**Journal of Information Systems Engineering and Management**
2025, 10(32s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

**Research Article**

# Car Dependency Reduction Potential by Shared Autonomous Vehicle (SAV): A System Dynamic Approach

Dea Merta Moriska [1], Simon Shepherd [2], Sutanto Soehodho [3*], R Ivan Adwitiya [4]
[1] *Department of Civil and Environmental Engineering, Faculty of Engineering, University of Indonesia, Depok, Indonesia. Email: moriskadea@gmail.com*
[2] *Scholar, Department of Transport Studies, Institute for Transport Studies, University of Leeds, Leeds, United Kingdom. Email: S.P.Shepherd@its.leeds.ac.uk*
[3] *Scholar, Department of Civil and Environmental Engineering, Faculty of Engineering, University of Indonesia, Depok, Indonesia. Email: ssoehodho@yahoo.com*
[4] *Department of Civil and Environmental Engineering, Faculty of Engineering, University of Indonesia, Depok, Indonesia. Email: ivan.adwitiya@ui.ac.id*

**ARTICLE INFO**

Received: 31 Dec 2024

Revised: 20 Feb 2025

Accepted: 28 Feb 2025

**ABSTRACT**

Car dependency has been perceived as a multifaceted problem for the externalities it causes. Autonomous vehicle (AV) comes with automation technology allowing people to not drive at certain levels. Despite the expensive purchase price of AV, it offers several promising benefits. Ridesharing as one form of shared mobility has been perceived as one of the solutions proposed by scholars to reduce people's dependency on private cars in the near future. As the use of AV as ridesharing is predicted to be normal in the future, it is reasonable to investigate the impact of shared autonomous vehicles (SAV) or driverless taxi service in convincing people to give up their private car. The SAV users come from people leaving their cars for SAV service represented by SAV fleet and waiting time. The provision of fleets directly affects the waiting time, with the higher number of fleets to meet the demand lowering the waiting time. A lower waiting time has a positive impact on increasing SAV users. This research aligns with SDG 11 by providing sustainable transport for a resilient and sustainable city.

**Keywords:** Car Dependency, Car Shedding, Shared Autonomous Vehicle, System Dynamic.

## INTRODUCTION

The use of private cars by people to get to the workplace is higher than other mode choices. A high dependency of private cars is shown by this phenomenon and has been a global problem for its negative impacts on the environment and human health. In year 2021, Department for Transport reported that 25.5% of total GHG emissions in the United Kingdom is accounted to transport sector [1]. As the impact, policy makers are looking for instruments to reduce car usage by lowering car ownership [2]. A wide range of measures has been perceived as solutions for this problem, several of them are pushing people opt for a more environmentally friendly vehicle such as electric vehicles (EVs) or public transport or other transport modes, among which 'ridesharing'[3].

Ridesharing such as Uber and Lyft have been unveiled to give a similar service as conventional taxi with a small difference for the service is provided as a platform-based service. Besides, as a form of shared mobility, ridesharing has been perceived to be a solution to push people in leaving their private car. By using the platform (app-based), this service is a mobility service, which is affordable, effective and sustainable to give a positive impact on society, economy, and environment [4].

The present of autonomous vehicles (AV) enables users to benefit from their technology which can reduce the cost, pollution, the consumption of energy and crashes. The fast development of AV's technology hastens people in choosing AV as their new form of vehicle and will have the potential to change people's behavior in traffic, road network system performance and travelling [5]). Furthermore, in [6] study, they delivered a finding that the use of AV in giving ridesharing services will be common in the future of transport. Research conducted by [7] in the United States conveyed that 24% of their respondents are incline to a self-driving taxi which only can be served by a high-level automation of AV rather than the conventional taxi. This self-driving taxi is a combination of ridesharing with a high-level AV which is called as shared autonomous vehicle (SAV).

People's preference towards AV is influenced by factors such as travel time, travel cost, and waiting time. Waiting time is perceived as the most important attribute because it will affect the provision of SAV and will have an impact on the cost of service. Thus, this research focuses on SAV service potential to reduce the car dependency, with the development of technology of AV which is uncertain in the future. Therefore, the adoption of SAV in this research will be modelled using the system dynamic approach to enable the analysis of the complex problems which consist of attributes and factors.

