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A SYSTEM DYNAMIC MODEL OF TRAIN REVITALIZATION TOWARD SUSTAINABLE URBAN TRANSPORTATION SYSTEM IN SURABAYA - INDONESIA

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ABSTRACT

Surabaya has the second largest population in Indonesia. The larger numbers of population will increase the population mobility. The high number of population mobility will raise many problems such as increase a traffic jam, oil and gas consumption, and air pollution in Surabaya. Train is one of the modes transportation which offers the solution in transportation problem in Surabaya. It provides the high capacity in the transportation which offers the cheap price in transportation. This research will study the revitalization planning of the train in Surabaya with using system dynamic approach. In addition, this system affords the complex system which related to economic, social, and environment aspect in order to create the sustainable transportation system. Also, the model will conduct 5 optional scenarios. The first scenario is increasing railway station in Surabaya. The second scenario is increasing parking lot capacity in railway station area. The third scenario is increasing the train lane. The fourth scenario is increasing the number of train's departure schedule. The fifth scenario is increasing the train series. Finally, the scenario which gives the significant effect to the environment and the social aspect is doing the increment of train's departure schedule.

Keyword: urban sustainable transportation system, revitalization, train, policy, system dynamic.

INTRODUCTION

Transportation is the important sector in the economic development (Qingyun, 2007) [1]. Transportation sector is needed for supporting the social life especially in urban transportation. Surabaya is second largest city and the second biggest number of population in Indonesia. There are 2.929.528 person who live in Surabaya [2]. Moreover, the enhancement number of the population will increase the population mobility. The enhancement of population mobility is demonstrated by the increment of private vehicle on the street. The high number of private vehicle could give the negative effect to the environment such as increasing the total number of traffic jam and spend the high number of oil consumption. The estimate cost that has charged by the government due to the traffic is around 1 trillion rupiah [3]. In another effect, the traffic jam could make the road users become stressed. Then, it could make the unproductive time, lost money, and lost energy. In environment effect, the high number of traffic jam could increase the air pollution. Based on the data national development planning agency [4] said that motor vehicle exhaust gas contribute 60-70% in the air pollution. This number is higher than the industrial sector which is 10-15% in the air pollution. In another hand, the high number of the population mobility gives the high contribution in the regional income. Therefore, it should find the solution problem in order to solve the high number of private vehicle in Surabaya.

Train is one of the alternative transportation modes who can develop the transportation in Surabaya. It gives the cheapest prices than other transportation modes. Moreover, it allocates many of the passengers who want to travel. Also, it could provide the fastest in mobility and accessibility to reach the destination places [5]. This transportation could give the solution problem in many aspects such as environment, economic, and social.

Furthermore, this research will study about the revitalization planning in Surabaya. This study is used to solve the private vehicle problem that will occur in the next period of time. Using the system dynamic model, this problem could be modelled without directly applied the government policy. The system dynamic approach is an appropriate method in this case problem because it can accommodate the interaction among variables in complex systems, and show the behaviour of variables available in the system.

RESEARCH METODOLOGY

Research methodology in designing simulation models of train revitalization in Surabaya. This research is used the system dynamic methodology. There are many of the stages that will take in the research. The first stage is the variable identification and conceptualization of the model using causal loops diagram that shows a causal relationship. The second stage is designing simulation model which is needed to carry out the simulations by formulating, running the simulation model and applying the scenarios. The third stage is the creation of verified and valid models using Vensim simulation software. Finally, the last stage is an analysis and policy scenarios.
However, input and output diagram is shown in the

Figure-1 This picture describes the general problem of transportation system in Surabaya. In the input and output diagram, there are 2 categories variable which influence to the system. There are uncontrollable input and uncontrollable output. Then, it has the variable which describe the behaviour system. It is the environment

variable. The last variable is the goal variable. There are expected input and expected output.

