Journal of System Dynamics

Journal Of System Dynamics
Volume 2 ● Number 1 ● Juni 2021 ● pp. 1-9

System Dynamics Model for Congestion Level Analysis in Yogyakarta City

Purnawan[1], Casnan[2], Hendar Kusnandar[3]

[1] *Ahmad Dahlan University*
[2] *College of Teacher Training and Education (STKIP) Muhammadiyah Kuningan*
[3] *Institute of Technology and Logistics (ITL) Trisakti*

Corresponding author:
STKIP Muhammadiyah Kuningan
Jl. R.A Moertasiah Soepomo No. 28 B Kuninga, West Java
Postal code 45511
e-mail: casnan@upmk.ac.id

ABSTRACT
This study aims to carry out various levels of congestion in Yogyakarta using the System Dynamics methodological approach. The research results on the congestion level in Yogyakarta reached the maximum value in 2033, based on research with the policy of reducing the number of motorcycles and passenger cars to reduce congestion levels until 2050. Policy Studies are significant to develop a dynamic simulation model to understand the interaction between various factors in the complex system, scenario policies are expected to reduce congestion in the future and are expected to provide better policy outcomes.

KEYWORDS
System Dynamics, Model, Congestion Level, Yogyakarta

Introduction

High economic growth impacts population movement from villages to urban areas, resulting in changes in the scope of life as an increase in the number of vehicles, income, and labor. The imbalance of road capacity with the increasing number of vehicles has an impact on traffic jams.

Congestion is a situation or condition that occurs in one or several traffic sections so that the flow moves very slowly even stops caused by an imbalance in the number of residents, the increase in the number of vehicles, and the availability of highways that disrupt activities and movements of road users [1]. Areas that regularly experience congestion affect resource inefficiency and disrupt the smooth running of environmental activities that have a broad impact on the smooth running of socio-economic activities [2].

The results of Ali Alhadar's research [3] analysis of road performance to overcome traffic congestion at signalized intersections in the city of Palu found that traffic congestion occurs due to vehicle volume approaching road capacity according to the Indonesian Road Capacity Manual standard degree of saturation Q < 0.75. Deden Firmansyah's research [2] analysis of traffic congestion in an area (a case study on Jalan Lenteng Agung) found that the causes of congestion on Jalan Lenteng Agung were due to pedestrian or pedestrian activities, urban transportation behavior, the number of vehicles, and road crossings. Abbas's research [4] analysis of congestion on several roads in Somba Opu, Gowa district found that congestion arises because it is drive by several factors like the increasing number of vehicles using the road, and road conditions are narrow even damaged.

Most cities in Indonesia have faced traffic congestion problems from year to year, including in Yogyakarta. In recent years, Yogyakarta has become increasingly dense with vehicles, recorded in 2017 there were 309373 units of motorized vehicles and 54346 units of passenger cars, this number increased in 2018 to 341986 units of motorized vehicles and 60780 units of passenger cars [5] even in 2017 the average level of traffic density or the value of the volume capacity ratio has approached the saturation point with a magnitude of 0.8 of the maximum value of 1 [6]. Efforts to anticipate the increase of volume capacity value include building new roads. Still, it has been hard to add new streets due to limited land in Yogyakarta and restrictions on the use of private vehicles, so to solve this problem, an integrated management system and the mechanism is needed that understands something complex in the systems approach as well as dynamic changes so that dynamic modeling can detect as early as possible the potential for congestion.

This study aims to review the level of congestion in Yogyakarta city with the System Dynamics methodological approach. In policy studies, it is crucial to develop dynamic simulation models to understand the interaction between various factors in a complex system, policy scenarios are expected to reduce congestion levels in the future and are expected to provide better policy outcomes.

Research methods

System Dynamics is a methodology that uses simulation modelling based on feedback systems theory and is an analytical approach that complements systems thinking. Applies to problems that arise in complex social, managerial, ecological systems, or economic. Every dynamic system has characterized by the interdependence of variables, the existence of reciprocal interactions, and information feedback, and Causal Loop [7].

System dynamics modelling can be used as consideration for policymaking by being carried out. The stages of system dynamics analysis consist of 1) needs analysis; 2) problem formulation; 3) system identification; 4) model simulation; 5) model validation.