**Table 1:** Variable description

| | **UNIT** | **DESCRIPTION** |
|---|---|---|
| r fully cle (PAV/FAV) | Dmnl | AUXILIARY: Utility function for FAV/PAV |
| he market) | Dmnl | AUXILIARY: Percentage of FAV market share |
| V/PAV | Vehicle/year | STOCK: total FAV/PAV |
| d car | Vehicle/year | AUXILIARY: total FAV/PAV being sold every year |
| | Vehicle/year | AUXILIARY: number of PAV and FAV |
| us Vehicle (SAV) | person/year | STOCK: number of SAV users |
| | Minute/year | STOCK: waiting time for customers to be served by SAV |
| | Vehicle/year | STOCK: total SAV vehicles |
| velled (VMT) | Miles/year | AUXILIARY: VMT for each modes |

Source: author's work (2024)

## LITERATURE REVIEW

A definition of car dependency based on [8] is a condition where the high level of car usage per capita reach followed by finite choice of transport mode. Ridesharing has been considered as solutions to push people in leaving their cars. Scholars found 7-9% ridesharing users will leave private car for the service [9] [10] [11]. In addition, that passenger with time concern is willing to take travel with a higher travel cost to save time, meanwhile people who have concern about travel cost are less concerned about the travel time. In addition, while new customers are more sensitive to the price, long-time customers care more about time [12].

The technology of AV is promised to give a better quality of vehicles compared to existing vehicles. Consists of six levels of driving automation, AV with level 4 and 5 adopt the high automation which allows the driver to have no control on the vehicles. Chng in [13] categorized SAV as a semi-private and limited public sharing. This form of mobility is claimed to have a positive impact in reducing transport expense, private car ownership and vehicle miles travelled (VMT) [14]. Some studies argued there is potential of SAV service to change people behaviour towards transport mode especially private vehicles. [15] conducted research focusing on preference of autonomous vehicle adoption using a utility function conveyed that the number of fleets will increase as a response to demand which also get impact from the waiting time of taxi.

Since transport problem is a complex system with multi-dimensional aspects, therefore system dynamic (SD) approach which enable to model and simulate complex dynamic system such as transport problem will be utilized to analyze the problem.

## METHODOLOGY

This chapter explains the methodology in conducting this research. System dynamic methodology is kind of approach which based on control theory to understand and investigate the system in the form of causal feedback relations which is represented by loops. The loops in the system dynamic are usually known as causal loop diagram (CLD). These loops contain of reinforcing (positive) or correcting (negative) feedback loops [16]. The model is a 80-year period model with 2020 as the starting year and ending in year 2100. Several variables description as displayed in Table to give the explanation of involved variables to create the model. The model structure is consisting of 3 main modules, private car module, SAV user's module and SAV fleet and waiting time module.

The private car module show people's willingness to pick between PAV or partially autonomous vehicle comprise of level 0-3 AV or FAV or fully autonomous vehicle which includes the level 4 and 5 of AV. Based on [17], the choice is affected by several attributes such as purchase price, operating cost, speed, fuel availability, emissions and range. In the model, the purchase price is affected by the learning curve such as shown in **Figure** .

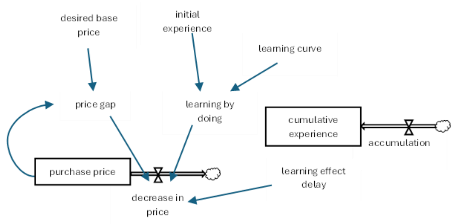



**Figure 1.** Structure of the purchase price

Purchase price ($pp$)

$$pp = pp_0 \left(\frac{E}{E_0}\right)^{lcd}$$

$pp_0$ stands for the initial price, $E$ stands for the level of experience while $lcd$ is the learning-by-doing curve. The $lcd$ effect shows the impact of cost which fall by a fraction of x in response to increasing experience in the order of magnitude ($\omega$)

Learning-by-doing curve

$$lcd = log_{\omega}(1 - x)$$

$E$ is obtained by calculating the sales of FAV.

Accumulation of experience

$$\frac{dE}{dt} = s$$

Learning-by-doing variable

$$lbd = 1 - \left(\frac{E}{E_0}\right)^{lcd}$$

Purchase price stock

$$\frac{dPP}{dt} = -dc$$

Price gap

$$price\ gap = PP - dbp$$

Decrease of price

$$dc = price\ gap * lbd * led$$

Besides, there are constants to be used in this model as displayed in

Table.

**Table 2:** Setting on parameters

| NAME | VALUE | UNIT |
|---|---|---|
| Initial PAV | 407,038 | vehicle |
| Initial figure of FAV | 0 | vehicle |
| Average car life | 10 | year |
| Initial fleet | 500 | vehicle |
| Initial demand | 10,000 | person |
| Initial wait time | 8 | minute |
| Adoption Fraction | 2.5 | percentage |
| PAV trip | 2 | times |
| FAV trip | 4 | times |
| Road length | 10 | miles |

Beside running the model, sensitivity analysis will be conducted to discover important information. Through sensitivity analysis, significant variables will stand out by giving a significant change of behaviour shown in the result.

