Modelling Reliability of Transportation Systems to Reduce Traffic Congestion E Suryani1, R A Hendrawan1, P F EAdipraja2, A Wibisono1, and L P Dewi3 1Information Systems, Institut Teknologi Sepuluh Nopember, Kampus ITS, Jalan Raya ITS- Sukolilo-Surabaya, 60111, Indonesia 2STMIK Asia Malang, Jl. Soekarno Hatta - Rembuksari 1A Malang, 61234, Indonesia 3Informatics Department, Petra Christian University, Jalan Siwalankerto 121-131 Surabaya, 60236, Indonesia erma.suryani@gmail.com Abstract. Reliability reflects the level of ease of people and goods to travel. Reliability relates with the variability of travel time, speed, and system usage and transportation system capacity. The higher the capacity of the system and the faster the travel time, the higher the level of reliability of the transportation system, so that it can reduce traffic congestion. Traffic congestion will occur when travel requests exceed road capacity. Our research attempts to provides a comprehensive and objective assessment of improving reliability of transportation systems and its impact to reduce traffic congestion. We utilized system dynamics simulation model to test and evaluate the alternatives of future strategies to increase the reliability of transportation systems and its impact to reduce traffic congestion. Systems dynamics models can be developed at the macroscopic and microscopic levels of transportation systems as well as to evaluate the effects of different transportation policies on traffic congestion. Simulation results show that reliability is determined by several factors such as travel time, headway (the time between two means of transportation to pass a point / place), passenger wait time; access time and egress time (the time needed to get off the vehicle when it arrives at the destination). Transportation systems reliability continues to decline so that in 2017, reliability was only around 41.5%. The improvement scenario of transportation system reliability can be done by conducting several strategies such as increasing road capacity, increasing public vehicle routes around public facilities, as well as increasing the supply of public transportation which has an impact on headway and waiting time. By conducting these strategies, the reliability of transportation systems could be increased to be around 53.3% and a gradual increase in road capacity could be done with a growth of 2.8% per year. Within this condition, the traffic congestion is projected to be around 74.9% -83.6% in the period 2019-2027, and then to be around 83-88% in the period 2028-2035. 1. Introduction Increasing vehicle volume results in smaller road capacity if it is not offset by the increased network and road capacity. Another thing that causes congestion is the awareness of the public to use increasingly diminished public transportation. This is because public transportation does not fully meet the standards and is not suitable for use so that people prefer to use private vehicles. Furthermore, some transportation problems [1] that influence the traffic congestion are as follows: 1) the maximum of road capacity, 2) no other alternatives for driving, 3) cash-based toll payments, 4) driver behavior, 5) no priority for public transportation, 6) not optimized traffic signals, 7) time required to search for parking. Reliability is the level of ease of mobility in the transportation system. The reliability factor is an important component of the efficiency of the transportation system. Some factors that influence reliability are travel time, speed, system capacity and usage. The higher the capacity of the system and Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1 the faster the travel time, the higher the level of reliability of the transportation system, so that it can reduce traffic congestion. Traffic congestion will occur when travel requests exceed road capacity. Therefore, our research attempts to provide a comprehensive and objective assessment of improving reliability of transportation systems and its impact to reduce traffic congestion. 2. Literature Review 2.1 Reliability of transportation systems Reliability of transportation systems is the probability that transportation network systems can perform the desired function until the level of performance that can be received for a certain period of time [2]. Reliability is determined by several factors such as travel time, headway (the time between two means of transportation to pass a point / place), and passenger wait time [3]. Meanwhile, reliability is determined by access time and egress time (the time taken when getting off the vehicle to arrive at the destination) [4]. Reliability is an important component of traffic efficiency. Reliability reflects the ease or difficulty of people and goods to make their journey [5]. Reliability is related to the variability of travel time, speed, system usage and their system capacity [5]. 2.2 Traffic Congestion

