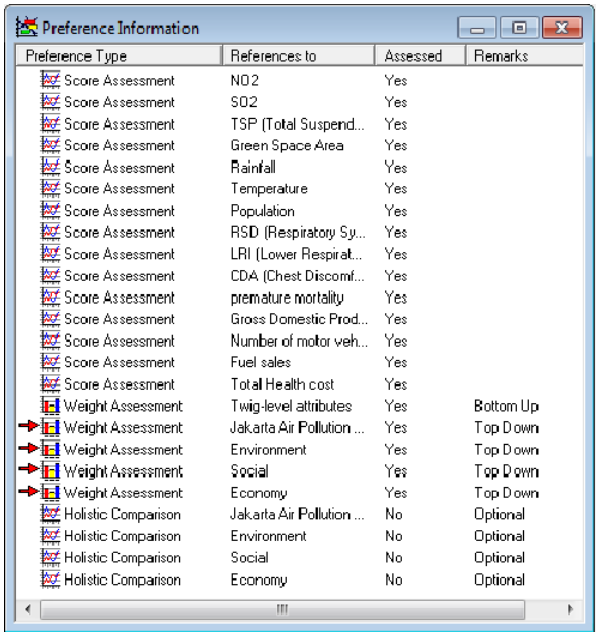

Fig. 3. Preference Information to make a choice by score assessment.

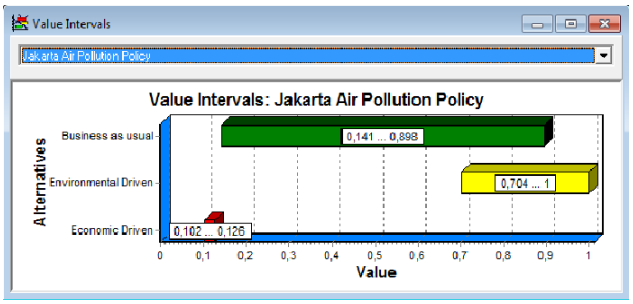

Fig. 4. The results of the value intervals.

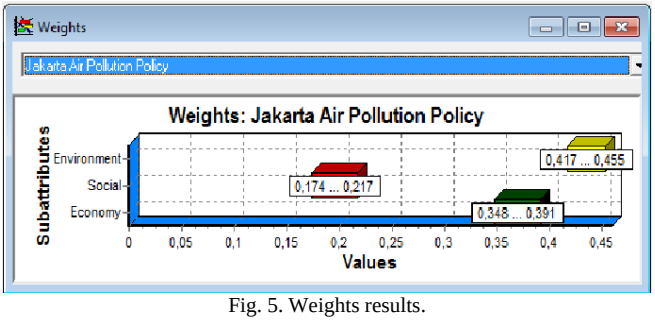

Fig. 5. Weights results.

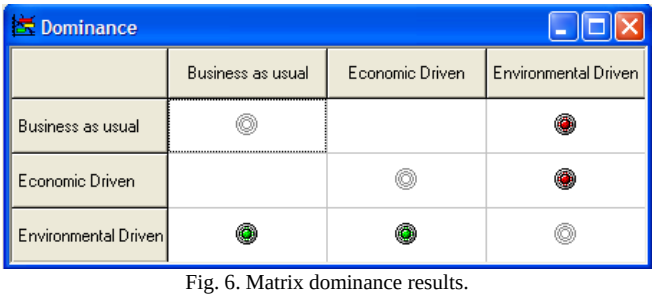

Fig. 6. Matrix dominance results.

This output shows that the scenario-development based on environment (environmental driven) dominated the

development as current conditions (business as usual) and the development which is designed based on the economy (economic driven). How much profit or loss that would be obtained if the three base scenarios development will be implemented can be seen in the last output, the decision rules, see Fig. 7.

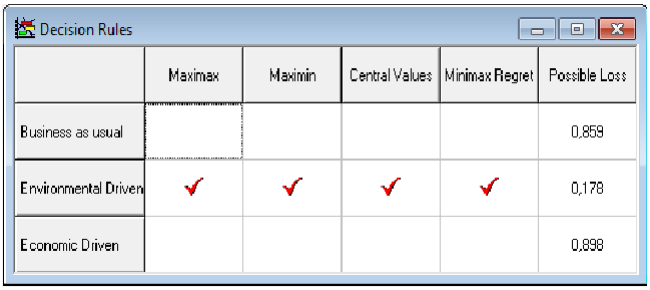

Fig. 7. The results of decision rules.

The results of the decision rules show that the most likely small losses would be obtained if the development is directed at the environment-based activities, and development intended to increase before the economic aspects. This is shown with ✓ mark obtained from the three indicators on decision rules. Development based on environmental aspects is the best policy alternative, because if this scenario is taken, it will be obtained a possible losses are 17.8 percent. In economic driven scenario possible economic losses are 89.8 percent. Whereas if the business as usual scenario is implemented the predicted economic losses could reach 85.9 percent.

Although the results of this research stated that the policy development based on the environment is the best, but environmental policy in the management of air pollution, should also consider the economic aspects and social aspects. One form of the air pollution development policy is the implementation of policies to reduce emissions of pollutant gases resulting from anthropogenic activities, such policies can be fine for the offender activities that exceed the emissions quality standards. Therefore, this penalty policy must begin with the determination of the emissions quality standards for NO_2, SO_2, and TSP. Such a policy is a concrete example that environmental policy will be implemented well if the base policy is a combination of CAC (command and control), in which case the determination of the emissions quality standards, and EI (economic instruments) in the form of fines.