## RESULT

Vensim software is utilized to analyze the model of problem by the system dynamic approach. The full appearance of model for this research is shown in Figure. Results and discussion focus on 2 parts consist of private vehicle and SAV module. This research has a main goal to find the potential of SAV in shifting people from their private cars which could reduce the car dependency. To begin with, in the private car module, the vehicle owned by people are divided into 2 categories which are partial autonomous vehicle (PAV) and fully autonomous vehicle (FAV). Both categories based on automation level, PAV for level 0-3 and FAV for level 4-5.

The first step is to define the parameter setting in creating the model. The consideration in people choosing FAV and PAV in this study is modelled using the settings in Table .

**Table 3:** Attributes settings

| Design variable | Beta | PAV | FAV |
|---|---|---|---|
| Price (£'000) | -0.215 | 60 | 120 |
| Costs (p/mile) | -0.072 | 20 | 11 |
| Max speed (mph) | 0.143 | 130 | |
| Availability of fuel (% of stations) | 0.234 | 100 | |
| Emissions level (1-10) | -0.212 | 5 | |
| Range (miles) | 0.478 | 700 | |

This result still does not take the car shedders into consideration, Figure displays the figures of PAV and FAV owners. As shown in that figure, in the first 13 years the line of PAV shows a steady flat trend in around 400,000 vehicles while the FAV giving the same trend as PAV but started from the bottom of graph which indicates that there are a few numbers of people choose FAV over PAV.

A significant move in 2043 is likely an effect of the price change of FAV when the price finally touches the same price as PAV. Despite the contribution of overall constant of other factors, but price and emission which change over time gives the significant role in this change. Later, there is car shedding that have another significant role in the model.

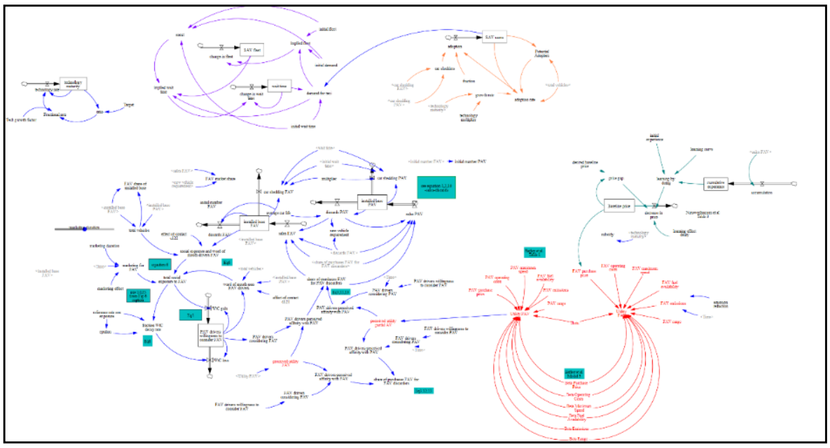
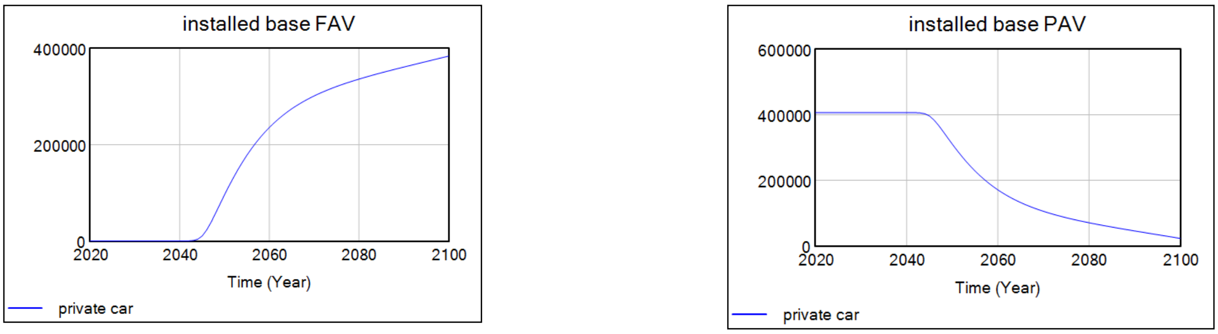


**Figure 2.** Full system dynamic model




(a)

(b)

**Figure 3.** Installed base FAV (a) and PAV (b)

The following step is to model the shifting of people who owned their private car whether it is FAV or PAV to shared autonomous vehicle (SAV) service. There is a car shedding variable as the connection between private car module and SAV module. Based on the stated preference conducted by [18], there are some attributes to be considered by people in choosing between private car and ridesharing among which is waiting time of the SAV service. From the calculation of that research, 0.17% people will give up their private car for a minute faster in waiting to be served by SAV service. Thus, 0.17% constant is used as car shedding percentage for the base case.

