ANALYSIS OF $PM_{2.5}$ EMISSIONS REDUCTION WITH THE SHIFT FROM PRIVATE LOCAL TRANSPORTATION TO PEDESTRIAN AND BIKE SHARING IN CENTRAL JAKARTA CITY: M.H. THAMRIN AREA

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Abstract

Central Jakarta as one of the administrative cities in the DKI Jakarta Province has the highest population density of 20,360 per km^2. The number of motorized vehicles in Jakarta is recorded at 23,025,101 units. This figure can be a crucial issue considering that the transportation sector is the largest contributor to air emissions with $PM_{2.5}$ as the main pollutant. Jakarta's air quality is monitored as unhealthy (for sensitive groups) with $PM_{2.5}$ concentrations reaching two and a half times the safe limit according to WHO standards. This study aims to determine the percentage of interest of private vehicle users in the M.H Thamrin Area, Central Jakarta switch to pedestrians or bike. The result were then be used to calculate the emissions that occur reduction followed by the changes. The survey's result were analyzed using the SPSS application to determine significant factors related to the interest of private vehicle users to switch. Emission calculations are carried out based on the Regulation of the Minister of Environment No. 12 in 2010. The result of this study indicate that 91.5% of private vehicle users from 12,830 residents of the M.H. Thamrin area are willing to switch to pedestrians consisting of 65.1% motorcycle users and 34.9% car users. As many as 94.4% of private vehicle users are willing to switch to bike sharing consisting of 63.2% motorcycle users and 36.8% car users. Several factors that significantly influence people's interest in switching are the availability of wide pedestrian paths (> 2 m) and the low cost of using bike sharing (Rp3,000 - Rp7,000 per trip). With the effort to move private motor vehicles to pedestrians, $PM_{2.5}$ emissions in the M.H. Thamrin Area, Central Jakarta can be reduced by 93.04%, which is equivalent to 0.656 tons of $PM_{2.5}$/year. On the other hand the shifting of private motor vehicles to bike sharing, will contribute to 92.87% of $PM_{2.5}$ reduction, or 0.778 tons of $PM_{2.5}$/year.

Keywords : Bike sharing, emission, pedestrian, $PM_{2.5}$, private vehicles

1. INTRODUCTION

Thamrin is an economic, political and social center so that it can attract more residents to carry out activities in the city. M.H. Thamrin Street stretches 2.5 km from the Bank Indonesia Fountain Roundabout, Gambir, Central Jakarta to Dukuh Atas, Tanah Abang, Central Jakarta. In this area there are also intermodal transfer facilities such as Light Rapid Transit (LRT) and Mass Rapid Transit (MRT). The Jakarta MRT facility with the Bundaran HI MRT station in the area is a factor in attracting pedestrians and bike sharing in the surrounding area (Aqli et al, 2019).

From the overall density of population activity, it has a serious impact on the environmental air. This decrease in air quality is caused by several factors, one of which is the emission of private motorized vehicles users (Martinez & Masron, 2020). The number of motor vehicles (motorcycles, passenger cars, cargo cars, special vehicles, and buses) in Jakarta is recorded at 23,025,101 units. In urban areas, traffic is often the main source of $PM_{2.5}$ pollution and can account for 37% of observed pollution levels (Zalakeviciute et al., 2018). Particulate matter is a mixture of solids and liquids with different sizes and characteristics, such as dust, dirt, soot, smoke, and water droplets emitted into the air. Humans can only

inhale particulates with a diameter of less than 10 μm (PM_{10})and those with a diameter of less than or equal to 2.5 μm ($PM_{2.5}$), and those with an aerodynamic diameter of ≤ 1 μm (PM_1) (Solihah et al, 2018).

