Carbon Dioxide (CO$_2$) Emissions Due to Motor Vehicle Movements in Pekanbaru City, Indonesia

Erza Guspita Sari [1], Muhammad Sofwan [2]*

[1] Departement Urban and Planning, Faculty of Engineering, Universitas Islam Riau, Pekanbaru, Indonesia.

* Corresponding author : muhammad.sofwan@eng.uir.ac.id
Tel.: +62-812-2007-0060

Abstract

Land use has a very close relationship with transportation. Transportation is formed as a result of the interaction between land use and its support system. Good land use supported by good infrastructure will result in good movement as well. Accessibility is one of the supporting factors for good interaction between transportation and land use—the better the land use conditions in an area, the greater the movement in that area. However, the interaction between land use and transportation can cause one of the problems: the increase in carbon dioxide emissions due to the more significant movement of motorized vehicles. Motor vehicles are the most significant contributor to carbon dioxide (CO$_2$) emissions in the world. The further the route traveled by motorized vehicles, the more carbon dioxide (CO$_2$) emissions will increase. This study aims to analyze the average total emission of carbon dioxide (CO$_2$) resulting from transportation activities in Pekanbaru City into two parts, namely: (1) Based on Travel Time (2) Based on the type of vehicle. Vehicle Kilometers of Travel (VKT) and Emission Factors are the primary data in calculating Carbon Dioxide (CO$_2$) Emissions. The research area consists of 12 zones involving 1,342 households in Pekanbaru City. Based on travel time, 52% of community motorized vehicle movement activities are carried out in the morning. Private cars contribute 65% of carbon dioxide (CO$_2$) emissions in Pekanbaru City based on the type of vehicle. This study found that a high number of motorized vehicles cannot be used as a benchmark that the resulting emissions will also be high. However, the emission of carbon dioxide (CO$_2$) depends on the fuel consumption of each vehicle. The higher the fuel consumption, the higher the amount of carbon dioxide (CO$_2$) emissions released by motorized vehicles.

Keywords: Land Use, Carbon Dioxide Emission (CO$_2$), Vehicle Kilometer Traveler (VKT), Motor Vehicles, Travel Behavior, Emission Factors

1. Introduction

One of the most active activities in landscape events globally is land use and land cover change (Foley et al., 2005; Song et al., 2009; Wu et al., 2021). Only 3% of the earth's surface is an urban area. However, urban areas experience many changes in land use and land cover (Liu et al., 2014; Wu et al., 2021). The system of activities in land use in an urban area can be interpreted as the place of origin and destination of activities. The correlation between land use and transportation can shape the movement system in urban areas. These correlations form dynamic relationships involving changes in the spatial and temporal dimensions. The transportation system can change if land use and travel demand patterns change (Shaw and Xin, 2003; Eboli, Forciniti and Mazzulla, 2012).

The pace of economic growth, technological progress, and regional development in urban areas triggers environmental problems and stagnant traffic (Zhu et al., 2018). The high level of urbanization is the cause of land cover changes that will affect and cause problems in the environment, one of which can increase global warming (Chapman et al., 2018; Wu et al., 2021). Global warming arises due to the interaction between land use and transportation.

The problem of global warming has become the main focus because it can create severe damage in the world. Experts argue that carbon dioxide (CO$_2$) emissions are one of the leading causes of global warming (Baek and Pride, 2014; Sohag et al., 2015; Rehman et al., 2021). Production Carbon dioxide (CO$_2$) emissions will directly affect the increase in greenhouse gases. The concentration of greenhouse gases consisting of carbon dioxide (CO$_2$) is 75%, and 25% comes from other gases. A study said that carbon dioxide (CO$_2$) emissions increased by 30% in the world after the industrial revolution in 1700 (Ehsani, Ahmadi and Fadai, 2016).

As much as 24% of the world's carbon dioxide emissions are produced by the transportation sector, sourced from the direct burning of fuels (Siskos and Moysoglou, 2019). Globally, the urban transportation sector generates the most significant carbon dioxide (CO$_2$) emissions (Li, 2011; Labib et al., 2018). In 2004, the world's transportation sector produced 6.3 Giga Tons of carbon dioxide (CO$_2$) emissions, and 74% came from motorized vehicles. The mode of transportation that people choose depends on their level of income. Motorized vehicles are one of the modes that are in great demand by the public. However, carbon monoxide (CO) and carbon dioxide (CO$_2$) emissions caused by motorized vehicles will exacerbate air pollution. The speed of the vehicle determines the number of compounds released in the air. The more volume of vehicles on the road, the vehicle's speed will decrease, so that vehicle exhaust emissions will also decrease (Kusumawati, Tang and Nurhidayah, 2013). In general, the fuel used by motorized vehicles is petroleum fuel (Nurdjanah, 2015).

Motorized vehicles are very influential in supporting community activities in urban areas. Long distances feel close if used in a motorized vehicle (Sengkey, Jansen and Wallah, 2011). Urban areas experience a relatively high movement of vehicles. The fuel consumption is also getting bigger, which causes the production of carbon dioxide (CO$_2$) emissions to increase (Dodman, 2009; Labib et al., 2018). Production of carbon dioxide (CO$_2$) emissions generally comes from motorized vehicle activities such as motorcycles, cars, pick-ups, trucks, buses, and other motorized vehicles. In Indonesia, 85% of urban air pollution is caused by transportation emissions increasing, motorized vehicle ownership. The lack of quality

fuel and poor maintenance of motorized vehicle engines will produce poor exhaust emissions (Gusnita, 2012).

