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Improved Engine Standard Scenarios to Reduce Emissions of Air Pollutants in Transportation Sector in Jakarta Indonesia

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Abstract. Jakarta Province is a metropolitan city that is the center of the business economy in Indonesia, which makes it as one of the cities with the highest pollution levels in Indonesia. One sector that significantly contributes is the transportation sector. This research study analyzes transportation sector emissions in DKI Jakarta Province, Indonesia. It is analyzed by comparing two scenarios, namely the Euro 4 scenario and the baseline scenario in 2030 to see the emission reductions that can be generated by implementing the Euro 4 scenario. This study uses the Atmospheric Brown Cloud-Emission Inventory Manual (ABC-EIM) in calculating the estimated emissions generated. In 2030 it is estimated that the transportation sector contributed 122271.17 tons of PM2.5 pollutant emissions, 137447.23 tons of NOx pollutants, 5005290.69 tons of CO pollution, and 131644.78 tons of SO2, where the most significant emissions produced by the transportation sector are CO emissions. CO pollutant is produced from incomplete combustion, which is common in vehicle engines. The application of euro 4 standard fuel is proven to reduce the number of emissions produced by the transportation sector, with emission reductions produced by 40.29% for NOx pollutants, reducing CO pollutants by 33.61%, reducing SO2 pollutants by 27.96% and reducing pollutants PM2.5 is 26.95%.

Keywords: DKI Jakarta Province, Transportation, Air Pollution, Euro 4, ABC-EIM.

INTRODUCTION

Jakarta, the capital city of Indonesia, is a metropolitan city that is the center of the business economy, this causes the city of Jakarta to have a high level of air pollution compared to other cities in Indonesia. Population growth in various big cities has an impact in the form of increased activities in meeting higher energy and transportation needs. These factors contribute significantly to urban air pollution from the main roads crowded with vehicles (Suleiman et al, 2019).

According to the Ministry of Environment and Forestry (KLHK), the most effective air quality management in improving air quality is to control emissions at the source. In order to carry out the types of control at the source, it is necessary to know the emission source, namely by conducting an emission inventory. The recording of pollutant sources and the amount of air pollutants is known as an emissions inventory. The inventory of air pollutant emissions is the basis for determining strategies and action plans for air quality management in an area. With the emission inventory, the strategy for reducing air pollutant emissions is prepared based on the priority of air pollutants to be handled, the number of pollutants to be reduced, and pollutant sources that contribute to air pollution (KLHK, 2013).

Air pollution sources consist of mobile sources and stationary sources. *Mobile sources* can move from one place to another. An immovable source is a stationary source (still) somewhere. Moving sources are divided into moving sources on the highway (on road) and moving sources not on road (non-road). Moving sources on the highway (on road) are cars, trucks, buses, and motorcycles, not on roads (non-road) are airplanes, ships, trains, agricultural and construction equipment, and lawnmowers. Furthermore, on-road and non-road moving sources can also be represented by line-moving sources and area-moving sources.

The Atmospheric Brown Cloud-Emission Inventory Manual (ABC-EIM) is a worksheet compiled by experts so that a comprehensive and user-friendly emission inventory can be carried out in both developed and developing countries. ABC-EIM is made to provide a compilation and source identification tool for the Atmospheric Brown Cloud for government, academia, and research institutions and a reliable reference for science-based decision-making.

The preparation of the Grand Design for Air Pollution Control (GDPPU) by the DKI Jakarta Provincial government is currently carried out as an effort to improve air quality in Jakarta and also to follow up on the decision of the Citizen Lawsuit on Air Pollution in Jakarta which was decided on September 16, 2021. As part of the preparation of an air quality control action plan, the DKI Jakarta Provincial Environment Service held a Public Consultation that invited some stakeholders. Academics, the central government, international and local non-profit organizations, the private sector, and the general public are invited to collaborate in preparing and implementing the action plan. In the presentation of this action plan, there are several targets for improving air quality based on the recommendations of the World Health Organization (WHO) guidelines. In 2030, the air quality improvement target for the PM2.5 parameter is an annual average of 25 ug/m3 or within the interim target 2 in the latest WHO guidelines. In addition, the Air Quality Index (KPI) is also targeted to improve to 76 in 2030.

