

The estimation of carbon emission on the result of road transportation reallocation

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Abstract. Carbon emission reduction becomes a concern in the development of road transportation. Government policy and direction perform a vital role in the current condition. This study aims to estimate the total carbon emission influenced by several conditions: vehicle volume, vehicle speed, public transportation involvement, and implementation of odd-even vehicle plate policy using system dynamics modeling. According to the result, it is shown that the involvement of public transportation and the effectiveness of odd-even plate implementation has been decreased sharply in 2030 to 2,79E+05 tons CO₂e from 7,00E+11 ton CO₂e. That condition is applied for the same assumption of 40% the effectiveness odd-even plate implementation, fuel economy ratio 16 km/l, total travel distance 214 km, and speed vehicle 70 km/h. Therefore, the Government's role in improving, providing, or adding public transportation frequency is highly recommended in future development.

1 Introduction

The greenhouse gas (GHG) effect plays a significant role in climate change. One of the concerns is that the increment of transportation gas emissions is becoming a global issue [1]. Carbon dioxide particularly being targeted to be substantial emission reduction in a metropolitan city such as Greater Jakarta. According to the Provincial Government of DKI Jakarta, GHG emission reduction is being forced to reach up to maximum 35 million tonnes of CO₂e in 2030, with current data presented that the transportation, commercial, and household are listed as second highest that contributed GHG emission up to 33.48% or equal to 19,269,210 ton CO₂e in 2018 after the electricity consumption on the point of 48,93% [2]. In addition to that condition, the Government offered several solutions in providing various public transportation such as Commuter line (KRL), Mass Rapid Transit (MRT), Light Rail Transit (LRT), Bus Rapid Transit (BRT), and other public transportations that have been implemented in order to occupy public mobility from one point to another point nearby Jakarta area. The objective of this study aims to estimate the total carbon emission emitted by public and private transportations in Jakarta using system dynamics modeling by considering their vehicle volume, public transportation ratio, odd-even policy effectiveness, and vehicle speed assumption. Therefore, it helps to determine

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the difference between each variable and their ratio to meet the maximum value GHG reduction in 2030.

Globally, road transportation implementation in developed and developing countries have similarity in term of road transportation type regardless of integrated technological implementation issues on public transportation and private car. They offered BRT, MRT, LRT, and KRL as their main public transportation. All those types of road transportation-related with its fuel, therefore its energy consumption reduction, have been linked to public transportation support variances to substitute private cars [3]. Besides, the increment of private car ownership is related to traffic conditions that caused the speed variation in a different hour [4]. In Jakarta, BRT is implemented after KRL that provides an articulated bus, single bus, and maxi bus to cover the Jakarta area's inner city with a special line. It differs with KRL that covers intercity between Jakarta – Bogor – Depok – Tangerang – Bekasi – Cikarang – Banten areas with a total length of 418.5 km. Compare to BRT and KRL, both MRT and LRT have less travel distance in kilometer. The first phase MRT is operated in 2019 about 16 kilometers from Lebak Bulus station to Bundaran Hotel Indonesia station [5], and LRT remains an in-progress project [6]. However, besides all the differences, BRT, KRL, MRT, and LRT are considered as massive progress from the Government to substitute and support GHG emission reduction and traffic congestion in the Jakarta area.

The number of vehicle volume increases up to 75% in Jakarta from 12 million to 21 million from 2016 to 2019 [7] reinforced the Government to be innovative to offer various public transportation. Although each of the solutions like BRT Jakarta encountered some difficulties in terms of several aspects [8], the Government fixed them in the upcoming year ahead and took an aggressive movement to operate the first MRT phase in 2019. The summary of public transportation available in DKI Jakarta is listed in table 1. The government's milestones are likely expanding the coverage of BRT, MRT, and KRL for future development, with the confirmation of the LRT project in the upcoming year 2021. Lastly, expand the coverage point for the implementation of the odd-even policy. Odd-even is implemented by the DKI Jakarta government starting in August 2016. Odd-even plate implementation aims to help reduce GHG emission [9] and alternate the vehicle usage inherent to the traffic reduction. However, other studies discovered that odd-even plate implementation ineffective in reducing GHG emissions due to shifting driving time behavior [10].

Table 1. Lists of public transportation availability in Jakarta area.