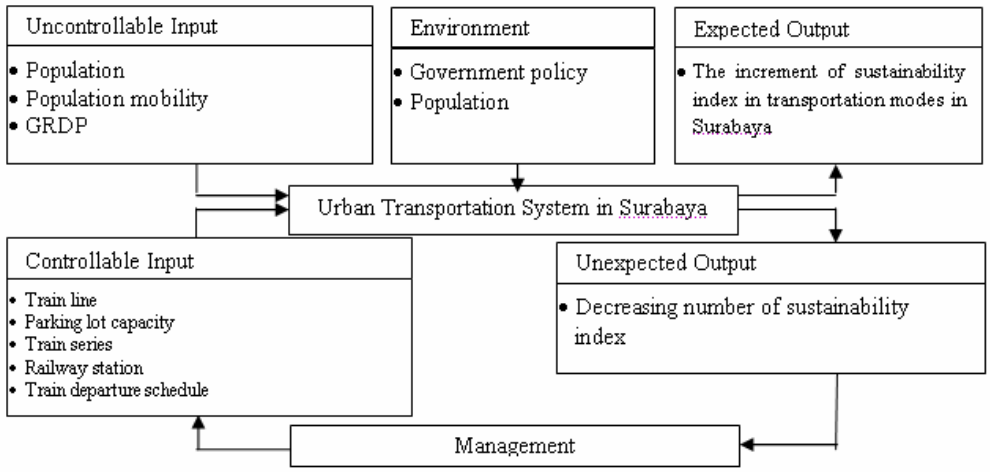

Figure-1. Input Output Diagram.

SIMULATION MODEL DESIGN

There are many of the steps for doing the simulation. This is step by step for doing the simulation:

- **Identification Variables**

The first stage for designing the model is identifying key variables and their interrelationship. Identification variables conducted by reading the literature either books, electronic media and journal. There are many of journals which are related to the study such as [6],[7],[8]. In addition, there is interview method which is used to support the identification variable. This method is conducted by using open questionnaire. The respondent of the questionnaire is a stakeholder that involved in the problems such as PT Pertamina regional V Surabaya, Regional Revenue Office in East Java Province, PT. DAOPS VIII Surabaya (the authority of train operation) and Central Bureau Statistic Indonesia in Surabaya.

- **Conceptual Model of System Dynamic**

The conceptual system is the stages to identify the relationship among variables through causal loop diagrams. The causal loop diagram defines the description of causal relationship as arrows. There are 2 closed relationships between variables which is the positive and negative effect on the system [9]. Figure-2 is showed the causal loop diagram in train revitalization.

- **Stock and Flow Diagram**

The next step is conducting the simulation with using the Vensim PLE software. This software will run for 20 years. Moreover, there are 5 sub modules in the train revitalization system:

1. Population and Mobility Sub module

This sub module is created for indicating the population in Surabaya. This sub module will describe the increasing and the decreasing factor in population. Also, the number of the population mobility in each transportation modes will be calculated from the number of population.

2. Personal vehicle preference index Sub module

The objective of this model is describing the passenger who chooses the private vehicle. There are some aspects which consider such as the train safety index, the speed of highway index, and the cost index.

3. CO_2 Emission Sub module

The purpose of constructing this sub module is describing the change in environment because of traffic jam. CO_2 emission is the represented variable for system. Moreover, this sub module describes many factors that influence the CO_2 emission. In order to calculate of CO_2 emission, the sub module is used the method of mobile combustion conversion. This calculation considers various types of vehicle and various type of fuel.

4. Regional revenue Sub module

The purpose for making this sub module is describing the regional economic aspect which is represented the regional revenue. The calculation of regional revenue is considering the 3 aspect such as vehicle tax, fuels tax, and parking levy.

5. Personal train preference index Sub module

The objective of this model is describing the passenger who chooses the transportation mode especially a train. There are some aspects which consider such as the availability index of railway station, the affordability index, the cost index, accessibility index and the availability of parking lot in the railway station.

- **Model Verification and Validation**

Verification is testing of conformity or model's logic accuracy and checking the error of the simulation

program. It is done by checking formulations, equations and unit parameter on the variable's model variables. This is the test to check the model whether the model can run properly without the formulation error. The verification of the system is used software ventana simulation on the vensim software.