In addition of CAC policy in the form of the emissions quality standards determination, it is important to also set the ambient air quality standards to protect public health. Both the CAC-based policies, namely the determination of the emissions quality standards and the ambient air quality standards, should be carried out with due attention to the interests of economic activities, in terms of setting and the emissions quality and the ambient air quality standards should not distort economic activities. During the monitoring of emissions is difficult because of the measurement of emissions requires significant costs, so the penalties for excess emissions difficult to apply. Actual monitoring of emissions need not be done through direct measurement, but by the prediction through emission factors. If the prediction exceeds the emissions quality standards, the principal activity can choose to use technology to reduce emissions or pay a fine of excess emissions.

In addition to efforts to reduce emissions of air pollutants such as NO_2, SO_2, and TSP the environmental based policy must also consider the adequacy of the green space area [15] (see Fig. 1). Policies regarding green space area can be as direct regulation (command-and-control, CAC) and soft instruments (do-it-yourself, DIY). The examples of CAC policies that has been applied by the Jakarta provincial government is to replace the land that has been built in the form of the gas stations or buildings for the green space area as it was planned. For the land that will be built in must leave 30% of land for green space area, as mention in the Jakarta Provincial Regulation No. 1 of 2014 about the Detail Spatial Plan and Zoning Regulations. On the other hand, the DIY for a green space area policy can be as awareness to expand the green area are made possible by the community, if the community realizes the importance of green area for all of humankind. Moreover, the Jakarta community should be given the information that the damages must be paid by the entire community in the form of health care costs, due to the air pollution.

It is recommended that the academic studies which support the development of a policy, such as this research results, should be accessible by the community to increase awareness and commitment. So that the policy implementation can be supported by the community.

IV. Conclusions

The results of the analysis on the MCDA model that has been developed states that the need to apply the environmental based policies to reduce air pollution, because environmental-based development is better than the economic-based development or business as usual. It is expected that the policies that is elaborated from the MCDA can be used to control the environmental damage caused by air pollution in the Jakarta Province. The policy applied can be as combination of the CAC-based policy, in this case the determination of the emissions quality standards and the ambient air quality standards, and IE-based policy in the form of fines for exceeding emissions activities the emissions quality standards, and also DIY policy in the form of awareness to expand the green area.

The transboundary air pollution gives a negative impact of air pollution can be in the local, regional, and global scales. However, this study only examined the local impact, while the regional and global impacts can be studied in further research. For further research, the first step recommended is to create a dispersion model. After the dispersion pattern air pollution gases emitted from Jakarta is stated, then data about the social conditions of the area demographics that are considered as accumulated receptors . The next research step may follow the steps that have been done in this study.

References

[1] S. Syahril, B. P. Resosudarmo, and H. S. Tomo, "Study on air quality in Jakarta, Indonesia: Future trends, health impacts, economic value and policy options," *ADB*, 2002.

[2] AQICN (Air Quality monitoring project). (August 2016). Indonesia real-time air quality monitoring project. [Online]. Available: http://aqicn.org/country/indonesia/
[3] B. Ostro. (1994). Estimating the health effects of air pollutans: A method with an application to Jakarta. [Online]. Available: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1994/05/01/000009265_3970716141007/Rendered/PDF/multi0page.pdf
[4] S. Listyarini, "Estimating the value of health degradation caused by SO2 gas air pollution in Jakarta," *Der Pharma Chemica*, vol. 7, no. 10, pp. 563-565, Oct 2015.
[5] J. Robert, *Environmental Policy*, London: Routledge, 2004.
[6] A. Potdar, S. Unnikrishnan, and A. Singh, "Study of energy regulations in India," *International Journal of Environmental Science and Development*, vol. 7, no. 11, pp. 835-842, Nov. 2016.
[7] BPS-Statistics of DKI Jakarta Province, *Jakarta in Figures* 2014; BPS: Jakarta, 2014.
[8] V. Belton and T. J. Stewart, "Multiple criteria decision analysis: An integrated approach," Boston: Kluwer Academic Publishers, 2002.
[9] E. Triantaphyllou and A. Sánchez, "Sensivity analysis approach for some deterministic multi-criteria decision making methods," *Decision Sciences*, vol. 28, no. 1, pp. 151-194, 1997.
[10] J. Gustafsson, A. Salo and T. Gustafsson. (2001). *PRIME Decisions: An Interactive Tool for Value Tree Analysis*. [Online]. Available: http://link.springer.com/chapter/10.1007/978-3-642-56680-6_15#page-1
[11] Indonesia Ministry of Economy. (2013). *Tarif Rawat Inap*. [Online]. Available: http://www.jdih.kemenkeu.go.id/fullText/2013/149~PMK.05~2013Perlamp.pdf
[12] A. Susandi. (2004). Future Emissions of air Pollutans in Indonesia: SO_2 and NO_x. [Online]. Available: http://ecomod.net/sites/default/files/document-conference/ecomod2004/235.pdf
[13] S. Syahril, B. P. Resosudarmo, and H. S. Tomo, *Study on Air Quality in Jakarta, Indonesia: Future Trends, Health Impacts, Economic Value and Policy Options*, Jakarta: ADB, 2002.
[14] Badan Pusat Statistik [BPS], Badan Perencanaan Pembangunan Nasional [Bappenas], United Nations Populations Fund [UNFPA]. (2013). Indonesia Population Projection 2010-2035. [Online]. Available: http://www.bappenas.go.id/files/5413/9148/4109/Proyeksi_Penduduk_Indonesia_2010-2035.pdf
[15] S. Listyarini, L. Warlina, E. Indrawati, and T. Pardede, "Optimization model for predicting green area in Jakarta to minimize impacts of climate change," *The Sustainable City IX*, vol. 191. pp. 305-315, 2014.

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