Improving Mobility Toward Sustainability

1st Suryani
Department of Information Systems
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
erma.suryani@gmail.com

2nd Hendrawan
Department of Information Systems
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
ruhendrawan@gmail.com

3rd Adipraja
Department of Informatics Engineering
Institut Teknologi dan Bisnis Asia
Malang, Indonesia
philipfaster@gmail.com

4th Widodo
Department of Mathematics
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
bwdantr@gmail.com

5th Chou
Department of Industrial Management
National Taiwan University of Science and Technology
Taipei, Taiwan
sychou2@gmail.com

6th Zahra
Department of Civil Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
alifia.ce.its@gmail.com

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Abstract— **Population growth will lead to increasing demand for an efficient transportation system. In response to this challenge, the environment must be adjusted to support the development of a larger transportation infrastructure. Additionally, the development of transportation systems must consider the concept of sustainability to minimize the negative impact on the environment and the mobility of future generations. As a tool to increase the sustainability of transportation systems, system dynamics is utilized to formulate models for policy analysis designs that can be applied to problems in complex social, managerial, economic, or ecological systems. A valid model's structure can be altered by including more feedback loops, introducing new parameters, and rearranging the feedback loop's components to see the effects on other variables. To create scenarios that increase the transportation system's sustainability, strategies and policies pertaining to boosting mobility are needed. In this analysis, we outlined a scenario that would begin in 2024 and would enhance the transportation system's infrastructure while offering tax exemptions for electric vehicles (EVs) and incentives and refunds for EV chargers. The percentage of public transportation, route length, and the ratio of supply to demand all affect how well public transportation performs in terms of mobility. The simulation results show that the proposed scenario can gradually increase sustainability over time, which shows an improvement from approximately 73% to 83% by 2040. Relevant stakeholders could play a key role in achieving this by implementing improvements to transportation system infrastructure, electric vehicle (EV) tax exemptions, and incentives and rebates on EV chargers.**

Keywords— sustainable infrastructure, public transport, mobility, model, system dynamics

I. Introduction

Transportation systems are pivotal in everyday life because they play an important role in the quick and easy movement of people, goods, and services. However, population growth poses a challenge to developing an effective and efficient transportation system. To address this issue, the surrounding environment is likely to be adjusted to support the development of a larger transportation infrastructure [1]. Additionally, the operation of transportation systems not only accounts for 64% of globaloil consumption but also contributes to 27% of global energy use [2]–[4]. The production of carbon dioxide emissions from transportation reaches 23% of the world's emissions. As a result, the development and operation of the transportation systems indiscriminately will negatively impact not only the environment but also on social and economic quality of the community and future generations. To this end, considering the concept of sustainability in the development of a transportation system is essential. It is expected to reduce the negative impact on the environment and the mobility of future generations.

Many recent studies are addressing the issue of the sustainability of transportation systems. Those studies are closely related to the 2030 Sustainable Development Goals (SDGs) agenda, adopted by the United Nations [5]–[7]. This connection relates to the alignment of the concept of sustainable transportation systems with the SGD, which considers social, economic, and environmental impacts [8]–[10]. However, the sustainability of transportation systems is a broad topic and associated with other sectors, such as the government (policy makers) to academia [11], [12]. As a result, numerous factors affecting the sustainability of transportation systems are very broad and interrelated. However, most of those studies on improving the sustainability of transportation systems only explain a few of the relevant factors. For instance, Li and Liu [13] have developed a model related to Electric multiple unit (EMU) routing plan optimization. They found that the number of EMU maintenance can be reduced to a certain extent through integrated task optimization, but it is difficult to reduce the number of EMUs due to the structure of train operational schedules. Urban sprawl can become congested zones if authorities ensure equal distribution of local services. The choice of housing location will not be a challenge for the movement of urban residents to settle closer to their place of work, so that residents will participate in realizing integrated and real urban control [14]. The adoption of electric vehicles in Malaysia can provide the basis for appropriate strategic policies and help policymakers in providing incentives to users [15]. Several previous studies focused on transportation system operations to support sustainable transportation systems.

