Transportation Mode Selection using System Dynamics Approach

by Mardhiah Masril

International Journal of Software Engineering and Its Applications
Vol. 11, No. 4 (2017), pp. 51-60
http://dx.doi.org/10.14257/ijseia.2017.11.4.04

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Widya Setiafindari[1], Afwan Anggara[2], and Mardhiah Masril[3]

[1]*Faculty of Science and Technology*
[2]*Faculty of Business and Information Technology*
Universitas Teknologi Yogyakarta
Kampus Jombor, Yogyakarta, Indonesia
[3]*Universitas Putra Indonesia YPTK, Padang, West Sumatera, Indonesia*
widyasetia@uty.ac.id, angga_afw@uty.ac.id, mardhiah_m@upiyptk.ac.id

Abstract

This paper provides an overview of the selection of problem-solving mode of transport that can contribute to the reduction of greenhouse gas emissions using the two perspectives, namely the government and user standpoint. The method used is the system dynamics, which is concerned with the goal of increasing the understanding of the behavior of a given policy structure. The advantages of the model created with this approach is that the system is actually fairly represents, that led to the analogy of the systems approach is not necessarily consistent data and models can not be implemented in accordance with the specifications. Therefore, if the model compared with the model already established can not be comparated. Expected to provide an understanding of the behavior of the structure of a given policy can help the decision-making process regarding the dynamic phenomena.

***Keywords**: System Dynamics; Transportation Mode; Simulation; Delay.*

1. Introduction

In the face of the increasing number of current transport mode, where the transport supports economic activity, and the interaction between people at all levels of society. To support that is necessary to support the choice of transport mode smoothness. According to the Environmental Protection Agency (EPA), transportation is one of the sectors that contribute most to greenhouse gas emissions. On one side of increasing the number of vehicles continues to increase from year to year. Several attempts have been made to reduce the use of private vehicles either by increasing the capacity and quality of public transportation, taxes, fuel subsidy reduction until the regulatory reduction in vehicle ownership. Transportation system is a complex system because it consists of several interacting parties, i.e. the government, users, etc. The government also took part in shaping the transport system either through policy (tax vehicles, fuel subsidies) or direct intervention (e.g. road construction). The transport system is also affected by vehicle users where each user has different attributes, e.g. in terms of financial ability, the need transportation (mileage and trip frequency), preference for type of vehicle, environmental awareness, and social networks. Besides influenced by infrastructure (e.g. road conditions, availability of type of vehicle, and etc.). Environmental issues discussed in this paper also occurred in China [1] about improvement transportation systems and in Taiwan [2] in which the Taiwan government to build a project Low Carbon Development Penghu Island. Building a low-carbon island is a complicated systems engineering challenge, because it affects factors related to the environment, economy and society. Overall, population, forest land, industrial and commercial activities, transport, energy use day-to-day, and the activities that generate carbon dioxide is only a few critical issues that must be considered. Simulations were conducted to evaluate the impact of policy and improve understanding

ISSN: 1738-9984 IJSEIA

of the changing behaviour of the transport system for the selection of problem-solving mode of transport that contributes the reduction of greenhouse gas emissions.

The purpose of the modelling is done is to provide an overview of the selection of problem-solving mode of transport that can contribute to the reduction of greenhouse gas emissions using the two perspectives, namely determining the mode of transportation from the point of view of the government and from the point of view of the user.

The rest of this paper is organized as follow: section 2 describes related works. Section 3 describes the proposed method. Section 4 describes obtained result and following by discussion about the simulation. Finally, the conclusion of this work is described in section 5.

2. Related Works

Researches related to the reduction of carbon emissions are also performed by [3], [4] and [5]. They have examined the relationship of fuel, CO2 emissions, greenhouse gases, increased energy consumptions, and carbon emission reduction policies. By building a focused CO2 inventory in the supply chain to form CO2 emissions of each sector, such as agriculture, industry, transport and tertiary industries [3]. Yang and Timmermans [4] indicate the negative affects and positive effects by increasing fuel prices. An island can be considered a controlled environment where the environmental problems associated with energy import dependence on fossil fuels, the availability of clean water, limited waste management, transportation and other energy consumption problem. Renewable energy technologies are viable solutions in generating energy by converting natural phenomena (or natural resources) to be a useful form of energy [6].