Emission factor (FE) is a coefficient that shows the amount of emissions produced per unit of activity (the unit of activity can be the volume produced or the volume consumed). In calculating the amount of emissions, the study employed the TIER 2 method where the emission factor refers to the national emission factor. Based on the Regulation of the Minister of Environment No. 12 of 2012, to calculate the level of emissions from transportation activities, the TIER 2 method is used according to equation 1 by using an emission factor based on vehicle kilometers (Vehicle Kilometer Traveled/VKT or average vehicle travel length per year) for on-road transportation. The formula approach used is as follows.

$$E_a = \sum_{b=1,c=1}^{n,m}(VKT_{b,c} \times FE_{a,b,c} \times 10^{-6}) \qquad (1)$$

According to the US Environmental Protection Agency (EPA), transportation is responsible for less than 10% of $PM_{2.5}$ emissions (Li and Managi, 2021). Based on data from ISPU air quality monitoring where the stations at proximity to the Bundaran HI, the $PM_{2.5}$ concentration is 64 μg/m³ so the air quality is categorized as moderate (DLH Provinsi Jakarta, 2024). The reduction effort of this $PM_{2.5}$ problem is encouragement of pedestrian program (Greenpeace, 2022). By expanding the network and increasing the accessibility of public transportation services, such as pedestrian infrastructure, people will prefer to use environmentally friendly public transportation.

However, there has been no specific research that identifies the percentage reduction in $PM_{2.5}$ emission levels as a result of shifting from private vehicle to pedestrians and bike sharing through infrastructure improvement. This research was conducted to obtain data as a reference for the community and government regarding the reduction in $PM_{2.5}$ emissions that would occur if people were willing to switch to walking and bike sharing. In addition, it is also to identify factors that can increase public interest in switching from private vehicles to pedestrian and bike sharing.

As a hypothesis, the percentage of private vehicle users' interest in switching to walking biking is correlated to infrastructure improvement. With infrastructure interventions, such as new walking infrastructure, it has been effective in encouraging a shift from car use to more sustainable transportation modes, encouraging more people to include active travel in their trips (Song et al., 2017).

According to Gong and Zhou (2018) in their study in Shenyang, a large city in Northeast China, by choosing to walk rather than drive, individuals can directly reduce the amount of $PM_{2.5}$ released into the atmosphere. For bike sharing, the percentage of the public who is interested in moving to bike sharing is also high. Bike sharing provides ease in accessing bikes in public spaces so that with the ease it makes many people interested in moving from private vehicles to bike sharing (Ahilllen et al., 2016). In big cities with a policy of transitioning to the use of personal mode of transportation to the bike sharing system can reduce $PM_{2.5}$ as many as 3.832 μg/m^3 (Cao et al., 2023). This research focuses on calculating $PM_{2.5}$ emission reductions in the area along M.H Thamrin, Central Jakarta City by collecting questionnaires from people who are active in the area on working days and hours and are interested in moving to pedestrians and bike sharing. The research was carried out for two months, namely February-March 2024.

2. RESEARCH DESCRIPTION

2.1. Data Collection

Research was conducted to analyze the percentage of motorized vehicle users in Central Jakarta City who are interested in switching from private vehicles to walking via pedestrian infrastructure and bike sharing. The data collected includes primary and secondary data. Primary data obtained through surveys by distributing questionnaires to 354 respondents using the random sampling method in busy spots in the M.H Thamrin area like that seen in **Figure 1** below.

Figure 1. M.H Thamrin Area

Secondary data required in this research is related to the number of vehicles in the area Central Jakarta City obtained from the Department of environmental of DKI Jakarta Province (DLH DKI Jakarta), vehicle emission factors based on Minister of Environment Regulation No. 12 of 2010, the amount of $PM_{2.5}$ emissions in Central Jakarta City was obtained from DLH DKI Jakarta Province.