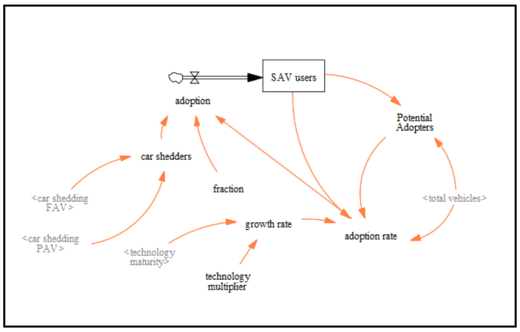



**Figure 4.** SAV user module

The SAV module consists of some factors as displayed in Figure. The SAV users are considered start with 10,000 people in Leeds as data from Travel to work survey in year 2022 reported that there are 2.5% users choose to travel to workplace by ridesharing. The stock only involves the adoption as the inflow without outflow to investigate the adoption of SAV based on number of SAV fleet and the waiting time which represent the SAV availability. There will be 2 scenarios which comprise of base case with 0.17% car shedders and the scenario without car shedders as comparison.

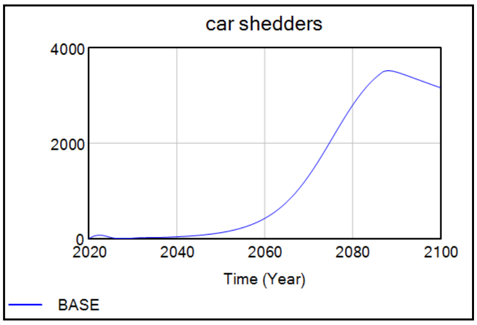



**Figure 5.** Car shedders for base scenario

In Figure, there is a slight rise in year for 7 years (2026-2032) which demonstrates a change of waiting time as response to the change of the car shedders which is affected by the wait time stock, initial wait time, and the multiplier of car shedding. The wait time exceeded the initial wait time in this period, while the wait time has a direct impact in making people leave their cars. Therefore, there are no car shedders when the wait time is longer than the initial wait time.

In year 2088, the number of car shedders reaches its peak with 3,526 people leaving their cars. Although, after that year, the number of car shedders endlessly decreased each year because of the potential adopters become less due to number of private vehicle owners also decreasing. The potential adopters adjust the number following the change of total vehicle and the updated number of SAV users. A faster waiting time will make the SAV service more appealing to be chosen.

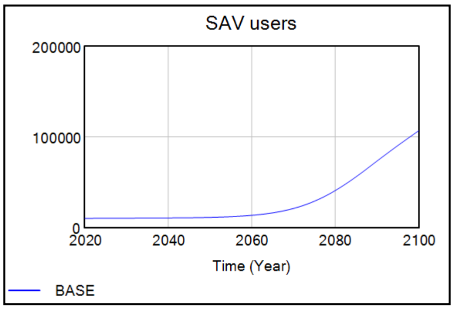


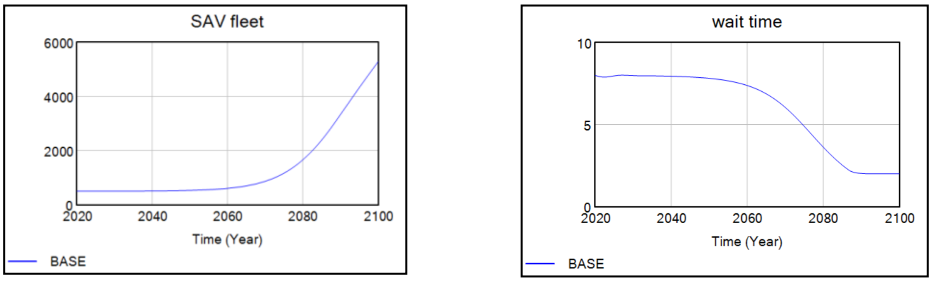

**Figure 6.** SAV users for base scenario

As shown in

Figure, the number of SAV users started with a flat trend before starting to rise after the year 2060 to the end of period with a peak at 106,731 of users in total. SAV users directly affect the number of SAV fleet and wait time, as the number of SAV users goes higher, it will also change the implied fleet to give a better service. Using 8-minute as the initial wait time, the inadequate figure of fleet to serve SAV customers generates a longer wait time. This longer waiting time happens for first few years or almost 10 years as shown in Figure . As displayed in that figure, 2027 is the year where customers need to wait for the longest time or for 8.017 minutes. Having an exceeding wait time compared to the initial figure, it happened because of the total of SAV fleet only have 2 addition fleets while the number SAV users has an addition of 247 customers compared to the first year. This implies that the non-stop addition of customers has not been followed by a sufficient provision of fleet. This imbalance growth between users and fleet gives a plausible reason to longer time of waiting.