Therefore, the holistic understanding of the factors influencing the sustainability of a transportation system may be fragmented across these studies. Additionally, optimization of one factor alone may not significantly affect the overall sustainability of transportation systems. In addition, differences in conditions between cities, regions, and countries may increase the complexity of planning for developing a transportation system. Based on these issues, the contributions of this research are as follows: (1) formulating the relationship among factors that influence the sustainability of a transport system as illustrated in a Causal-Loop diagram, and (2) developing scenarios for increasing the sustainability of a transport system by increasing mobility factors.

This research is beneficial for transportation system management. First, this research facilitates the decision-makers to formulate current policies, conditions, and impacts of the transportation systems by knowing the interrelationships of factors that influence sustainability. Second, the decision-makers can easily analyze the impact of policy scenarios according to the conditions and available data. The data used for model simulations are obtained from reputable sources, such as the Central Statistics Agency of Indonesia, journal publications, as well as data from relatedarticles and statistics websites.

The rest of this research is structured as follows:. Section 2 describes the design of the proposed model using system dynamics, which includes the causal loop and the stock-and-flow diagrams. Section 3 describes the validity of the proposed model. Section 4 describes the proposed scenario to increase the sustainability of a transport system. The final section concludes the study.

II. Model Development

The system dynamics model is a continuous simulation model that uses hypothesized relationships to represent system characteristics [16]. It allows the modeler to insert qualitative relationships expressed in a specific diagram of the model. Interrelated system components have feedback loops that respond to system conditions and provide a degree of self-correction and control. The system dynamics continues to be a very popular mode of software process modeling and has been applied in an interactive simulation of projects to train project managers. The advantages of continuous simulation models include their ability to capture project-level and system-related aspects of a software process project. System dynamics modeling typically follows these five steps [17]: 1) problem articulation; 2) dynamic hypothesis; 3) model formulation; 4) testing (model validation); and 5) policy formulation and evaluation (scenario development). Essentially, the first three steps of system dynamics modeling aim to create causal-loop diagram (CLD) and stock-and-flow diagrams (SFDs), which show the relationships between factors related to mobility and sustainability. The CLD is a causality diagram that helps visualize the interrelationship of various variables in a system. Meanwhile, the SFD is a computable representation of a system (simulation), where each variable is defined and assigned the correct units. Subsequently, the models are validated to ensure that they accurately represent the real-world system. Finally, scenarios are built to improve the sustainability of the transportation system by improving its mobility factors.

A. CLD Development

A CLD is a key analytical tool that helps identify and visualize the key variables and the relationships between them, which influence system behavior. It generally has four basic elements: the variables, relationships between them, markings on the links (showing how the variables are related), and loop signatures (positive (R) and negative (B) feedback loops) [18]. The CLD describes a causal perspective, which describes hypotheses related to the behavior of the modeled system. A positive feedback loop indicates that the two connected variables will increase or decrease simultaneously (in the same direction). Whereas a negative feedback loop indicates an inverse or opposite (opposite) relationship; an increase in one variable causes a decrease in other related variables and vice versa.

In this study, we developed a CLD to describe the indirect effect of mobility toward sustainability, as illustrated in Fig. 1. Although the amenities and convenience directly affect the sustainability of transport systems [10], both are influenced by social aspects and mobility. In more detail, the mobility of transport systems is influenced by infrastructure and automation [19]. In comparison, the social aspects are influenced by automation, electric vehicles, affordability, and passenger drones [20], [21]. Furthermore, the infrastructure is affected by the mobility-as-a-service platform and connectivity [22], [23].