METHODOLOGY

This study uses secondary data. Secondary data used are obtained from various types of sources, these sources are in the form of agency annual report books, general information listed on the agency's official website, and other data sourced from previous research and journals. This research was conducted with a quantitative research approach with descriptive analysis. Quantitative research methods are based on the philosophy of positivism, used to examine specific populations or samples, collect data using research measuring instruments (instruments), and analyze quantitative/statistical data, aiming to test and prove hypotheses that have been made/set. Descriptive statistics are methods related to collecting and presenting data to provide helpful information (Walpole, 1995). Descriptive statistics function to describe or provide an overview of the object under study through sample or population data (Sugiyono, 2007). The data presented in descriptive statistics are usually in the form of a data concentration measure (Kuswanto, 2012). This method is used to identify the number of transportation activities, sources of emissions and the amount of emissions.

Data Collection

Data collection is carried out to obtain the data needed to be carried out. The types of secondary data collected in this study are provincial and national level regulations and policies, data on the number of vehicles, Vehicle Kilometers Traveled (VKT), Density Fuel, % Fuel Use, and % Euro Standard. The secondary data used in this study were obtained from various types of sources: the agency's annual report book, general information listed on the agency's official website, and other data sourced from previous research and journals. Emissions calculation using the emission factor method requires activity data. This activity data refers to the magnitude of transportation activities that produce emissions in a certain period. The literature study is briefly presented in **Table 1.**

TABLE 1. Secondary Data and Data Sources

No	Data Description	Purpose of Data Use	Data Source
1	Specific number of vehicles	Calculation of emissions from specific vehicles	BPS DKI Jakarta and Statistik Transportasi DKI Jakarta
2	The average length of vehicle trip in one year	Calculation of the vehicle road kilometer-based emission factor method	Kim Oanh N. T, et al, 2018 and Pongthanaisawan, J., et al, 2007.
3	Euro standard for each type of vehicle	Calculation of emissions from specific vehicles	Syafrizal M., et al, 2016

The primary data preparation for calculating the transportation emission load is categorizing the vehicle class and each fuel type used from the data on the number of vehicles. This categorization stage is needed before inputting and processing data in the ABC-EIM Excel Workbook. The data was prepared in the form of vehicle grouping, preparation of density change data, and some data preparation in the form of Vehicle Kilometers Traveled (VKT), and the density of each fuel used.

To calculate and analyze the estimated vehicle emissions, it is necessary to know the fuel used for each type of vehicle. Because the emission factor depends on the vehicle technology and the fuel type, the data on the number of vehicles will then be divided based on the percent use of fuel distribution for each type of vehicle. The data was obtained from research that was conducted in 2018 in the city of Jakarta.

TABLE 2 Data on the Distribution of Consumption of Types of Fuel in Each Type of Vehicle in the Transportation Sector

Transportation Type	Fuel Consumption (%)		City
	Gasoline	*Diesel*	
Bus	0	100	Jakarta
Passenger car	8	92	Jakarta
Truck	0	100	Jakarta
Motorcycle	100	0	Jakarta

After dividing the number of vehicles by fuel use, the data are regrouped according to the Euro standard for vehicle and engine age. The grouping is based on the input data needed in the ABC-EIM Excel Workbook and research in DKI Jakarta Province. Based on the PermenLH no. 12 of 2010, to calculate the estimated road transportation sector, it is expressed as the length of the entire vehicle journey. Vehicle Kilometers Traveled (VKT) data or the average vehicle mileage is needed in this study based on previous research in other cities in Indonesia.

TABLE 3 Data Vehicle Kilometers Traveled (VKT) Road-Based Land Transportation Sector

Transportation Type	Average VKT (km/day)	City
Motorcycle	25	Bandung
Gasoline-PC	40	Jakarta
Diesel (bus&truck, etc)	35	Jakarta

The emission factor depends on the type of fuel with its specific characteristics, one of which is the density or specific gravity of the fuel itself. The type of pollutant fuel released by the engine with gasoline or diesel fuel is the same, but will affect the proportion due to differences in the operation. (Rose and Tualeka, 2014). Data density or specific gravity of the fuel used, can be seen in **Table 4**.

TABLE 4 Data on the Density of Fuel for the Road-Based Land Transportation Sector

Fuel Type	Specific Gravity (Kg/m3)	Cst, sulfur content, %	Energy Content (Tj/tonne)
Gasoline	715 - 770	0,05	44,8
Diesel	815 - 880	0,35	43,33

The emission factor values used in this research are stated in the categories of sources and fuels used in each activity, collected from various literature in most emission inventory manuals and publications (EMEP/CORINAIR, 2019) bulk emission factors differ from country to country. Data emission factors, can be seen in **Table 5**.