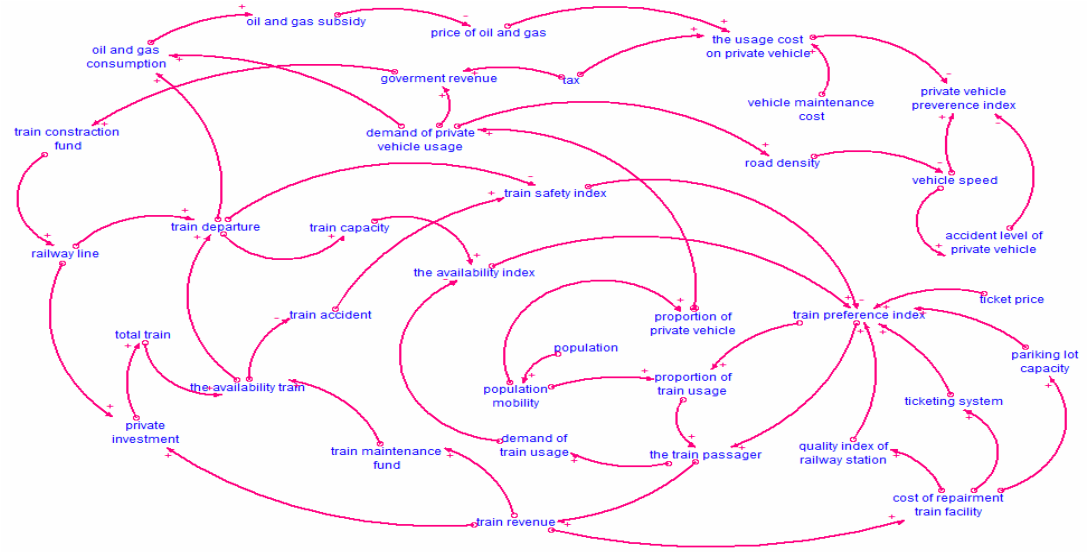

Figure-2. Causal loop diagram

On the other hand, the validation test has the goal to ensure that the model has represented the actual system. This model used 5 validation test which are structure model test, model parameters test, boundary adequacy test, extreme conditions test and behavior model test [10].

POLICY SCENARIO MODELS

There are 5 optional scenarios. The parameter of sustainability index is used for measuring the 5 optional scenarios. Then, it will choose the best one who gives the optimal number in the environmental, economic, and social aspects.

- **Scenario 1: Add the railway station**

This has the purpose to increase railways station. Today, the number of railway station in Surabaya is 16 stations where the 12 of the station is used as a passenger station. In scenario, all of 16 stations in Surabaya will be optimized as a passenger station. After running the scenario 1, there are 3 parameter aspects that will be considered. There are environment, economic, and social aspects. The result of scenario 1 with environmental aspect is shown in table-1. Moreover, there are 3 parameters which are used in measurement such as CO2 emissions, premium consumption and diesel consumption.

Table-1. The result of scenario 1 - Environment aspect.

Environment Aspect	Scenario 1
CO2 Emissions (Kg)	2,106,360,320
Premium consumption (litre)	1,849,244,416
Diesel consumption (litre)	130,282,424

Table-2 will show the result of scenario 1 with economic aspect. There are 4 parameters that will be measured in this scenario such as local revenue, subsidies of oil and gas, KAI'profits (Indonesian Railways), and revitalization train by government alocation.

Table-2. The result of scenario 1 - Economic aspect.

Economic Aspect	Scenario 1
Local revenue (Rp. 000.000)	2,263,504
Subsidies of oil and gas (Rp. 000.000)	4,801,885
Profit of KAI (Rp. 000.000)	22,705
Revitalization train by Government alocation (Rp. 000.000)	4,800

Table-3 shows the the result of scenario 1 with social aspect. There are various parameters in the social aspect which are motor cycle speed, car speed, alocation time of motor cycle and train passager.

Table-3. The result of scenario 1 - Social aspect.

Social Aspect	Scenario 1
Motor cycle speed (Km/hour)	14.04
Car speed (Km/hour)	11.52472
Alocation time of motor cycle (hour/day)	220,528
Alocation time of car (hour/day)	269,505,072
Train passager (people/day)	4210

- **Scenario 2: Add the parking lot capacity in railway station area.**

The purpose of the scenario is increasing the supporting facilities in railway station which is the parking lot capacity at railway station area. Today, the number of parking capacity is 225 cars and 1050 motorcycles. In this scenario, there are additional parking lot capacity which is to be 850 cars and 2800 motorcycles. There are 3 scenario results in this scenario. The result of scenario 2 with environment aspect is shown in table-4. Then, Table-5 is shown the result of scenario 2 with economic aspect. Finally, Table-6 is shown the result of scenario 2 with social aspect.

Table-4. The result of scenario 2 - Environment aspect.

Environment Aspect	Scenario 2
CO2 Emissions (Kg)	2,106,360,064
Premium consumption (litre)	1,849,244,160
Diesel consumption (litre)	130,282,424

Table-5. The result of scenario 2 - Economic aspect.

Economic Aspect	Scenario 2
Local revenue (Rp. 000.000)	2,263,504
Subsidies of oil and gas (Rp. 000.000)	4,801,885
Profit of KAI (Rp. 000.000)	31,465
Revitalization train by Government aloocation (Rp. 000.000)	0

Table-6. The result of scenario 2 - Social aspect.