System Requirements

At this stage, an inventory of the needs of the factors that influence congestion through brainstorming and a literature study of the research results on the level of congestion in Yogyakarta is carried out.

Problem Formulation

The formulation of the problem is obtained from the variables in the analysis of the factors that affect the level of congestion through brainstorming and literature study of the research results on the level of congestion in Yogyakarta.

System Identification

System identification is the stage to see the existing system. By identifying the initial and fundamental problems, it is hoped that alternative solutions to problems will be obtained according to the raised level. There are six groups of variables that affect the performance of a system in general, namely: (1) the desired output variable, which is determined based on the main objective in the system, (2) unwanted output variables, (3) controlled input variables, obtained from the driving factors of the basic model and the leveraging factors of the analysis results [8] (4) uncontrolled input variables, (5) environmental input variables and (6) system control variables according to Manect and Park 1977 [9].

In technical development, Causal Loop diagrams are used to make SFD (Stock Flow Diagrams) flow diagrams simulated using Powersim Studio 10. Powersim can provide an overview of system behaviour. In the system being studied, the best alternative can be determined based on the simulation results. After that, an analysis is carried out to obtain conclusions and what policies must be taken to anticipate/change the system's behaviour according to the desired output.

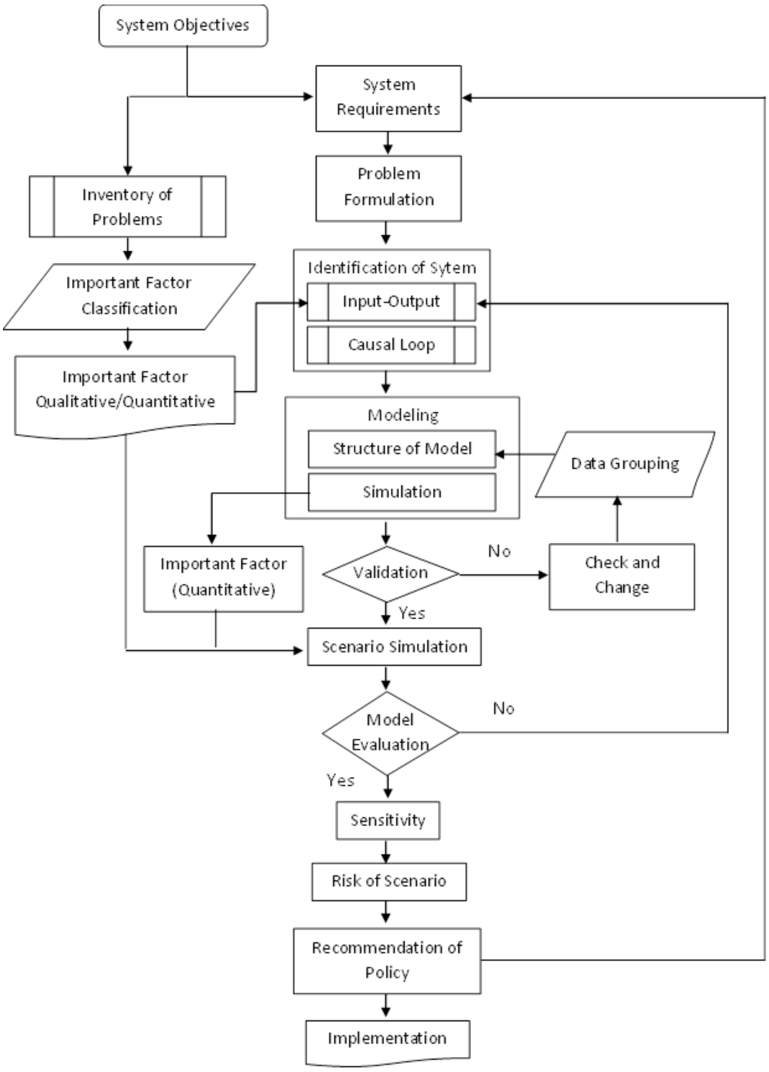

Fig 1. Stages of System Dynamic

Model Simulation

The results of dynamic system modelling based on simulation are used to see the pattern of model behaviour tendencies. The model simulation results are analyzed and traced to the factors that cause the trend pattern to occur and explain how the mechanism occurs based on the analysis of the model structure.