System Dynamics can use to conduct research in the Waste Electrical and Electronic Equipment (WEEE) management systems [7]. Ahmad, *et al*. [8] show the complexity in decision making using system dynamics (SD) modelling and simulation technique. To reduce the emissions, Jo, *et al*. [9] use combination of system dynamics (SD) and agent-based modelling (ABM) to analysis for public investment projects through an integrated simulation model. Transportation problems also occur in the industry, which in the selection of the mode of transport can be performed in several ways. One of the major issues raised is the problem of transportation for one echelon, multi-facility service parts logistics systems with time-based service-level constraints [10]. While Lee, *et al*. [11] developed a single-vendor, multi-buyer inventory-transportation integrated supply chain model synchronized. The problem is different with the study, but the way of solving problems that used to serve as a reference in the transportation problems. Jifeng, *et al*. [1] make improvements to the urban transport system modelling using system dynamics approach based on the cause-and-effect analysis and feedback loop structures. The Impacts of different policy scenarios on urban development and transportation system are analysed. Suggests it should restrict the total number of vehicles to improve the sustainability of transportation systems. Such research is almost the same with the inscription written in which the discussion is written that is transportation system modelling using system dynamics approach in an effort to reduce greenhouse-gas emissions. The hybrid model were used by Egilmez and Tatari [12], they develop the calibration for policy making using the developed dynamic simulation similar to the approach used this paper.

Gas emissions analysis approach to sub-input-output system provide a detailed insight into the generation of pollution in an economy. Structural decomposition analysis, on the other hand, identifies the factors behind changes in key variables over time. Where Butnar and Lliop [13] proposed a decomposition of the changes in the components of captured CO2 emissions by sub-representation of the input-output system. Empirical application to Spanish services sector, and environmental and economic data for 2000 and 2005. The result shows that the increase in services CO2 emissions they mainly due to an increase in generated by non-services to cover the final demand for services. Different from [14] adopt the input-output analysis based hybrid life cycle to evaluate water consumption and CO_2 emissions using wind power in China. With the water crisis, China's energy policy will reap double benefits through progressive energy policy when increasing the share of wind power as part of the overall effort to diversify its electricity generation technologies. CO_2 intensity are used in the analysis to presents a simple model development using multiple regression with interactions for estimating carbon dioxide emissions in Malaysia and Thailand [15].

In Jeddah city Saudi Arabia has witnessed dramatic changes in its urban area, population and transportation. Aljoufie, *et al*.[16] conduct research using the eight urban growth and transportation indices to analyse the relationship between spatial-temporal changes of urban growth and transportation. In the same year to explore the reciprocal spatial-temporal effects of transport infrastructure and urban growth in Jeddah city from 1980-2007, Aljoufie, *et al*.[17] detect the spatial temporal mutual effects of transport infrastructure and urban growth using study approach for the case of mono-centric urban structure cities. Tuzkaya and Önüt [18] combining many detailed criteria in an evaluation study and synthesizing them to obtain a transportation-mode selection with FANP model was applied to a large-sized real-life problem related to the transportation project between Turkey and Germany.

In a study conducted by Trappey, *et al*.[2] mentioned that the green transportation policy is measured using variables such as the population in certain areas (Penghu Islands), the number of tourists, the number of electric scooters, government subsidies for the replacement of scooters, motorcycles and license control, system approach used to develop dynamic models to explore green transportation policy. A green transportation scheduling problem addresses [19]. They have formulated as a bi-objective mixed-integer nonlinear program and the experimental results demonstrate that the proposed approach can effectively solve the investigated problem by generating much better solutions than 3 other metaheuristic-based Pareto optimization approaches and the industrial method do.

In this paper will be the effect of the reduction of carbon emissions by using the point of view of the government and its point of view, where the variables used are the number of vehicles affected by the purchase of the vehicle and the level of environmental awareness, the lack of awareness of the environment seen from the road, vehicle purchase rate is affected by the financial ability and preference for type of vehicle, financial ability, preference for type of vehicle seen from the types of vehicles available compared with transportation needs, where the transportation needs based on the frequency of trips and mileage as well as social networking than the number of vehicles, and the last variable is the type of vehicle availability.

3. Proposed Method

The method used is the system dynamics, which is concerned with the goal of increasing the understanding of the behavior of a given policy structure in the transport mode selection. This understanding is important in the design of effective policy, because the decision-making process regarding the dynamic phenomena. The simulation was performed using Vensim PLE software. The first will be made Causal Loop Diagram (CLD) models [20] from the government and users, then made Stock and Flow Diagram (SFD) models by the user to be able to develop three scenarios using mathematical formulation in order to see whether the policies transportation mode selection can influence the decisions taken. Conceptual models of simulations are carried out will provide translation analysis of CLD and SFD [21] transport mode selection model.

