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Regional Case Study

Analysis of Carbon Monoxide on Transportation Along the Eastern Crossroad of Jambi

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Abstract

The Eastern Crossroad is one of the national roads that connect the city of Jambi with other cities, districts, and provinces, resulting in relatively heavy traffic and frequent congestion on this road. This has led to the concentration of carbon monoxide (CO), which can result in a decline in ambient air quality. The research used a quantitative descriptive approach aimed at depicting the ambient air quality of CO on Mendalo Darat Road, which is part of Eastern Crossroad. The research revealed the highest vehicle density of 17,954 units in the morning on Tuesday, with the highest emission rate of 114,290 µg/m.s, and the lowest density on Sunday morning with 6,568 units and an emission rate of 44,207 µg/m.s. The highest accumulation of CO emission levels occurred on Tuesday evening, reaching 38,536.44 µg/Nm^3. Overall, the ambient air quality of CO on Mendalo Darat Road tends to exceed the quality standards. The accumulation of increased CO emissions correlates closely with the road's national status, increased vehicle density due to high community activity, changes in the day's status (working day), and road conditions with traffic signal devices.

Keywords: Air quality assessment; carbon monoxide; traffic emissions

1. Introduction

In the era of globalization and rapid economic growth, the mobilization of the population through motor vehicles has become inevitable, especially in urban areas and national transportation centers. Although providing comfort and efficiency in travel, its impact on air quality and the environment has increasingly become the focus of research and public concern. The combustion process of motor vehicles produces various gases that significantly affect the environment and human health. Some types of gases produced include Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydrocarbons (HC), Nitrogen Oxides (NOx), particulate matter, volatile organic compounds, Ammonia (NH_3), and other compounds. One aspect that receives serious attention is the emission of CO originating from vehicular traffic. CO is a colorless and odorless gas generated from the combustion process of fossil fuels which is produced from vehicle emissions due to incomplete engine combustion, with the highest emissions being around 70% (Damara et al., 2017).

The increasing ownership of motor vehicles in the Province of Jambi has led to frequent traffic congestion due to the density of transportation mobility, especially on national roads. National roads connect provincial capitals and strategic national roads, including toll roads. National roads themselves form a primary road network system that connects provinces (Fermi et al., 2021). National roads tend to have traffic density dominated by motorcycles, light vehicles, and heavy vehicles, which may lead to an increase in the concentration of CO. This can interfere with the oxygen-binding sites on hemoglobin in the blood, potentially causing asphyxia or oxygen deficiency (Rizaldi et al., 2022).

Eastern Crossroad is one of the national roads. This road, chosen as the observation location, connects the city of Jambi with districts and is thus one of the busiest points in the Province of Jambi. It has the potential for an increased CO concentration, leading to a decline in ambient air quality. Mendalo Darat road is prone to traffic congestion due to the density of motor vehicle movement, resulting in a decrease in air quality due to CO, which can have health impacts if CO concentrations exceed established quality standards (Rambing et al., 2022). A case in Muaro Jambi Regency involved a high level of Total Suspended Particulate (TSP), dominated by CO due to incomplete combustion from forest fires and the congestion of coal trucks around the location of Eastern Crossroad. It cannot be denied that motor vehicles also significantly contribute to CO, which can decrease ambient air quality and have health impacts on the surrounding community if it exceeds the quality standards set by Government Regulation Number 22 of 2021 on the Implementation, Protection, and Management of the Environment, which is 10,000 µg/m3.

The measurement of CO showed that changes in time result in an increase in the volume of vehicles, affecting an increase in the pollutant load of CO. The higher the number of vehicles, the higher the CO concentration produced. CO increases at certain temperatures, with the highest levels during the daytime and afternoon, decreasing at night. This is influenced by traffic density and weather climate changes (Gusrianti et al., 2017). Different road conditions and intersections can cause traffic density, increasing the concentration of CO in ambient air. The distance also influences the concentration of CO (Turmuzi et al., 2018). Several previous studies on the concentration of CO emitted from vehicles on roads have focused on factors such as traffic density (Joshua et al., 2023), road conditions, environmental influences, driver behavior, and road characteristics (Ramadan et al., 2022). However, this study shifts its focus towards examining the influence of time, road types, traffic density, and vehicle types traversing the Mendalo Darat Road area, which forms a part of the Eastern Crossroad network. Unlike previous research, which often emphasized static factors, such as road infrastructure or driver behavior, this study seeks to understand how dynamic variables like time of day and varying vehicle types impact CO concentration levels. By exploring these aspects, the research aims to provide a more comprehensive understanding of the factors contributing to CO emissions on roadways, potentially offering insights for more effective air quality management strategies.

2. Methods

The research conducted is of a quantitative descriptive nature, aiming to provide a comprehensive portrayal of the ambient air quality concerning CO along the Mendalo Darat road as part of The Eastern Crossroad of Jambi. The methodology employed involves the utilization of emission rate calculations based on vehicle volume and direct field measurements using equation 1.

$$Q_{co} = \left(\sum_{i=1}^{n} \times Ef_i \times V\right) \times t \quad (1)$$

Equation 1 serves as the foundation for these calculations, providing a systematic approach to assess the impact of vehicular emissions on air quality, where QCO is CO pollution rate with unit g/km.hour, Efi is emission factor for each vehicle type with unit g/km, V is volume of vehicles in unit vehicles/hour, T is duration of observation in unit seconds, and I is vehicle type.