Model Validation

Model validation is done by comparing the magnitude and nature of the error [10], namely: 1) Absolute Mean Error (AME) is the deviation between the average value (mean) of the simulation results and the actual value; 2) Absolute Variation Error (AVE) is the deviation of the value the variance of the simulation to the actual. The acceptable deviation limit is <10%.

AME = [(Si – Ai)/Ai]... ....(1)

Si = Si N, where S = simulation value

Ai = Ai N, where A = actual value

N = observation time interval

AVE = [(Ss – Sa)/Sa].. ....(2)
Ss = ((Si – Si)2 N) = simulation value deviation
Sa = ((Ai – Ai) 2 N) = actual value deviation

The system dynamics approach is used to formulate, simulate and validate by looking at the system's behaviour in the future. This process makes it possible to design policy plans well and can be implemented [11]. Figure 2 is a causal loop diagram used in this study. This causal loop provides a big picture of the model used and the systems thinking used in this study.

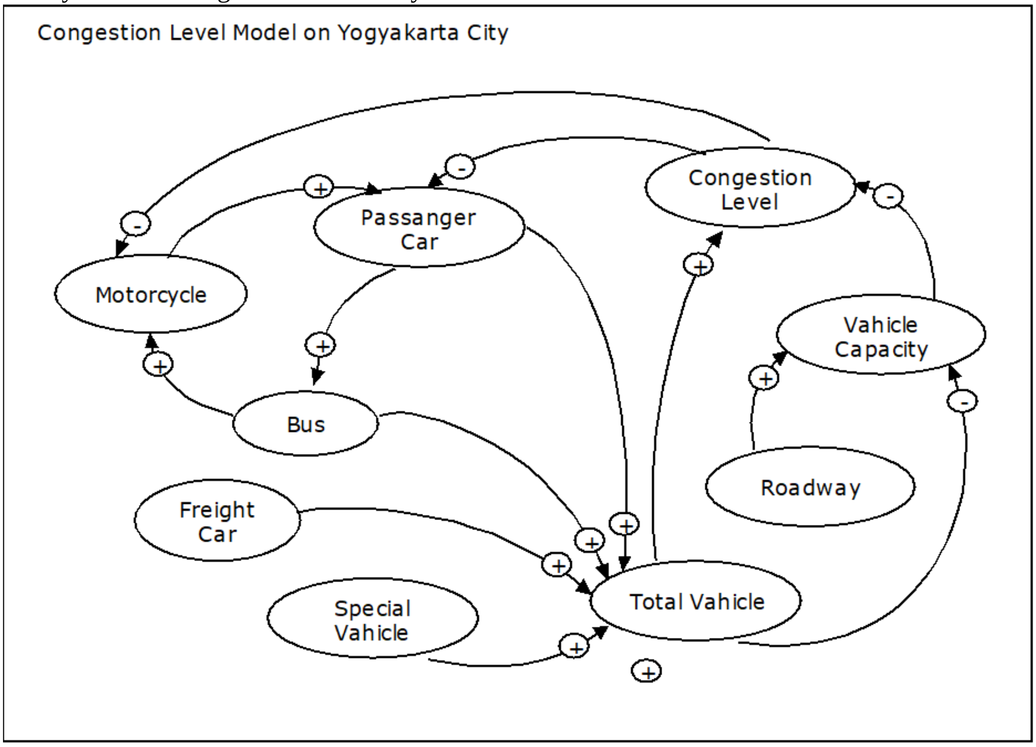

Fig. 2. Causal Loop Diagram

Results and Discussion

Economic growth in Yogyakarta makes transportation a necessity aligned with primary needs, which can be seen with transportation that continues to grow every year. People who initially use public transportation such as buses, if they get an increase in income, will switch to using motorbikes, just like those who initially used motorbikes will switch to using passenger cars, so in the future public transportation users, private vehicle users will continue to increase. This will undoubtedly affect the capacity of the road as a transportation medium. The continued increase in the total number of vehicles will increase the imbalance of road capacity and vehicles, resulting in congestion. Based on Figure 2, passenger car users will return to using buses. Following Pamudi's opinion, economic growth in Surabaya is the cause of a person's increased mobility. The need for movement significantly increases beyond the capacity of the road and causes congestion [12]. Actions that can be taken to minimize congestion include reducing the number of vehicles. The dynamic system modelling to calculate the congestion level in the city of Yogyakarta is shown in Figure 3.