Pekanbaru City is one of the capitals of Riau Province with the highest population growth. This growth will affect the consumptive behavior of the community towards motor vehicle ownership. What recorded that in 2018 the number of motorized vehicle ownership in Pekanbaru City was 720,737 units, while in 2019, the number of motorized vehicle ownership in Pekanbaru City experienced an increase of 770,836 units (Badan Pendapatan Daerah Provinsi Riau, 2019). Based on these data, the higher ownership of motorized vehicles and the greater fuel use will directly impact the addition of motor vehicle gas emissions in Pekanbaru City.

This study aims to analyze the average total emission of carbon dioxide (CO_2) resulting from transportation activities in Pekanbaru City to predict how these transportation activities cause much environmental burden. This study only focused on carbon dioxide (CO_2) emissions generated from motorized vehicles, including motorcycles and private cars in Pekanbaru City.

2. Method

2.1 Correlation between movement patterns and land use

The relationship between transportation and land use activities must be balanced to achieve the main objectives of the transportation system and land use (Khisty and Lall, 2005). Land use is closely related to transportation. Every activity carried out on specific land use will cause the generation of movement and the pull of movement in meeting needs. Carrying out the movement requires a transportation network, thus creating a macro and micro transportation system. The micro transportation system consists of (1) Activity System, (2)

Network System, (3) Movement System, (4) Institutional System (Tamin, 2000). The activity system is related to land use in a specific area to generate and attract transportation activities. The network system is a medium of transportation in carrying out the movement. The relationship between land use and transportation media gives rise to a movement pattern called the movement system.

If the activity system changes, the network system and movement system will also change. Land use that is changed its designation will cause the generation and attraction of different movements. The higher the intensity of land use, the higher the level of its ability to attract movement. In Fig. 1, the distribution of movements carried out by the community such as work, school, shopping, recreation, socializing, and other activities can determine the location by route selection. Distribution of movement causes an interaction between the movement system and the transportation system so that the distance traveled to the destination location of the movement is obtained. The existence of transportation infrastructure forms an interaction with one land use to another called accessibility. Accessibility affects the movement that occurs in the land use so that it will cause changes to the land use system (Wegener and Fürst, 1999; Wegener, 2004; Eboli, Forciniti and Mazzulla, 2012).

To create accessibility and stable activities, good transportation and land-use relations are needed. Transportation produces distance, travel time, and cost. If the accessibility during the transportation is good, the activities on land use are also suitable. Distance, travel time, and cost are obtained from route selection, mode selection, location selection, and vehicle ownership. Meanwhile, land use must attract the movements carried out and provide comfort in the form of transportation infrastructure so that the movements carried out can run well.
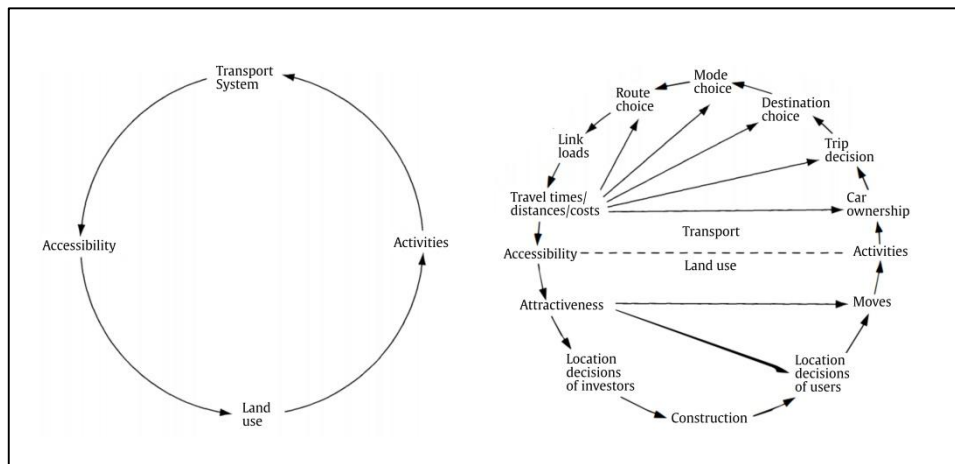

Fig. 1 The land use transport feedback cycle

2.2 Research Area

The study area in this research consists of the origin zone and destination zone of the movement to be carried out. This zoning is based on the division of administrative areas in Pekanbaru City. This study uses household sample data. The collection of data and travel information for family members (respondents) involved 1,342 households, or 0.5% of the total household population spread across 12 sub-districts in Pekanbaru City. In conducting this research, the primary data collection used a home interview survey, which is a survey to collect travel data for each family member on weekdays (Monday-Friday).

The research location consists of the origin zone and the destination zone. A zone is the boundary of the study area,

which consists of several sub-regions. Each zone consists of a zone centre, which is assumed to be the initial location of movement from the zone and the end of traffic movement to the zone (Intari, 2015). Fig. 2 describes the division of zones in Pekanbaru City, which comprises 12 zones covering all sub-districts in Pekanbaru City.