The primary objective is to gauge the concentration of CO in the ambient air, employing a thorough examination of the road's characteristics, traffic patterns, and emission sources. This involves not only the measurement of CO levels but also an exploration of the contributing factors such as traffic volume and potential influences of variations in time. The fieldwork, conducted for three days from September 3 to 5, 2023, focuses on capturing a comprehensive dataset that encapsulates diverse scenarios, including weekend and weekday traffic patterns. The sampling frequency is set at one-hour intervals (60 minutes) to ensure a detailed understanding of the fluctuations in CO levels throughout different times of the day. To facilitate accurate measurements, advanced instruments were deployed for CO monitoring in the field. The KMOON CO Meter GM8805 and the CO Meter A58700A were selected for their precision and reliability in capturing real-time data. The measurements were recorded in parts per million (ppm) and subsequently converted to micrograms per cubic meter (μg/Nm3) following the specifications outlined in SNI 7119.10.2:2011. This standard delineates the Ambient Air Quality Standards Part 10, specifically designed for CO testing using the Non-Dispersive Infrared (NDIR) method. The choice of the Non-Dispersive Infrared (NDIR) method underscores the commitment to employing cutting-edge technology for accurate and reliable results. This method is known for its sensitivity to low concentrations of CO and is widely accepted as a standard practice in air quality assessments.

Measurements of meteorological parameters were conducted as additional variables to understand the influence of weather conditions on the concentration of CO in the air. Measurements were performed using specialized devices, including an anemometer to measure air temperature, humidity, air pressure, and wind speed. An anemometer was chosen for its ability to provide accurate and consistent readings of these parameters. Additionally, wind direction measurements were conducted using a weather meter to understand better how airflow affects pollutant dispersion. Direct observations were also made to record overall weather conditions, such as whether it was sunny, cloudy, or overcast. Considering these meteorological parameters, it can be seen to what extent the weather influences the concentration of CO in the air.

The research design incorporates a strategic temporal dimension, considering both weekday and weekend scenarios. This temporal variation allows for the identification of patterns and trends in CO levels, acknowledging the potential impact of distinct activity levels during these periods. Weekdays, characterized by heightened vehicular and human activities, may exhibit different air quality dynamics compared to weekends when overall human activity tends to be lower.

3. Result and Discussion

3.1. Vehicle Volume at Sampling Locations

Observation of vehicle volume was conducted for 3 days, namely on September 3, 2023 (Sunday), September 4, 2023 (Monday), and September 5, 2023 (Tuesday), with hourly intervals during peak morning (07:00 GMT+7 - 08:00 GMT+7), midday (13:00 GMT+7 -14:00 GMT+7), and afternoon (16:00 GMT+7 -17:00 GMT+7). The selection of observation days was based on the need to capture a representative sample of typical traffic patterns throughout the week. Incorporating both weekdays (Monday and Tuesday) and a weekend day (Sunday) allows for the consideration of potential changes in traffic volume and composition influenced by varied daily routines and activities. Additionally, conducting observations during peak morning, midday, and afternoon hours allows for a comprehensive understanding of traffic dynamics during various times of the day when vehicular activity typically peaks. The selection of sampling sites adheres to the guidelines outlined in SNI 19-7119.6-2005, which dictate conducting air quality assessments along the roadside, targeting the most secure positions for CO sampling. The areas chosen for measuring CO concentration span from the emission source (facing south) and extend straight towards the north (adjacent to residential zones). Calculations for CO concentration is carried out along the roadside, positioned at intervals of 100 m, 200 m, and 300 m from the initial point. There were three observation points for vehicle volume:

1. Point I with coordinates 1°37'03" LS.103°31'43" LE
2. Point II with coordinates 1°36'56" LS.103°31'42" LE
3. Point III with coordinates 1°36'53" LS.103°31'41" LE

