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Application of Dynamic Model as Decision Making in Vehicle Emissions Pollution Control at Makassar City

M. Ahsan S. Mandra[(1)]
[(1)]Department of Education for Automotive Engineering
Universitas Negeri Makassar, South Sulawesi, Indonesia.

Abstract

Makassar as a metropolitan has currently is facing the problem of rapid growth of the number of vehicle, which caused traffic jam and decrease of air quality as the result of vehicle emissions. The analysis of emission load, ambient concentration level, and air pollution control scenario are needed as the main goal of the research to determine the appropriate strategy of pollution control in Makassar. The model developed in this research is consist of six steps such as: (1) needs analysis, (2) formulation of the problem, (3) identification of the system, (4) modeling system, (4) validation, and (6) scenario implementation. The data was collected by using a survey method such as field observations and measurements, and documentation. The model simulations showed that in the early years of simulation (2011), ambient concentration value of SO_2 dan PM_{10} are still below the ambient air quality standard (AAQM). Whereas, at the end of the simulation (2026), pollutants which mostly has reached the air quality standard. Implementation of the model scenarios such as busway, gas fuel, and combined scenarios can reduce ambient concentration level about 7.77 to 156.49 percent.

Keywords: emission load, ambient concentration, pollutant, air pollution.

INTRODUCTION

Air pollution has become a serious problem in big cities in the world. Urban air pollution impact on human health and the environment have been widely recognized over the last 50 years [2], [6], [13]. In addition to the impact on human health, air pollution can also have a negative impact on ecosystems, materials and buildings, vegetation and visibility [8]. Some results of the study concluded that the transport sector gives a significant contribution to urban air pollution in major cities in Indonesia. The transportation sector accounts for 65% to 75% of the nitrogen oxides (NO2) pollutants and 15% to 55% of the particulate matter (PM10) pollutants [15], [16]. According to [9], motor vehicles are a major source of air pollution in urban areas and emissions accounted for 70% of NO2, 52% of VOC and 23% of particulate.

Makassar city as a regional development center located in eastern Indonesia, are likely to experience rapid growth in a variety of fields including transportation sectors as supporting community activity which is very important nowadays. Economic growth and increasing population growth impact the transport sector is increasing very rapidly. This is evident from the increasing number of vehicles in the city of Makassar, both public and private vehicles to reach about 856 thousand units in 2010 with a growth rate of 12% per year [3]. Results of research conducted by the Ministry of Environment (KNLH) in 2006 to 2008 in 30 major cities in Indonesia, including Makassar showed increasing concentration value emissions of sulfur dioxide (SO_2) by 23.10 to 45.29 μ g/m3, and nitrogen dioxide (PM_{10}) of 14.80 to 62.11 μ g/m3. Particulate measurement results which is conducted by the Regional Environmental Agency (BLHD) Province of South Sulawesi in 2009 one of the vehicle congested area of 256.97 μg/m3 or has exceeded the quality standards set by Governor decree no.14 of 2003 by 230 μg/m3. Reference [12] shows, every 10 μg/m3 increase in PM_{10} concentrations in the long term associated with an increased risk of 12% incidence of Acute Respiratory Infections (ARI).

Some studies also mention that the decrease in air quality in urban areas can be expected from the high consumption of fossil fuels for the transportation sector, about 53%, [11]. The high use of fossil fuels causes the transport sector's contribution to the decline in air quality in major cities in the world large enough that an average of 70%, [17]. Reference [10] shows, Indonesia's annual emissions from the energy sector reached 275 million tons of carbon dioxide equivalent, or about 9% of Indonesia's total emissions. Estimated, with the current government policies that tend to favor the development of fossil fuels coupled with the resistance development of renewable energy, emissions from the energy sector will tend to increase sharply to three-fold in 2030. In a per capita basis, Indonesia's greenhouse gas emissions have grown 173% since 1980, or 75% since 1990 [18].

To plan for air pollution control policies in Makassar will require basic information about the characteristics of issuance costs and air pollution caused by transport activities at this time. The information in the form of characteristic number and types of air pollutant emissions, meteorological conditions affect pollution, and pollutant concentrations that occurred in the city of Makassar. Therefore, research is needed to examine the characteristics and build models of motor vehicle emission control in Makassar.