The division of zones is needed to see how significant the movement is that is the reference in calculating carbon dioxide (CO_2) emissions in Pekanbaru City. Each sub-district can be a movement origin zone and a movement destination zone. The selection of this zone can also determine how far the distance travelled in one trip from the origin zone to the destination zone. The choice of moda is based on which zone people want to pass through in carrying out their daily movements.
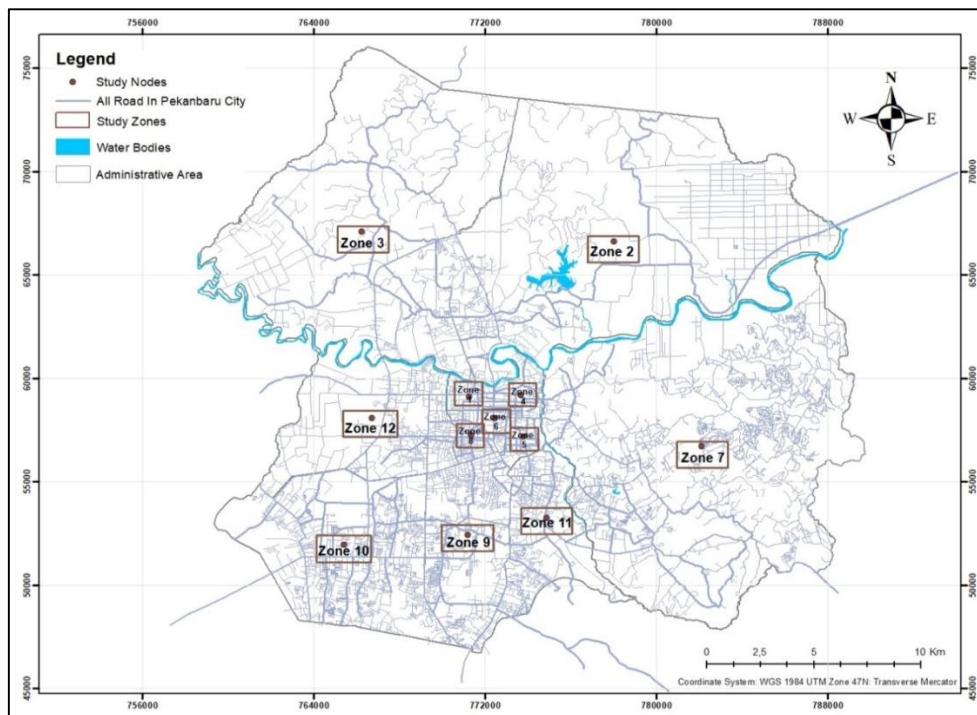
Fig. 2 Research Zone

2.2 Correlation between movement patterns and vehicle activity

The calculation of carbon dioxide (CO_2) emissions in Pekanbaru City cannot be separated from the existence of a four-step model, namely movement generation, movement distribution, mode selection, and route selection in a study. Movement generation is a pattern that is assumed to be in the form of the number of movements originating from one origin zone to the destination zone. The destination zone in question is a zone that is outside the zone of origin (Tamin, 2000).

The more people who are awakened in carrying out the movement will cause the distribution of various movements. The distribution of movement shows where and from where the movements made by the people in Pekanbaru City. The generation and distribution of community movements in Pekanbaru City will affect the choice of modes and the community's routes in carrying out their movements. The choice of Moda is based on the purpose of the movement, the cost of the trip, and the time travel. Usually, people in Pekanbaru City are faced with two choices of transportation Moda, namely public transportation and private transportation.

The selection of routes for public transportation modes is usually predetermined, and the public cannot determine which route they want to take. In contrast to the private mode of transportation, the public can determine which of the shortest and fastest routes they want to pass to avoid congestion so that it is more efficient in terms of time travel. The choice of mode and route can also be influenced by people's income and the ease of getting a mode of transportation. So that from the trip generation, the trip distribution of movement, the Moda choice, and the selection of routes, the pattern of community movement in Pekanbaru City is obtained.

The pattern of community movement produces vehicle activity data which is the primary data in calculating carbon dioxide emissions. The Vehicle activities are divided into two, based on the time of movement, and the type of vehicle used when moving. Vehicle Kilometers of Travel (VKT) are strongly influenced by data from the movement patterns carried out. The

data needed to calculate VKT is the road's length and the total number of vehicles that move in a day. From the generation and the selection of Moda of achieved results to the total number of vehicles of the movement carried out every day.

Similarly, with the distribution, and the route selection, the results obtained from the length of the path traversed the community to get to the destination zone. The pattern of movement of community-generating activities of the vehicle so in the get data on Vehicle Kilometres of Travel (VKT). The calculation of the emissions of carbon dioxide (CO_2) in the City of Pekanbaru requires the data type of the fuel on the mode used, Vehicle Kilometers of Travel (VKT), and Emission Factors.

