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The Global Warming Impact Evaluation of Public Transportation During the COVID-19 Pandemic Using the Life Cycle Assessment Approach

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ABSTRACT

The transportation industry plays an integral role in the daily lives of Indonesians. However, it also contributes to environmental degradation, particularly in terms of air quality, which impacts public health. This research applies the Life Cycle Assessment (LCA) method, a sustainability matrix, to gauge the environmental impact of Jakarta's public transportation system. Our study aims to identify car emissions and understand the environmental consequences they pose. The research was scoped to examine both the raw materials and energy input and the resultant emissions. Specifically, we analyzed the electricity consumption of Jakarta's MRT, Bus Trans Jakarta, and online taxi services. We utilized the LCA methodology and the SimaPro 9.1 software for assessment. Prior research data were incorporated to enhance the accuracy of our LCA model. A notable observation is the decline in public transportation usership since the onset of the COVID-19 pandemic. Current health protocols allow only half the usual passenger capacity, compounded by a sluggish economy. Our findings reveal that the Mass Rapid Transit (MRT)'s CO_2 emissions, at 0.019 kg/passenger/kilometer, are significantly lower than that of the BRT at 0.036 kg/passenger/kilometer. One recommendation to further reduce emissions is to transition buses from diesel to compressed natural gas (CNG) fuel. However, public adoption of these changes will largely hinge on individual preferences.

1. Introduction

Transportation is an essential field of activity in the life of the Indonesian people [1,2]. The function of transportation is to move people and goods from one place to another place to place, using a particular system for a specific purpose. As the development of transportation increases, so does the problem. Owning a private vehicle causes congestion on the highway because it has exceeded its capacity [3], especially during rush hours, such as going back and forth from the office. Therefore, public transportation is easy for residents of a metropolitan city like Jakarta. This is also in line with the increase in customers for other modes of transportation such as the Jakarta Mass Rapid

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Transit (MRT), Jakarta Light Rail Transit (LRT), and the Commuter line Electric Train (KRL) which connects the capital city of Jakarta as an economic center with other satellite cities. Following the principles of Good Governance, namely effectiveness and efficiency in serving the community. The Government should create public facilities, especially public transportation facilities, that make it easier for its people to carry out activities in a country, to measure whether a country is seen as a developing country in the future.

The primary objective of this study was to assess the environmental impact of public transportation modes in Jakarta, particularly in terms of CO_2 emissions. Given the challenges posed by the COVID-19 pandemic, the study also sought to understand current transportation behaviors and provide recommendations to transition towards cleaner, more sustainable public transport options. The direction of transportation development triggered by traffic density due to population growth and the dynamics of big cities tends to move towards the MRT system. The destructive impact of pollutant gas on the environment is in the form of polluted air quality, which can interfere with public health. Efforts to overcome and control the setting need to be carried out to address environmental issues in DKI Jakarta, which are increasingly worrying [4,5]. One of the efforts that have been made is to estimate the reduction in the potential generation of greenhouse gas impacts using the appropriate environmental impact determination Life Cycle Assessment (LCA) method. It is hoped that implementing these efforts can reduce the potential for vehicle exhaust emissions that are not environmentally friendly to the ambient air quality in Jakarta. One of these efforts is the LCA analysis of the number of passengers in each public transportation in Jakarta.

LCA is a methodology that can be used as a sustainability matrix [6]. This LCA method can evaluate raw materials and energy consumption so that data on emission expenditures and environmental impacts of a process can be obtained. So, this study aims to estimate the environmental impact of public transportation in Jakarta. The limitation of this study is the time of research conducted during large-scale social restrictions in Jakarta so that it will produce different values under normal conditions. In addition, the area is also limited to protocol roads, namely Jalan Jenderal Sudirman, Senayan's, with public transportation services such as MRT, Trans Jakarta Bus, and online taxis.

2. Method

The research focuses on the environmental impact of vehicle emissions. The scope was deliberately chosen to emphasize both the causes (input) and consequences (output) of these emissions. For the input, the study considers electricity consumption from Bus Trans Jakarta, online taxis, and MRT. For the output, the focus is on the emissions produced, their environmental consequences, and passenger count.

A primary concern of this study is the Global Warming Potential (GWP). GWP pertains to the consequences of increasing earth's surface temperature, mainly due to escalating greenhouse gas (GHG) emissions in the atmosphere. Given that the transportation sector is a significant GHG contributor, this research zeroes in on its GWP impact. To evaluate these effects, the SimaPro 9.1 software, equipped with the Ecoinvent v.3 databases and the 2018 EPD method, was utilized. The Life Cycle Assessment (LCA) methodology was employed to guide the research. LCA typically unfolds in four stages:

1. Defining goals and scope.
2. Compiling a life cycle inventory.
3. Assessing the life cycle's impact.
4. Presenting the findings.