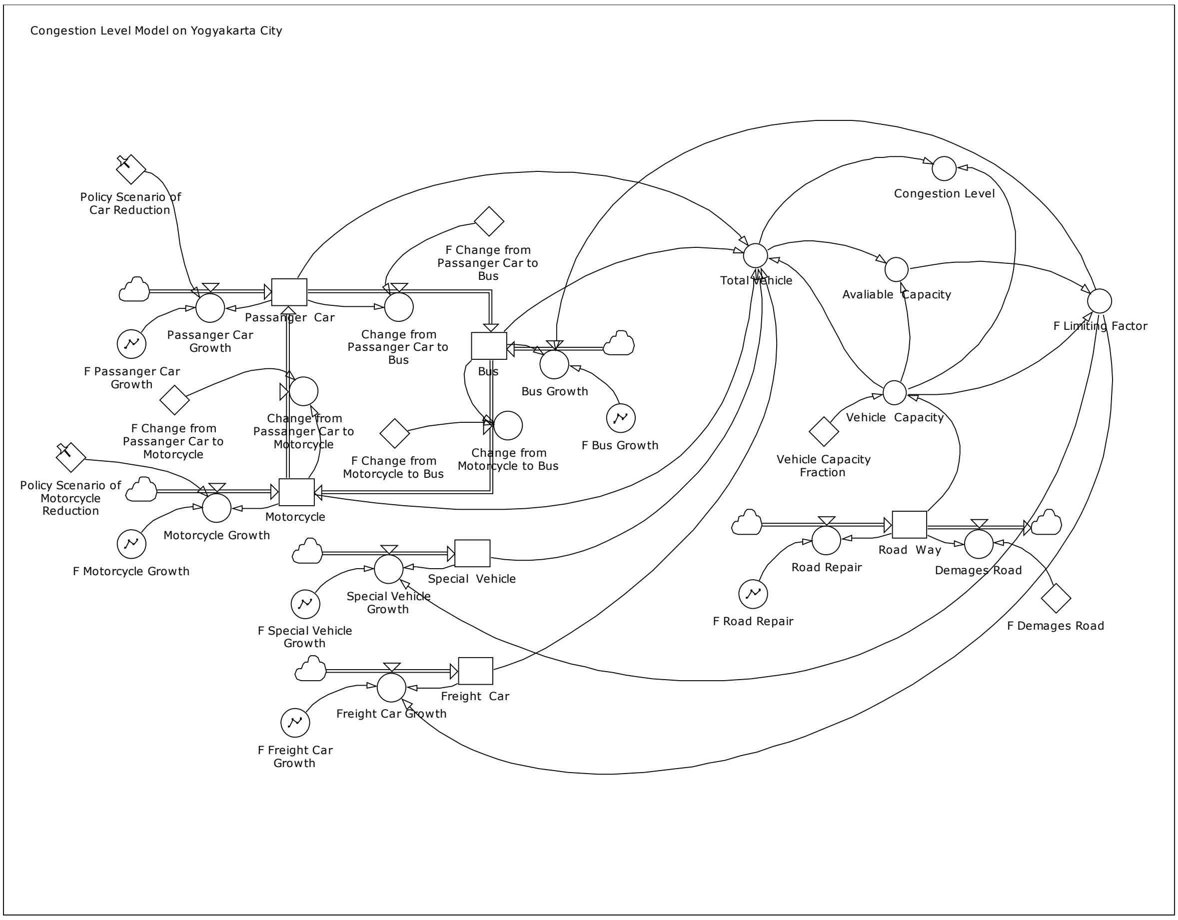

Fig. 3. Number of Vehicles and Available Road Capacity

The number of vehicles in Yogyakarta in 2015 was 48439 passenger cars, 293843 motorcycles, 1094 buses, 10011 transport cars, and 583 special vehicles. In 2017 there were 54346 passenger cars, 309373 motorcycles, 1147 buses, 10623 transport cars, and 701 exceptional vehicles, so that the average level of traffic density or the value of the volume capacity ratio is approaching the saturation point with a magnitude of 0.8 from the maximum value of 1 [6]. The policy scenario following the stock flow in Figure 3 is to reduce the number of passenger cars and motorcycles. Figures 4 and 5 show the simulation results of the dynamic system of congestion levels in Yogyakarta.