2.3 The Concept of Calculation of Motor Vehicle Carbon Dioxide (CO2) Emissions

The household data collected is related to the travel pattern of each family member on weekdays. From this data, information will be obtained in the origin zone, destination zone, time of movement, routes, Moda used, and the distance travelled by the people in Pekanbaru City. The amount of carbon dioxide (CO_2) emissions are strongly influenced by Moda selection, route selection, and fuel type. The farther the distance travelled in carrying out the movement, the more carbon dioxide (CO_2) emissions generated from the mode used. The choice of fuel type also dramatically affects the amount of carbon dioxide (CO_2) emissions. The better the choice of fuel, the less polluting carbon dioxide emissions are released when moving. The distance the vehicle travels from the origin zone to the destination zone can determine how much fuel consumption is needed in one trip made by each family member. To calculate the amount of carbon dioxide emissions required an average fuel consumption. The specific fuel consumption multiplied by the average mileage by vehicle type gives the total fuel consumption. Tabel 1 It is assumed that each mode of transportation in one litre per 100 kilometres has the same specific fuel consumption (Jinca, 2009).

Table 1. Specific Fuel Oil Consumption for each type of vehicle in Pekanbaru City

Transportation type	Fuel Type	Specific Energy Consumption (Liters/100 kilometers)	Specific Energy Consumption (Liters/kilometers)
Motorcycle		2,66	0,0266
Passenger car	Gasoline	11,79	0,1179
	Diesel Fuel	11,36	0,1136
Big Bus	Gasoline	23,15	0,2315
	Diesel Fuel	16,89	0,1689
Medium Bus		13,04	0,1304
Mini Bus	Gasoline	11,35	0,1135
	Diesel Fuel	11,83	0,1183
Bemo, Bajaj		10,99	0,1099
Taxi	Gasoline	10,88	0,1088
	Diesel Fuel	6,25	0,0625
Big Truck		15,82	0,1582
Medium Truck		15,15	0,1515
Mini Truck	Gasoline	8,11	0,0811
	Diesel Fuel	10,64	0,1064

The moda of transportation in Pekanbaru City, motorbikes and private cars, primarily uses fuel oil types fuel. This fuel oil type is more in demand than other fuel types because the selling price of fuel oil is low, even though the content in fuel oil is not very good for public health and air quality. To calculate the amount of carbon dioxide emissions also need an emission factor. The emission factor is the emission produced every time we carry out an activity expressed by the coefficient (Kementerian Energi dan Sumber Daya Mineral, 2017). Tabel 2 presents the emission factor values per type of fuel. Premium fuel has the most significant emission factor compared to diesel fuel (Badan Perencanaan Pembangunan Nasional, 2014).

Table 2. Transportation fuel emission factor

Type of fuel	Emission Factor (Kilogram CO2/liter fuel)
Diesel Oil	2,2
Fuel Oil	2,6

After getting the results from the travel pattern, Vehicle Kilometer of Travel (VKT), and selecting the appropriate emission factor, total carbon dioxide emissions can be calculated. Calculation of total carbon dioxide (CO_2) emissions in Pekanbaru City is based on the vehicle type and time. Based on certain types of vehicles, total carbon dioxide (CO_2) emissions can be calculated by multiplying the number of vehicles originating from daily vehicle activities or daily vehicle mileage (VKT) by the vehicle emission factor. To calculate the emission of carbon dioxide (CO2) can be done with equations (1) and (2) (Kamruzzaman, Hine and Yigitcanlar, 2015; Pan, Yao and Yang, 2016; Labib et al., 2018).

$$Eik = \sum_{j=1}^{n} \sum_{k=1}^{n} \times EF_{ijk} \times V_{ijk} \qquad (1)$$

Where;
Eik = Emissions of pollutant
n = Vehicle Average
j = Fuel consumed (e.g., CNG, Gasoline)
k = Emitting Vehicular type
i = Emission Type (in the case CO_2)
EFijk = Emission Factor (g/km)
VKTijk = Daily vehicle activity or daily mileage

Daily vehicle activity or daily vehicle mileage (VKT) is obtained from the equation (2);

$$VKT = L_k \times AV_k \qquad (2)$$

Where;
VKT = Vehicle Kilometers Traveled (km/day).
Lk = Road Length of the selected links within the study area (Kilometers)
AVk = Average number of moving vehicles/day

Fig. 3 explains that the vehicle travel pattern and four-step model result in Vehicle Kilometer Traveler (VKT) and Carbon Dioxide (CO_2) emissions. Calculation of Vehicle Kilometer Traveler (VKT) is divided into two, based on travel time and vehicle type. Vehicle Kilometer Traveler (VKT) based on travel time is divided into three times is morning, afternoon, and evening.

Meanwhile, based on the type of vehicle, it only includes two motorized vehicles, is two-wheeled motorized vehicles in the form of motorcycles and four-wheeled motorized vehicles in the form of private cars. From the results of multiplying the Vehicle Kilometer Traveler (VKT) and Carbon Dioxide Emissions (CO_2), the results for daily Carbon dioxide (CO_2) emissions can then be converted into annual carbon dioxide emissions in Pekanbaru City.
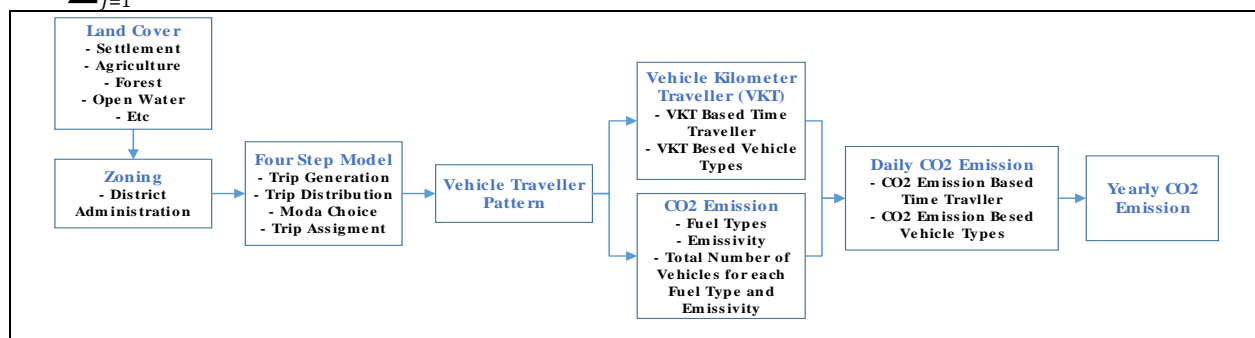