No	Types	No. of Unit Operation	Total routes/stations	Total customer	References
1.	BRT	870 units	55 routes	152 million annually	[11]
2.	MRT	N/A	13 stations	89,000 daily	[5]
3.	KRL	1,100 units	10 routes	979,853 daily	[12]

Therefore, to examine the total performance of public transportation response and odd-even implementation effectiveness towards the amount of total carbon dioxide emission produces, this study initiates to develop the model using system dynamics modeling with aims to address various dependent and independent variables in a system with value changes over a certain period [13].

2 Method

This study covers five major tolls in the Jakarta area, including Jagorawi, Jakarta-Cikampek, Jakarta-Tangerang, Camareng, and Lingkar Luar, a total distance of 214 kilometers. The vehicle volume is taken according to the total number of vehicle travel passing each gateway in 2019. This study has limitations in excluding the total registered vehicle in Jakarta and other types of roads; therefore, it is beneficial for further study improvement.

This study aims to identify the factor that caused the carbon emission problem on road transportation and uses system dynamic modelling (Vensim software 8.1.0 version) to perform the causal loop diagram (CLD), as shown in figure 1. It emphasizes the relationship factor such as fuel economy, public transportation ratio, odd-even policy effectiveness, and vehicle speed that subsequently influence the system, subsequently running and simulating the given equation in each variable. At the beginning of the process, dependent and independent variables are set up inherently to the factor that leads to road transportation [14].

All those variables will be executed in the simulation, where the result helps to find the estimation of total carbon emission. It will persuade the Government to track the current condition towards the target in 2030. Therefore, if the analysis has shown the result greater than the Government's expected target, the necessary improvement shall be taken, else the emission reduction target remains. Not only mentioning the achievement target of Government but also it aims to reduce GHG emission [15] in overall.

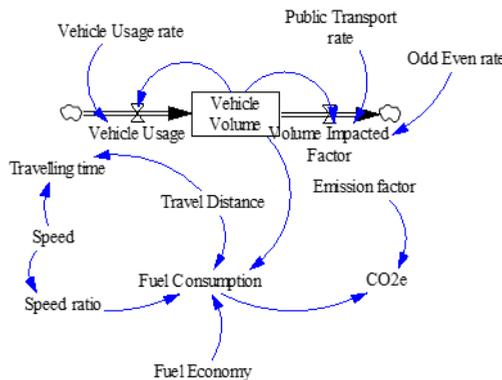


Fig. 1. Causal loop diagram.

The analysis of total emission in road transportation deploys by several variables that interact to the activity movement [16]. It produces carbon dioxide as their main emission [17], and further known as global particle reductions against GHG emission. The general formula for this study is shown below:

$$CO_{2a,b} = FC_{a,b} * EF * 10^{-6} \quad (1)$$

where,

CO_{2a,b} is the total amount of carbon emission in tones unit that influenced by the length of travel distance from origin 'a' to destination 'b,' fuel economy of the vehicle, vehicle volume that travels from origin 'a' to destination 'b,' speed ratio from origin 'a' to destination 'b,' and emission factor.

EF is the characteristic of pollutant release to the atmosphere per litter for each type of vehicle. The setting values are 3,172 and 3,180 [18]. and,

$$FC_{a,b} = (TD_{a,b}/FE) * Vev_{a,b} * SR \quad (2)$$

where,

FC is the fuel consumption in a litter for each vehicle that travels from origin 'a' to destination 'b.'

TD is the length of distance from origin 'a' to destination 'b' in kilometer. The setting values from 2 to 214 [19].

FE is the added value of the economy for each type of vehicle in kilometer per litter. The setting values between 3.5 to 16 [18].

SR is the comparison between speed constant to speed variation from origin 'a' to destination 'b' with assumption of speed constant 70 km/h [20] and speed variation at traffic condition 20 km/h [21]. and,

$$Vev_{a,b} = [UV_{a,b} - (PT_{a,b} + OE_{a,b})] \quad (3)$$

where,

Veva,b, is the annual cumulative of vehicle volume. The setting value is 8,20659E+08 [7].

UVa,b is the amount of vehicle usage rate. The setting value is 100%.

OEa,b is the amount of odd-even policy effectiveness rate that affected to the vehicle volume. The setting values are made by assumption effectiveness 0 and 40% [22].

PTa,b is the amount of public transportation rate that affected the vehicle volume. The setting values are made by assumption effectiveness 0 and 15% [23].