TABLE 5 Vehicle Bulk Emission Factors in g/km

Fuel	Vehicle Class	NOx	CO	$PM_{2.5}$	SO_2
Gasoline	Passenger cars (Euro 2)	2.6	30	0.073	0.13
	Passenger cars (Euro 4)	0.26	2	0.014	0.13
	Motorcycles (4-stroke) (Euro 2)	0.06	14	0.35	0.06
	Motorcycles (4-stroke) (Euro 4)	0.06	14	0.35	0.06
	Paratransit (Euro 2)	2.6	30	0.073	0.13
	Paratransit (Euro 4)	0.26	2	0.014	0.13
	Taxi (Euro 2)	2.6	30	0.073	0.13
	Taxi (Euro 4)	0.26	2	0.014	0.13
Diesel	Passenger cars (Euro 2)	2.05	7.3	0.84	1.41
	Passenger cars (Euro 4)	1.5	0.9	0.07	1.41
	Light-duty vehicles (Euro 2)	3.15	8.7	0.32	1.41
	Light-duty vehicles (Euro 4)	1.28	5.1	0.5	9.51
	Heavy-duty vehicles (Euro 2)	6.54	5.2	2.2	9.51
	Heavy-duty vehicles (Euro 4)	9.15	3.6	0.42	0
	Paratransit (Euro 2)	2.05	7.3	0.84	1.41
	Paratransit (Euro 4)	1.5	0.9	0.07	1.41

Data Processing

Activity data processing to estimate emissions in this study was carried out using the Excel Workbook ABC-EIM. The data needed to calculate the estimated emissions in the road-based land transportation sector are the specific gravity of the fuel (Kg/m3), the number of vehicles based on the vehicle class category and the type of fuel (units), data uncertainty (%), then the average mileage annual average (km/unit) for a vehicle (km/year/unit).

Total emissions are calculated by considering activity data for each vehicle category and appropriate emission factors. These emission factors vary according to input data (driving situations, climatic conditions, and so on). Data on emission factors, number of vehicles and mileage per vehicle need to be provided specific to each vehicle class and category (Shrestha, et al, 2013). The formula for calculating emissions is presented in eq. 1, where j,r is vehicle class j and road type r (urban, rural); $Em_{i,j,r}$ is emission of pollutant i in gram (g), produced in the reference year by vehicle class j driven on road type r; Nv_j is number of vehicles (veh.) of class j in circulation in the reference year; Mvj,r is annual mileage per vehicle (km/veh.) driven on road type r by vehicles class j; $e_{i,j,r}$ is average fleet representative baseline emission factor in g/km for pollutant i, relevant for vehicle class j, operated on road type r.

$$Em_{i,j,r} = Nv_j \ x \ Mv_{j,r} \ x \ e_{i,j,r} \tag{1}$$

Emission inventory for on-road transportation will take into account emission per vehicle distance or emission per fuel mass.

RESULTS AND DISCUSSION

1. Data on the Number of Vehicles in DKI Jakarta Province

The database that needs to be known before starting to plan a scenario for reducing emissions in the DKI Jakarta Province vehicle sector is the number of vehicles in DKI Jakarta Province for at least the last ten years, this data will later aim to see vehicle trends in the future.

2. Vehicle Projection

The projection the number of vehicles is one of the necessary steps in calculating the prediction of the number of emissions in the future, where the projection of the number of vehicles will be carried out until 2030 (10 years), the number of emissions caused by the transportation sector is oriented to the number of vehicles.

