Understanding Dynamics of Green House Gases Impacts on Jakarta's Urban Development Using Model-Based Policy Simulator to Support Policy Making

Akhmad Hidayatno, Irvanu Rahman and Ricki Muliadi
System Engineering, Modeling, and Simulation Laboratory
Department of Industrial Engineering
University of Indonesia
Depok 16424, Republic of Indonesia

Abstract

The rise of Green House Gases (GHG) emission in an urban city could threaten the sustainability of growth and development of the city, like Jakarta. The current condition of Jakarta must be evaluated to get a better understanding on how GHG emission affects Jakarta's urban system structure. Policy makers need a tool to support decision making which are not just given impacts on the development, but also could give a structural understanding how the results was produced. This research is developing a model-based policy simulator of Jakarta using system dynamics to facilitate policy makers to understand dynamic interaction between GHG emission impacts on economic, social, and environmental aspects of the capital city. The simulator shows that GHG emission would harm all sectors of city's development, especially health equity of people which play a main role as the backbone of Jakarta's economic.

Keywords

Climate change, urban development, system dynamics, decision making

1. Introduction

Cities are the most contributed area to climate change impacts because of its greenhouse gases (GHGs) emission. Fong et al. (2009) described that more than a half of the world's population now lives in urban areas. These numbers emit eighty-percent of total GHGs emission on the planet through economic activities such as transportation, industrial production, and energy consumption. However, the rise of GHGs concentration in the atmosphere would give negative impacts directly to air quality, especially in cities. Reduction of air quality would severely trigger many pathogen and vector of respiratory diseases that lead to health quality reduction in urban and rural areas (Kjellstrom et al., 2007). Cole & Neumayer (2006) also argued that a disease has a fatal effect on individuals then it will lower the amount of labor supplied and will cause economic loss of productivity. Moreover, these adverse impacts could harm the sustainability of urban development, especially city with a large service production sector such as Jakarta. As the capital city of Indonesia, Jakarta is a service city that relies heavily on the productivity of its people. Dealing with these GHGs emission impacts in an urban area requires first understanding the system structure of urban development to identify which city's sectors are mainly affected. These efforts must be attributed to the city-planning system of Jakarta, since GHGs emission is one of continuing challenges to city development. The aim of this research is to evaluate current condition of Jakarta in dealing with GHG emission impacts using a model-based policy simulator. Furthermore, the use of model will facilitate future research on policy making of GHG mitigation strategy in Jakarta.

2. Basic Theory

Modeling impacts of GHGs emission has received wide attention on economics literature. Several studies quantify this effect with widely used of methods and purposes. Cai *et al.* (2008) conduct a study of emission on China's major sectors using a scenario-based modeling platform: LEAP model (Long-range Energy Alternative Planning System). This model would inform possible climate policy recommendations for China and sectoral mitigation opportunities. Similar studies also have been done in city level. Han (2008) and Fong *et al.* (2009) use a system dynamics model as a decision making tool in urban planning process to control emission and sustain economic development in populous cities.

In dealing with air pollution problems in Jakarta, the present authors have reviewed an empirical study carried by World Bank in quantifying benefit and cost of air pollution effect in application to Jakarta (Ostro, 1994). This study assesses both the cost and benefits that may result by measuring the level of air pollution related to its impact on public health. In this paper, the term 'air pollution' is referred as a suspended particulate matter, called PM10, which are smaller than 10 microns in size and have strong impacts with respiratory illness and even mortality. We apply Ostro's estimation in measuring the number of sick days (RAD – *restricted activity days*) with equation as follow: Central change in RAD per person per year = 0.0575 * change in PM10 concentration. This number of sick days then is combined with other factors that affecting labor productivity through endogenous structure of Jakarta Sustainable Urban Model, our previous work.

Jakarta Sustainable Urban Model is developed based on National Sustainability Development Model developed by Millennium Institute using system dynamics (Millennium Institute, 2000), and translated into urban settings of Jakarta. The model consists of three dimensions of sustainable development: economic; social; and environmental aspects, which has interconnected relationships among its endogenous structure (Hidayatno, Rahman, & Muliadi, 2012). Integration of air pollution problem-based-model with Jakarta Sustainable Urban Model will allow the city government to estimate the economic impacts of GHGs emission in simultaneously with development aspects and identify which factors are significantly affected in urban system.