3 Results and discussion

Studies in the past shown that the development of public transportation [24], energy efficiency acceleration through fuel economical vehicle [25], and traffic condition [26] are part of carbon emission reduction application and odd-even effectiveness to reduce air pollution [27] are essential to GHG movement [28]. According to the result in figure 2, it is inline that the resulting output between the x-axis and y-axis has a positive impact on carbon emission reduction with several probabilities to estimate the total carbon emission with changing of public transport ratio odd-even ratio, fuel economy, and speed. It is shown that probability 5 – 8 created the best combination to perform carbon emission reduction between 2,79E+05 ton CO2e to 1,74E+09 ton CO2e compared with probability 1 – 4 that varies between 2,45E+11 ton CO2e to 4,35E+12 ton CO2e. These happened because several factors have a major influence on carbon emission reduction with further explanation through the following subsection.

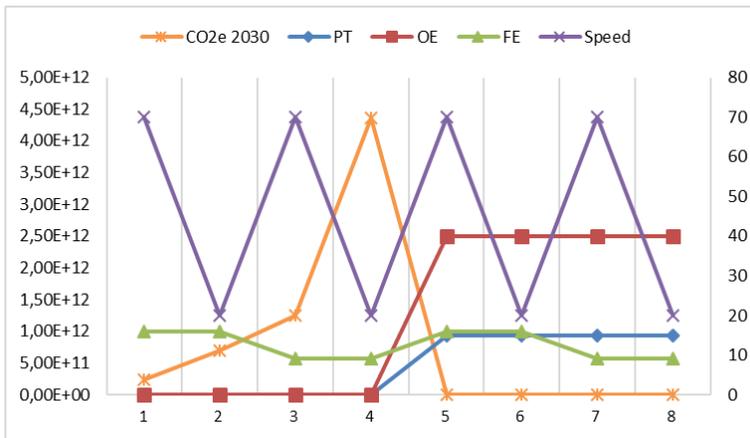


Fig. 2. Probability matrix of carbon emission estimation in 2030.

3.1 Public transportation

This study set the initial value of 0 to 15 percent of public transportation usage effectiveness by reducing private vehicle density volume, showing a major effect on carbon emission reduction. It is shown that higher involvement possibilities tend to reduce carbon emission gradually. Besides, it reduces carbon emissions, and indirectly it has a social impact on controlling car ownership [29] and considers public tendency to move from private vehicles to a mass transit system. Aside from the previous view, controlling public transportation and other vehicles with energy efficiency or eco-friendly environment technology could significantly reduce carbon emissions.

3.2 Odd-Even policy

Another solution provided is the implementation of an odd-even policy. This solution is applicable only in certain areas with a higher carbon emission concentration, reducing an individual vehicle travel movement. It is relevant to Metropolitan cities such as Jakarta, which has a high-density level in industries, offices, and residential. Therefore, the tendency for human mobilization, especially in the transportation sector, will likely higher than any other area. This study set the effectiveness rate between 0 to 40 percent, showing the same result from the previous solution; the higher successful implementation rate will result in the lowest carbon emission. However, this is inversely proportional to another study that mentioned that an odd-even policy is applicable for the short term period only [30] because it motivates the drivers to look for alternative routes to avoid its implementation. In addition, it is also shifting the habit of driving at certain hours.

3.3 Fuel economy

Fuel economy is part of technological advances. Europe has set the emission threshold for new and old vehicle generation using the Euro emission standard. Therefore, many vehicles have implemented eco-friendly environmental engine technology [31]. As a capital city of Indonesia, Jakarta adopted carbon emission test for diesel and gasoline fuel type of vehicle starting 2019 [32]. It does not only help to reduce the GHG emission but also controlling the effect of fuel consumption.

3.4 Speed

As one of high populated vehicle ownership, Jakarta has affected traffic congestion in a certain area and during peak hours. As the traffic became congested, speed variation occurs. The lower the vehicle's speed, the longer it stays in an area and increases fuel consumption. Thus, it will affect a higher ratio of carbon emission. This study set the value of normal conditions at 70 kilometers per hour [20] and 20 kilometers per hour [21] at traffic conditions to calculate the impact on the total amount of carbon emission reduction.

4 Conclusion

According to the solution provided in this study, the Government is encouraged to expand the frequency and improve the diversity of public transportation; hence it possible to enforce private vehicle usage and to reduce the traffic congestion. In addition, the commitment between the Government and the industrial automotive sector to support eco-friendly environment vehicles is highly recommended to improve engine efficiency. Therefore, energy-saving, fuel economy, and carbon emission tests are being subjective control items for further improvement.

Acknowledgements

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