3.1. Causal Loop Diagram (CLD) Models from the Government and Users

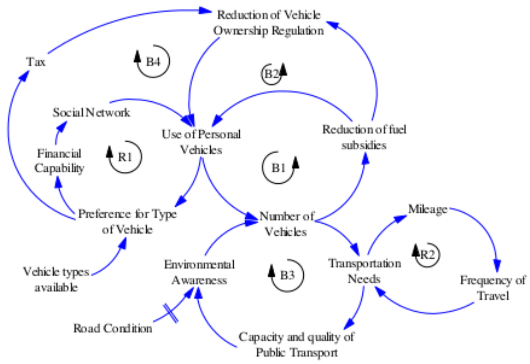

Figure 1. Causal Loop Diagram (CLD) Models by the Government and Users

From Causal Loop Diagram (CLD) (Figure 1) is seen in the balancing loop B1: "Reduction of fuel subsidy" is a lever to reduce the "use of private vehicles". Public awareness to limit the use of private vehicles will affect the number of vehicles on the road (the amount of carbon produced was reduced). By way of reduction in fuel subsidies also can provide positive results for reduction in vehicle ownership regulations (B2), which can even affect also the preference of the type of vehicle, where the vehicle is raised if the tax would give a positive result against the government regulation (B4). On Reinforcing loop R1, the use of private vehicles can be seen from the preferences of the type of vehicle and the financial ability of the community itself that the social networks formed will make increasing use of private vehicles. Where there are exogenous variables such as type of vehicle availability will affect the preference for type of vehicle. The influence on the number of vehicles here, may also be due to the high demand for transport due to the far distance and the frequency of trips made (R2), but if look at the capacity and quality of public transport should be improved (currently lacking), will have a positive impact form of environmental awareness for people to understand that with the increasing number of vehicles on the road will increase the level of air pollution (from carbon generated), can be seen in B3. To the level of environmental awareness is also influenced by exogenous variables such as the condition of the road (which is now much damaged) that environmental awareness will be increased if people realize that it is mutually influential. Although the delay occur, but has a separate progress for greenhouse gas emission reductions to be achieved.

3.2. Stock and Flow Diagram (SFD) Models by Users

This paper emphasizes on the simple model of transportation mode selection by the user which is a major factor is the number of vehicles affected by several factors from the user side. Stock and Flow diagram of the model by the user is shown in Figure 2.

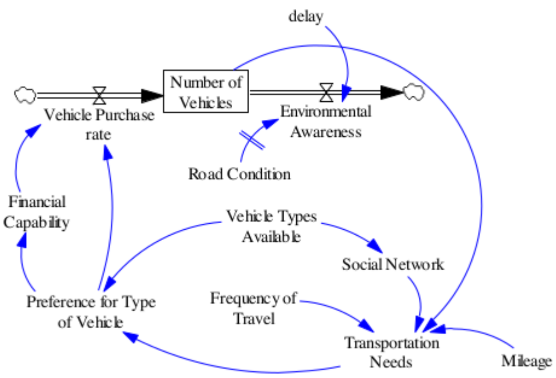

Figure 2. Stock and Flow Diagram (SFD) models by users

Increasing number of vehicles will cause environmental awareness (here analogous to outflow, with a time delay) because it felt the effect of increasing carbon in the air. Will be three scenarios with the following mathematical formula:

a. Vehicle purchases = level of environmental awareness
b. Initial value = 1000
c. Vehicle purchase rate = financial capability * preference to this type of vehicle
d. Awareness of the environment = road conditions * delay
e. Financial capability * 1 = preference
f. Preference for type of vehicle = vehicle types available / transportation needs
g. Transportation needs = [(frequency of trips * distance) + social networking] / number of vehicles
h. Trip frequency = 5
i. Mileage = 20
j. Social network = type of vehicle * 1
k. Types of vehicles available = 2
l. Delay = 100 + STEP (50.20)
m. Road condition = 2

In the following section we present simulation results and following by discussion.

4. Result and Discussion

This section presents obtained results and following by discussion.