Based on the existing/baseline simulation results, congestion in Yogyakarta will continue to occur and even worsen; without any scenarios or simulations in 2033, the value of the volume capacity ratio will reach the maximum value.

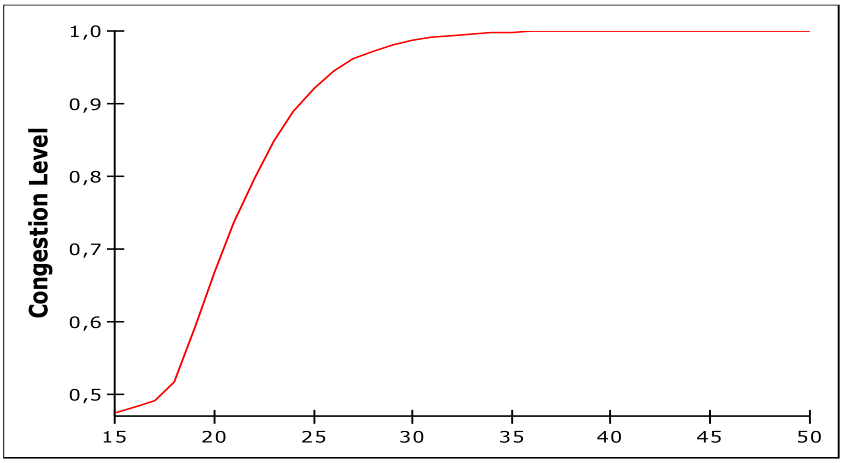

Fig. 4. Congestion Level Baseline in Yogyakarta City

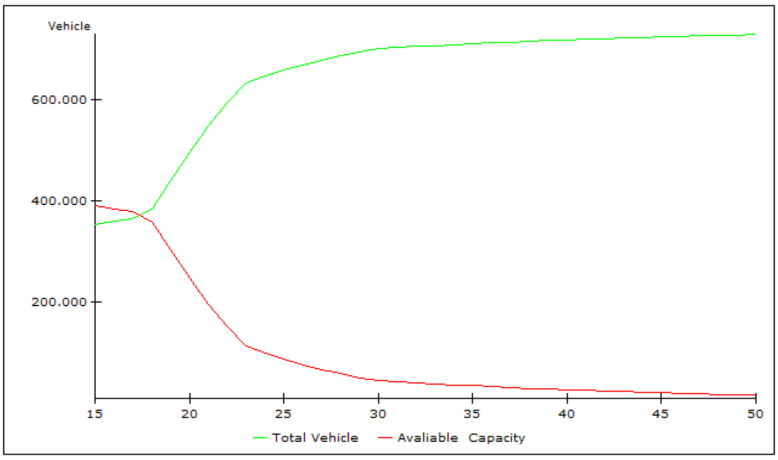

Fig. 5. Baseline Graph of Total Vehicles and Available Vehicle Capacity

Based on the results of the baseline simulation of total vehicles and vehicle capacity as shown in Figure 5, it is shown that the entire vehicle continues to increase, inversely proportional to the available vehicle capacity, which decreases every year. Based on the simulation results, several model variables are validated by comparing the simulation data and real data, as shown in Table 1 and Table 2.

Table 1. Number of Real Vehicles and Simulation Results

Year	Passenger Car		Motorcycle	
	Real	Simulation	Real	Simulation
2015	48439	48439	293843	293843
2016	50562	50562	303403	303402
2017	54346	54346	309373	309373
2018	60780	60780	341986	341987
2019	66489	66489	459579	459579

Based on Table 1, value validation using the Absolute Mean Error (AME) method for passenger cars is 0%, and it is 0.000124 % for motorcycles. Value validation using the Absolute Variation Error (AVE) method for passenger cars is 0% and for motorcycles is 0.000413 %. The simulation produces a good level of validation because the deviation value is still below 10% (<10%).