METHODOLOGY

The data used in this study is primary data and secondary data to describe the characteristics of the existing condition of issuance costs and predictions of future air quality in the city of Makassar. Primary data were collected through interviews, questionnaires, and direct measurement in the field to the number of vehicles on each road segment which has been determined. The data required to design models of motor vehicle emission control is the number of vehicles on each road section and the emission factor of each parameter to determine the burden of emission and ambient air concentration levels for each road section. Collecting data for the number of vehicles of each type of vehicle for 5 years is using secondary data. Design of the model is done to see the behavior of the system in the planning of motor vehicle emission control strategies in Makassar. The model is based on the results of black-box approach and factual conditions combined with the results of a study of the theoretical concept of the published literature.

Model design is done with a systems approach, which is a method of problem solving that begins with the identification of needs that result in an efficient operational system. Pollution control models are built based on the load of motor vehicle emissions and meteorological characteristics that affect pollutant concentrations. System Approach is characterized by three characteristics of the system that are complex, dynamic and probabilistic. Underlying mindset of problem solving system according to [7] namely: (1) cybernetics or goal-oriented, (2) holistic or unified perspective to the problems of the system, and (3) effectiveness or more important to the operational results for the search efficiency decisions. System approach provide problem resolution methods and tools capable of identifying, analyzing, simulating and designing systems with components that are interrelated, interdisciplinary formulated and complementary. Systems methodology in principle through the six stages of analysis, namely: (1) needs analysis, (2) formulation of the problem, (3) identification of the system, (4) modeling system, (5) verification and validation, and (6) implementation, [7]. Stages of a systems approach is illustrated in Figure 1 below.

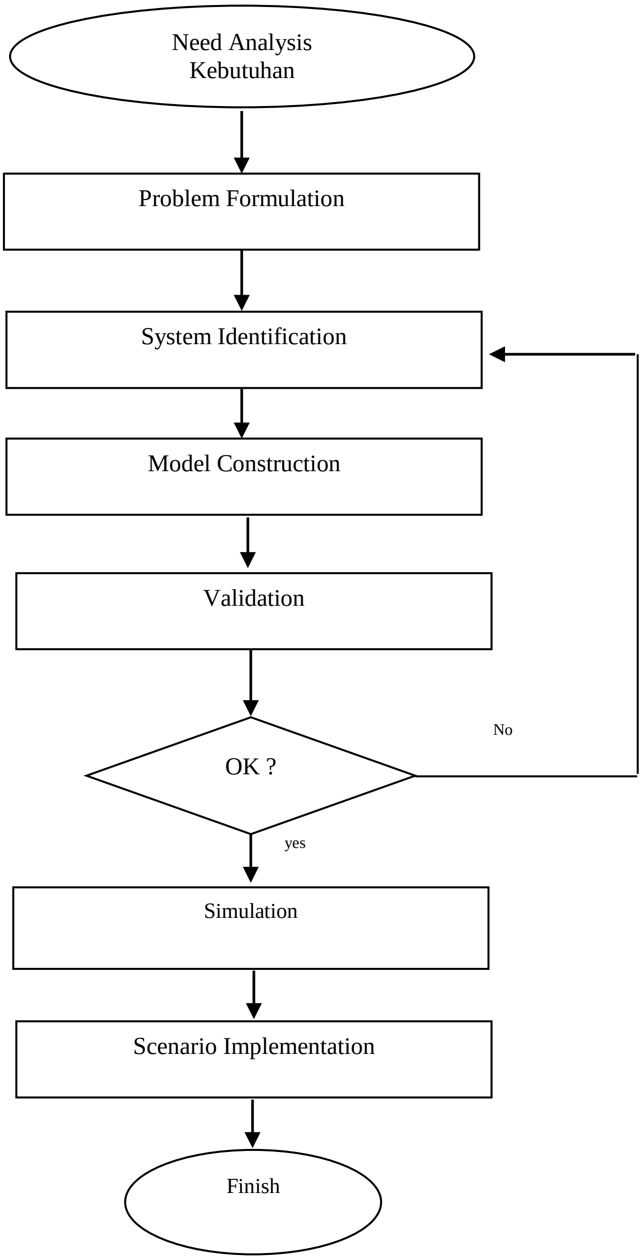

Figure 1. Stages of a systems approach

RESULT AND DISCUSSION

Growth estimates of vehicle

Vehicles trend growth in Makassar shown on the model simulation results indicate on increasing growth trend (Figure 2). In the beginning of the simulation in 2008 is 880.588 units of the vehicle and continued to increase until 2026 to reach nearly 6 million vehicles, an increase of 5.84 times of the beginning of the simulation.