2.2. Emission Change Scenario $PM_{2.5}$

In this $PM_{2.5}$ emission change scenario, it is used to determine the magnitude of $PM_{2.5}$ emissions in existing conditions and in conditions after the transition of private vehicle users to pedestrians, where if some vehicle users continue to use private vehicles, some switch to pedestrians. The same scenario is also used to determine the magnitude of $PM_{2.5}$ emissions in existing conditions and in conditions after the transition of private vehicle users to bike sharing, where if some vehicle users continue to use private vehicles, some switch to bike sharing. In this mode of transportation transition, it is expected that there will be a decrease in $PM_{2.5}$ emissions. The scenario description can be seen in F**igure 2** and **Figure 3** below.

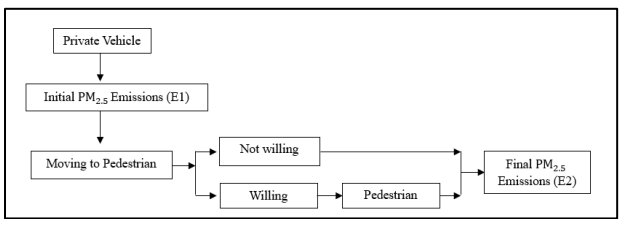

Figure 2. Emission Change Scenario of Pedestrian

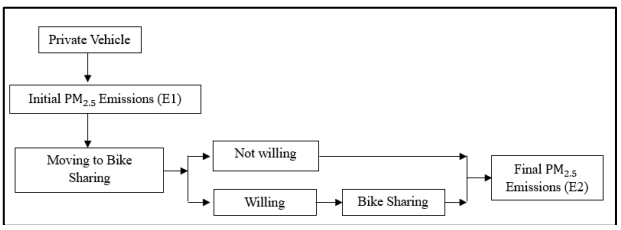

Figure 3. Emission Change

2.3. Research Work Steps

The work steps in the study consist of two aspects. First, the technical aspects studied include technical matters related to the number of vehicle users who have the potential to shift their mode of transportation from private vehicles to pedestrians and from private vehicles to bike sharing, as well as the calculation of potential changes in $PM_{2.5}$ emissions that occur due to the shift in mode of transportation. Second, the institutional aspects studied are related to new policies that can be used by the government/related agencies to support emission reductions from the transportation sector. In the initial stage, a preliminary survey was conducted and a questionnaire was created as a survey method by interviewing 354 respondents with an error rate of 5% when calculated using the Isaac and Michael formula related to the questions in the questionnaire, then the questionnaire maker will collect and record the answers. The sample used came from the population of people who are active in the Thamrin Area, which is 12,813 workers in all buildings in the Thamrin Area. The data collection from respondents was carried out online in the form of a google form as a whole, although the search for respondents was carried out directly in the M.H Thamrin Area, Central Jakarta.

All questionnaires that have been completed and returned are then processed. The purpose of this stage is to simplify and tabulate the data. At this stage, data tabulation is carried out with the respondents' answers calculated with the help of the SPSS program. If 354 questionnaires have been filled out, then the total number of cars (X) and the total number of motorbikes (Y) are analyzed. After that, the percentage of vehicle user interest is analyzed based on the answers of respondents who choose "Yes" to change their mode of transportation. Then, from the respondents who

choose to change their mode of transportation, the number of cars (X1) and motorbikes (Y1) will be calculated. This number will describe the percentage (%) of car users and the percentage (%) of motorbike users who are willing to switch to pedestrian and bike sharing. For data analysis related to potential changes in $PM_{2.5}$ emissions, it is done by calculating $PM_{2.5}$ emissions in one year (tons of $PM_{2.5}$/year) from cars and motorbikes in Central Jakarta City before the transfer of transportation modes, which is symbolized by E1 (Initial Emissions). Then after knowing each percentage of vehicle users who switch, both from cars and motorbikes which is symbolized by n%, the amount of emission changes that occur can be determined through the following equation.