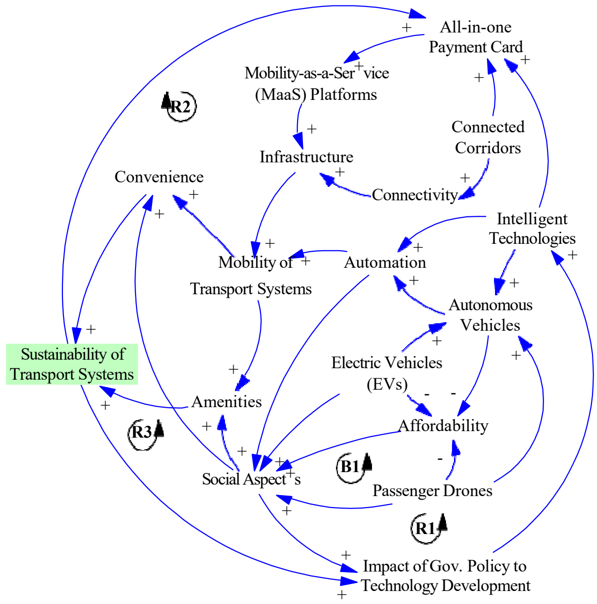

Fig. 1. The Causal Loop Diagram of Mobility Toward Sustainability

B. SFD Development

A system is a set of interconnected elements, resulting in different behavior over time (dynamic). The SFDs (Stock and Flow Diagrams) are the foundation of system dynamics models. Stock represents an entity that can be accumulated or depleted, such as inventory, whereas Flow represents an entity that can increase or decrease the stock, such as purchasing or selling inventory. In addition, stock variables are measured at a particular point in time and represent the quantity on hand at that point in time, which may have accumulated in the past.

1) SFD Models: Fig. 2. represents the SFD of perception of the transport system, which describes how people (especially passengers) perceive the quality of the transportation system. It can be divided into 2 indicators: the passenger perception of the transport performance and of the bus crew performance. Passenger perception of transport performance depends on the waiting time, cost, distance to the bus stop, travel time, and average bus speed [24]. Meanwhile, passenger perception of bus crew performance depends on the driving technique, hospitality service, responsiveness of the bus crew, and work discipline [25], [26].

Fig. 3. represents the SFD of mobility of public transportation. Initially, the mobility performance of public

transportation may be influenced by the ratio of public transport supply and demand, public transportation percentage, and the length of routes [27]. The supply and demand ratio for public transportation is influenced by how much the population needs transportation and how big the capacity of the existing transportation system is. That said, the populations influence public transportation demand. Whereas the public transport supply depends on the number of buses, taxis, and Lyns (minibus public transport) and the total of their capacity.

Figure 4 illustrates the standard deviation of the ratio of total cost of travel to per capita income, as determined by Tirachini and Antoniou's study [28]. The average cost per trip and the average number of journeys made by an individual are used to compute the ratio of the total cost of trips to income per capita compared to per capita income in a specific country. In addition, per capita income is a metric used to determine the average amount of money earned per individual.

Fig. 5. represents the overall SFD of the sustainability of transport systems. It refers to how sustainable the transportation system is in terms of its economic, social, and environmental impacts.