Table 2. Number of Real Vehicles and Simulation Results

Year	Bus		Freight Car		Special Vehicle	
	Real	Simulation	Real	Simulation	Real	Simulation
2015	1094	1094	10011	10011	583	583
2016	1056	1056	10266	10266	656	656
2017	1147	1147	10623	10620	701	701
2018	1230	1230	11223	11223	768	768
2019	2561	2561	13939	13939	161	161

Based on Table 2, value validation using the Absolute Mean Error (AME) method for buses is 0%, for freight cars, it is 0.00565%, and for special vehicles, it is 0%. Value validation using the Absolute Variation Error (AVE) method for buses is 0%, for freight cars, it is 0.03501%, and for special vehicles, it is 0%. The simulation produces a good level of validation because the deviation value is still below 10% (<10%)

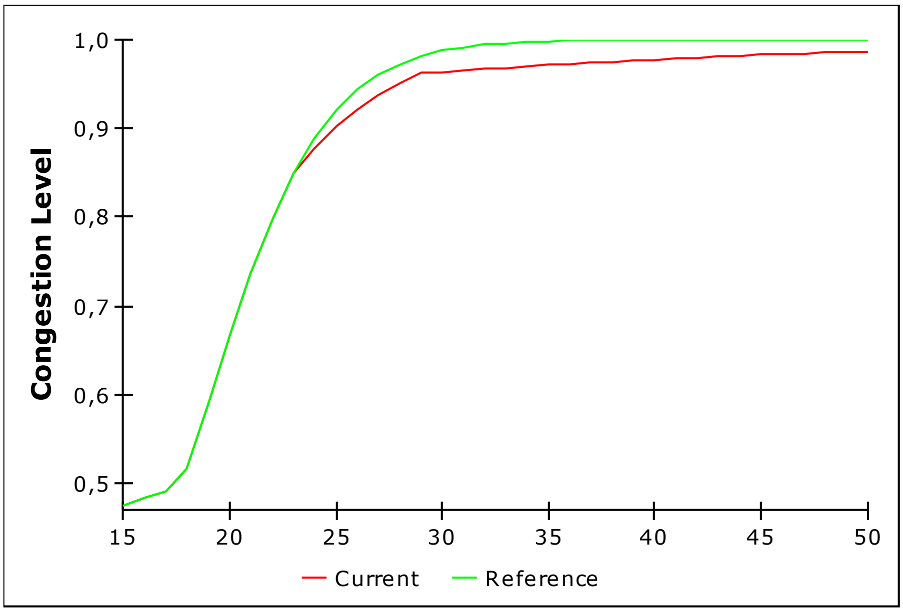

Fig. 6. Results of Scenario 1 Congestion Level in Yogyakarta City

Based on Figure 6 with the scenario in 2023, motorcycles are reduced by 10%, and passenger cars are reduced by 5%. In 2029 the reduction of motorcycles is 30%, and the decrease in passenger cars is 8%. In general, the congestion level has decreased. In 2025 the congestion level of around 0.92 decreased to 0.90, while in 2033, the congestion level, which was initially estimated to reach a value of 1, reduced to 0.97.