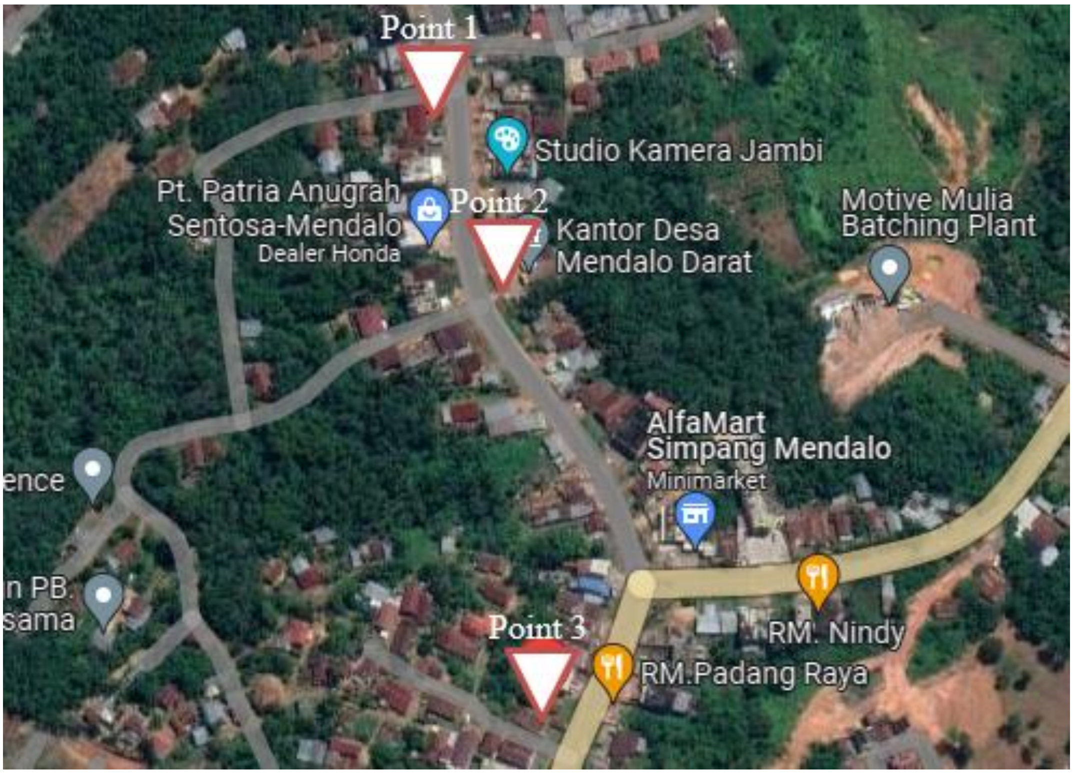

Figure 1. Observation points locations

The types of vehicles observed in this study were heavy vehicles, light vehicles, and motorcycles (Campagnolo et al., 2023). The road segment observed was the intersection of the Mendalo Darat Road starting from the Mendalo Darat Village Office. Vehicle volume data during the observation period at the three points can be seen in Table 1, Table 2, and Table 3.

Table 1. Vehicle volume on Day 1

Time	Vehicle Type	Point I	Point II	Point III
07.00-08.00	Motorcycle	7.995	2.334	2.332
	Bus	115	58	56
	Truck	897	401	398
	Passenger Car	6.391	3.784	3.782
Total		**15.398 units**	**6.577 units**	**6.568 units**
13.00-14.00	Motorcycle	7.064	3.270	3.268
	Bus	23	15	15
	Truck	724	323	320
	Passenger Car	6.587	3.492	3.488
Total		**14.398 units**	**7.100 units**	**7.091 units**
16.00-17.00	Motorcycle	8.001	3.063	3.060
	Bus	18	23	23
	Truck	931	545	545
	Passenger Car	6.986	4.379	4.378
Total		**15.936 units**	**8.010 units**	**8.006 units**

Tabel 2. Vehicle volume on Day 2

Time	Vehicle Type	Point I	Point II	Point III
	Motorcycle	8.317	6.724	6.722

Time	Vehicle Type	Point I	Point II	Point III
07.00-08.00	Bus	28	27	27
	Truck	542	331	331
	Passenger Car	6.836	5.105	5.105
Total		**15.723 units**	**12.187 units**	**12.185 units**
13.00-14.00	Motorcycle	7.081	7.160	7.158
	Bus	24	11	11
	Truck	601	324	324
	Passenger Car	7.136	5.976	5.976
Total		**14.842 units**	**13.471 units**	**13.469 units**
16.00-17.00	Motorcycle	8.478	7.924	7.920
	Bus	29	26	26
	Truck	780	421	421
	Passenger Car	7.981	6.100	6.102
Total		**17.268 units**	**14.471 units**	**14.469 units**

Table 3. Vehicle Volume on Day 3

Time	Vehicle Type	Point I	Point II	Point III
07.00-08.00	Motorcycle	8.145	5.628	5.076
	Bus	25	10	13
	Truck	846	697	697
	Passenger car	8.938	7.785	7.785
Total		**17.954 units**	**14.120 units**	**13.571 units**
13.00-14.00	Motorcycle	6.857	5.998	5.996
	Bus	29	20	20
	Truck	782	497	495
	Passenger car	7.987	8.075	8.073
Total		**15.655 units**	**14.590 units**	**14.584 units**
16.00-17.00	Motorcycle	8.251	6.956	6.951
	Bus	20	19	19
	Truck	856	591	588
	Passenger car	8.367	7.989	7.986
Total		**17.494 units**	**15.555 units**	**15.544 units**