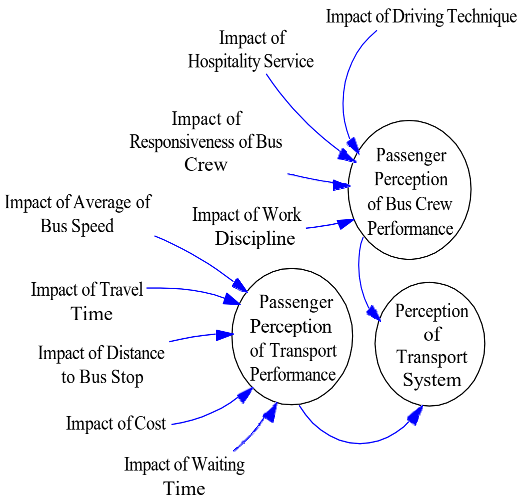

Fig. 2. SFD of Perception of Transport System

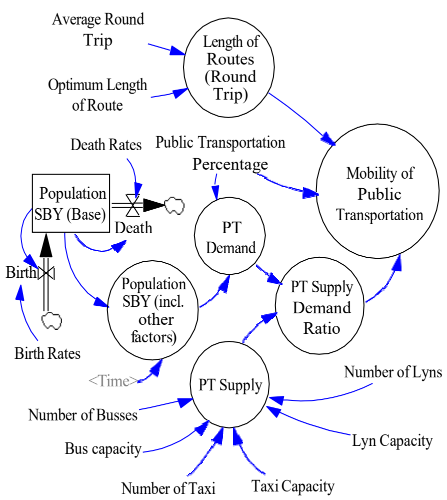

Fig. 3. SFD of Mobility of Public Transport

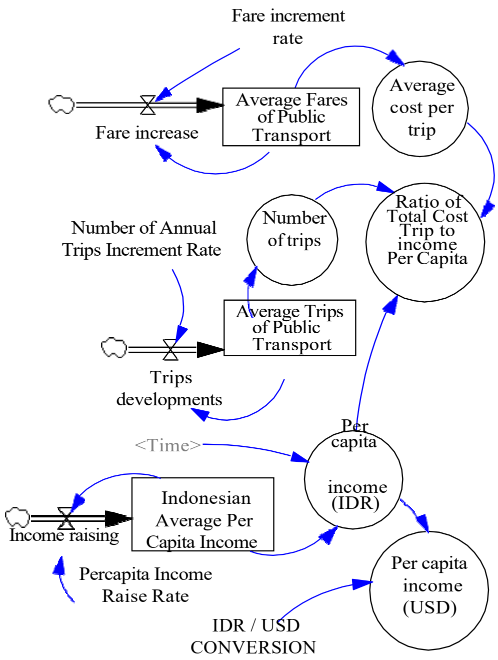

Fig. 4. SFD of Per Capita Income

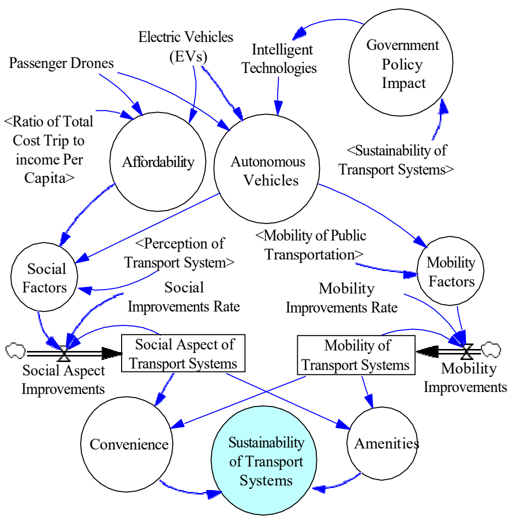

Fig. 5. SFD of Sustainability of Transport Systems

2) Simulation Result : The mentioned SFDs are simulated using the actual data in Indonesia and the results are shown in Fig. 6 to 8. The data was collected from various reputable sources, including the central statistics agency in Indonesia, several journal publications, as well as data from related articles and statistic websites. Fig. 6. shows that although the mobility of transport systems was increased from approximately 60% in 2000 to approximately 67% in 2022, it is considered relatively low due to the low mobility of public transportation and autonomous vehicles. The low mobility of public transportation is caused by the low use of autonomous vehicles. Several factors that influence autonomous vehicles include intelligent technologies, electric vehicles (EV), and passenger drones. Meanwhile, Fig. 7. shows the simulation result of social aspects of transport systems, which increased from approximately 70% in 2000 to approximately 78% in 2022, due to affordability, autonomous vehicles, and perception of transport systems. Affordability of transport systems is influenced by the use of passenger drones and the ratio of total trip cost to income per capita. On the other hand, Fig. 8. shows the simulation result of the sustainability of transport systems. Although the sustainability of transport system was increased from approximately 65% in 2000 to approximately 72% in 2022, it is considered relatively low due to the low convenience and amenities of transport systems. It is indirectly caused by mobility and the social aspect of the transport system. Social aspects of transport systems and mobility of transport systems influence convenience and amenities factors which also influence the sustainability of transport systems.