$$PE = n\% \times E1 \quad (2)$$

In the data tabulation stage to interpret the respondent's answer data to suit the research objectives, the factor analysis stage is carried out. The factor analysis method that can be used is the KMO and Barlett's Test in SPSS because the factors to be analyzed have a fairly large number. If the value of the KMO and Barlett's test with the total square of the partial correlation between all pairs is smaller when compared to the sum of the squares of the correlation coefficient, then in this case the KMO value will approach 1. The KMO value is considered to be met if it is greater than 0.5. Between variables can be mutually independent if the correlation matrix between variables forms an identity matrix. If the KMO value in the KMO and Barlett's Test table is more than 0.5, it will fail to reject H0. In this case, it can be interpreted that the KMO assumption of the data has been met. In the Barlett test, it is known that the p-value is less than α (0.005), then it is stated to reject H0. Furthermore, an examination of the diagonal value of the anti-image matrix in the correlation matrix is carried out. To determine significant factors, the data were analyzed using the Binary logit model. The data were tested to obtain the dominant factors that influence people in changing transportation modes.

In this case, the factors that influence people in changing transportation modes are the independent variables (X), while the interest in using pedestrian infrastructure is the dependent variable (Y). The X variables in this study are traffic congestion (X1), age (X2), access to public transportation networks (X3), fuel costs (X4), quality of pedestrian infrastructure (X5), health (X6), more practical (X7), more affordable (X8), distance between places (X9), gender (X10) and duration of time to move (X11), and temperature or weather (X12). While the Y variables in this study are pedestrians (Y1), do not want to move (Y2).

In calculating the bike sharing aspect data, the factors that influence people in changing transportation modes are the independent variables (X), while the interest in using bike sharing is the dependent variable (Y). The X variables in this study are traffic jams (X1), the cost of parking at the destination (X2), the limited parking lot (X3), the cost of fuel (X4), the chance of stress while driving (X5), is more practical (X6), more affordable (X7), more comfortable for a trip (X8), the presence of centralized parking (X9), the odd even plate (X10). As for the variable, Y in this study is the bike sharing (Y1), not wanting to change (Y2). The analysis will be carried out separately for each variable Y or every transportation chosen.

3. RESULT

From the survey that has been conducted, data was obtained on the type of transportation used by respondents to move between buildings. Respondents in this study were private motor vehicle users who used cars or motorbikes as daily during activities and rest time in the M.H Thamrin area. A total of 223 respondents or 63% of respondents surveyed used motorbikes as a means of transportation used daily, and 131 respondents or 37% of respondents used cars as their daily private vehicles. This study examines how private vehicle users are interested in pedestrian and bike sharing, and examines whether private vehicle user respondents are willing to use pedestrian and bike sharing for short-distance mobility in the future.

3.1. Pedestrian Aspect

The percentage of private motorcycle drivers is 94.62% and private car drivers who are

interested in moving to the pedestrian is 86.23%. The number of private vehicles in Central Jakarta, both cars and motorcycles, reached 1,271,535 vehicles (908,070 motorcycles and 363,465 cars). From the calculation results, it was found that motorcycle emissions were 0.017 tons of $PM_{2.5}$/year and car emissions were 0.004 tons of $PM_{2.5}$/year to move between buildings within a relatively close distance from building A and building B on weekdays and during working hours. It is assumed that the duration of travel or mobilization between buildings is 1 hour during break time. The VKT value in the calculation is obtained from the distance traveled by motorcycle users which can be known from the annual fuel costs used. The total VKT value is obtained from the average of each motorcycle VKT used by respondents in one year and multiplied by its fuel economy. Furthermore, the emission factor is known from the Regulation of the Minister of Environment Number 12 of 2010 that the $PM_{2.5}$ emission factor is assumed to be 80% of the TSP emission factor.