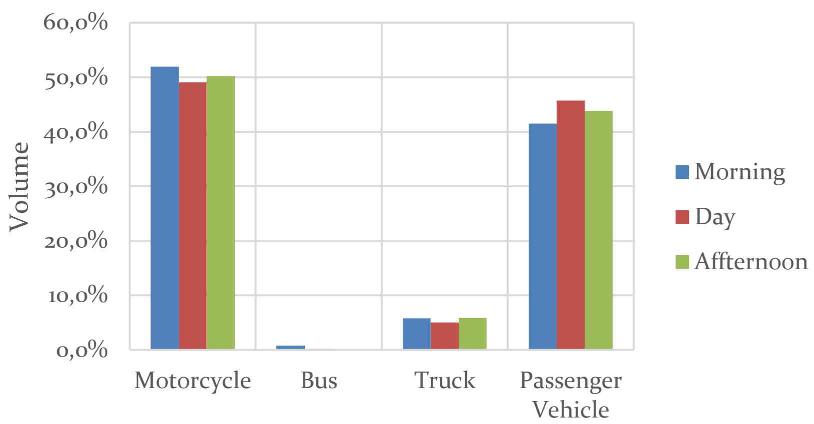

Figure 2. Vehicle volume at point I on Day 1

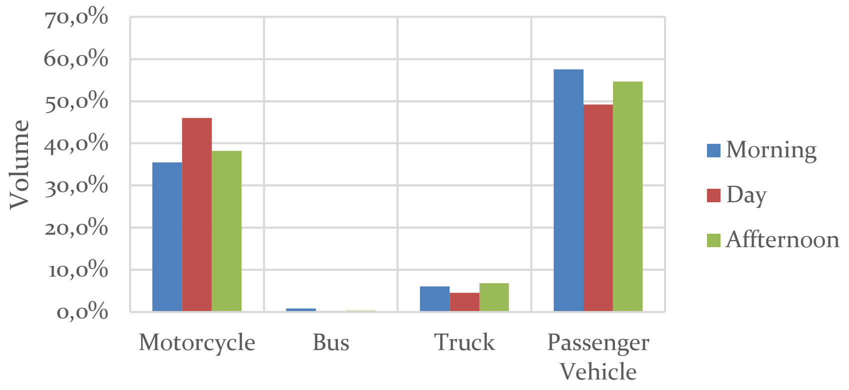

Figure 3. Vehicle volume at point II on Day 1

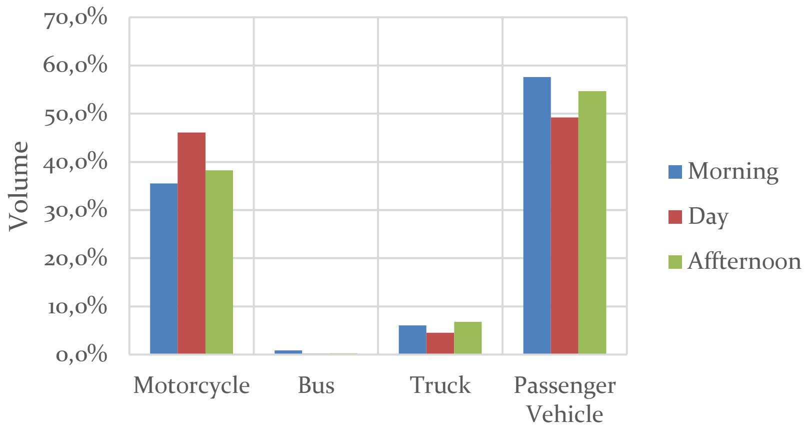

Figure 4. Vehicle volume at point III on Day 1

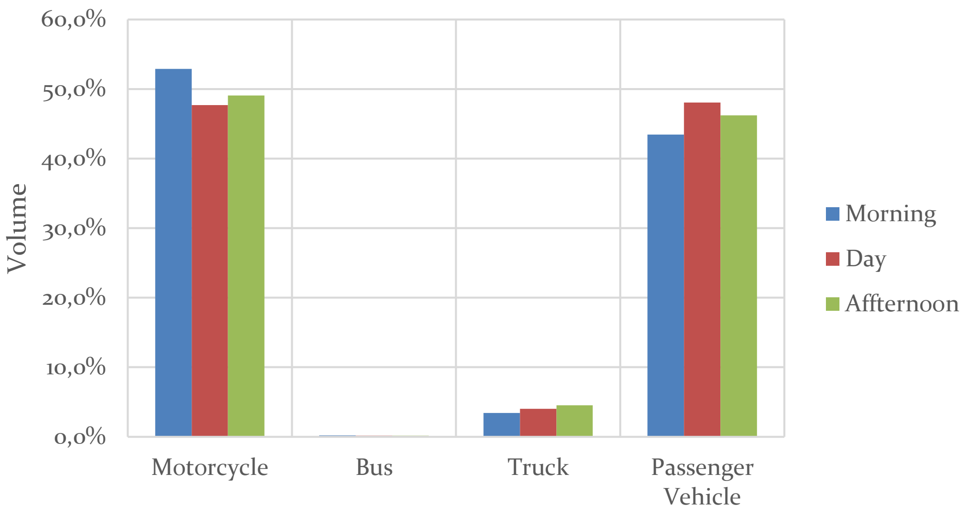

Figure 5. Vehicle volume at point I on Day 2

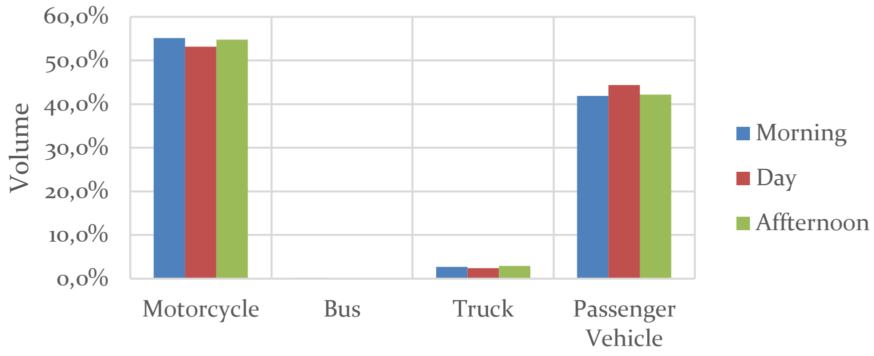

Figure 6. Vehicle volume at point II on Day 2

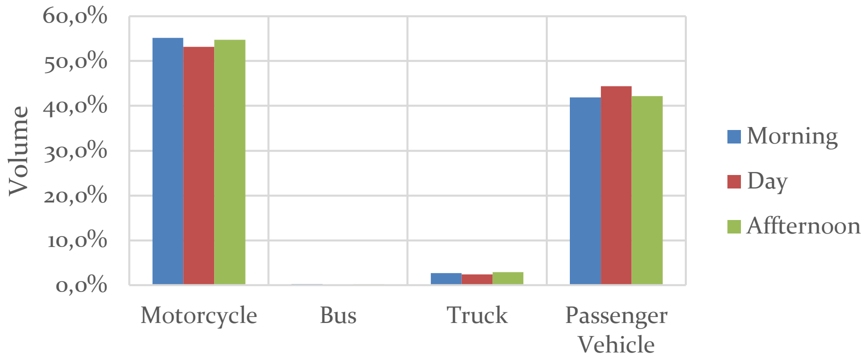

Figure 7. Vehicle volume at point III on Day 2

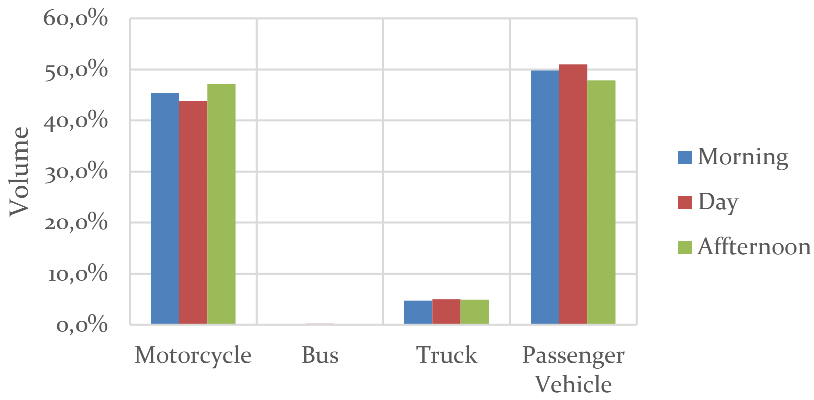

Figure 8. Vehicle volume at point I on Day 3

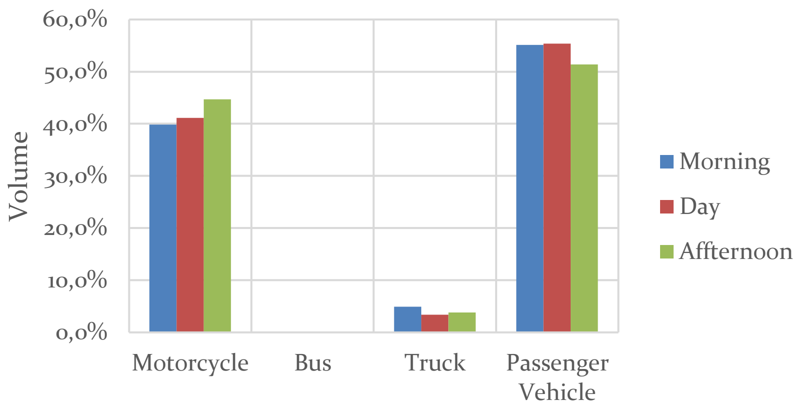

Figure 9. Vehicle volume at point II on Day 3

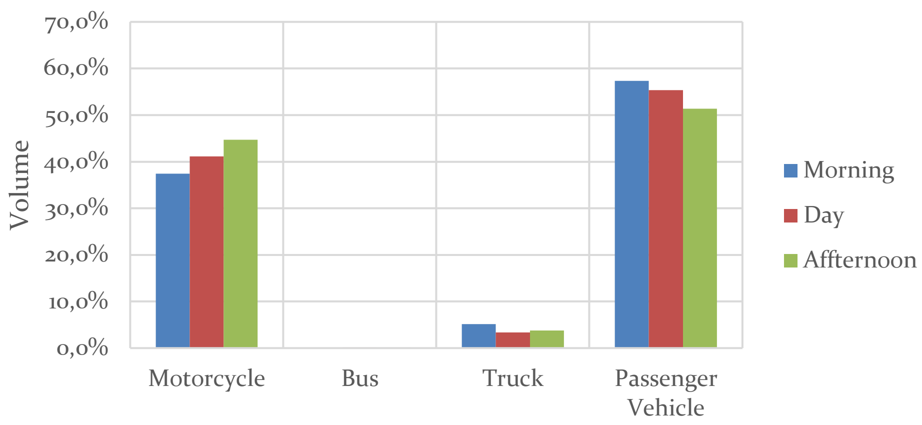

Figure 10. Vehicle volume at point III on Day 3

Based on the Figure 2 – 10, there is a consistent pattern of change in the percentage of vehicle volume along the Eastern Crossroad in Jambi. In general, there is an increase in vehicle volume in the morning at all observation points, which then slightly decreases in the afternoon, and increases again in the evening. This change may be related to the daily routines of the community, where there is an increase in traffic when people go to work in the morning and return in the evening. This finding is consistent with Campagnolo et al. (2023) which drop-off and pick-up activities can increase vehicle volume. Additionally, Turmuzi et al. (2018) reveal that vehicle volume per hour in the morning is higher, reaching 140% compared to the evening, due to commuting to and from work.

The monitoring results over three days showed differences in the dominant types of vehicles at each time point. In the morning, motorcycles dominated the vehicle volume at all observation points, with an average percentage of 49.4% at Point 1, 46.1% at Point 2, and 46.1% at Point 3. Passenger cars dominated in the afternoon and evening, with an average percentage of 46.4% at Point 1, 51.8% at Point 2, and 51.5% at Point 3. Yulianti et al. (2013) indicated that two-wheeled vehicles dominate during peak hours in the morning on both weekdays and weekends. Furthermore, Damara et al. (2017) highlighted that the motor vehicle volume on arterial roads within the city is predominantly two-wheeled vehicles on weekends compared to four-wheeled vehicles.

