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Congestion Mitigation Scenario through Public Transportation Improvement Erma Suryani1, *, Rully A. Hendrawan1, Phillip F. E. Adipraja2, Lily P. Dewi3 1Information Systems,

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2STMIK Asia Malang, Indonesia 3Informatics Engineering, Petra Christian University, Surabaya, Indonesia Abstract. Congestion can be recognized through roads filled with cars, trucks, buses, and sidewalks filled with pedestrians. It usually relates to an excess of vehicles at a particular time resulting in lower speeds, sometimes much slower than normal speeds. Public transportation is a vital element in solving the congestion problem in the city. In Indonesia, currently, we do not yet have easy, safe, and convenient transportation modes to move from one point to another. Therefore, the growth rate of personal vehicles soaring from year to year. Therefore, in this research we developed a set of simulation models to mitigate congestion through the improvement of public transportation. As a method we utilized in developing the model, we utilized system dynamics based on consideration that the method can accommodate nonlinear relationships between factors that have significant contribution to mitigate the traffic congestion. Research results show that the improvement of public transportation through comfort, safety, reliability, and affordable cost can mitigate the traffic congestion. 1 INTRODUCTION Transportation has an important role in supporting economic development and social development for the welfare of society [1]. Generally, in Indonesia, we do not yet have easy, safe, and convenient transportation modes to move from one point to another. Therefore, the growth rate of personal vehicles soaring from year to year. Congestion can be recognized through

roads filled with cars, trucks, buses, **and sidewalks filled with pedestrians.** **9**

Congestion usually relates to an excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower—sometimes much slower—than normal or"free flow"**speeds** [2]. Several sources **of congestion** **3**

are: a)

Traffic-Influencing Events such **traffic** incident, **work zones,** and **weather;** b) **Traffic Demand** **10**

that includes special events and

fluctuations in normal traffic, c) **Physical Highway Features** such as **traffic control devices** **10**

and road capacity. Public transport that exists today, some of its forms are less feasible and less secure, the fleet of trains is still minimum so crowded and often there is interference. Based on this condition, we

need a transportation revolution in Indonesia. The existence of easy, safe, and convenient public transportation is very important not only to congestion mitigation, but also to reduce fuel consumption, as well as to improve the efficiency in mobility.

> **The primary survey has been conducted to collect the data for identifying public preferences for public transport characteristics under four criteria,** those are **reliability, comfort, safety and cost** 4

[3]. Motorcycles in developing countries are a major

> **cause of traffic congestion, accidents, environmental pollution and other social tensions, it is** required **to plan an appropriate transport system. Although bus service constitutes a small part towards** several **trips,** 2

> **they are still regarded as an alternative to motorcycle** 2

[4]. Previous study has developed a "web based monitoring traffic system". This system is useful in terms of providing surveillance, control and road network monitoring services. The system can integrate

> **complex components in a modular, flexible, and open structure to validate models** 7

and includes

> **tools to simulate various traffic scenarios and communication technologies** 7

[5]. Other study has exploited

> **the emergence of** new **technologies such as the Internet, to design an intelligent Traffic Management System (TMS) that can monitor** traffic **and control network traffic located** in **different** locations [6]. **The** 5

system utilizes a Web-based Embedded Web Server (EWS). Therefore,

> **in this** research, **we** proposed **a system dynamics** simulation **model to** 18

mitigate traffic congestion as a solution to transportation management in urban area. * Corresponding author: erma.suryani@gmail.com 2 LITERATURE REVIEW 2.1 Transportation Mode Choice According to research that have been conducted by Corpuz [7] and Buehler [8], key factors of transportation mode choice are accessibility, waiting time, transportation availability, pleasure, safety, privacy, travel time, distance, price, and fare as seen in Figure 1. Fig. 1. Key Factor of Transportation Mode Choice According to Jain et al. [3], there are several factors effecting the choice of public transportation mode, as seen

in Table 1. The weights of sub-criteria for global priority **and**	**17**
sub criteria can be seen in **Table 2.**	**20**

These weights are gathered by conducting questionnaire to people who select public transportation such as metro that

is a successful example in terms of offering a comfortable, reliable, and safe mode of public transport.	**1**
Metro is more reliable and comfortable due to its frequency and adherence to schedule, as well as **less travel time with air-conditioning facility at most of the metro stations and metro coaches.**	**1**

Table 1. Factors affecting Public Transportation System [3] Factors affecting Public Transportation System Sub-factors Comfort Cleanliness

Air Conditioning Seating Availability Low Floor Not Crowded Accessibility Less Travel Time Safety Lesser Accident	**1**
Personal Safety Staff behaviour and Attitude Reliability Good Frequency	**1**
Adherence to Schedule Cost Cost of Travel	**1**