4.1. Simulation Results

Here performed 3 simulated scenarios using Vensim PLE software as follows:

a. The first is the current simulation with the mathematical formulation as initial SFD models were made. Where are the results obtained with these values, it can be seen that the initial value of 1000. Simulation results shown in Figure 3, showed that:
   1) Decreasing the number of vehicles, however environmental awareness was low, in subsequent years to increase better.
   2) Vehicle purchase rate was decreased, in the years that followed it back to its original value.
   3) Transportation needs in the early years has increased sharply, then in the following year returned to the point of 0 (zero).

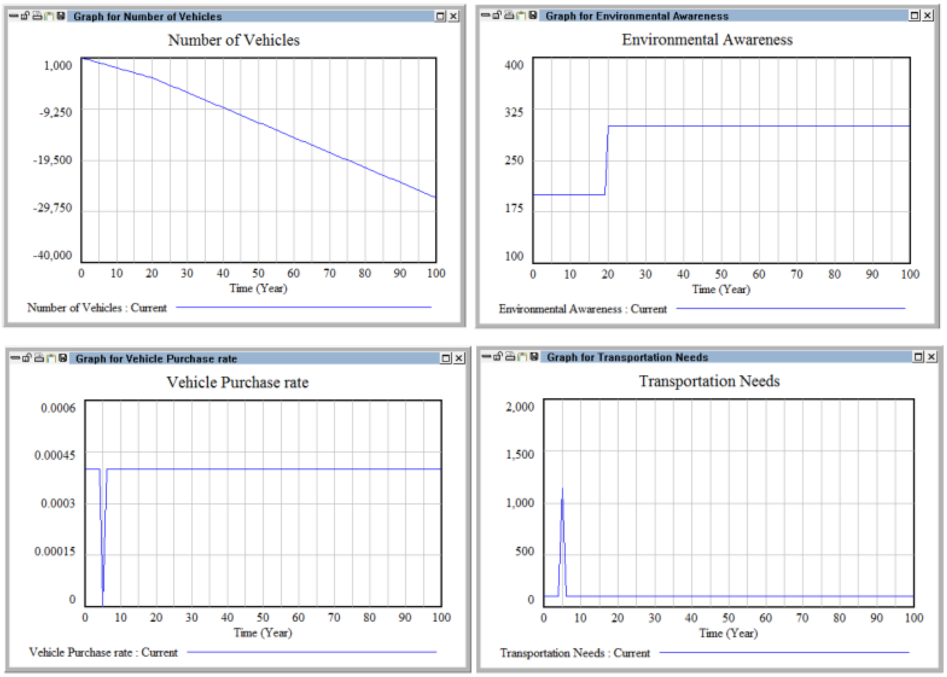

Figure 3. Graphic Simulation Results I (*current simulation*)

b. The second scenario with the initial value on the number of vehicles was changed to 800, the frequency of travel = 8, vehicle type available = 5, and the condition of the road = 4(mean where the condition of road is good). Second simulation results shown in Figure 4, showed that:
   1) Decreased number of larger vehicles, where environmental awareness is much higher than the initial scenario (current simulation).
   2) Which is unfortunate, in this scenario vehicle purchase rate instead it is huge, because the vehicle type available that is much in this scenario, i.e. 5.
   3) Transportation needs stable from year to year over the amount of transportation needs in the initial scenario.

c. The 3rd Scenario with the initial value on the number of vehicles was changed to 600, the frequency of travel = 10, vehicle types available as well as the second scenario = 5, and the condition of the road is good = 4 . 3rd simulation results shown in Figure 5, showed that :
   1) The number of vehicles has decreased but not by decreasing the number of vehicles in scenario 2, where environmental awareness was not as high as environmental awareness in scenario 2 .
   2) In scenario 3 the vehicle purchase rates are stabilized at a value, it number is above initial scenario, but lower than in 2nd scenario. The number of the vehicle purchase rate did not experience such fluctuations in the initial scenario and the 2nd scenario (in scenario 3 the value of the vehicle purchase rates tend to be more stable) .
   3) Transportation needs stable from year to year more the amount of transportation needs in scenario 2 and the initial scenario. It happens because there are 4 factors that affect the transportation needs, including the frequency of travel, mileage,

social networks and the number of vehicles. Where the fewer the number of vehicles, the transportation needs even greater.