The results of this study indicate that 94.62% of motorcycle users and 86.23% of car users are willing to switch to using pedestrians. This shows that efforts to move private motor vehicles from 354 respondents to pedestrians can reduce $PM_{2.5}$ emissions by 0.019 tons of $PM_{2.5}$/year or equal to 0.00055 g $PM_{2.5}$/second. The percentage of total $PM_{2.5}$ emission reduction is 90.48%. After obtaining the $PM_{2.5}$ emission reduction value for 354 respondents, the total emission reduction value of the entire working population in the M.H. Thamrin area can be calculated. The percentage of motorcycles is 63% and cars is 37% of all private vehicles in the M.H. Thamrin area. The total number of M.H. Thamrin workers in 2024 is 12,830 people with 8,083 motorcycles and 4,747 cars. Efforts to move private motorized vehicles from the M.H. Thamrin area to pedestrian areas can reduce $PM_{2.5}$ emissions by 0.656 tons of $PM_{2.5}$/year or equal to 0.019 g $PM_{2.5}$/second. The percentage of total $PM_{2.5}$ emission reduction is 93.04%.

The level of $PM_{2.5}$ emissions can be significantly reduced by reducing emission sources including minimizing the amount of emissions released from motor vehicles. This form of minimization effort can be in the form of a pedestrian program in Central Jakarta. There are many specific factors that influence people to switch to pedestrians. However, in this case it is necessary to know the most significant factors that can support people to switch from private vehicles to pedestrians. In this study, the results were obtained from 354 respondents, 324 respondents were interested in switching to using pedestrian modes. This is based on various reasons including: Traffic congestion,Distance Between Places/Buildings, Access to Public Transportation Networks, Fuel Costs, Pedestrian Infrastructure Quality, Health, More Practical, More Affordable, Age, Gender, Duration of Time to Move, and Temperature or Weather. These reasons were analyzed using the SPSS in the form of factor analysis. The results of data processing show that there are two new most significant reason components in influencing respondents' interests, namely Comfort and Efficiency. The variable Distance Between Places/Buildings can be said to have a significant influence on people's interest in choosing pedestrians.

By expanding the network and improving the accessibility of public transportation services, such as pedestrian infrastructure, people will prefer to use environmentally friendly public transportation. However, it is also necessary to consider and know what factors can attract more of private vehicle users to switch to pedestrians as shown ini **Figure 4**.

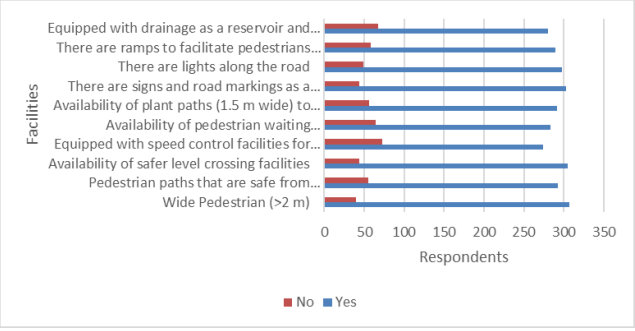

Figure 4. Factors Can Increase the Attractiveness of Private Vehicle Users to Switch to Pedestrians

Wide pedestrians (> 2 m), the availability of safer level crossing facilities, and Pedestrian paths that are safe from motorcycle interference (ex: installation of bolar).

3.2. Bike Sharing Aspect

The emission reduction of $PM_{2.5}$ occurs after as many as 94.6% of motorcycle users and 93.9% of private car users switch to using bike sharing. The transfer of private vehicles to bike sharing can reduce $PM_{2.5}$ emissions by 0.0215 tonnes of $PM_{2.5}$ /year in workday and working hours. In this study, a shift in $PM_{2.5}$ emissions occurred in the form of reduction (reduction). The transfer of private vehicles to bike sharing resulted in initial emissions produced from respondent private vehicles by 0.0231 tons of $PM_{2.5}$ /year to 0.00165 $PM_{2.5}$ /year on work and working hours. In the M.H. Area. Thamrin reduced emissions for $PM_{2.5}$ occurred after the transition using bike sharing by 0.775 tonnes of $PM_{2.5}$ /year in working days and working hours. The relocation of private vehicles at the M.H. Thamrin Area to the bike sharing immediately resulted in the starting emissions resulting from private vehicles by 0.8372 tonnes of $PM_{2.5}$ /year to 0.0597 $PM_{2.5}$ /year in working day and working hours. From this calculation, it is known that the percentage decrease in emissions from the transfer of private vehicles to bike sharing which is 92.87%.