3. Materials and Method

There are four common stages in the system dynamics methodology: model conceptualization, formulation, and verification-validation and scenario analysis. In model conceptualization, this research developed a causal-loop diagram to visualize interaction of key variables of Jakarta urban system related to impact of air pollution. In this case, health equity of people, whic has a greater impact towards Jakarta's economic, is the most affected factors of air pollution. The increasing number of sick days will induce productivity loss and possibly slow economic growth. The causal relationship is represented in Figure 1.

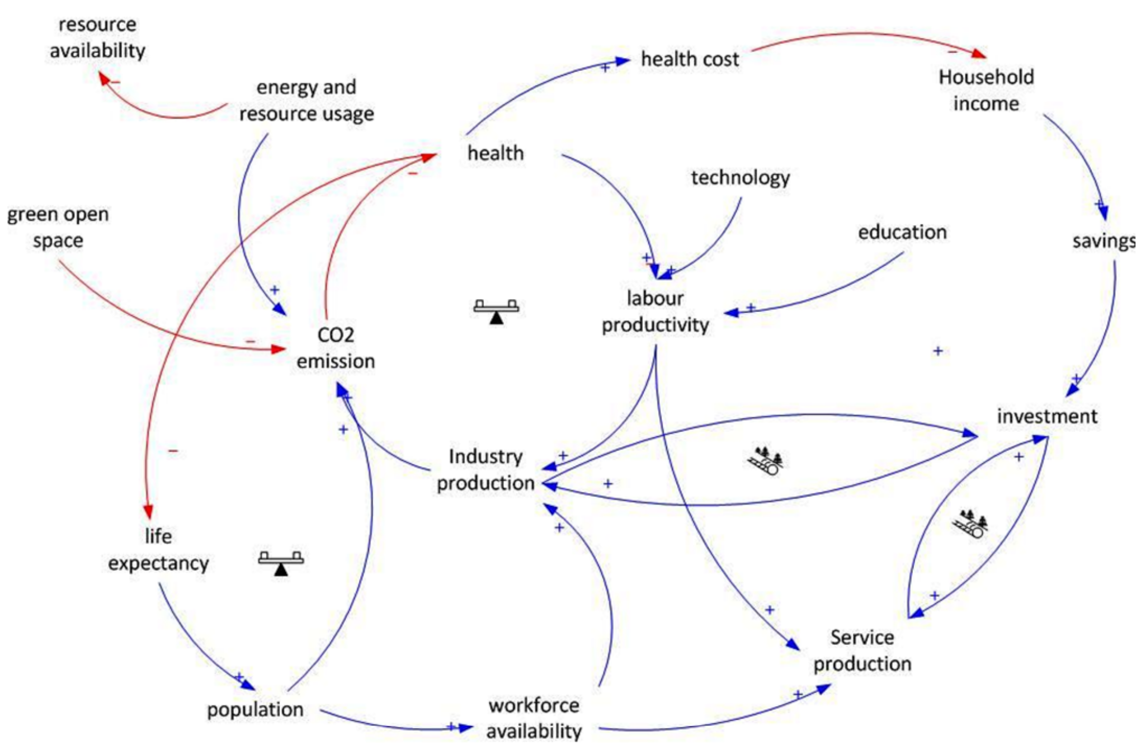

Figure 1: Model Conceptualization of Jakarta's Model-Based Policy Simulator

In model formulation, the model is developed based on relationship structure of T21 Papua (Millennium Institute, 2000) and T21 Indonesia Sustainability model (Hidayatno, Sutrisno, Zagloel, & Purwanto, 2011) and translated into city level by using yearly statistical data officially published by the city government (Jakarta in Figure, 2002-2011) and national statistics numbers (Central Bureau Statistics, 2009). The further model is justified with surrounding situation of air quality to measure emission impacts on public health equity. In validation process, we use common methods used in system dynamics, such as dimension consistency, structure assessment, and sensitivity analysis. The overview of model is shown in Figure 2.