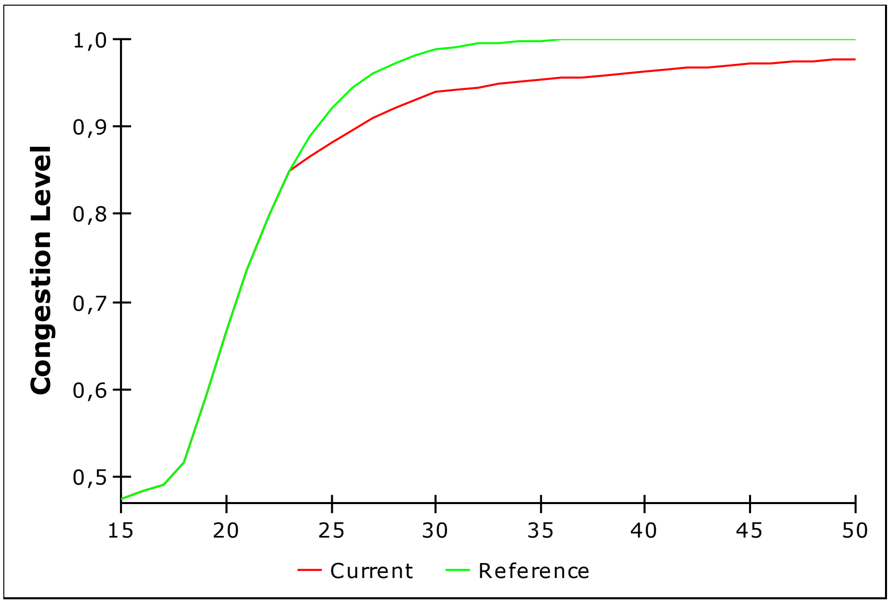

Fig. 7. Results of Scenario 2 Congestion Levels in Yogyakarta City

Based on Figure 7 with the scenario in 2023, the reduction of motorcycles is 20 %, and in 2023 the decrease in passenger cars is 5 %. By 2030, reduce motorcycles by 30% and minimize passenger cars by 8%. The results of scenario 2 find that the congestion level has decreased. In 2025 the congestion level of around 0.92 decreased to 0.88, while in 2033, the congestion level, which was initially estimated to reach a maximum value of 1, was reduced to 0.95.

Conclusion

The congestion level, which was initially projected to reach the maximum value in 2033, based on research with the policy of reducing motor vehicles and passenger cars, can reduce congestion until the maximum congestion level occurs around 2050.

Graphical Abstract and Research Highlight

[1] W. Mustikarani and Suherdiyanto, "Analysis of Factors Causing Traffic Congestion Along with H Rais A Rahman Streets (Sui Jawi) Pontianak City," J. Education, vol. 14, no. 1, pp. 143–155, 2016.

[2] D. Firmansyah and I. A. . Tjahjani, "Analysis of Traffic Congestion in an Area (Case Study on Lenteng Agung Streets)," in National Seminar on Civil Engineering UMS, 2012, pp. 134–140.

[3] A. Alhadar, "Analysis of Road Performance to Overcome Traffic Congestion at Signalized Intersections in Palu City," J. SMARTek, vol. 9, no. 4, pp. 327–336, 2011.

[4] I. Abbas, N. Badwi, Suprapta, and D. Qaiyimah, "Analysis of Congestion in Several Roads in Somba Opu, Gowa Regency," J. Environ. Sci., vol. 3, no. 1, pp. 50–52, 2020.

[5] B. P. S. K. Yogyakarta, City of Yogyakarta in Figures (Yogyakarta Municipality In Figures). Yogyakarta: BPS Yogyakarta City, 2019.

[6] "Damn! Traffic Density of Yogyakarta Approaching Saturation Point," 2021. https://news.okezone.com/read/2017/09/30/510/1786214/gawat-kepadatan-lalu-lintas-yogyakarta-dekati-titik-jenuh (accessed Jul. 09, 2021)

[7] E. T. Mukti, A. Sjafruddin, and A. Kusumawati, "A Review of the Use of System Dynamics Models in Transportation Safety Policy," 17th FSTPT Int. Sym. Jember Univ., pp. 1045–1053, 2014.

[8] I. Firmansyah, Powersim Studio Application for Dynamic Systems. Bogor: Triwala Press, 2015.

[9] H. H, System Dynamics: System Concepts and Modeling for Industry and the Environment. Bogor: SEAMEO BIOTROP, 2007.

[10] Muhammadi, A. E, and S. B, Dynamic System Analysis. Jakarta: UMJ Press, 2001.

[11] Widiatmaka, W. Ambarwulan, I. Firmansyah, K. Munibah, P. Santoso, and Sudarsono, “Land Suitability and Dynamic System Modeling To Define Priority Areas Of Soybean Plantation In Paddy Fields In Karawang, West Java,” Agrivita, vol. 3, no. 36, pp. 235–248, 2014a.

[12] Pamudi, "Application of Dynamic Systems in Intelligent Transportation Systems to Reduce Traffic Safety Increase (Case Study of the Surabaya City Transportation Service)," Sepuluh Nopember Institute of Technology Surabaya, 2018.