Ownership of private vehicles is something that has already occurred in society. The public must have certain reasons in choosing the type of vehicle used in its mobilization activities. These reasons such as traffic jams, parking fees are on the destination, parking limitations, fuel costs, stress when driving, more practical, more affordable, more comfortable for travel, there is centralized parking, and odd even plate. The result of this analysis shows that there are two new factors that form in the reason respondents choose to use bike sharing, namely efficiency and flexibility. It is known that the limited parking lot is an influential factor for the community to switch bikes. The existence of limited parking space can be said to have an effect on people's interest in choosing bikes sharing bikes but not significant. According to Sugiyanto et al. (2021), people's interest in choosing transportation is influenced by very basic things such as safety, security factors, reliability, comfort, cleanliness, travel time, costs and accessibility. Here are the answers of the respondents in choosing several facilities that can be offered and the percentage that choose to agree and disagree with the existence of the facilities offered.

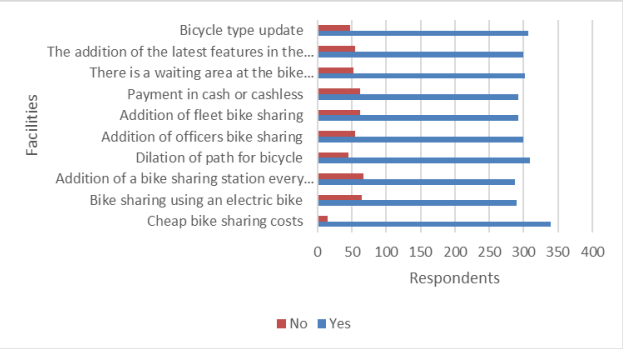

Figure 5. Factors Can Increase the Attractiveness of Private Vehicle Users to Switch to Bike Sharing

Of the 10 facilities offered, the 3 most options chosen by the public are with the high cost of bike sharing, the existence of lanes for bicycles, and the presence of bicycle-type updates used for bike sharing. In China, the tariff for using bike sharing is RMB0,5 or around Rp2,000 per hour (Salmah, 2018). According to Zamroni (2018), in Singapore there is a bike sharing called Ofo where the rate is S $1 or around Rp. 12,000 per hour. In the city of Berlin Germany there is a bike sharing with a rate of around 3€ or Rp17,000 per hour. When compared to the rate of bike sharing in other countries, the rates chosen by respondents are almost the same as the rate of bike sharing in China. The costs selected by the respondents are the price range of Rp3,000 to Rp7,000 per trip.

4. CONCLUSION

The percentage of interest of private vehicle users in the M.H Thamrin Area who are willing to switch to pedestrian is 91.50% with a significant factor, namely the availability of wide pedestrian paths (> 2 m) so that the emission reduction produced by this transfer is 0.656 tons of $PM_{2.5}$ /year with a decrease of 93.04%.

The percentage of interest of private vehicle users in the M.H Thamrin Area who are willing to switch to bike sharing is 91.50% with a factor that has no significant effect, namely the availability of cheap bike sharing usage costs so that the emission reduction produced by this transfer is 0.7775 tons of $PM_{2.5}$ /year with a

decrease of 92.87%. Then, ongoing research is needed to determine $PM_{2.5}$ emissions based on the fuel used and in-depth research can be carried out on facilities and infrastructure that can be built or added to attract public interest in choosing a replacement for motorized vehicles.

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