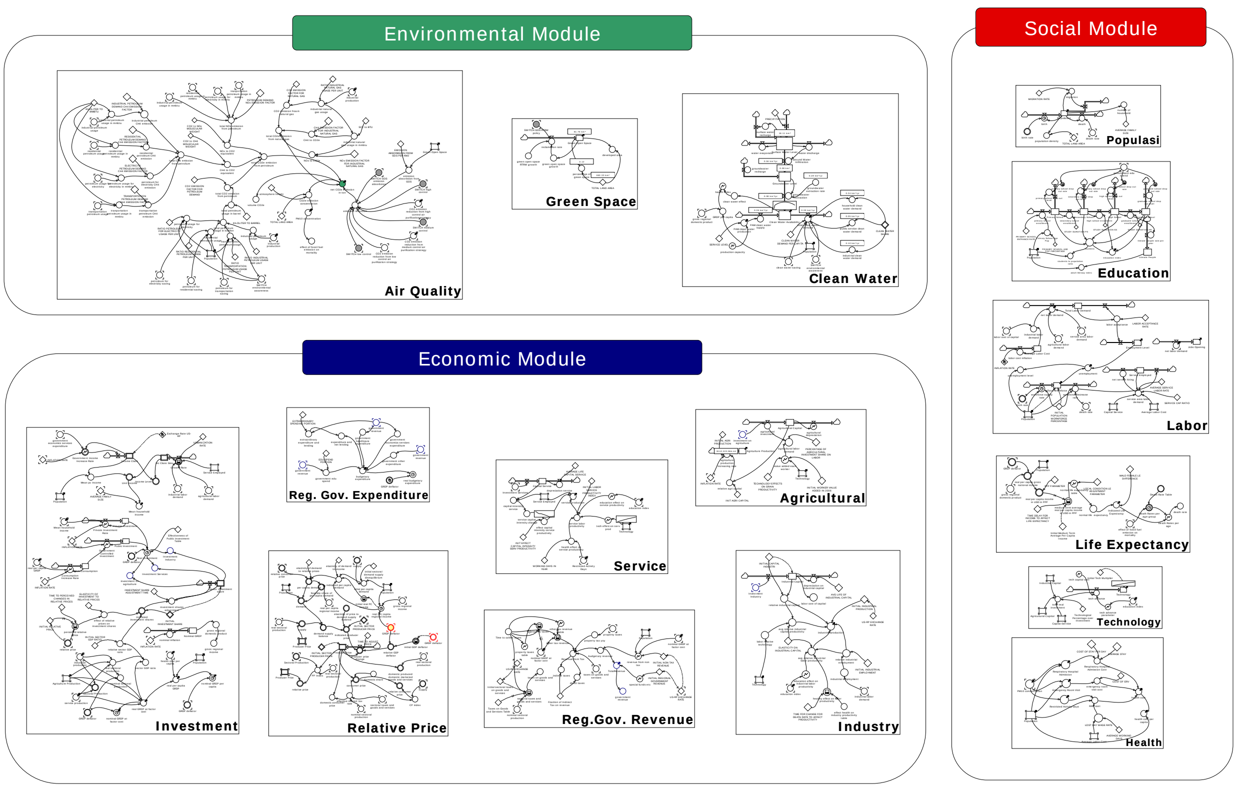

Figure 2: Structure of Jakarta's Model-Based Policy Simulator

The validated-model will be run from 2006 to 2030 to see the behavior over time (BOT) of indicators and capture interaction between endogenous–exogenous variables in the model structure. These sustainable-city indicators would be a baseline for our future work in composing mitigation strategy, as an option for Jakarta's government in reducing emission impacts on city's development.

4. Results and Discussion

The simulation results show Behavior over Time (BOT) graphs of selected indicators, shown in Figure 4. In the environmental aspect, the model presents causal relationship of economic and social activities by having greater impacts to the ecosystem, indicated by the rise of green house gas emissions which could harm the citizen health. The bad condition of public health will reduce the labor productivity and life expectancy of citizen. The green open space could reduce the green house gas emission but the proportion of green open spaces is quite low that reaches only 12 percent or 81.76 km^2 by 2030.

In the social aspect, the model predicted that the city will experience the escalation levels of income, indicated by the Real GDRP per capita, as the impact of rapid economic growth. However, this growth was not last long since the population exceeded its carrying capacity. The deteriorating condition of citizen health because of rising green house gases will also caused extra expenditure for maintaining their health. This extra health cost would decrease the income of citizen that slows down the economic. The population of Jakarta would reach over thirteen million by 2030 with sustained growth. The large number of people in Jakarta triggered many social problems by enlarging the number of unemployment in capital city.

Variables		2006	2030	Change	
Economic Indicators					
Real PDRB	USD	35.159.022.970	79.974.364.824	127%	↑
Service Production	USD	29.847.528.520	70.705.365.349	137%	↑
Social Indicators					
Population	person	8.961.680	13.363.175	49%	↑
Employment	person	3.531.799	5.206.481	47%	↑
Unemployment	person	473.176	774.906	64%	↑
Unemployment Rate	%	12%	13%	1%	↑
Real PDRB Per Capita	USD/Person	3.834	5.212	36%	↑
Number of Sick Days	days	20	32	60%	↑
Environmental Sustainability Indicators					
GHG Emission	ton	34.215.285	55.129.906	61%	↑
Green Open Space (GOS)	km^2	24,61	81,76	232%	↑
GOS Emission Absorption	ton	1.400.481,27	4.652.830,71	232%	↑