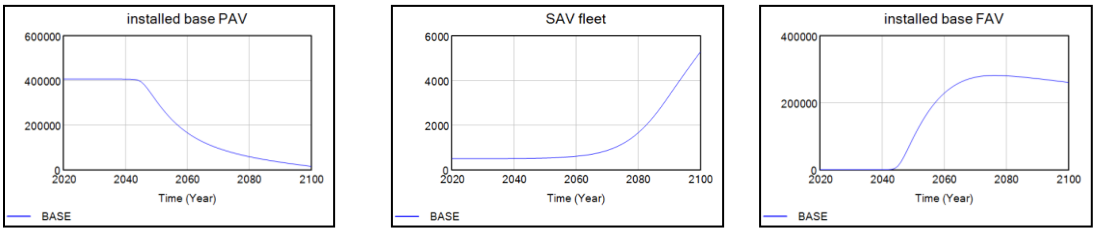
More closely examine the number of private cars and the provision of SAV vehicles, the car shedding connects the private car and SAV fleet variables. The following figure (Figure) displays the result of the base scenario with considering people leaving their private cars. These figures show similar trends in the first few years with a flat line before showing change after this period. Although figure a and c show almost the same result as in

Figure, but there is still a slight difference with a slightly under due to car shedding. Table displays the comparison between a no-car-shed scenario and the base case with 0.17% of people leaving their private car for a minute faster of SAV service. In the final year, the private car ownership for the base scenario is at 310,307 which means there are 96,731 private vehicles being sold by the owners. In addition, with those private cars being shed, there are 5,281 vehicles additions for SAV fleets at the same year. Averagely, these SAV fleets, if the vehicles always fully occupied by 4 passengers can run for 5 times daily at the end of the period.




(a) (b)

**Figure 7.** Number SAV vehicle/fleet (a), waiting time (b)




(a) (b) (c)

**Figure 8.** Installed base PAV (a), SAV fleet (b), Installed base FAV (c)

**Table 4:** Total vehicles

| Scenarios | 2020 | | | 2100 | | |
|---|---|---|---|---|---|---|
| | PAV + FAV | SAV fleet | Total | PAV + FAV | SAV fleet | Total |
| No-car-shed | 407,038 | 500 | 407,538 | 407,038 | 500 | 407,538 |
| Base | 407,038 | 500 | 407,538 | 310,307 | 5,281 | 315,588 |

**Vehicle Miles Travelled**

An additional result is the comparison of vehicle miles travelled between base scenario and the no-car-shed scenario. At the end of period, the total VMT for no-car-shed scenario experienced a significant increased by 15.7% while for the base scenarios by 16.7% as the comparison to the starting year. By 2100, the base scenario yields a 0.7% higher VMT compared to the no-car-shed scenario. This result has taken attention for the number of total vehicles of the base case scenario is less than the no-car-shed case (Table ), but the VMT per vehicle shows a higher figure for the average. In this case, the additional VMT occurs could be the result of unoccupied travel when SAV run without passengers. Although a higher VMT could be the reason of an increased greenhouse gas emission (GHG) and energy consumption, but it can be eliminated by the using of SAV technology, therefore it can be concluded that the additional VMT will generate a lower negative impact compare to the conventional taxi with internal combustion engine (ICE) vehicles [19]. Moreover, Ma et al. in [20] gave the opinion about the increased VMT as compensation of private vehicles reduction and the trip optimization. Besides the potential effect of VMT on environment, congestion could be another problem caused by high VMT. Hence, there is a need to take an action to tackle this potential problem before it happens such as dynamic pricing, traffic management and dedicated lane for SAV [21].

**Table 5:** Total fleet mileage (miles/vehicle)

| Scenario | 2020 | | | 2100 | | |
|---|---|---|---|---|---|---|
| | PAV + FAV | SAV | Total | PAV + FAV | SAV | Total |
| No- car- shed | 5,200 | 26,000 | 31,200 | 10,109 | 26,000 | 36,109 |
| BASE | | | | 10,112 | 26,275 | 36,387 |

**Variations**

This section is to show the result of sensitivity analysis which is argued will give an important information for the researcher [22]. Change of several variables such as subsidy policy and changing the waiting time threshold will be conducted in the sensitivity analysis.