The figure above illustrates the differences in vehicle volume between weekdays and weekends. On Sunday (day 1), a holiday, there is a higher vehicle volume than on Monday and Tuesday (working days), especially in the morning, potentially attributed to increased community activities on holidays. Conversely, Fermi et al. (2021) suggest that vehicle volume is higher on Mondays than on Sundays due to activities such as schools, markets, and offices. Moreover, on Tuesday (day 3), a significant increase in vehicle volume was observed compared to Monday (day 2), particularly in the morning. This observation is supported by Payus et al. (2020), indicating that public facilities such as schools, places of worship, and offices contribute to the heightened vehicle volume, especially on weekdays.

The conditions at the observation points also affect the vehicle volume pattern. Point 1, located near public facilities such as schools, may experience an increase in vehicle volume in the morning due to student drop-off and pick-up activities. Meanwhile, point 3, which is close to traffic lights, may experience a decrease in vehicle speed, which can result in an increase in vehicle volume at certain times, especially in the evening. This aligns with Yang et al. (2020), indicating that traffic volume increases while speed decreases. The status of the road as a national road may also impact the types of vehicles passing through. Most likely, national roads will attract more four-wheeled vehicles than local roads, which may result in an increase in four-wheeled vehicle volume along the Eastern Crossroad. This finding is consistent with Gusrianti et al. (2017), which indicates that vehicle volume on national roads remains relatively stable throughout the morning and afternoon due to the road's national status.

3.2. CO Emission Rate at Three Sampling Points

Table 4. CO Emission Factors

Vehicle Type	EF CO (g/km)
Motorcycle	14
Bus	11
Truck	8,4
Passenger car	32,4

The CO emission rate (Qco) at the research location was calculated using Equation 1 with CO emission factors for the types of vehicles used in the calculation, as listed in Table 4, and a measurement time of 60 min. The computed CO emission rates (Qco) across the three sampling points during the 3-day observation period are tabulated in Tables 5, 6, and 7.

Table 5. CO Emission Rate (QCO) on Day 1

Time	Emission Rate (μg/m.s)		
	Point I	Point II	Point III
Morning	91.055	44.246	44.207
Afternoon	89.634	44.944	44.893
Evening	97.114	52.665	52.644

Table 6. CO Emission Rate (QCO) on Day 2

Time	Emission Rate (μg/m.s)		
	Point I	Point II	Point III
Morning	95.276	72.885	72.859
Afternoon	93.237	82.807	82.781
Evening	106.830	86.795	86.759

Table 7. CO Emission Rate (QCO) on Day 3

Time	Emission Rate (μg/m.s)		
	Point I	Point II	Point III
Morning	114.290	93.636	93.601
Afternoon	100.554	97.221	97.191
Evening	109.601	100.389	100.341

Referring to Table 5, the emission rate on day 1 from vehicles passing from Point I to Point III was highest in the morning at Point I, with a total CO emission rate (Qco) of 91,055 μg/m.s. In the afternoon, the emission rate (Qco) decreased to 89,634 μg/m.s due to a decrease in the volume of vehicles passing through the observation point. In the evening, there was an increase to 97,114 μg/m.s. At Point II, the emission rate (Qco) continued to increase with each change in time, with morning, afternoon, and evening rates of 44,246 μg/m. s, 44,944 μg/m.s, and 52,665 μg/m.s, respectively. Unlike Point II, Point III had nearly the same emission rate, with morning, afternoon, and evening rates of 44,207 μg/m.s, 44,893 μg/m.s, and 52,644 μg/m.s, respectively.

From Table 6, the CO emission rate (Qco) for day 2 from vehicles passing through Points I to III was the highest in the morning at Point I, with an emission rate of 95,276 μg/m. s. Points II and III had rates of 72,885 μg/m. s and 72,859 μg/m.s, respectively. In the afternoon, the emission rate (Qco) at Point I decreased because of the decrease in the volume of vehicles passing through the observation point, resulting in a total emission rate (Qco) of 93,237 µg/ms. Point II and Point III had rates of 82,807 µg/m.s and 82,781 µg/m.s, respectively. In the evening, during the rush hour, there was an increase in the volume of vehicles from the community and heavy vehicles after work, with the highest emission rate (Qco) at Point I of 106,830 µg/m.s, followed by Point II at 86,768 µg/m.s and Point III at 86,734 µg/m.s. Based on Table 7, on day 3 from vehicles passing through Point I, Point II, and Point III, the highest emission rate was in the morning at Point I, with a total emission rate of 114,290 µg/m.s. In the afternoon, the emission rate (Qco) at Point I decreased to 100,554 µg/m.s. In the evening, there was an increase to 109,601 µg/m.s. Point I represents a very busy road, especially in the morning and evening, representing the rush hours of work and school, resulting in a higher emission rate compared to Sunday (weekend). Point II had morning, afternoon, and evening emission rates of 93,636 µg/m.s, 97,221 µg/m.s, and 100,389 µg/m.s, respectively. Point III had similar emission rates, with morning, afternoon, and evening rates of 93,601 µg/m.s, 97,191 µg/m.s, and 100,341 µg/m.s, respectively.