Table 2. The Weights of Sub-Criteria of Public Transportation Mode Choice [3] Sub-criteria Global Priority Weights Sub Criteria Percentage

Comfort Cleanliness 0. 02 **0.** 12 **Air conditioning 0.** 01 **0.** 05 **Seating availability 0.** 02 **0.** 12 **Low floor 0.** 01 **0.** 08 **Not crowded 0.** 03 **0.** 16 **Accessibility 0.** 04 **0.** 25 **Less travel time 0.** 04 **0.** 25 **Reliability Good frequency 0.** 16 **0.** 61 **Adherence to schedule 0.** 11 **0.** 39 **Safety Lesser accident 0.** 12 **0.** 33 **Personal safety 0.** 15 **0.** 42 **Staff behaviour and attitude 0.** 09 **0.**

1

25 2.2 System Dynamic Simulation Simulation is a technique to mimic operations or processes that occur in a system with the help of computer devices and based on certain assumptions so that the system can be learned scientifically [9]. Simulation is an appropriate tool to use, especially if it is required to conduct experiments in order to find the best comments from system components. By conducting a simulation, the study can be conducted in a short time and can provide the right decision, because everything is done with the computer. This system dynamics approach begins with the development of a real system model. The model should be able to show how the various components in the system are interacting so as to truly describe the behaviour of the system. Once the model is created, then the model is transformed into a computer program. System dynamics simulation is a tool for analysing and developing policies. System dynamics is very suitable to be used in handling complex system problem, which is a combination

of qualitative and quantitative analysis, and based on system thinking and general reasoning.

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According to Sterman [10], there are five steps in developing a dynamic system model as shown in Figure 2. Fig 2. Steps in Developing System Dynamics Simulation [10] 1. Problem articulation: in this stage the modeller need to find the problem, determine the significant variables, determine the time period of the simulation, and identify the problem dynamically to provide a basic understanding in designing the policy to solve problems. 2. Dynamics hypothesis: in this stage, we need to develop a theory of how the problem arises, creating a causal loop diagram (CLD) that explains the causal relationship between variables, and converts the CLD to the level and rate (Stock and Flow) diagram. 3. Formulation: in this stage the modeller needs to define equations that describes the relationship between the variables, estimates the parameters, as well as determine the initial condition. 4. Testing: this stage is required to check the model validity, identify the model behaviour, as well as to check whether it can represent the behaviour of real systems. 5. Policy formulation and evaluation: this stage is the formulation and evaluation of the policy that is proposed. If the structure and model behaviour are in accordance with the actual system, then the model can be utilized to design and evaluate the policy by changing the parameter values or redesigning the new structure to improve the system performance. 3. MODEL DEVELOPMENT This model was developed to perform congestion analysis caused by the internal and external factors. The congestion analysis model consisted of two submodels, those are average daily traffic (ADT) and traffic congestion. 3.1 Average Daily Traffic Submodel Figure 3 shows the average daily traffic volume flow diagram. As we can see from Figure 3, the average daily traffic can be grouped into three categories, those are non-passenger, public, and private transportation. Public transportation mode choice is one of several factors that influences the volume of private vehicle transportation. Fig. 3. Flow Diagram for Average Daily Traffic (ADT) From the

simulation result, average daily traffic on Wonokromo road has reached 594,985 vehicles per day as seen on Figure 4. Meanwhile, public transportation mode choice has an impact of around 40% to the number of private transportation, as seen in Figure 5. Average Daily Traffic (WK) 700,000 525,000 vehicles/day 350,000 175,000 0 2000 2002 2004 2006 2008 2010 2012 2014 2016 Time (Year) "Average Daily Traffic (WK)" : ES BM 6Spt For IC Fig. 4. Average Daily Traffic (ADT) in Wonokromo Street Public Transportation Mode Choice Impact 40 37.5 35 32.5 30 2000 2002 2004 2006 2008 2010 2012 2014 2016 Time (Year) Public Transportation Mode Choice Impact : ES BM 6Spt For IC Fig. 5. Public Transportation Mode Choice Impact 3.2 Traffic Congestion Submodel The flow diagram of the traffic congestion model can be seen in Figure 6. This flow diagram is developed by considering several research results that have been done by Jain [3], Corpuz [7], and Buehler [8]. Fig. 6. Traffic Congestion Flow Diagram As we can see form Figure 6, traffic congestion depends on the bottleneck (internal factors) and external events (external factors). Some internal factors that affect the bottleneck include road capacity and average daily traffic (ADT). While internal factors are influenced by several factors

such as traffic incidents, exclusive lanes, **work zones, and special events.** **9**

Simulation result shows traffic congestion in Wonokromo Road was around 184% in 2016 as seen in Figure 7. Congestion (Wonokromo) 200 150 Percent 100 50 0 2000 2002 2004 2006 2008 2010 2012 2014 2016 Time (Year) "Congestion (Wonokromo)" : ES BM 6Spt For IC Fig. 7. Simulation Result of Traffic Congestion in Wonokromo Street 4. MODEL VALIDATION Model validation is required to check the model accuracy.