### a. Subsidy Policy

The UK government has taken an attempt to push the adoption of AV, especially for the high automation AV or self-driving vehicles (FAV). Hence, this scenario will give £5,000 subsidy to be given for the FAV purchasing if the technology maturity ($tm$) is higher than 40% as shown in the formula below:

Subsidy function

$subsidy = IF\ THEN\ ELSE\ (tm > 0.4; 5000; 0)$

The result of applying the subsidy policy gives a slight change to the final purchase price at a certain time as displayed in Figure . In that graph, the changing of final purchase price is not only based on the goal seeking of the baseline price, but there is subsidy as additional subtraction with condition to be reached. Since the technology maturity finally reaches 40% in year 2058 therefore the additional subsidy gives a lower price for FAV compared to PAV price. Consequently, this result has a direct effect to FAV's utility function in a good direction., as the subsidy policy will likely encourage people in choosing FAV over PAV as their private vehicles.

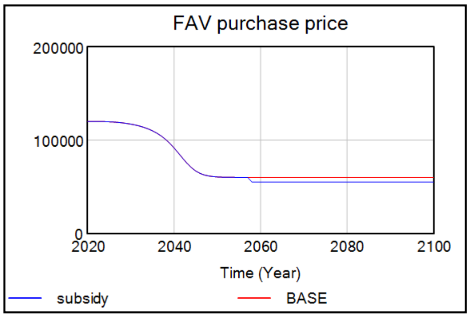



**Figure 9.** Purchase price with subsidy

Look into the base case without subsidy policy, this subsidy policy results in a significant jump in the market share. As predicted, the market share of FAV in year 2058 soared from 79% to 92% only in a year. This happens at the same year as the technology reaches 40% of maturity which means the subsidy is levied to the purchase price of FAV. Beside the effect to the market share, this outcome also changes the total number FAV as displayed in Figure .

Despite its effect on several variables mentioned before, the subsidy apparently has no impact on shifting people to choose SAV over private vehicles. This phenomenon happens possibly because of the total number of private vehicles (PAV and FAV) has the same figure as the starting number with no reduction, therefore is no possibility to shift people preference from private cars to SAV service. Nevertheless, this result still gives a positive outcome as if there are more people shift to the more advance automation of AV means that fewer emissions will be generated. Although they still use private car, but at least private car owners cause less externalities.

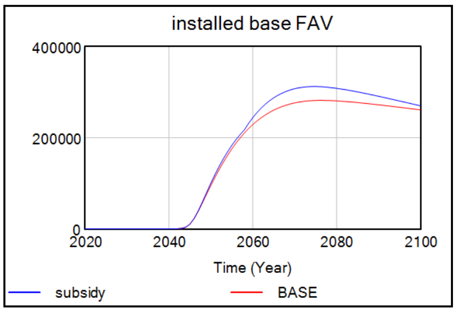



**Figure 10.** Comparison of installed base FAV between base and subsidy scenario

### b. Waiting Time

In this model, the number of SAV fleet will have an impact to the waiting time. The number of SAV fleet and waiting time has an ongoing relationship which is modelled to meet a certain number as well as the implied fleet and wait time. A higher number of demands to the SAV straightly affect the number of SAV vehicles. Moreover, when the provision of SAV fleet meets the demand will enable in waiting time reduction.

Based on Uber in 2022, a threshold of waiting time is given in considering the customer's convenience. In Leeds city, the 3-minutes of waiting time is considered as the threshold by the Uber which means that after passing that threshold of waiting time, customers have rights to cancel the order. Therefore, this research applies 2-minutes of waiting time.

As mentioned in the beginning about waiting time to be considered as the main reason of people leaving their private cars, while previous scenarios use 2-minutes as the waiting time threshold, current scenario will allow waiting time to the lowest point. It means, customers will have rights to cancel the order whenever they feel uncomfortable to wait. The new threshold will be 0.001-minutes and will be compared to the base case. This new threshold allows the wait time curve to continue lower at any time. Meaning, a better service can be provided by the new threshold. This test does not include the no-car-shed scenario, because after looking at the results, the alteration or wait-time threshold have no effect on the no-car-shed case.

There are 2 additions of scenario in this wait time scenario which include the change of car shedding percentage by 1% and the extreme case with 7% people leave their cars for a minute faster in waiting time, therefore there will be 3 scenarios included in the wait scenario (base, 1 % and 7% scenario).

As shown in Figure , for the extreme scenario (7% car shedders) with the new threshold shows the same pattern as the regular extreme scenario (0.17% car shedders) until year 2038 before the line shows a continuing move to the lower point as until it reach its lowest point at 0.13 minute of wait time. Meanwhile, the 1% of car shedders scenario reaches its fastest waiting time at 0.14 minutes after 71 years. Lastly, the base scenario demonstrates a result with 1 minute of wait time as its fastest waiting time to be attained by SAV service during the period.