Traffic congestion occurs when travel demand exceeds the road capacity. 6

Excess vehicles on the highway usually cause congestion at any given time resulting in a slower speed than normal speed [6]. Traffic congestion will increase the business operations cost and reduce productivity due to delay in delivering goods which can impose additional inventory and logistics costs [7]. Different types of events such as sport, entertainment, comedy, and concerts as well as event time could have a different impact on traffic congestion and behavior [8]. Work zone is an important part of improving urban mobility. With many work zones in urban areas and heavy traffic volume will increase traffic congestion. 2.3 System Dynamics Currently

system dynamics and simulation modelling **has** improved **in the field of traffic engineering and traffic planning.** 2

Dynamic

system structures can lead to unpredictable behavior through a complex chain of causes and effects 2

that have led to widespread interest in modelling dynamics systems

in the field of intelligent traffic. The central concept of this framework is to model all objects in complex systems that interact with each other through feedback loops, where changes in one variable can affect other variables. 2

System dynamics is a modelling methodology that has been developed to characterize the aggregate behavior of a complex system [9]. System dynamics can be used to identify specific system behavior and also provide a framework for theoretical analysis for researchers in analyzing system sensitivity to structural changes. The main advantages of system dynamics are better control of complex systems as well as faster and easier sensitivity analysis, through the application of model structure testing. Systems dynamics models can be developed at the macroscopic and microscopic levels of traffic to explore transport interactions

and urban planning or to evaluate the effects of different transport policies on 5

traffic congestion. The planning method has a history of development and application of transportation to be used in accordance with best practices. This method involves data and representation of system behavior. A broad approach can connect several models. Interoperability is the key to successful integrated planning. System dynamics is a powerful tool in learning the behavior of organizations, markets, and competitors to describe the cognitive boundary of information gathering and the processing power of the human mind; facilitate consideration of opinion; and support the "What if" scenario development.

There are five steps in developing system dynamics simulation model 1

[9], those are: 1) problem formulation; 2) dynamic hypothesis 3) simulation model development; 4) model validation ; 5) scenario development. 3. Model Development In this section, we provide causal loop diagram and model development for reliability of transportation systems, as well as traffic congestion model.

3.1 Causal Loop Diagram Causal loop diagram for the reliability of 7

transportation systems

can be seen in Figure 1. This causal loop diagram was developed by referring 1
some previous research that have been done by

Liu and Sinha (2007) and Oort (2011) [3, 4]. Std of Travel Time Avg Travel Time Avg Access Time of Lyn + + + Avg Headway Lyn Travel Time Acess Time + + Avg Acess Time Avg Headway Bus + Headway - - of Bus - Reliability - - Waiting Time of E+gress Time + Lyn +Passenger Wait + Time Std of Egress Time Avg Egress Time Waiting Time of Bus Figure 1. Causal loop diagram of reliability of transportation systems [3, 4] According to their research findings, the reliability of transportation systems is determined by several factors such as travel time, headway (time between two public transports to pass a point /place), passenger wait time, access time, and egress time (time between getting off the vehicle and arriving at the destination). <Avg Travel Time> Travel Time Std Deviation of Travel Time Reliability <Std of Headway> <Avg Headway> Headway Reliability Average Scheduled Wait Time <Avg Actual Wait Time> Passenger Wait Time Reliability Reliability <Avg Access Time> Access <Std of Access Time> Time Avg Egress Time Std Egress Time Egress Time Figure 2. The flow diagram of reliability of transportation systems 3.2 Reliability of transportation systems The reliability of transportation systems model is developed from the

causal loop diagram which can be seen in Figure 8

2. As we can see from Figure 2, reliability is determined by several factors such as travel time, headway, passenger wait time, access time and egress time. The simulation results of the transportation systems reliability model can be seen in Figure 3. As we can see from Figure 3, transportation systems reliability continues to decline so that in 2017, the reliability was around 41.5%. 3.3 Traffic congestion model Traffic congestion will occur if the daily traffic volume exceeds the road capacity. Some factors that influence the

traffic congestion include the average daily traffic and road capacity [10]. The formulation of the traffic congestion is explained in the Eq. 1. Congestion = Daily Traffic / Road Capacity * 100 (1) The diagram flow of

traffic congestion model can be seen in Figure 1

4. Reliability 50 45 Percent 40 35 30 2000 2002 2004 2006 2008 2010 2012 2014 2016 Time (Year) Reliability : ES BM Reliability Congestion Figure 3. Reliability of transportation systems in 2000-2017

<Average Daily Traffic Percentage> Average Daily Traffic Daily Traffic 1

(SMP) 2014 (Surabaya) Rate Daily Traffic Daily Traffic (SMP) Base Increase Daily Traffic Weight Daily Traffic (SMP) <Effectiveness Surabaya Factors> <Mean Road V/C Ratio> Road Capacity based on Vehicle 2014 Congestion (EFF) Figure 4.