3.3. CO Concentration on Eastern Crossroad of Jambi

The concentration measurements of CO in the ambient air along the Eastern Crossroad for three days, encompassing the morning, afternoon, and evening periods, are presented in Tables 8, 9, and 10.

Table 8. CO Concentrations on Day 1

Time	Results (µg/Nm³)			Standard (µg/Nm³)
	Point I	Point II	Point III	
Morning	12,362.90	11,231.59	7,877.68	1,000
Afternoon	19,889.37	17,679.44	5,514.10	1,000
Evening	22,077.84	18,792.59	7,734.75	1,000

Table 9. CO Concentrations on Day 2

Time	Results (µg/Nm³)			Standard (µg/Nm³)
	Point I	Point II	Point III	
Morning	24,725.80	20,919.78	7,869.89	1,000
Afternoon	19,844.37	18,741.90	6,614.78	1,000
Evening	27,561.62	24,293.49	9,944.69	1,000

Table 10. CO Concentrations on Day 3

Time	Results (µg/Nm³)			Standard (µg/Nm³)
	Point I	Point II	Point III	
Morning	35,741.02	27,922.67	10,118.43	1,000
Afternoon	19,825.14	17,616.66	7,707.28	1,000
Evening	38,536.44	26,399.42	8,811.17	1,000

Examining Table 8 reveals that on the first day (Sunday), the pinnacle of CO concentration in the ambient air occurred at Point I during the evening, registering at 22,077.84 µg/Nm3. In contrast, the lowest concentration was observed at Point III in the afternoon, at 5,514.10 µg/Nm3. Moving on to Table 9, the concentration of CO on Monday exhibited its zenith at Point I during the evening period (16:00-17:00), reaching 27,561.62 µg/Nm3. Conversely, the nadir of the CO concentration was discerned at Point III during the afternoon, quantifying at 6,614.78 µg/Nm3. A comprehensive overview continues with Table 10, portraying the CO concentration results on the third day (Tuesday). Notably, the zenith was documented at Point I during the evening, attaining a concentration of 35,741.02 µg/Nm3. The lowest CO concentration on Tuesday was observed at Point III during the afternoon, with a measurement of 7,707.08 µg/Nm3.

3.4. Analysis of Vehicle Volume on CO Concentration

The research data provides a comprehensive insight into the patterns of vehicular movement and CO concentrations along points I, II, and III of Mendalo Darat Road from Sunday to Tuesday. Notably, Tuesday mornings emerge as a focal point, witnessing the highest vehicular density recorded at 17,954 units. This heightened density is attributed to the fact that Tuesday is considered a day with the highest community activity level. This surge in activity, predominantly driven by students and residents, contributes to the notable increase in the volume of vehicles passing through the observation points during these peak hours. Conversely, the lowest volume of vehicles is observed on Sunday mornings at point III, totaling 6,568 units. This dip in vehicle volume aligns with the characteristic decrease in community activity during weekends, reflecting a stark contrast to the bustling traffic observed on weekdays. The observed variations in vehicle volume underscore a clear correlation between the level of community activity and the influence of holidays, indicating a direct impact on both vehicular density and the concentration of CO in the ambient air (Alchamdani et al., 2021; Condorí et al., 2021; Yulianti et al., 2013).

The changing landscape of vehicle types passing through the observation points further contributes to the dynamic nature of the data. Over time, there has been a discernible increase in the number of passenger cars, motorcycles, buses, and trucks traversing the road segment. This upward trend can be attributed to the strategic importance of Mendalo Darat Road, which serves as a vital link between the district and the city, and functions as a national road catering to the transit of coal trucks (Ramadan et al., 2022). The consistent rise in vehicle volume emphasizes the evolving nature of traffic dynamics in response to the multifaceted roles of roads. The concentration of CO exhibits distinct patterns along the observation points, with point I dominating from morning to afternoon. This dominance is directly tied to the sheer number of vehicles passing through point I, surpassing the counts at points II and III. The concentration of CO correlated positively with the volume of vehicles, illustrating that as the number of vehicles on the road segment increased, so did the concentration of CO. Conversely, when vehicle volume decreases, the concentration of CO decreases noticeably (Setyo et al., 2021).

An intriguing observation is the highest concentration of CO at point I during periods from morning to afternoon. This occurrence is ascribed to the frequent stops of vehicles at point I, primarily due to traffic signal devices. The interruptions in vehicular movement lead to elevated engine loads and lower RPM (revolutions per minute), contributing to increased pollutant emissions from motor vehicles during traffic jams (Payus et al., 2020). This finding underscores the significant influence of traffic management infrastructure on CO concentrations, shedding light on the nuanced factors affecting the air quality in a specific road segment. In essence, the elaboration of this research data elucidates the intricate interplay between vehicular movement patterns, community activities, and CO concentrations along Mendalo Darat Road. A detailed examination of peak periods, vehicle types, and pollutant concentrations offers valuable insights into the complex dynamics shaping air quality in this particular road segment.

3.5. Analysis of Time and Vehicle Type on CO Content

The three-day assessment of CO concentrations in the ambient air along Mendalo Darat Road, spanning from Sunday (weekend) to Tuesday (weekday), revealed a trend wherein the air quality tended to surpass the standards outlined by Government Regulation No. 22 of 2021, which stipulates a limit of 10,000 μg/Nm3. This predicament is particularly pronounced at points I and II, with Tuesday afternoon at point I registering the highest concentration of CO at 38,536.44 μg/Nm3. Notably, Sundays, designated as holidays, exhibit a mitigating effect on CO concentrations due to a reduction in community activities.