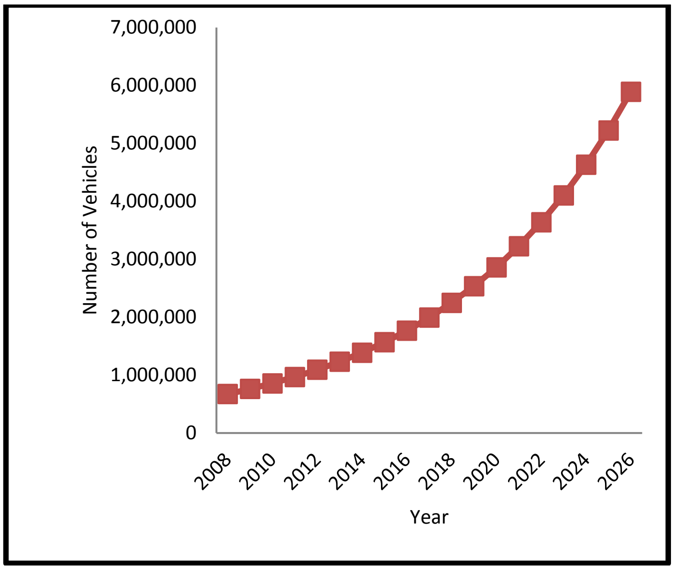

Figure 2. Simulation of the number of vehicles in the city of Makassar in the year of 2008 to 2026.

Ambient concentrations of SO_2

Results of dynamic simulation models for ambient **SO_2** concentrations on several roads in the city of Makassar is shown in Figure 3 below.

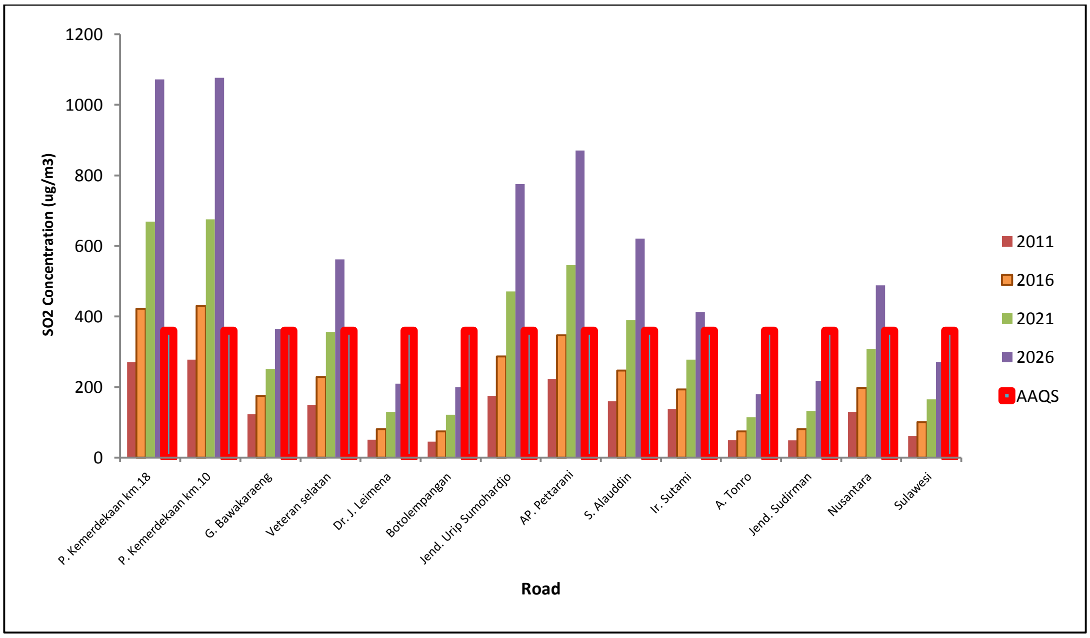

Figure 3. Distribution of ambient concentrations of **SO_2** (year of 2011 – 2016) compare to Ambient Air Quality Standard (AAQS)