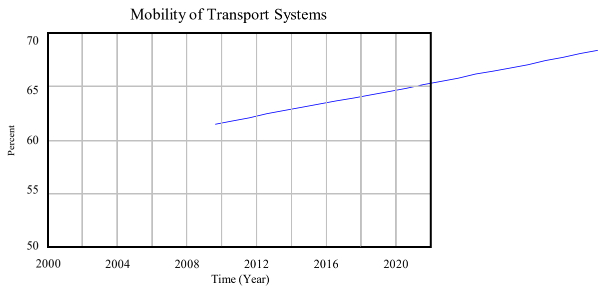

Fig. 6. The Simulation Result of Mobility of Transport Systems

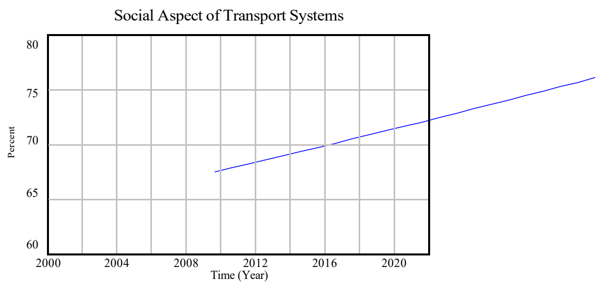

Fig. 7. The Simulation Result of Social Aspect of Transport Systems

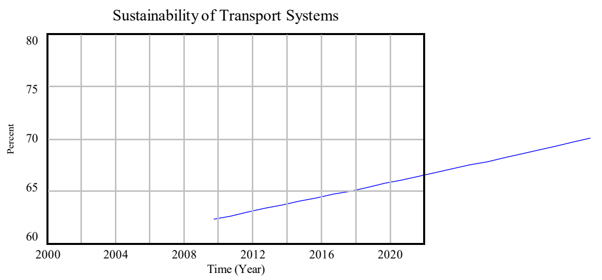

Fig. 8. The Simulation Result of Sustainability of Transport Systems

III. Model Validation

Model validation aims to build confidence in the usefulness of the model in relation to its purpose. Giannasi [29] define validation as the process of determining the validity of a simulation model based on an accurate and acceptable representation of reality. Validation is a comparative assessment between simulation computational results and actual data [30].

Model validation requires two stages [31], [32] namely model validation with the average comparison test (or mean error, represented by E_1) and model validation with amplitude variation comparison test (or variance error, represented by E_2). The model is declared valid if $E_1 \leq 5\%$ and $E_2 \leq 30\%$. The E_1 and E_2 are expressed in Eq. (1) and Eq. (2), respectively.

$$E_1 = \left|\frac{\bar{S}-\bar{A}}{\bar{A}}\right| x\ 100\ \% \qquad (1)$$

where:
$\bar{S}$ = the average rate of the simulation result
$\bar{A}$ = the average rate of the data

$$E_2 = \left|\frac{S_s-S_a}{S_a}\right| x\ 100\ \% \qquad (2)$$

where:
Ss = the standard deviation of the simulation result
Sa = the standard deviation of the data

In our study, the validation of Surabaya population, per capita income, and average fares of public transport are as follows:

Surabaya's population

$$E_1 = \left|\frac{2{,}900{,}212 - 2{,}899{,}344}{2{,}899{,}344}\right| x\ 100\ \% = 0.03\ \%$$

$$E_2 = \left|\frac{219{,}450 - 205{,}613}{205{,}613}\right| x\ 100\ \% = 6.73\ \%$$

per capita income

$$E_1 = \left|\frac{2{,}985 - 2{,}933}{2{,}933}\right| x\ 100\ \% = 1.77\ \%$$

$$E_2 = \left|\frac{768 - 773}{773}\right| x\ 100\ \% = 0.64\ \%$$

average fares of public transport

$$E_1 = \left|\frac{4{,}122 - 3{,}979}{3{,}979}\right| x\ 100\ \% = 3.59\ \%$$

$$E_2 = \left|\frac{1{,}214 - 1{,}238}{1{,}238}\right| x\ 100\ \% = 1.93\ \%$$

Based on these results, all E_1 are below 5% and E_2 are below 30%. It means that the Surabaya population, per capita income, and average fares of public transport are valid. Therefore, the developed models are considered valid.