Table 1: Indicators of Jakarta's Sustainable Development Model Simulator

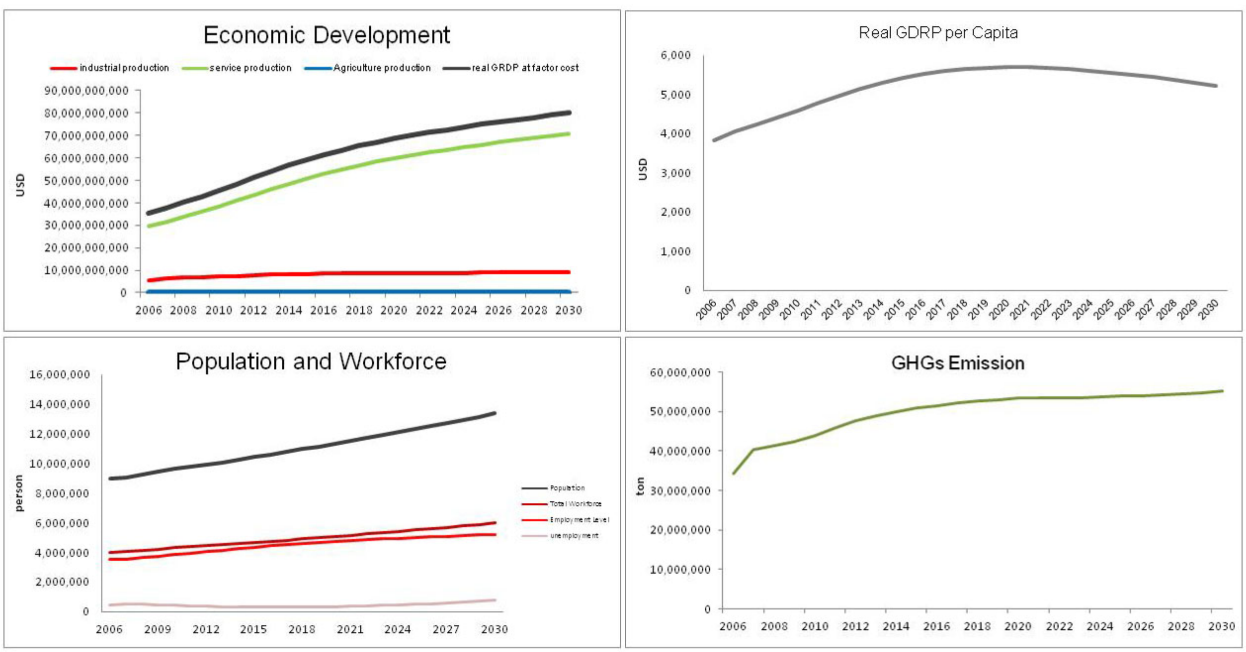

Figure 3: The Behavior Over Time (BOT) Graph of Selected Indicators

In the economic aspect, the model result showed rapid economic development with significant growth of Gross Domestic Regional Product driven mostly by the increase of service production, and then followed by industrial production. However, this growth was not directly influenced by agriculture production, although it has the most rapid increase among other sectors (as shown in Table 1). Although the GRDP has the significant growth, the growth is slowing down in the end of simulation. The deteriorating public health could be one of the reasons that cause the economics slow down.

5. Conclusion

The Jakarta Sustainable Urban Model could generate a set of sustainable indicators based on its endogenous structure which allows it to have a longer time horizon of analysis, comparing to other methods. It is already capable of highlighting the dynamic interaction between sustainability variables of economy, social and environment in the long term. It could be used as supporting tools in evaluating the GHG strategy adopted by the Jakarta governments.

In the business-as-usual scenario, Jakarta will have a significant progress towards its development, economically and socially. The rapid growth of sectoral productions will bring the people of Jakarta towards the increase of income levels. However, this advancement will directly trigger many problems, such as explosion of population, unemployment, and reduction of life expectancy. The progress will also directly affect the environment in terms of rise of green house gas emissions. These escalating green house gas emissions would harm the public health that lead to reducing labor productivity, decreasing citizen life expectancy, and increasing health cost. As the public health goes down, the economic will also slow down as the effect of green house gas emission escalation.

This is still a work in progress and would still need further improvement. Future research will be focusing on developing policy model about green house gas mitigation and integrate it within this urban model as a medium for policy testing tools and support the government in decision making .

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