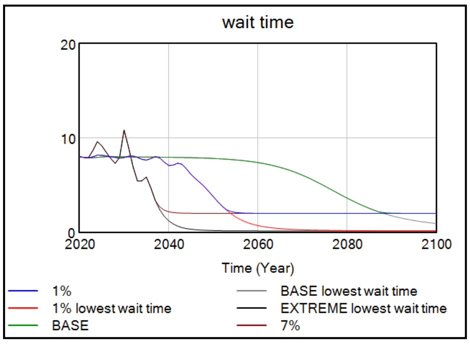



**Figure 11.** Comparison of wait time.

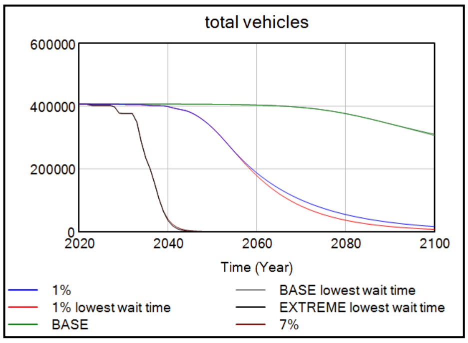



**Figure 12.** Total private vehicles with different wait-time threshold

These scenarios give a different result in total vehicles as shown in Figure . For the base case result, the new threshold generates 1.2% gap between this scenario and the original base scenario at the end of period, whilst the widest gap (55.4%) has been gained by the 1% scenario (original and lowest wait time threshold) as detailed in Table . More than 50% of car owner shed their vehicles when the new threshold enables people to be served by the SAV service in faster waiting time while the previous scenario gives 2-minutes as the fastest waiting time. By looking to this outcome, it can be concluded that waiting time significantly affect the SAV's service level.

## CONCLUSION

This research points out the potential impact of SAV service to the car dependency with study case in Leeds, United Kingdom using system dynamic approach. The adoption of private autonomous vehicles is affected by some attributes such as costs, speed, fuel, range, emissions and vehicle's price. With 2 groups of autonomous vehicle consists of partially AV (PAV) and fully AV (FAV), the purchasing price has the crucial role in pushing people to choose FAV rather than PAV. Meanwhile, emissions have an insignificant role for the result.

Other than that, from this study, it has been found the SAV potential to shift people from their private cars which in this research is SAV service. From running some scenarios, subsidy policy does not have the impact in shifting people from their private cars to SAV. In addition, main variable that could accelerate people leaving their cars are the waiting time and number of SAV fleet, with the most significant results shown by a lower threshold of waiting time of SAV service. With this level of service, the potential to reduce the car dependency by influencing people in leaving their cars can be achieved by giving a better service of SAV.

**Table 6:** Total private vehicles for different scenarios

| Year | TOTAL VEHICLE | | | | | |
|---|---|---|---|---|---|---|
| | BASE new threshold | BASE | | 1% new threshold | 1% | |
| 2100 | 306,514 | 310,307 | 1.2% | 7,032 | 15,757 | 55.4% |

**Acknowledgement**

This study is funded by a collaboration program between the University of Indonesia and the Ministry of Transportation's HR in implementing the double degree program. In this collaboration, UI through the Department of Civil and Environmental Engineering, Faculty of Engineering, provides a postgraduate program in Civil Engineering for specialization in transportation. As for the foreign universities that will be addressed, the University of Leeds through the Institute for Transport Studies (ITS) which provides master's programs in various fields of transportation expertise.

## REFERENCES

[1] Departement for Transport. (2023). Transport and environment statistics: 2023. Retrieved from https://www.gov.uk/government/statistics/transport-and-environment-statistics-2023/transport-and-environment-statistics-2023

[2] Vega-Gonzalo, M., Gomez, J., Christidis, P., & Manuel Vassallo, J. (2024). The role of shared mobility in reducing perceived private car dependency. Transportation Research Part D: Transport and Environment, 126, 104023. https://doi.org/https://doi.org/10.1016/j.trd.2023.104023

[3] Kurisu, K., Tsuji, K., Nakatani, J., & Moriguchi, Y. (2023). What are important factors to determine CO2 reduction by car sharing? Simulation of car-sharing impact in cities with different car dependencies considering variable uncertainty. Resources, Conservation and Recycling, 193, 106967. https://doi.org/https://doi.org/10.1016/j.resconrec.2023.106967