Ambient concentration values of **SO_2** showed an increase in the concentration value starting at the beginning of the simulation in 2011 ranged from 45.38 to 278.17 µg/m3, increased to 209.85 to 1076.99 µg/m3 in 2026. The highest value area is Perintis Kemerdekaan Street and the lowest value area is Andi Tonro Street. Concentrations of ambient **SO_2** simulation results also showed that at the beginning of the simulation (2011) there was no concentration value beyond Ambient Air Quality Standard (AAQS), whereas at the end of the simulation (2026) most of the areas will have exceeded the AAQS, which are Nusantara (488.23µg/m3), AP. Pettarani (870.50µg/m3), S. Alauddin (621.05µg/m3), Jend. Urip Sumohardjo (774.89µg/m3), Ir. Sutami (411.76µg/m3), Perintis Kemerdekaan Km.18 (1071.96µg/m3), and Perintis Kemerdekaan Km.10 (1076.99µg/m3). As for the other regions by the end of the simulation have not exceeded from AAQS.

Ambient Concentrations of PM_{10}

Results of dynamic simulation models for concentrations ambient PM_{10} in several streets are shown in Figure 4 below.

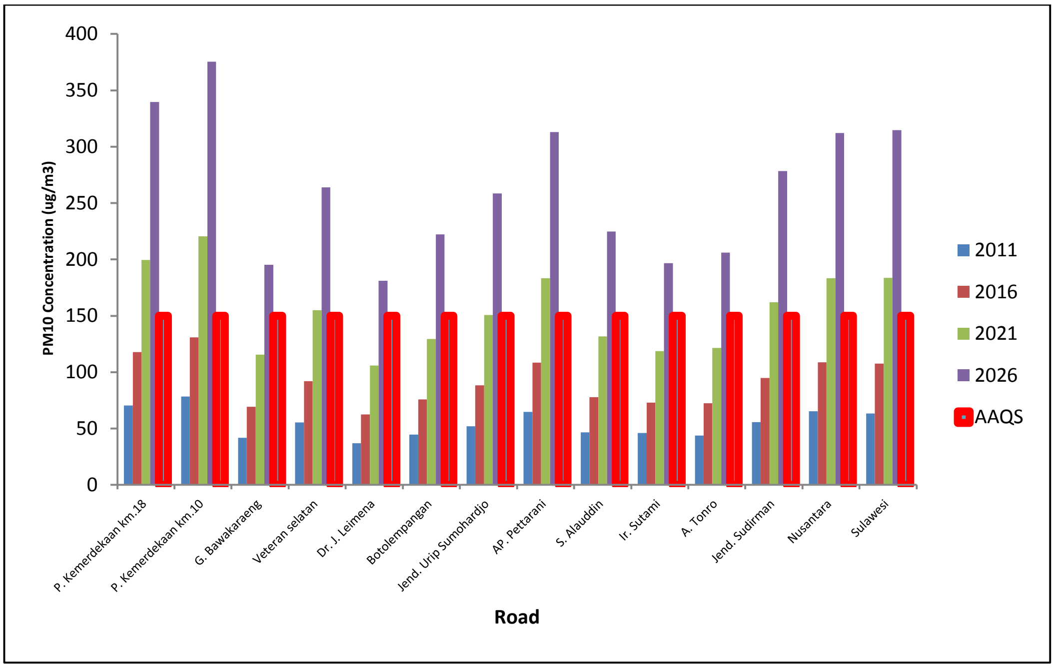

Figure 4. Distribution of ambient concentrations of PM10 (year of 2011 – 2016) compare to Ambient Air Quality Standard (AAQS)

Ambient concentration values for PM_{10} show an increase concentration at the beginning of the simulation in 2011 ranged from 41.86 to 78.33 µg/m^3, then increased from 14.63 to 467.93 µg/m^3 at the end of the simulation in 2026. In further, Simulation results demonstrate the concentrations of PM_{10} which exceeded AAQS in 2021 such as P. Kemerdekaan (km.18) (199.43μg/m^3), P. Kemerdekaan (km.10) (220.64μg/m^3), Veteran Selatan (155. μg/m^3), Urip Sumohardjo (150.68μg/m^3), AP. Pettarani (183.40μg/m^3), J. Sudirman (162.09μg/m^3), Nusantara (183.27μg/m^3), Sulawesi 183.58μg/m^3). Whereas at the end of the simulation (2026) for all areas has exceeded from AAQS.