Fig.3 Design Concept of Carbon dioxide (CO_2) Emissions

3. Results & Discussion

3.1 Land Cover In Pekanbaru City

Plantation areas dominate as much as 75.2% of land cover in Pekanbaru City and 12.6% residential areas. The city center of Pekanbaru is dominated by built-up areas in the form of settlements and places of activity, namely in zone 1, zone 8, zone 4, and zone 5. Meanwhile, the other zones are mixed lands whose land use consists of settlements and gardens or shrubs. As seen from Fig. 4, directions of land cover development in Pekanbaru City are in the southern and western parts or, more precisely, the southwest part of Pekanbaru City. The eastern, southern, and northern parts are dominated by undeveloped areas, and there are some built-up areas, but they do not dominate.

In this study, 12 zones are used, which are all sub-districts in Pekanbaru City. These zones will be the origin zone and destination zone in the movement to be carried out. Land use of an area can attract and generate movement. The majority of people in the city of Pekanbaru carry out movements on land use where there are activity centers and settlements, and this is what attracts and evokes movements made by the community.
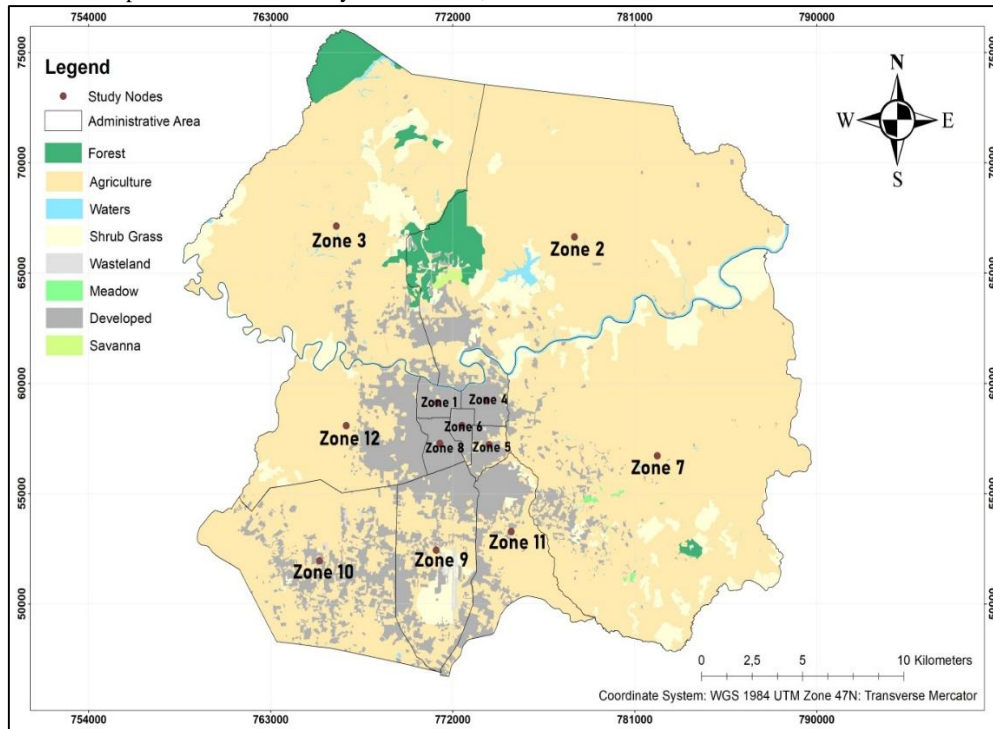

Fig. 4 Land Cover in Pekanbaru City

3.2 Traveller Profile

Pekanbaru City consists of 12 districts with 83 villages and has Siak, Kampar, and Pelalawan districts. Pekanbaru City is the most important economic centre on the island of Sumatra. It is also one of the cities with the highest growth, migration, and urbanization rates in Riau Province. Population growth in Pekanbaru from year to year has increased significantly, affecting the number of movements carried out. Tabel 3 presents data on the profile of travellers in Pekanbaru City. The ratio of the number of family members in Pekanbaru City in 2018 consisted of four people, both from the external zone and the internal zone. So it is estimated that in a household in the two zones. Four people will carry out the movement.

When moving, people must choose the mode of transportation to support their daily activities. People tend to choose fast and cheap modes of transportation when moving. Motorized vehicles are one of the leading choices of people in Pekanbaru City. Ownership of motorized vehicles certainly influences the movement of zones that occur in every household.