To ensure the accuracy of our results, we also incorporated data from previous studies into our LCA model [7–10].

Identifying and framing the problem marks the beginning of the research process. At this early stage, the research site and sample strategy were chosen. Additionally, literature reviews were conducted to support this study. Early calculations of the CO_2 emissions produced by the MRT Jakarta, Bus Transjakarta, online motorbike taxis, and online taxis were based on literature reviews. Jalan Jenderal Sudirman, Senayan's served as the location for all survey segments. The decision was made based on the Senayan area's status as a TOD area, where a TOD area employs the idea of integrated spatial management and transportation [11]. Various types of transportation, including the Jakarta MRT, city buses with multiple routes, and Trans Jakarta, further demonstrate this.

As illustrated in Figure 1, the transportation routes in Jakarta for different modes are delineated as follows: The MRT Jakarta runs between Stasiun Senayan and Stasiun Istora Mandiri. The Bus Transjakarta operates from Halte Bundaran Senayan to Halte Polda Metro. Online Motorcycle Taxis ply the route from Halte Bundaran Senayan II to Halte Gbk Gate 7. Similarly, Online Taxis also cover the stretch between Halte Bundaran Senayan II and Halte Gbk Gate 7. These transportation networks provide essential connectivity across the city.

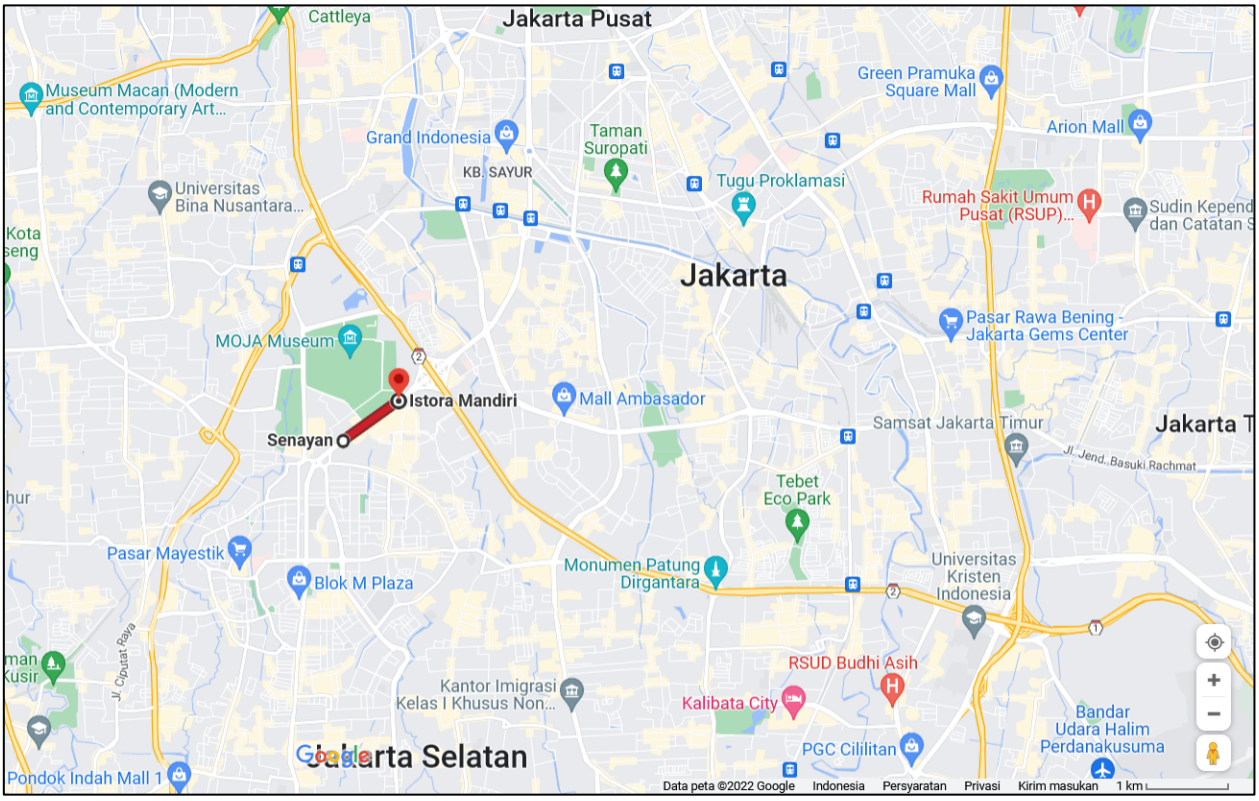

Fig. 1. Scope Area in Jakarta (Source from: Google Map, 2024)

The average number of occupancy surveys in a segment is based on the Ministry of Transportation's Directorate General of Land Transportation's Guidelines for Data Collection on Urban Public Transport [12]. Therefore, a dynamic survey was the technique utilized. This poll was conducted by counting the passengers in each vehicle in a specific section.