Application of Scenario Model

As a follow-up result of existing conditions analysis and dynamic modeling of pollution control of motor vehicle emissions in Makassar city is a forming of scenario or intervention model like alternative policies draft that can be implemented based on existing conditions which applied. Through intervention, the desired system behavior can be obtained while the undesirable behavior of the system can be avoided [1]. The application of the model scenarios through simulation models to see the trend behavior of the system which analyzed. Simulation model that is needed is a model that can provide insight into the cause of the management problems (undesirable behavior), and through this comprehension, a policy to fix the issue can be designed (policy directions) [4].

Scenario control is based on the analysis of emission load reduction strategy based on expert judgment. Model simulations conducted with several scenarios and analyzed based on the basic scenario (existing condition) before assuming no controls are made (technological change) and there was no change in policy during the planning period. The basic scenario (BS) is a *business as usual* scenario in which no intervention on the model so that the condition of the model is its current state without any effort or strategy to repair the system. Scenarios that will be applied, namely: 1) the vehicle numbers reduction or limitation scenarios through the application of mass transportation called Busway scenario (BWS), 2) the concentration of emission reduction scenarios through the application of environmentally friendly fuel that is the application of Fuel Gas for transport vehicles with large capacity (buses and trucks) referred to CNG scenarios (CNGS), 3) inspection and maintenance scenarios (inspection and maintenance) vehicle or IMS, and 4) the combined scenario (SC), namely the application of the three scenarios (BWS), (CNGS) and (IMS) simultaneously.

Ambient concentrations of SO_2

Model simulation results for the concentration of SO_2 ambient on each scenario, indicate that there are differences in the concentration of the four scenarios (BWS, CNGS, IMS, and CS) applied as shown in Figure 5. Increasing of SO_2 emissions concentration value which began in year of 2011 until the end of the simulation in 2026 visible in applied four scenarios. Model simulation results illustrate the value of SO_2 ambient concentrations on the application scenario model can be seen in Figure 5 below.

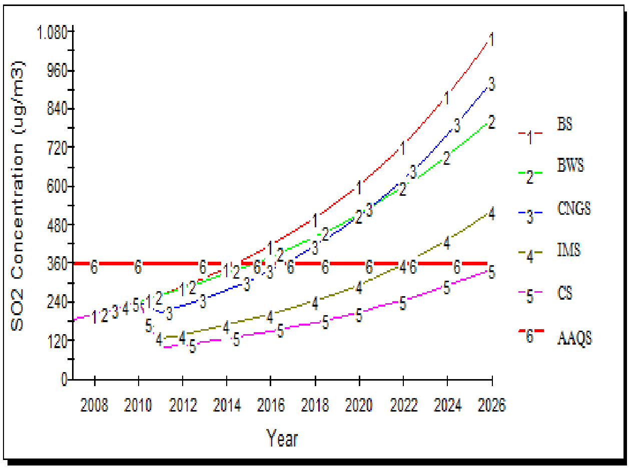

Figure 5. Predictions of SO_2 ambient concentration scenario simulation results.

Figure 5 illustrates that the ambient of SO_2 concentrations is produced in the existing condition (BS), higher than the three other scenarios (BWS, CNGS, IMS, and CS), amount 278.17 µg/m3 in 2011 and increased in 2026 to 1076.99 µg/m3. This value has far surpassed the existing AAQS of 360 µg/m^3 as it would be very dangerous to human health as well against other living things if there is no pollution control effort. From the simulations results show that the application of the busway scenario has not given satisfactory results with a reduction of the value of ambient concentrations by an average of 7.77% compared to the baseline scenario (BS) until the end of the simulation in 2026. Study results [15], stated that the implementation of public transport in Jakarta can reduce the burden of SO_2 emissions to 18.49% during the simulation period from year of 2005 to 2015.
Scenario application of CNGS, IMS, and CS of SO_2 concentration values decreased continously at amount 784.42µg/m3, 558.16µg/m3 and 397.74µg/m3 at the end of the simulation (2026) or a reduction in the concentration of emissions amount to 46.14 % , 95.82 % and 156.45 % compare to the basic scenario (BS). The obtained simulations result also showed that the SO_2 concentration values to all applied scenario has exceeded the AAQS, although the value of ambient concentrations reduction output in the application of IM scenario and Combined scenario significantly reduce the rate of the increase in the value of the ambient concentration of SO_2 pollutant.