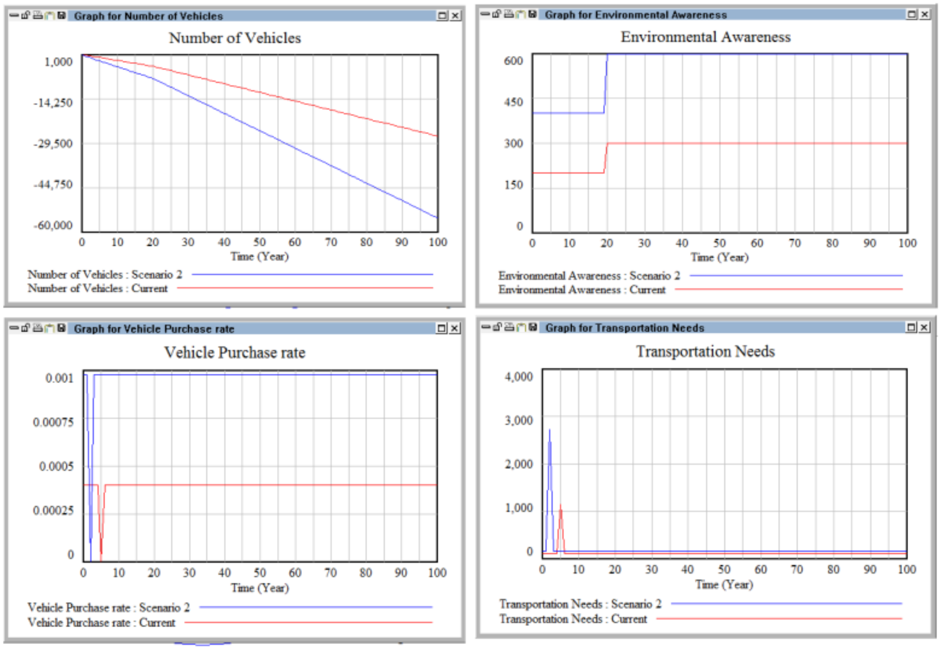

Figure 4. Graphic Simulation Results II

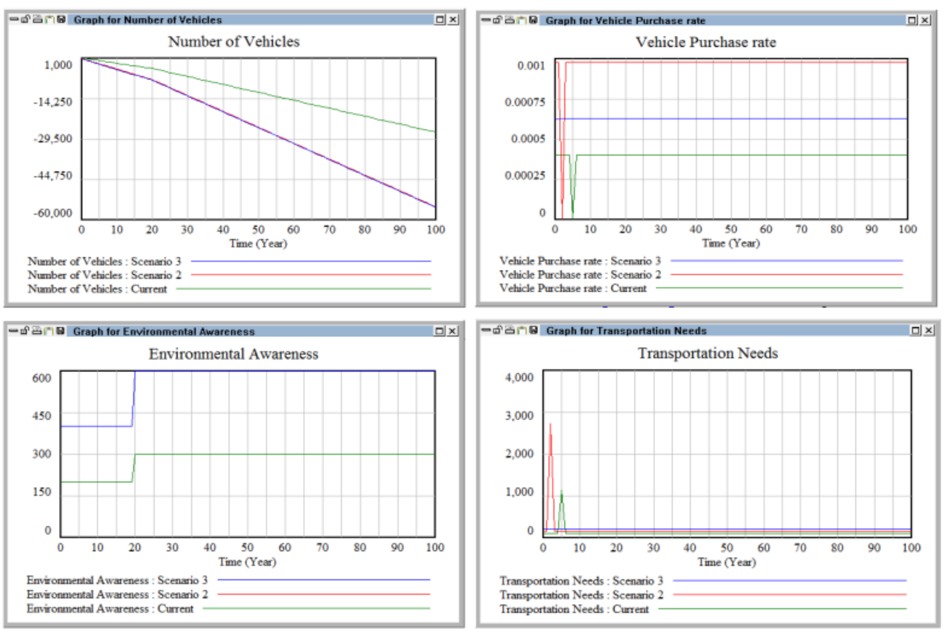

Figure 5. Graphic Simulation Results III

d. The 4th Scenario with the initial value on the number of vehicles was changed to 400, the frequency of travel = 5 (same as initial scenario), vehicle types available as well as the 2nd scenario and the 3rd scenario = 5, and the condition of the road = 2 (same as initial scenario) . 4th simulation results shown in Figure 6, showed that :
   1) The number of vehicles has decreased almost equal to the number in scenario 1, but the amount exceeds the number of vehicle in scenario 2 and scenario 3, where environmental awareness was not as high as environmental awareness in scenario 2.
   2) In scenario 4 the vehicle purchase rates are stabilized at a value, it number is the highest value.
   3) Transportation needs stable from year to year, the lowest because the level of vehicle purchase are very high that greatly affect the level of transportation needs. It happens because of the factors the frequency of travel, mileage, social networks and the number of vehicles more significant in influencing the transportation needs.