IV. Scenario Development

A scenario is a predictive technique that creates multiple potential alternative future scenarios based on available facts. A valid model's structure can be altered by adding new parameters, adding more feedback loops, and adjusting the feedback loop's structure to observe how it impacts other variables. Strategies and policies related to increasing the mobility of the transportation system are needed to design scenarios to increase the sustainability of the transportation system. For instance, it can be made through improvements to the infrastructure of the transportation system, electric-vehicle (EV) tax exemption, and EV-charger incentives and rebates [33], [34]. The scenario to increase the sustainability of the transport system is represented in Fig. 9. Meanwhile, the simulation result of this scenario is shown in Fig. 10. It shows that increasing the infrastructure quality will increase the overall quality of mobility of the transport system. In addition, providing the EV tax exemption and the EV charger incentives and rebates will increase the affordability and social aspect of transport systems.

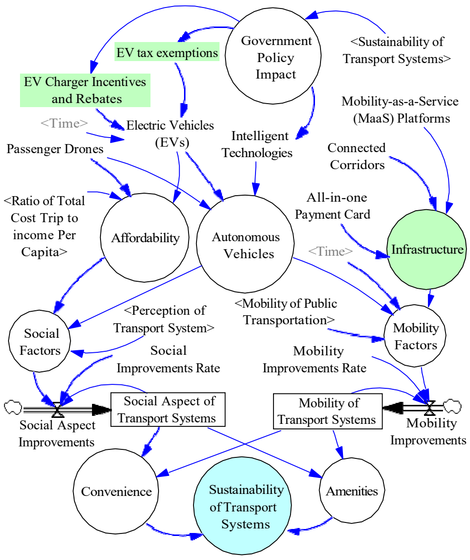

Fig. 9. SFD of Scenario to Increase the Sustainability of Transport Systems

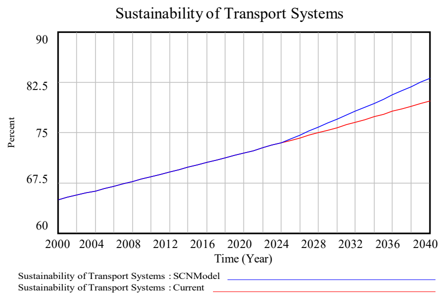

Fig. 10. The Simulation Result of Scenario to Increase the Sustainability of Transport Systems

Fig. 10. shows the projected improvement in the sustainability of transport systems from approximately 73% in 2024 to approximately 83% by 2040, due to the improvement in the social aspect and mobility of transport systems. It is indirectly caused by improvements in the infrastructure of the transportation system, electric vehicle (EV) tax exemption, and EV charger incentives and rebates.

V. Conclusion And Further Research

This research is beneficial in the management of transportation systems. By understanding the interrelationships of factors that influence sustainability, decision-makers can formulate current policies, conditions, and impacts of the transport systems. Subsequently, they can plan the development of the transportation system by considering the concept of sustainability. In addition, they can easily analyze the impact of policy scenarios according to the conditions and available data.

A valid model's structure can be altered by including more feedback loops, introducing new parameters, and rearranging the feedback loop's components to see the effects on other variables. To create scenarios that increase the transportation system's sustainability, strategies and policies pertaining to boosting mobility are needed.

The simulation results show that the proposed scenario can increase sustainability from approximately 73% in 2024 to approximately 83% by 2040. It is due to the improvement in the infrastructure of the transportation system, electric vehicle (EV) tax exemption, and EV charger incentives and rebates. Further research can be carried out by calculating the benefits and costs of each alternative scenario which includes improvements in transportation system infrastructure, implementation of electric vehicle (EV) tax exemptions, as well as providing EV charger incentives and rebates.

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References

[1] T. Brown, “Transportation Infrastructure,” *National Geographic Society*, 2022. education.nationalgeographic.org/resource/transportation-infrastructure

[2] L. Mead, “The Road to Sustainable Transport,” *International Institute for Sustainable Development (IISD)*, 2021. International Institute for Sustainable Development (IISD)

[3] R. Van den Berg and P. W. De Langen, “Environmental sustainability in container transport: the attitudes of shippers and forwarders,” *Int. J. Logist. Res. Appl.*, vol. 20, no. 2, pp. 146–162, Mar. 2017, doi: 10.1080/13675567.2016.1164838.