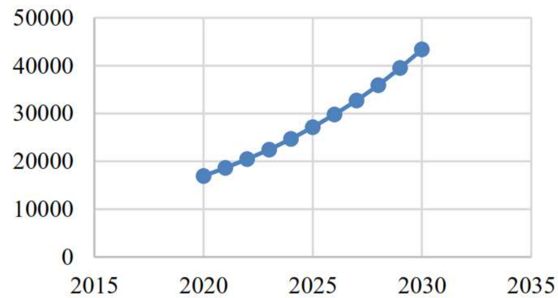

FIGURE 1 Paratransit Vehicle Projection Result Data

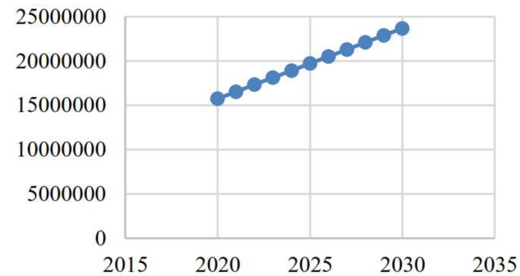

FIGURE 2 Motorcycle Vehicle Projection Result Data

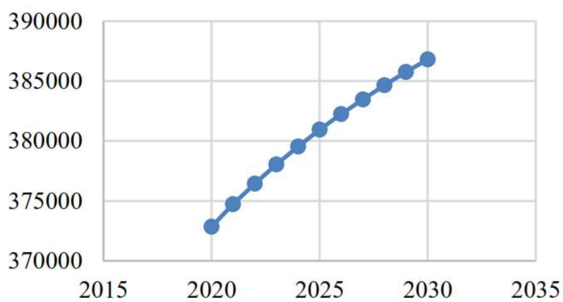

FIGURE 3 Bus Vehicle Projection Result Data

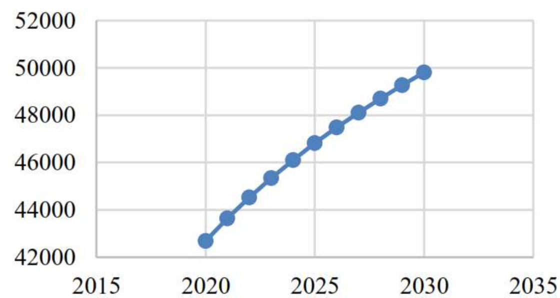

FIGURE 4 Truck Vehicle Projection Result Data

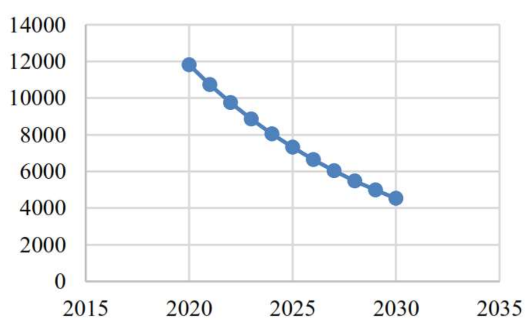

FIGURE 5 Taxi Vehicle Projection Result Data

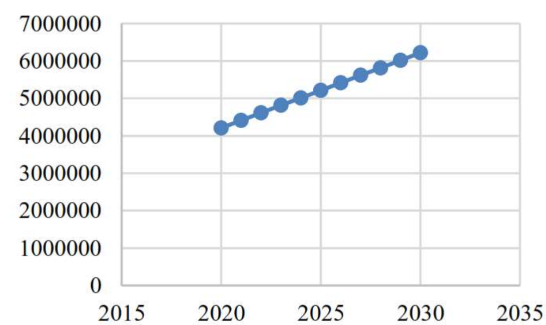

FIGURE 6 Passenger Car Bus Vehicle Projection Result Data

3. BaU Scenario (Business as Usual) VS Euro 4 Scenario

The calculated data from the Business as Usual (BaU) scenario will later become a baseline for comparison with the estimated emission reductions for the Euro 4 scenario. This is done to see how much emission reductions occur if this scenario is used. In the BaU scenario, the calculation is divided into two parts, namely Non-Euro and Euro fuels, where Non-Euro means that the fuel used in the engine is pre-Euro fuel and Euro means that the fuel used is Euro 2, while in the Euro 4 scenario the fuel used is Euro 4 fuel engine fuel is divided into Uncontrolled and Controlled, where Uncontrolled means that the fuel used in the engine is Euro 2 fuel, and Controlled means that the fuel used is Euro 4. Comparing these two scenarios will show how large the ratio of emissions released from each scenario will later conclude whether Euro 4 fuel is proven to produce more negligible emissions than the emissions released by fuels commonly used in DKI Jakarta Province today. The following is the reduction data generated for each pollutant by applying the Euro 4 scenario compared to the actual data (BaU).

a) NO_x

TABLE 6. Data on NOx Pollutant Emission Reduction Using the Euro 4 Standard Implementation Scenario

Year	Tonnes/year		
	BaU	**Euro4**	**Reduction (%)**
2018	99237.15	99237.15	0.00
2030	137447.23	82067.06	40.29