A model will be valid if the error rate is less **than 5%** **14**

and error variance is less than 30% [11]. We validate the average daily traffic by utilizing the error rate and error variance formulation as defined in Eq. (1)- (2). ErrorRate ? ?S ? A? A (1) ErrorVariance ? Ss ? Sa (2) Sa Where: = the average rate of simulation = the average rate of data = the standard deviation of simulation = the standard deviation of data Data use in this research is obtained from city transportation office in Surabaya. Error rate of some variables of daily traffic volume in Wonokromo and A Yani Street are as follows: Error rate “daily traffic volume in Wonokromo Road” Error rate “daily traffic volume in A Yani Road” Error variance of some variables of daily traffic volume in Wonokromo and A Yani Street are as follows: Error variance “daily traffic volume in Wonokromo Road” Error variance “daily traffic volume in A Yani Road” Based on the above calculation, all the error rates are less than 5%, and error of variance are less than 30% which means that our model is valid. 5. SCENARIO DEVELOPMENT This scenario is developed to mitigate traffic congestion through the improvement of public transportation. Several efforts need to be conducted such as increasing comfort, reliability, safety, and affordable cost [3] as seen in Figure 8. Those factors will determine the level of user satisfaction in selecting public transport and

will have to be raised a shifting **from private vehicles to public transport.** **1**
This is because user **would only be willing to shift to** transportation
modes with greater comfort, reliability, **and**

safety. Fig. 8. Scenario of Public Transportation Improvement Public transportation reliability can be done

through more frequent of public transport and integrating the scheduling systems [3] as seen in Figure 9. Fig. 9. Reliability Improvement Safety can be improved through the improvement of cautions, car personal safety, as well as staff behavior and attitude [3] as seen in Figure 10. Fig. 10. Safety Improvement Comfort can be improved through the improvement of cleanliness, air conditioning, seat availability, floor level, level of cored accessibility, travel time [3] as seen in Figure 11. Fig. 11. Comfort Improvement Affordable cost improvement can be done through the increase in parking cost for private transportation, increase Pertamax price, and increase yearly tax of private transportation [12] as seen in Figure 12. Passenger cars and freight cars with an allowable amount of weight of less than or equal to 3,500 kg (three thousand five hundred kilograms), including: a) mini truck vehicle or other similar vehicle, imposed retribution of Rp5,000. b) sedan vehicle, pick up or other vehicle some kind of levy is Rp3,000 . Passenger cars and freight cars with an allowable amount of weight of more than 3,500 kg (three thousand five hundred kilograms), including: a) truck vehicle with trailer, trailer or vehicle other similar type, imposed a levy of Rp8,000; b) vehicle truck, bus or other large / heavy equipment se type, charged Rp7.000. Fig. 12. Cost Improvement Simulation result of traffic congestion mitigation can be seen in Figure 13. As we can see from Figure 13, after the improvement of public transportation such as the improvement of comfort, safety, and reliabilty, as well as the decrease in cost, congestion can be reduced to be around 62%. The congestion mitigation is due to the decrease in traffic volume as many users choose public vehicles and the decrease in the impact of external events that can be done through the control of incident traffic, exclusive lanes, traffic signal improvements, as well as work zones and special event policies. Congestion (Wonokromo) 200 150 Percent 100 50 0 2000 2004 2008 2012 2016 2020 2024 2028 2032 2036 2040 Time (Year) "Congestion (Wonokromo)" : ES SCN 3SP Fig. 13. Congestion Mitigation after the Improvement of Public Transportation 6. CONCLUSION In developing system dynamics model, system understanding is required as the basic building block for the model development. Traffic congestion depends on the bottleneck (internal factors) and external events (external factors). Some internal factors that affect the bottleneck include road capacity and average daily traffic (ADT). While external factors are influenced by several factors

such as traffic incidents, exclusive lanes, **work zones, and special events.** Traffic congestion mitigation **can be** **15**

done through the improvement of public transportation. Several efforts need to be conducted such as increasing comfort, reliability, safety, and affordable cost. Traffic congestion mitigation after the improvement of public transportation can be reduced to be around 62%. Acknowledgment This research is a collaboration research supported by ITS Research Center and Ministry of Research, Technology, and Higher Education. [7] [8] [9] G. Corpuz,

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