[4] E. Suryani, R. A. Hendrawan, P. F. Eka Adipraja, B. Widodo, U. E. Rahmawati, and S.-Y. Chou, “Dynamic scenario to mitigate carbon emissions of transportation system: A system thinking approach,” *Procedia Comput. Sci.*, vol. 197, pp. 635–641, 2022, doi: 10.1016/j.procs.2021.12.184.

[5] United Nations, “Sustainable transport, sustainable development,” 2021. [Online]. Available: sdgs.un.org/sites/default/files/2021-10/Transportation Report 2021_FullReport_Digital.pdf

[6] S. Nundy, A. Ghosh, A. Mesloub, G. A. Albaqawy, and M. M. Alnaim, “Impact of COVID-19 pandemic on socio-economic, energy-environment and transport sector globally and sustainable development goal (SDG),” *J. Clean. Prod.*, vol. 312, p. 127705, 2021, doi: 10.1016/j.jclepro.2021.127705.

[7] F. Johnsson, I. Karlsson, J. Rootzén, A. Ahlbäck, and M. Gustavsson, “The framing of a sustainable development goals assessment in decarbonizing the construction industry – Avoiding ‘Greenwashing,’” *Renew. Sustain. Energy Rev.*, vol. 131, p. 110029, 2020, doi: 10.1016/j.rser.2020.110029.

[8] A. M. Bassi, G. Pallaske, N. Niño, and L. Casier, “Does Sustainable Transport Deliver Societal Value? Exploring Concepts, Methods, and Impacts

with Case Studies," *Future Transportation*, vol. 2, no. 1. pp. 115–134, 2022. doi: 10.3390/futuretransp2010007.

[9] P. Liu, C. Liu, J. Du, and D. Mu, "A system dynamics model for emissions projection of hinterland transportation," *J. Clean. Prod.*, vol. 218, pp. 591–600, 2019, doi: 10.1016/j.jclepro.2019.01.191.

[10] S. Sultana, D. Salon, and M. Kuby, "Transportation sustainability in the urban context: a comprehensive review," *Urban Geogr.*, vol. 40, no. 3, pp. 279–308, Mar. 2019, doi: 10.1080/02723638.2017.1395635.

[11] J. Zhou, "Sustainable transportation in the US: A review of proposals, policies, and programs since 2000," *Frontiers of Architectural Research*, vol. 1, no. 2. pp. 150–165, 2012. [Online]. Available: https://journal.hep.com.cn/foar

[12] X. Zhao, Y. Ke, J. Zuo, W. Xiong, and P. Wu, "Evaluation of sustainable transport research in 2000–2019," *J. Clean. Prod.*, vol. 256, p. 120404, 2020, doi: 10.1016/j.jclepro.2020.120404.

[13] W. Li and P. Liu, "EMU Route Plan Optimization by Integrating Trains from Different Periods," *Sustainability*, vol. 14, no. 20. 2022. doi: 10.3390/su142013457.

[14] T. O. Alshammari *et al.*, "The Compactness of Non-Compacted Urban Developments: A Critical Review on Sustainable Approaches to Automobility and Urban Sprawl," *Sustainability*, vol. 14, no. 18. 2022. doi: 10.3390/su141811121.

[15] N. A. Muzir, M. R. Mojumder, M. Hasanuzzaman, and J. Selvaraj, "Challenges of Electric Vehicles and Their Prospects in Malaysia: A Comprehensive Review," *Sustainability*, vol. 14, no. 14. 2022. doi: 10.3390/su14148320.

[16] M. J. Radzicki, "System Dynamics and Its Contribution to Economics and Economic Modeling BT - Complex Systems in Finance and Econometrics," R. A. Meyers, Ed. New York, NY: Springer New York, 2011, pp. 727–737. doi: 10.1007/978-1-4419-7701-4_39.

[17] J. D. Sterman, *Business Dynamics, Systems Thinking and Modeling for a Complex World*. McGraw-Hill Inc, 2000.