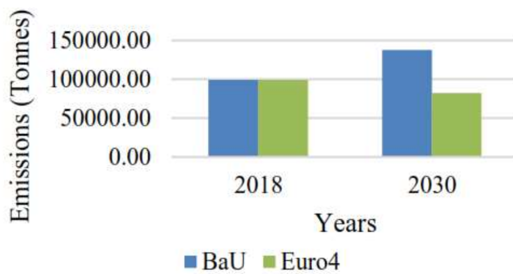

FIGURE 7. Comparison Graph of BaU Scenarios and Implementation of Euro Standard for NOx Pollutants

b) CO

TABLE 7. Data on CO Pollutant Emission Reduction Using the Euro 4 Standard Implementation Scenario

Year	Tonnes/year		
	BaU	**Euro4**	**Reduction (%)**
2018	2327698.70	2327698.70	0.00
2030	5005290.69	3323090.87	33.61

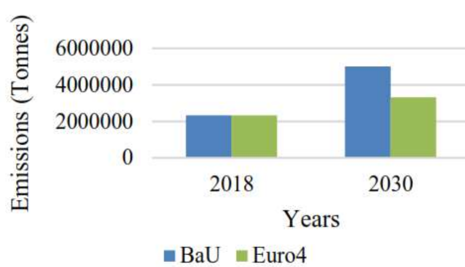

FIGURE 8. Comparison Graph of BaU Scenarios and Implementation of Euro Standard for CO Pollutants

c) SO_2

TABLE 8. Data on SO_2 Pollutant Emission Reduction Using the Euro 4 Standard Implementation Scenario

Year	Tonnes/year		
	BaU	**Euro4**	**Reduction (%)**
2018	104229.58	104229.58	0.00
2030	131644.78	94834.93	27.96

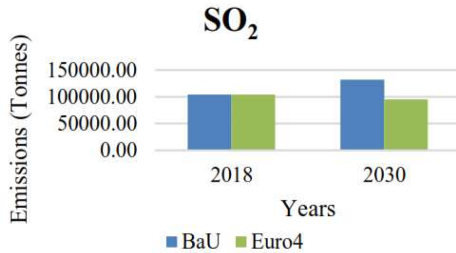

FIGURE 9. Comparison Graph of BaU Scenarios and Implementation of Euro Standard for SO_2 Pollutants

d) $PM_{2.5}$

TABLE 9. Data on $PM_{2.5}$ Pollutant Emission Reduction Using the Euro 4 Standard Implementation Scenario

Year	Tonnes/year		
	BaU	**Euro4**	**Reduction (%)**
2018	57753.89	57753.89	0.00
2030	122271.17	89317.37	26.95

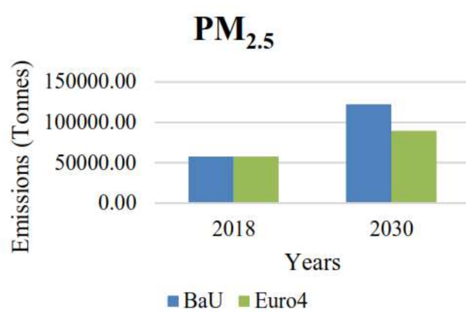

FIGURE 10. Comparison Graph of BaU Scenarios and Implementation of Euro Standard for $PM_{2.5}$ Pollutants

In the BaU scenario, with the increase in the number of vehicles, it is estimated that the total emissions released will increase with an estimated growth rate of 50% within ten years. With a high growth rate, private transportation produces the highest emissions in this sector. The available data shows that the largest emitters in the transportation sector are motorcycles and passenger cars. In addition, the available data shows that diesel is the primary fuel used in the transportation sector, as listed in **Table 2**. The number of emissions released by Euro 4 fueled vehicles is proven to be less than the emissions issued by Euro 2, the application of the use of Euro 4 standard fuel can be a way to reduce the number of emissions originating from the transportation sector.

CONCLUSION

Transportation is the sector that contributes the most emissions in DKI Jakarta Province, where the pollution is caused mainly by motorcycles and passenger cars, this is in line with motorcycles and passenger cars which are the vehicles with the most units in DKI Jakarta Province.. The pollutant with the largest concentration in the air of the DKI Jakarta provision based on the data and analysis results is CO. CO pollutant is produced from incomplete combustion produced in motor vehicles. The use of Euro 4 standard fuel produces lower emissions than Euro 2 or Pre- Euro, where the use of Euro 4 has succeeded in reducing NOx pollutants by 40.29%, reducing CO pollutants by 33.61%, reducing SO2 pollutants by 27.96 % and reducing PM2.5 pollutant by 26.95%. The use of Euro 4 standard fuel in DKI Jakarta Province can be an attractive strategy because it tends to be more likely to be implemented because many vehicles are made with engines that support the use of Euro 4 standard fuel.

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