In our research, we conducted a dynamic survey thrice a week to capture various workweek conditions. Mondays were selected to represent the busy start of the week. Thursdays provided insights into a more moderate, yet still active, weekday. Saturdays helped us understand weekend work trends. As for the timings, we focused on the morning rush hour from 7 am to 9 am WIB and

the evening rush hour from 5 pm to 7 pm WIB. We also gathered data during off-peak hours, specifically from 2 pm to 4 pm WIB [13].

3. Results and Discussion

3.1 Occupancy

The number of people using public transportation has dropped by a sizeable amount since the beginning of the COVID-19 pandemic. In addition to the stagnant economy, the requirements of the COVID-19 health protocol dictate that only fifty percent of passengers be allowed to be transported by public transit. During the period of adjustment to the new routines brought on by the COVID-19 pandemic, the purpose of this study is to investigate the utilization of public transportation and the elements that influence such utilization [14]. The COVID-19 pandemic has significantly impacted several industries, including public transportation. As a direct result of this impact, ridership on public transportation has dropped by an amount ranging from 50–100% over this period [15]. Even if the pandemic is under control, it is anticipated that some passengers will refrain from using public transportation.

According to our research findings, the average occupancy of an MRT Jakarta train is 63 passengers, but the average occupancy of a Trans Jakarta bus is 21 (Table 1) [13]. In the meantime, the regulatory framework for online automobiles can be found at the DKI Jakarta Provincial Transportation Agency. Regarding the particulars of the passenger configuration, two-line taxis are only permitted to transport a maximum of two people, with the composition of one driver in front of the vehicle and two passengers in the back. Regarding automobiles with three rows, the maximum number of passengers allowed is three, including one driver in the front seat, one in the middle seat, and one in the back seat.

Table 1
Length and Occupay of Transportation Mode

Transportation Mode	Segment	Length (km)[1]	Occupancy (person)[1]
Mrt Jakarta	Stasiun Senayan – Stasiun Istora Mandiri	0.841	63
Bus Transjakarta	Halte Bundaran Senayan – Halte Polda Metro	1.272	21
Online Motorcycle Taxis	Halte Bundaran Senayan II – Halte Gbk Gate 7	1.097	2
Online Taxis	Halte Bundaran Senayan II – Halte Gbk Gate 7	1.097	4

[1]: [13]

3.2 LCA Result

The analysis using the Life Cycle Assessment (LCA) was conducted through the SimaPro version 9.1 software. This analysis leveraged data from the Ecoinvent v.3 database and employed the 2018 EPD method. The primary environmental impact explored in this research was the Global Warming Potential. When evaluating the transportation modes based on their CO_2 emissions using the LCA method in SimaPro, Bus Trans Jakarta emerged as the highest CO_2 emitter, as illustrated in Figure 2. The outcomes from SimaPro's analyses consider emissions in terms of CO_2-equivalents, encompassing various greenhouse gases beyond just CO_2. A limitation in using SimaPro is that its database, especially when calculating emissions for online Transjakarta and taxis, relies on generalized global emission factors rather than specific local data. Furthermore, our findings are

consistent with previous research conducted, which compared the CO_2 emissions of Bus Rapid Transit (BRT) and MRT in New Delhi, India [16,17].

The observed decline in passenger numbers aligns with reported decreases following the implementation of the Micro Community Activity Restrictions (PPKM) Level 4. Prior to the COVID-19 pandemic, Transjakarta could serve up to 1 million passengers daily [18]. However, during the Micro PPKM period from May to June 2021, passenger numbers dropped by 50%, with only 500,000 daily passengers [18]. The COVID-19 pandemic has made emphasized that his party is currently not focusing on the number of customers but rather on a safe and comfortable service during the COVID-19 pandemic.