Ambient concentrations of PM_{10}

The results of pollution control model simulation that illustrate the value of PM_{10} ambient concentrations in the application of scenario models during the simulation period up to 2026 can be seen in Figure 6. From Figure 6, explains that the PM_{10} ambient concentrations that occur in the existing condition (baseline scenario), is higher than the three other scenarios (BWS, CNGS, IM and CS), which amount 78.33 µg/m3 in year of 2011 and increase to 375.36 µg/m3 (2026). While the Busway scenario (BWS), IMS and CNGS a decline in the each concentration of PM_{10} amount 294.35µg/m3, 189.43 µg/m3, and 138.10µg/m3, into 286.21 µg/m3 at the end of the simulation (2026) or a decrease in the concentration of pollutants respectively 14.68%, 29.77%, 98.85% and 139.63% from the basic scenario (BS). According to [15], the application of public transport in Jakarta can reduce the load of PM_{10} emissions by 26.38% during the simulation period. While the results of the study [14], states that the total burden of emission reduction potential with the application of CNGS policy for PM_{10} pollutants by 18% in 2020.

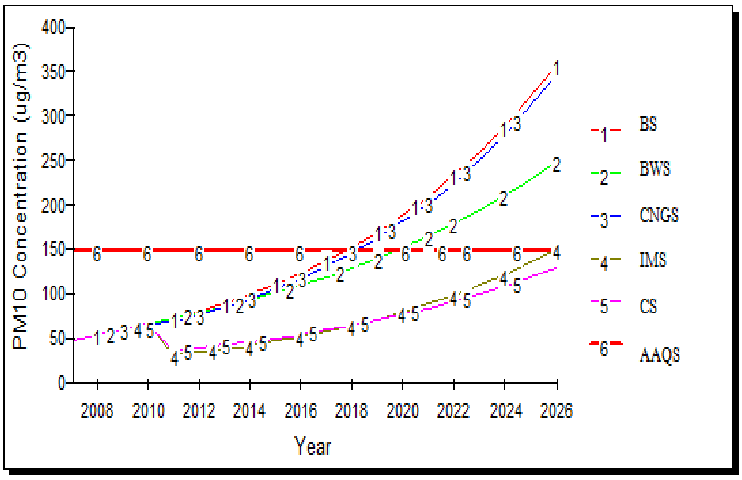

Figure 6. Prediction of ambient PM10 concentrations scenario simulation results.

According to [16], the reduction of vehicles volume through the use of public transport, buses, can reduce PM_{10} emissions by 46.7% through simulation during the period of 20 years (2005-2025). Meanwhile, according to [15], the development of public transportation can reduce PM_{10} emissions by 27.06% during the simulation period (2005-2015). Further study [14], states that the CNGS and IMS application scenarios can reduce PM_{10} emissions respectively by 61% and 78% with the 12 years simulation period (2008-2020). The comparison between the applications of ambient concentration scenario of all parameters expressed as a percentage reduction of the existing condition (baseline scenario), are presented in Table 1.

Table 1. Comparison of percent concentrations reduction compare to base scenario.

No	Pollution Type	Percent Reduction compare to Base Scenario (%)			
		BWS	CNGS	IMS	CS
1	SO_2	7.77	46.14	95.82	156.49
2	PM_{10}	14.68	29.77	98.85	139.63

From Table 1 shows that the existing condition (baseline scenario) generally have an impact on the deterioration of air quality conditions in Makassar when compared to the other four scenarios (BWS, CNG, IMS and CS). BWS implementation can reduce the

concentration of SO2 ambient about 7.77% and PM_{10} ambient about 14.68% when compared to the basic scenario. Application of CNGS can reduce concentrations of SO2 ambient at 46.14 and PM_{10} ambient at 29.77%.
In the IMS application can reduce concentration of SO2 ambient at 95.82% and PM_{10} ambient at 98.85%. While the application of the combined scenario produces the greatest reduction in ambient concentrations that can reduce ambient concentrations of SO2 at 156.49%, and PM_{10} ambient at 139.63% compare to basic scenario.