The presence of a vehicle will certainly make it easier for someone to move from the origin zone to the destination zone. The movement is related to the selection of routes that the community in their activities will pass. The people of Pekanbaru City, as described in Tabel 4, mostly use motorbikes in their movement. The growth of motorcycle ownership has consistently increased compared to private car ownership, and this is due to the practicality and economics of motorcycles compared to private cars. In addition, the movement of motorbikes is more flexible than private cars when traffic jams occur.

Table 3. Profile of Travelers in Pekanbaru City in 2018

Population (Thousand)	Number Of Households (Thousand)	Population Density (people/Sq.km)	Annual Population Growth Rate (%)	Household Size
1.112.490	268.844	1.767	2,70	4,13

Table 4. The Average number of vehicle ownership by type in Pekanbaru City in 2018

Number Of Households (Thousand)	Transportation Type	Number of vehicles (units)	Average Ownership (household/units)
268.844	Motorcycle	917.200	3,41
	Private Car	252.400	0,93

Table 5. Number of vehicles based on travel time in Pekanbaru City in 2018

Time	Transportation Type	Number of vehicles (units/hour)	Total Vehicle (vehicle/hour)
Morning	Motorcycle	273.400	342.200
	Private Car	68.800	
Afternoon	Motorcycle	181.000	242.000
	Private Car	61.000	
Night	Motorcycle	18.000	21.100

Every household in Pekanbaru City owns a motorized vehicle in the form of a car or a motorcycle. From vehicle ownership data and the number of households, it can be estimated that for every one resident, there is one motorbike. For every two residents, there is one private car. In one household, many also have more than one vehicle. With an average family size of four people, it means that on average, one car is owned by every two families, or for every two households, there is one household that owns a car. As for motorcycles, each household has two or more motorcycles.

Most of the people of Pekanbaru City on weekdays move to work and go to school. Homemakers usually do it for activities such as shopping, so the percentage generated is not too large. Only a tiny part of the community can carry out activities such as socializing and traveling because these activities are usually carried out on weekends (Fig.5). Community activities in Pekanbaru City such as working, going to school, shopping, traveling, and socializing are usually carried out in the morning until noon, causing the movement of people using motorbikes and private cars to increase. Meanwhile, at night, people generally stop their activities and stay at home, thereby reducing the movement they make. 97% of community movements in Pekanbaru City are carried out in the morning until noon (Tabel 5). Motorcycles dominate the movement of people in the city of Pekanbaru from the morning until the evening. Respondents prefer private vehicles, especially motorcycles with relatively high mobility and economical fuel use, and are very quickly owned by zone movement actors. In addition, private vehicles are much more comfortable and safe than current public transport conditions, especially in Pekanbaru City.

3.2 Travel Pattern

As many 67% of the people in Pekanbaru City carry out movements outside their original zones, referred to as a generation. Awakening creates a pattern of travel from the initial zone to the end zone of community movement. The distribution of community movements in Pekanbaru City spreads throughout the sub-districts. Private transportation is the primary choice in Pekanbaru City when making movements. People choose motorbikes as the primary vehicle they will use when moving (Fig.6). Motorcycles are widely chosen as a mode of transportation because of the cheap, easy, and efficient purchase price factor. In addition, most of the people in Pekanbaru City are of medium and low income.

The route that the community chooses to move varies depending on the distance to the destination zone. The length of travel time taken by the community in Pekanbaru City is strongly influenced by selecting travel routes. Private cars cover a longer average trip length than motorbikes (Tabel.6). Pekanbaru City usually uses motorbike transportation modes if the distance between the origin and destination zones is not too far. However, if the distance they want to go is very far, people tend to use private cars to move.
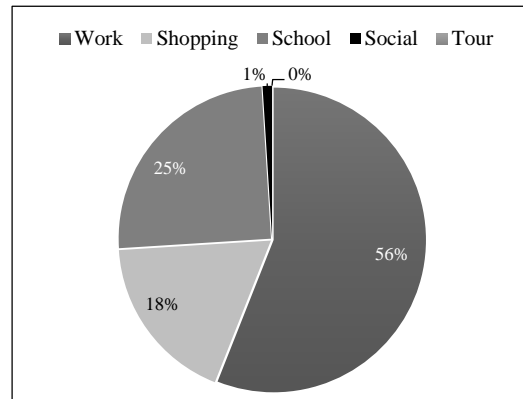

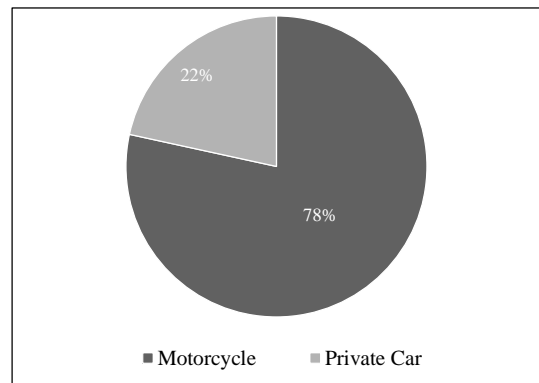Fig. 5 Percentage of community activities in Pekanbaru City

Fig. 6 Percentage of Transportation Mode Selection in Pekanbaru City

Table 6. Average Travel Length in Pekanbaru City

Transportation Type	Average trip length (Kilometers)
Motorcycle	3,97
Private Car	5,59