[18] C. Lannon, *Causal Loop Construction: The Basics*. Pegasus Communications, Inc. [Online]. Available: https://thesystemsthinker.com/causal-loop-construction-the-basics/

[19] M. Alonso Raposo, M. Grosso, A. Mourtzouchou, J. Krause, A. Duboz, and B. Ciuffo, "Economic implications of a connected and automated mobility in Europe," *Res. Transp. Econ.*, vol. 92, p. 101072, 2022, doi: 10.1016/j.retrec.2021.101072.

[20] T. Cohen, P. Jones, and C. Cavoli, *Social and behavioural questions associated with automated vehicles.* 2017. doi: 10.13140/RG.2.2.15165.67041.

[21] T. Cohen and P. Jones, "Technological advances relevant to transport – understanding what drives them," *Transp. Res. Part A Policy Pract.*, vol. 135, pp. 80–95, 2020, doi: 10.1016/j.tra.2020.03.002.

[22] C. B. Casady, "Customer-led mobility: A research agenda for Mobility-as-a-Service (MaaS) enablement," *Case Stud. Transp. Policy*, vol. 8, no. 4, pp. 1451–1457, 2020, doi: 10.1016/j.cstp.2020.10.009.

[23] B. Maas, "Literature Review of Mobility as a Service," *Sustainability*, vol. 14, no. 14. 2022. doi: 10.3390/su14148962.

[24] S. Sinha, H. M. Shivanand Swamy, and K. Modi, "User Perceptions of Public Transport Service Quality," *Transp. Res. Procedia*, vol. 48, pp. 3310–3323, 2020, doi: 10.1016/j.trpro.2020.08.121.

[25] D. Quy Nguyen-Phuoc, O. Oviedo-Trespalacios, N. S. Vo, P. Thi Le, and T. Van Nguyen, "How does perceived risk affect passenger satisfaction and loyalty towards ride-sourcing services?," *Transp. Res. Part D Transp. Environ.*, vol. 97, p. 102921, 2021, doi: 10.1016/j.trd.2021.102921.

[26] K.-C. Hu and V. Salim, "Combining Kano’s Model, IPA, and FMEA to Evaluate Service Quality Risk for Bus Service: Case of Bangkok Bus Service," *Applied Sciences*, vol. 13, no. 10. 2023. doi: 10.3390/app13105960.

[27] J. Narayan, O. Cats, N. van Oort, and S. Hoogendoorn, "Integrated route choice and assignment model for fixed and flexible public transport systems," *Transp. Res. Part C Emerg. Technol.*, vol. 115, p. 102631, 2020, doi: 10.1016/j.trc.2020.102631.

[28] A. Tirachini and C. Antoniou, "The economics of automated public transport: Effects on operator cost, travel time, fare and subsidy," *Econ. Transp.*, vol. 21, p. 100151, 2020, doi: 10.1016/j.ecotra.2019.100151.

[29] F. Giannasi, P. Lovett, and A. N. Godwin, "Enhancing confidence in discrete event simulations," *Comput. Ind.*, vol. 44, no. 2, pp. 141–157, 2001.

[30] M. S. Martis, "Validation of simulation based models: A theoretical outlook," *Electron. J. Bus. Res. Methods*, vol. 4, no. 1, pp. 39–46, 2006.

[31] Y. Barlas, "Multiple tests for validation of system dynamics type of simulation models," *Eur. J. Oper. Res.*, vol. 42, no. 1, pp. 59–87, 1989, doi: 10.1016/0377-2217(89)90059-3.

[32] H. Qudrat-Ullah, "On the validation of system dynamics type simulation models," *Telecommun. Syst.*, vol. 51, no. 2, pp. 159–166, 2012, doi: 10.1007/s11235-011-9425-4.

[33] S. LaMonaca and L. Ryan, "The state of play in electric vehicle charging services – A review of infrastructure provision, players, and policies," *Renew. Sustain. Energy Rev.*, vol. 154, p. 111733, 2022, doi: 10.1016/j.rser.2021.111733.

[34] S. P. Sathiyan *et al.*, "Comprehensive Assessment of Electric Vehicle Development, Deployment, and Policy Initiatives to Reduce GHG Emissions: Opportunities and Challenges," *IEEE Access*, vol. 10, pp. 53614–53639, 2022, doi: 10.1109/ACCESS.2022.3175585.