Overall ambient air concentration values for all pollutant parameters that produce the lowest concentration value that is on the application of the combined scenario (BWS, CNGS, and IM) so that it can be said that the application of the combined scenario (CS) can improve the air quality in the city of Makassar.

CONCLUSIONS

1. Concentrations of SO_2 and PM_{10} ambient in Makassar has increased during the period of the simulation, where the value of the concentration at the beginning of the simulation in 2011 is still entirely under the AAQM has been determined. At the end of the simulation in 2026, the pollutant parameters have exceeded the AAQM.
2. Based on the results of the model simulation scenario is known that the application of the combined scenario (BWS, CNGS, and IM) can improve the air quality in the city of Makassar when compared to the baseline scenario (BS).

REFERENCES

[1] Avianto TW. 2010. Dynamic System: Policy Analysis using Dynamic System Model. Bandung: ITB.
[2] Azmi SZ, Latif MT, Ismail AS, Juneng L, Jemain AA. 2010. Trend and status of air quality at three different monitoring stations in the Klang Valley, Malaysia. *Air Qual Atmos Health*. 3:53-64.
[3] Transportation Agency Makassar, 2011. Capacity Roads in Makassar.
[4] Development Studies Foundation [DSF]. 2011. Policy Analysis using Dynamic System Model.
[5] Gorham R. 2002. Air Polution from Ground Transportation; an Assessment of Causes, Strategies and tactics, and Proposed Actions for the International Community. United Nations.
[6] Gurjar BR, Buttler TM, Lawrence MG, Lelieveld J. (2008). Evaluation of emissions and air quality in mega cities. *Atmos Environ*. 42: 1593-1606.
[7] Hartrisari. 2007. Dynamic System: Concepts and Modeling Systems for Industry & Environment. Bogor: SEAMEO BIOTROP.
[8] Ilyas SZ, Khattak AI, Nasir SM, Qurashi T, Durrani R. (2009). Air pollution assessment in urban areas and its impact on human health in the city of Quetta, Pakistan. Clean , 1 – 9.

[9] Japan International Cooperation Agency ([JICA]. 2004. The Study of Transportation Master Plan for Jabodetabek.
[10] The Ministry of Finance and the World Bank. 2008. Indonesia Low Carbon Development Options: Strategies Country Case. Jakarta: WBI.
[11] Lvovsky KG, Hudges D, Maddison B, Ostro, Pearce D. 2000. Environmental Cost of Fossil Fuels. Pollution Management Series. The World bank Environment Department.
[12] Mehta S, Shin H, Burnet R, North T, Cohen AJ. 2011. Ambient particulate air pollution and acute lower respiratory infections: a systematic review and implictations for estimating the global burden of disease. *Air Qual Atmos Health* 10. 1007/s11869-011-0146-3.
[13] Osden O, Dogeroglu T, Kara S. 2008. Assessment of ambient air quality in Eskisehir, Turkey. *Environ Intern* 34: 678-687.
[14] Rahmawati. 2009. Application Analysis of Air Pollution Control Policy of the Motor Vehicle Emission Based Load Estimation (case study of DKI Jakarta) [Thesis]. Bogor. Graduate school, IPB.
[15] Syahril S, Resosudarmo BP, Tomo HS. 2002. Study on the Air Quality in Jakarta, Indonesia. Future Trends, Health Impacts, Economic Value and Policy Options.
[16] Suhadi dan Damantoro. 2005. Emission Strengths and Spatial Distribution of Emissions of Primary Pollutants in Agglomeration of Jakarta.
[17] Tietenberg T. 2003. Environmental and Natural Resource Economics. Ed-6. Eddison Wesley: Boston.
[18] World Resources Institute (WRI). 2008. Climate and Atmosphere, Emission of CO_2: Indonesia.
[19] Tietenberg T. 2003. Environmental and Natural Resource Economics. Ed-6. Eddison Wesley: Boston.