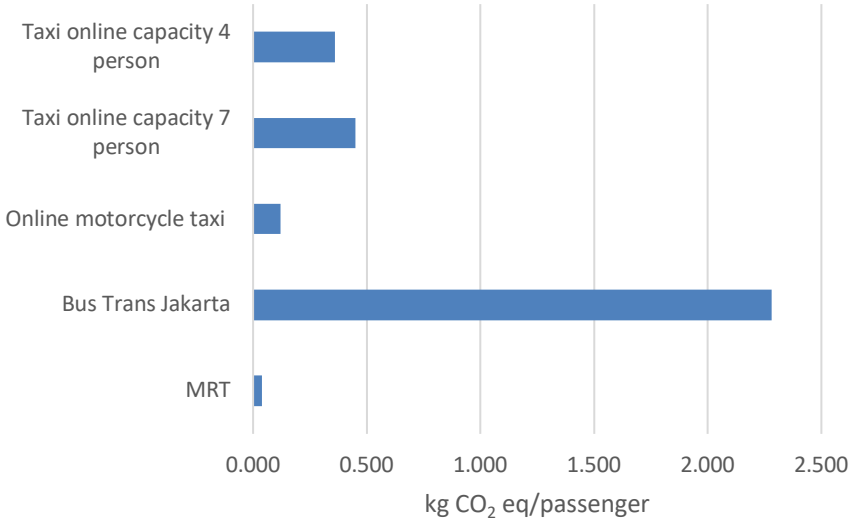

Fig. 2. Global Warming Potential for Public Transportation in Jakarta

Efforts to reduce CO_2 in the Trans Jakarta and taxis' online mode of transportation can also be made by replacing buses fueled by diesel fuel with Compressed Natural Gas (CNG). According to Satiennam *et al.,* [19], CNG fuel emits less air pollution than diesel fuel. Also [20], using CNG fuel in the bus transportation mode contributes to achieving the goals of sustainable development and clean production in the urban transportation sector.

It was necessary to reduce the potential for global warming across all modes of transportation. The Sustainable Development Goal (SDG) number 13 was entitled "Addressing Climate Change," and one approach to support this goal was to make efforts to limit the potential for global warming. MRT Jakarta's efforts aim to get MRT Jakarta Phase II operational as soon as possible. Research conducted by Khwan [21] indicates that running the Malaysia MRT with two lines (lines) will result in a reduction of 242,200 tCO_2-eq per year due to changes in the activity level of motorized vehicles. One of the things that may be done to cut down on the amount of CO_2 that is produced by the Bus Trans Jakarta form of transportation is to increase the amount of time that passes between buses, often known as the "headway," during off-peak hours on workdays (weekdays).

In the quest for a sustainable public transportation system, several challenges and policy implications emerge [22]. As we navigate the aftermath of the pandemic, a dual focus is paramount ensuring a resurgence in public transportation usage while upholding rigorous safety protocols. The decreased use of public transportation has multiple ramifications - from increased private car usage, leading to traffic congestion and higher emissions, to the economic strain on the public transport sector due to decreased revenues. Given these challenges, policy initiatives could involve increased public awareness campaigns highlighting the stringent disinfection and safety measures

implemented in public transport systems. Such campaigns can restore commuter confidence, emphasizing that public transport is both safe and environmentally beneficial.

When it comes to emissions, the variance in output between modes like MRT and BRT points to a pressing need for a more uniform and greener approach across the board. Transitioning from diesel to cleaner fuels like Compressed Natural Gas (CNG) is a promising measure. This isn't just a logistical challenge but also a policy one. Supportive regulations could incentivize the adoption of CNG, perhaps through tax breaks or subsidies for transportation companies making the switch. Simultaneously, infrastructure developments, like setting up more CNG refueling stations, will be crucial. Lastly, stricter emission standards can be enforced for public transportation vehicles. By establishing clear benchmarks and offering a grace period for compliance, the government can ensure a gradual definitive move towards reduced emissions. Additionally, in research and development for even cleaner energy alternatives for public transport and creating avenues for private-public partnerships in this domain could further bolster the sustainability of the sector. Through a combination of public awareness, infrastructure development, and supportive regulations, a greener and more efficient urban landscape can be realized [23,24,25].

Conclusion

Since the COVID-19 pandemic started, the number of people using public transportation has dropped significantly. Due to the COVID-19 health protocol, only 50 percent of passengers are allowed to use public transportation. In addition to the slow economy, this is happening. The MRT gives off 0.019 kg of pollution per passenger per kilometer, while the BRT gives off 0.036 kg per kilometer. This means that the MRT has lower CO_2 emissions than the BRT. In addition, compressed natural gas (CNG) can be used instead of diesel fuel to power buses. This is another step that can be taken to reduce CO_2 emissions from TransJakarta and online taxi services. People's willingness and ability to adapt this way vary greatly depending on their wants. This is true for how willing the population is to change and how well it can change.

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