In Fig.7, the most significant community travel pattern in Pekanbaru City is in zone 10 to zone 9, zone 9 to zone 11, zone 11 to zone 6. The number of movements in this zone is due to the factor of community activities that tend to be dense because there are educational facilities and economic facilities in the area, resulting in a large pull and generation. Land use in Zone 10, zone 9, zone 11, and zone 6 is dominated by residential areas and the center of community activities, so land use attracts more significant movement than other zones. The movement of people in the city of Pekanbaru generally leads to land use which is the center of community activity. The moves made by the community influence the length of the trip, and the more actions carried out, the longer the journey taken by motorized vehicles, so the higher the emission of carbon dioxide (CO_2) produced by motorized vehicles.
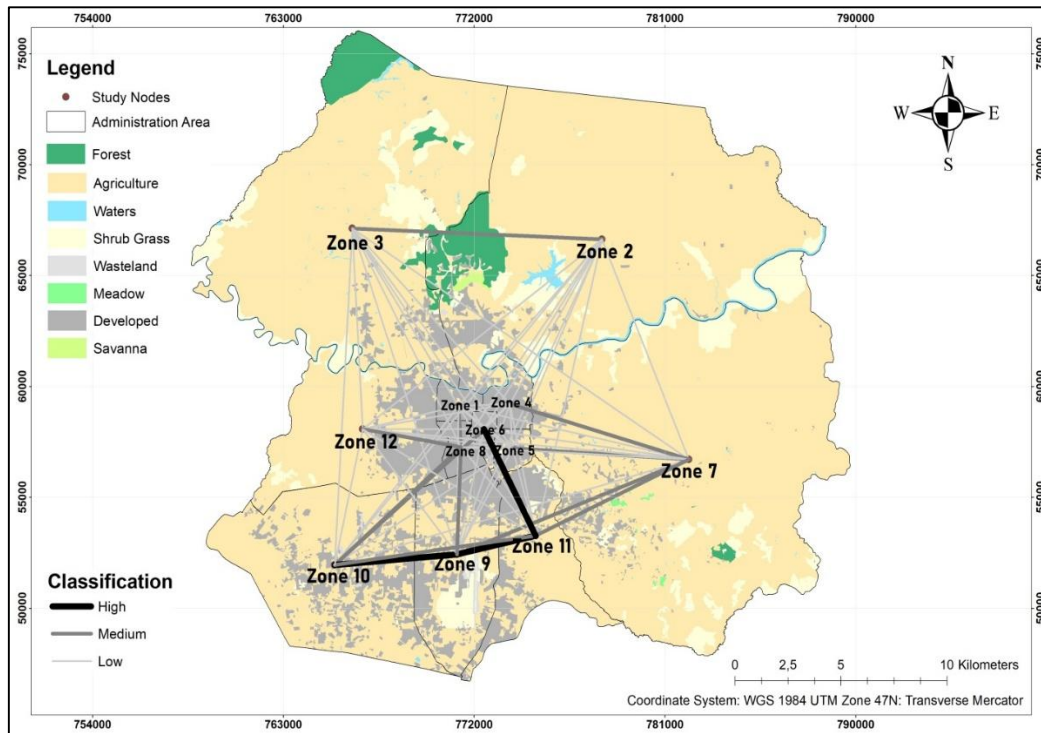
Fig. 7 Travel Patterns in Pekanbaru City

3.4 Total Carbon Dioxide (CO_2) Emissions in Pekanbaru City

Calculation of the total emission of carbon dioxide (CO_2) can be done with three conditions, namely using the emission factor (FE) IPPC 1996, emission factor (FE) Local IPPC 2011, and emission factor (FE) BAPPENAS. In this study, the total emission of carbon dioxide (CO_2) is calculated using the emission factor (FE) of BAPPENAS because the 1996 IPPC Emission Factor and the 2011 Local IPPC are the standards used to calculate the emission factor of motorized vehicles in the world, so the scope is too large. While in this study focused on certain vehicles in Indonesia. The calculation of carbon dioxide (CO_2) emissions using these three emission factors is not much different. Some of these reasons underlie this research using the Emission Factor (FE) of the National Development

planning Agency to determine the total carbon dioxide (CO_2) emissions produced in Pekanbaru City. The emission factor for premium fuel is 2,600 grams/liter and 2,200 grams/liter for diesel fuel.

Data on the average number of vehicles per hour (vehicles/hour), total vehicle mileage (kilometers), emission factors (grams/liter), and fuel consumption (liters/kilometers) are needed to obtain the total results of carbon dioxide (CO_2) emissions in the Pekanbaru city. The most significant contributor to carbon dioxide (CO_2) emissions based on travel time is 52% of 394.57 tons/hour in the morning. Tabel 7 shows the total carbon dioxide (CO_2) emissions by travel time in Pekanbaru City. It is predicted that in a day, motorized vehicles can produce 9,469.75 tons of carbon dioxide (CO_2) emissions due to the movement of motorized vehicles.

Table 7. Total Carbon Dioxide (CO_2) Emissions based on travel time in Pekanbaru City.