The flow diagram of traffic congestion model 1

The

simulation result of traffic congestion can be seen in Figure 1

5. As we can see from Figure. 5, traffic congestion in 2017 has reached 86.4%. This was due to the daily traffic volume and road capacity. The maximum saturation level of traffic congestion is 85% [11]. Therefore, we need a strategy to reduce the traffic congestion through the development of scenario base modelling. 100 75 Percent 50 25 0 2000 2002 2004 2006 2008 2010 2012 2014 2016 Time (Year) "Congestion (EFF)" : ES BM UG Figure 5. Traffic congestion in 2000-2017 4. Model Validation

Model validation constitutes a very important step in system dynamics framework. To conduct this process, we need historical data during the time horizon, in this case from 2000 to 3

2017. We consider the time frame based on the data availability and system behavior.

A model will be valid if the error rate is ≤ 5% and the error variance is ≤ 30%	4

[12]. The formulations of

error rate and error variance are demonstrated in Eq.	1

2-3. Error Rate = ⌈S−̅A⌉̅(2) Error Variance = ⌈Ss−Sa⌉ A̅(3) Sa Where: S=̅

the average rate of simulation; A=̅ the average rate of data;	1

A= Data at time t; S = Simulation Result at time t ; Ss=

the standard deviation of simulation; Sa= the standard deviation of data	1

Error rate and error variance of	9

some variables that have significant impact to the reliability of transportation systems are described in Table 1. Table 1. Error Rate and Error Variance Variable Error Rate Error Variance Access time 0.0336 0.0186 Wait time 0.0253 0.0217 Headway 0.0052 0.0099 5. Scenario Development The scenario of the improvement of transportation system reliability and traffic congestion can be done by carrying out several strategies such as increasing road capacity, increasing public vehicle routes around public facilities, increasing public transportation supply which has an impact on headway and waiting time. Simulation result of transportation systems reliability improvement can be seen in Figure 6. 60 52.5 Percent 45 37.5 30 2000 2005 2010 2015 2020 2025 2030 2035 Time (Year) "Reliability (SCN)" : ES SCN RELCG UG Figure 6. Transportation Systems Reliability Improvement As we can see from Figure 6, reliability of transportation systems can be increased to be around 53.3% as the impact of increasing public vehicle routes around public facilities and public transportation supply which has an impact on headway and waiting time. With transportation systems reliability of around 53.3% and gradual increase in road capacity with growth of 2.8% per year, traffic congestion is projected to be decreased to be around 74.9% -83.6% in the period 2019-2027, and then to 83-88% in the period 2028-2035. 6. Conclusion and Further Research The reliability of transportation systems is determined by several factors such as travel time, headway, passenger wait time, access time and egress time. Transportation systems reliability continues to decline so that in 2017, the reliability was around 41.5%. Traffic congestion will occur if the daily traffic volume exceeds the road capacity. Some factors that influence the traffic congestion include the average daily traffic and road capacity. The improvement of transportation system reliability and traffic congestion can be done by carrying out several strategies such as increasing road capacity, increasing public vehicle routes around public facilities, increasing public transportation supply which has an impact on headway and waiting time. Reliability of transportation systems can be increased to be around 53.3% as the impact of increasing public vehicle routes around public facilities and public transportation supply which has an impact on headway and waiting time. To reduce the traffic congestion, besides the reliability improvement, another strategy that we can conduct is increasing the road capacity. With transportation systems reliability of around 53.3% and gradual increase in road capacity with growth of 2.8% per year, traffic congestion is projected to be decreased to be around 74.9% -83.6% in the period 2019-2027, and then to 83-88% in the period 2028-2035. Further research is required to improve the operational efficiency of transportation systems by considering the internal and external factors.

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