[4] Zhang, Y., & Zhang, Y. (2018). Examining the Relationship between Household Vehicle Ownership and Ridesharing Behaviors in the United States. Sustainability, 10(8), 2720. https://www.mdpi.com/2071-1050/10/8/2720

[5] Zhang, Z., Liu, W., & Zhang, F. (2023). On the joint network equilibrium of parking and travel choices under mixed traffic of shared and private autonomous vehicles. Transportation Research Part C: Emerging Technologies, 153, 104226. https://doi.org/https://doi.org/10.1016/j.trc.2023.104226

[6] Gurumurthy, K. M., & Kockelman, K. M. (2022). Dynamic ride-sharing impacts of greater trip demand and aggregation at stops in shared autonomous vehicle systems. Transportation research. Part A, Policy and practice, 160, 114-125. https://doi.org/10.1016/j.tra.2022.03.032

[7] Jiang, Z., Wang, S., Mondschein, A. S., & Noland, R. B. (2020). Spatial distributions of attitudes and preferences towards autonomous vehicles. Findings.

[8] Litman, T., & Laube, F. (2002). Automobile dependency and economic development. Victoria Transport Policy Institute, Canada.

[9] Clewlow, R. R., & Mishra, G. S. (2017). Disruptive transportation: The adoption, utilization, and impacts of ride-hailing in the United States.

[10] Hampshire, R. C., Simek, C., Fabusuyi, T., Di, X., & Chen, X. (2017). Measuring the impact of an unanticipated suspension of ride-sourcing in Austin, Texas. SSRN Electron. J, 10.

[11] Henderson, P. (2017). Some Uber and Lyft riders are giving up their own cars: Reuters/Ipsos poll. Reuters (May 25, 2017), https://www. reuters. com/article/us-autos-rideservices-poll/some-uber-and-lyft-riders-are-giving-up-their-own-cars-reuters-ipsos-poll-idUSKBN18L1DA.

[12] Kostorz, N., et al. (2021). "Usage and user characteristics—insights from Moia, Europe's largest ridepooling service." Sustainability 13(2): 958.

[13] Chng, S., Anowar, S., & Cheah, L. (2022). Understanding Shared Autonomous Vehicle Preferences: A Comparison between Shuttles, Buses, Ridesharing and Taxis. Sustainability, 14(20), 13656. https://www.mdpi.com/2071-1050/14/20/13656

[14] Narayanan, S., Chaniotakis, E., & Antoniou, C. (2020). Shared autonomous vehicle services: A comprehensive review. Transportation Research Part C: Emerging Technologies, 111, 255-293. https://doi.org/https://doi.org/10.1016/j.trc.2019.12.008

[15] Nieuwenhuijsen, J., de Almeida Correia, G. H., Milakis, D., Van Arem, B., & van Daalen, E. (2018). Towards a quantitative method to analyze the long-term innovation diffusion of automated vehicles technology using system dynamics. Transportation Research Part C: Emerging Technologies, 86, 300-327

[16] Shepherd, S. (2014). A review of system dynamics models applied in transportation. Transportmetrica B: Transport Dynamics, 2 (2), 83–105. In.

[17] Batley, R., Toner, J., & Knight, M. (2004). A mixed logit model of UK household demand for alternative-fuel vehicles. International journal of transport economics: Rivista internazionale di economia dei trasporti: XXXI, 1, 2004, 1000-1023.

[18] Safdar, M., Jamal, A., Al-Ahmadi, H. M., Rahman, M. T., & Almoshaogeh, M. (2022). Analysis of the Influential Factors towards Adoption of Car-Sharing: A Case Study of a Megacity in a Developing Country. Sustainability, 14(5), 2778. https://www.mdpi.com/2071-1050/14/5/2778

[19] Gruel, W., & Stanford, J. M. (2016). Assessing the Long-term Effects of Autonomous Vehicles: A Speculative Approach. Transportation Research Procedia, 13, 18-29. https://doi.org/https://doi.org/10.1016/j.trpro.2016.05.003

[20] Ma, J., Li, X., Zhou, F., & Hao, W. (2017). Designing optimal autonomous vehicle sharing and reservation systems: A linear programming approach. Transportation Research Part C: Emerging Technologies, 84, 124-141. https://doi.org/https://doi.org/10.1016/j.trc.2017.08.022

[21] Wallace, R. L. (2017). Mobility: The Socioeconomic Implications of Autonomous Vehicles. Science.

[22] Hekimoğlu, M., Barlas, Y., & Luna-Reyes, L. (2016). Sensitivity analysis for models with multiple behavior modes: a method based on behavior pattern measures. System dynamics review, 32(3-4), 332-362. https://doi.org/10.1002/sdr.1568