Time	Transportation Type	Type of fuel	Emission Factor BAPPENAS (gram/liter)	Energy Consumption (liter/km)	Total Energy Consumption (liter)	Average CO_2 Emissions (gram/hour)	Emisi CO_2 Average (kg/hour)
Pagi	Motorcycle	Fuel Oil	2.600	0,0266	29.122,39	75.718.207,66	75.718,21
	Private Car	Fuel Oil	2.600	0,1179	50.413,33	131.074.664,76	131.074,66
Siang	Motorcycle	Fuel Oil	2.600	0,0266	22.310,40	58.007.050,92	58.007,05
	Private Car	Fuel Oil	2.600	0,1179	45.923,94	119.402.234,64	119.402,23
Malam	Motorcycle	Fuel Oil	2.600	0,0266	1.826,89	4.749.908,80	4.749,91
	Private Car	Fuel Oil	2.600	0,1179	2.161,81	5.620.717,44	5.620,72
						Kg/hour	394.572,78
						Ton/hour	394,57

Table 8. Total Carbon Dioxide (CO_2) Emissions by Vehicle Type in Pekanbaru City.

Transportation Type	Type of fuel	Emission Factor BAPPENAS (gram/liter)	Energy Consumption (liter/km)	Total Energy Consumption (liter)	Average CO2 Emissions (gram/day)	Average CO2 Emissions (kg/day)
Motorcycle	Fuel Oil	2.600	0,0266	106.083,60	275.817.355,63	275.817,36
Private Car	Fuel Oil	2.600	0,1179	197.184,92	512.680.793,04	512.680,79
					Total	788.498,15
					Ton/day	788,50

In Tabel 8, the details of carbon dioxide (CO_2) emissions by type of vehicle in Pekanbaru are presented using the Emission Factor (FE) of the National Development Planning Agency. The total emission of carbon dioxide (CO_2) in Pekanbaru City in 2018 was 788.50 tons/day, and it is estimated that it will be every year. Types of vehicles that contribute the most to carbon dioxide (CO_2) emissions are private cars with 65% of total emissions. As many as 252,400 private cars cover a total distance of 1,672,476 Kilometers. The handsome sub-district and the Tenayan Raya sub-district have the most significant vehicle ownership and the largest population in Pekanbaru City.
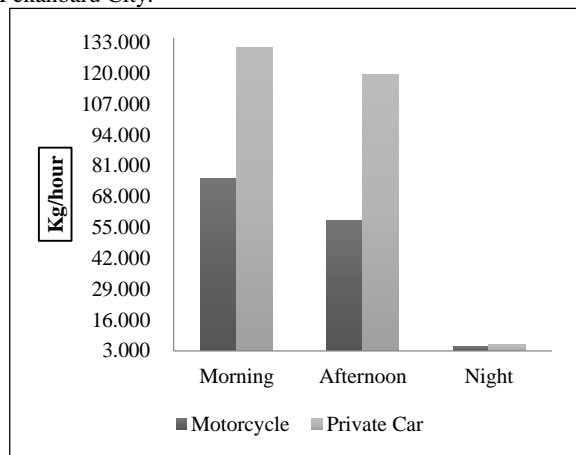

Fig. 8 Average CO_2 Emissions (kg/hour) by vehicle type in Pekanbaru City

Fig.8 Explains that the highest carbon dioxide (CO_2) emissions are produced in the morning, with vehicles that contribute the most carbon dioxide emissions are private cars. Most community activities in Pekanbaru City are carried out in the morning. The volume of vehicles traveling is also getting bigger, which will affect the production of carbon dioxide (CO_2) emissions. At night the amount of carbon dioxide emissions produced by motorized vehicles decreases because the vehicles that move are also reduced.

4. Conclusion

Concern for carbon dioxide (CO_2) emissions due to motorized vehicle activities are becoming increasingly important, so it is necessary to understand and identify which areas need to be controlled to produce carbon dioxide emissions. This research begins by analyzing the four-step model, then calculating the Vehicle Kilometer Traveler (VKT), determining the type of fuel used, calculating fuel consumption, and determining the emission factor.

So that the results obtained based on the type of motor vehicle carbon dioxide emissions in Pekanbaru City produced 788.50 tons/day. Meanwhile, based on time, the carbon dioxide emission in Pekanbaru City produced 394.57 tons/hour. The most significant carbon dioxide emission in Pekanbaru City comes from motorized vehicles in private cars. Although motorcycles are the most numerous vehicles based on the data obtained, compared to private cars, the immense amount of carbon dioxide emissions is produced by private cars.

The carbon dioxide emissions of private cars are more significant than motorcycles because the energy consumption of private cars is much higher than that of motorcycles. The high number of motorized vehicles cannot reference that the emission of carbon dioxide (CO_2) produced will also be high. The high emission of carbon dioxide (CO_2) produced by motorized vehicles is determined by fuel consumption. The greater the fuel consumption, the greater the carbon dioxide (CO_2) emissions released by motorized vehicles.

The area of Pekanbaru City is dominated by agricultural land use and also settlements. The direction of land cover development in the city of Pekanbaru is in the western and southern parts of the city of Pekanbaru. As a result of land development in the western and southern regions, the movement of motorized vehicles is higher in these areas. People in Pekanbaru make the most significant movement on land use, which functions as a center of community activity. So that certain zones have the highest value of the activities carried out. The higher the movement of motorized vehicles on land use, the longer the distance traveled by motorized vehicles, the greater the emission of carbon dioxide produced.

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