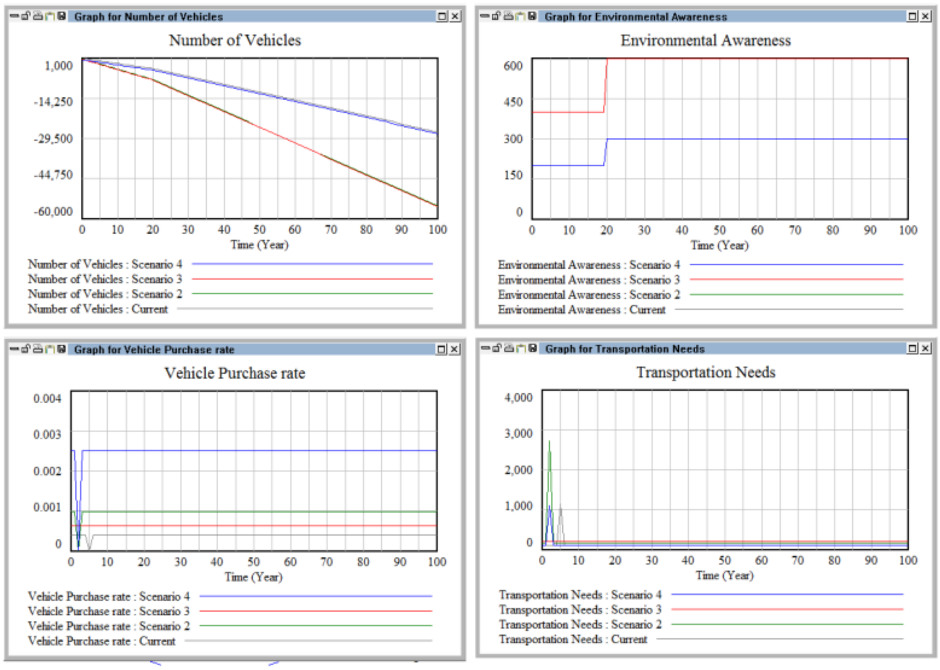

Figure 6. Graphic Simulation Results IV

Of the four scenarios are done, it can be concluded that the existing number of vehicles affected by the level of vehicle purchase. Where the level of vehicle purchases are influenced by many types of vehicles available. However, the level of awareness of the environment is not affected on the existing road conditions, the authors analogize that when road conditions were better, environmental awareness was lower, but it can be seen that when the value for the high awareness of the condition of the road environment can be seen in the chart higher. Transportation needs were not much changed here, because of the variables that affect the transportation needs is the type of vehicles availability.

4.2. Model Verification and Validation Methods

Verification is to evaluate whether the model could have been implemented in accordance with the specifications. Conceptual model must be fit for purpose and in accordance with the requirements modeling. Validation method that the authors chose is a static method, which in this model, only the data analysis performed, and validation of cause effect graphing views. The data used in this modeling is not the actual field data, due to unavailability of data estate. And conclusion and modeling results are also seen from the output of the 4 scenarios comparison chart done. This validation is used to answer the question "how to make a model that fits the model and the actual purpose?".

5. Conclusion

The advantage of the model is made is that the system dynamics approach is fairly represents the actual system (refer to the existing literature), and the shortcomings of this approach is the lack of real data leads to the analogy of the systems approach is not necessarily consistent data and models can not be implemented in accordance with the specifications. So if the model compared with the model already established can not be dikompasi. In accordance with the original purpose of that modeling is done is to provide an overview of the selection of problem-solving mode of transport that can contribute to the reduction of greenhouse gas emissions. Authors should provide more variables representing mode of transportation. In this paper, the authors much more emphasis on the number of vehicles, vehicle purchases and the level of transportation needs that are expected to provide increased awareness of the environment is precisely the result is not very significant. However, it can be seen that by using the system dynamics approach, the understanding of the behavior of the structure of a given policy can help the decision-making process regarding the dynamic phenomena such.

Acknowledgment

This research is supported by Universitas Teknologi Yogyakarta. The work of Mardhiah Masril is supported by Universitas Putra Indonesia YPTK, Padang, Indonesia.

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