Social Aspect	Scenario 2
Motor cycle speed (Km/hour)	14.04
Car speed (Km/hour)	11.52472
Alocation time of motor cycle (hour/day)	2,205,281
Alocation time of car (hour/day)	269,505,119
Train passager (people/day)	4210

- **Scenario 3: Reactive and increasing the railway lane**

This is the scenario for increasing the railway lane. Today, the number of railway line has only one. For the next scenario, the number of railway lane will increase to be 2. Moreover, this scenario will also reactive the railway line that has already activated before. For example the railway line in Gubeng Boulevard. It is a lane in Surabaya which has been operated by PT. DAOP VIII Surabaya. The result of scenario 3 is same with the previous scenarios which are environment, economic, and social aspect. Table-7 shows the environment aspect. Table-8 shows the economic aspect. Then, Table-9 shows the social aspect.

Table-7. The result of scenario 3 - Environment aspect.

Environment Aspect	Scenario 3
CO2 Emissions (Kg)	2,112.277,632
Premium consumption (litre)	1,854,036,096
Diesel consumption (litre)	130,282,424

Table-8. The result of scenario 3 - Economic aspect.

Economic Aspect	Scenario 3
Local revenue (Rp. 000.000)	2,263,504
Subsidies of oil and gas (Rp. 000.000)	4,801,885
Profit from KAI (Rp. 000.000)	22,455
Revitalization train by Government alocation (Rp. 000.000)	60,000

Table-9. The result of scenario 3 - Social aspect.

Social Aspect	Scenario 3
Motor cycle speed (Km/hour)	14.04
Car speed (Km/hour)	11.52472
Alocation time of motor cycle (hour/day)	220,528
Alocation time of car (hour/day)	269,505,072
Train passager (people/day)	4210

- **Scenario 4: Increasing the number of train's departure schedule**

This is the scenario for increasing the schedule time of the train. Today, the number of train's schedule is 18 units. In this scenario, this number will be increased become 24 units. These are the scenario results which are shown in Table-10, Table-11, and Table-12.

Table-10. The result of scenario 4 -Environment aspect.

Environment Aspect	Scenario 4
CO2 Emissions (Kg)	2,105,187,072
Premium consumption (litre)	1,848,085,248
Diesel consumption (litre)	130,282,424

Table-11. The result of scenario 4 - Economic aspect.

Economic Aspect	Scenario 4
Local revenue (Rp. 000.000)	2,263,082
Subsidies of oil and gas (Rp. 000.000)	4,799,250
Profit of KAI (Rp. 000.000)	41,493
Revitalization train by Government alocation (Rp. 000.000)	0

Table-12. The result of scenario 4 - Social aspect.

Social Aspect	Scenario 4
Motor cycle speed (Km/hour)	14.06
Car speed (Km/hour)	11.53005
Alocation time of motor cycle (hour/day)	220,427
Alocation time of car (hour/day)	26,942,966
Train passager (people/day)	6549

- **Scenario 5: Increasing the train series.**

This is the scenario for increasing the train series in Surabaya. This scenario has a purposed for increasing the facility of utility in railway station. The result of scenario 5 will be shown in Table-13, Table-14 and Table-15.

Table-13. The result of scenario 5- Environment aspect.

Environment Aspect	Scenario 5
CO2 Emissions (Kg)	2,112,277,760
Premium consumption (litre)	1,854,036,224
Diesel consumption (litre)	130,282,424

Table-14. The result of scenario 5 - Economic aspect.

Economic Aspect	Scenario 5
Local revenue (Rp. 000.000)	2,263,504
Subsidies of oil and gas (Rp. 000.000)	4,801,885
Profit from KAI (Rp. 000.000)	22,455
Revitalization train by Government alocation (Rp. 000.000)	25,000

Table-15. The result of scenario 5 - Social aspect.

Social Aspect	Scenario 5
Motor cycle speed (Km/hour)	14.04
Car speed (Km/hour)	11.52472
Alocation time of motor cycle (hour/day)	220,528
Alocation time of car (hour/day)	269,505,119
Train passager (people/day)	4210

CONCLUSIONS AND RESEARCH RECOMMENDATIONS

The simulation results is showed that the variable who gives the most significant impact in sustainability parameters are the number of railway stations in Surabaya, parking lot capacity in railway station area, the number of railway lane, the number of train's schedule departures and the number of train circuit.

Moreover, there are 5 optional scenarios which are offering to improve the system. The scenario's result is showed that the scenario 4 give a significant impact on the environmental and social aspects. It shows that the number of CO2 emissions will decrease after implemented the scenario 4. In the social aspect, the parameters are increasing when the scenario 4 has been implemented.

Then, scenario 2 provides the most significant impact on the economic aspects. The other scenarios give a lack impact on the sustainability indicators such as environment, social, and economic aspect.

In a future, there is a study that can be discussed regularly. The study is discussed about the continuity of railway transportation with another other modes of transportation such as taxi or bus. This study has a purposed to increase personal train preference on the mass transportation in Surabaya.

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