The temporal dynamics of CO concentrations are accentuated in the afternoon, a period marked by heightened motor vehicle activity, especially on a national road characterized by a greater volume of motorized vehicles compared to typical roads. The scenario is further complicated by interruptions in traffic flow induced by traffic signal devices, contributing to an escalation in CO concentrations. Intriguingly, the cessation of vehicles during idle periods results in a higher concentration of CO emitted by motor vehicles, where the gas production is approximately 7%, in contrast to about 1% when the vehicles are in motion (Hall-quinlan et al., 2023). The escalating volume of motorized vehicles passing through the observation point exerts a tangible influence on CO concentrations, with afternoons demonstrating a consistent pattern of higher concentration. This correlation underscores the direct proportionality between the volume of vehicles traversing the observation point and the resultant CO concentration (Li et al. 2022; Sharmilaa et al. 2022).

The intricacies of CO concentrations transcend vehicular counts alone, extending to environmental factors such as temperature (Asubiojo et al., 2023). Analysis of the obtained data reveals a tendency for higher CO concentrations at lower temperatures. During daylight hours with clear weather conditions, elevated air temperature, induced by sunlight exposure, causes air expansion or rarefaction, resulting in lower CO concentrations. Conversely, lower temperatures contribute to denser air, thereby elevating CO concentrations. Although these concentrations may not reach alarming levels, their impact on human health is discernible, affecting the cardiovascular system, nervous system, and all oxygen-sensitive organs (Aryanta et al., 2023; An et al., 2021; Chen et al., 2021; Dzhambov et al., 2023; Sartori et al., 2024). Prolonged exposure to elevated CO levels carries the risk of Parkinson's disease (Kwon et al., 2024). Beyond health implications, heightened CO concentrations have the potential to inflict damage to public buildings along the road, producing acidic content (Alberti et al., 2024).

3.6. Meteorological Conditions

In this study, one aspect that served as an influencing factor was the weather or meteorological conditions at the sampling points. Several measured variables include air temperature, air humidity, air pressure, wind speed, wind direction, and overall weather conditions. The average weather parameter data for the three-day measurement period are presented in the following table.

Table 11. Meteorological parameters in 3 sampling points

Parameters	Average Results			Unit
	Point I	Point II	Point III	
Temperature	35.741,02	27.922,67	10.118,43	°C
Humidity	83,50	79,50	80,80	%
Air Pressure	753,40	755,20	756,10	mmHg
Wind Speed	0,40	0,60	2,00	m/s
Wind Direction	North	North	North	-
Weather Condition	Overcast	Cloudy	Overcast	-

Based on Table 11, it can be observed that the average air temperature during the measurement period varied between 27.40°C and 28.50°C at the three measurement points. The difference in air temperature did not significantly affect the level of CO originating from traffic. This can be seen at point 1, which has a lower air temperature than the other sampling points but has a higher CO content. Furthermore, the average air humidity varied between 79.50% and 83.50%. High air humidity can affect the level of pollutant dispersion in the air, including CO. High humidity levels may have reduced the dispersion of CO, resulting in increased concentrations in the environment around the measurement point. This can be observed from the lowest air humidity at point 1, which has the highest CO content.

The average air pressure during the measurement period ranged from 753.40 mmHg to 756.10 mmHg. Although changes in air pressure usually do not have a direct impact on vehicle emissions, lower air pressure can result in more stagnant atmospheric conditions, which can lead to pollutant accumulation, including CO. This is evident from the lowest air pressure at point 1, which has the highest CO content. The average wind speed during the measurement period varied from 0.40 m/s to 2.00 m/s. Low wind speeds tend to reduce pollutant dispersion in air, whereas high wind speeds can assist in pollutant dispersion. Therefore, measurement points with low wind speeds may have higher CO concentrations than others. This is consistent with the results of the high CO levels at point 1, which had the lowest wind speed. The wind direction during the measurement period was towards the north at all measurement points. This indicates that emission sources located to the south carry pollutants from the emission source to the north. It can be assumed that point 3, located to the south with a high airspeed, carries CO pollutants generated to the north, namely points 2 and 1. This is consistent with the average CO content at point 3 being lower than points 2 and 1. Overall weather conditions during the measurement period included cloudy skies at Point I, overcast skies at Point II, and cloudy skies at Point III. These weather conditions can affect the level of community driving activity because sunny weather conditions may encourage more people to use vehicles, which can increase CO emissions.

3.6.1. Carbon reduction scheme for Eastern Road of Jambi

Based on these research findings, an effective scheme for carbon reduction can be devised. First, traffic management has emerged as pivotal, necessitating policies such as vehicle restrictions during peak hours (Ghaniyyu and Husnita, 2021), adaptive traffic control systems for intersections (Zhang et al., 2024; Singh et al., 2022), and road network transformation (Zhang et al., 2023). Additionally, infrastructure improvements are imperative, including increased green spaces in high-density road areas (Yang et al., 2020 and Saputra et al., 2020) and the development of efficient public transportation systems (Zhang et al., 2020). Strengthening environmental awareness campaigns is equally crucial to educate individuals about the benefits of eco-friendly transportation options (Bakibillah et al., 2024 and Zhai et al., 2023). Source control measures, such as effective catalytic converters for vehicles, play a crucial role in managing CO emissions (Dey et al., 2020). Lastly, embracing green technologies, such as electric vehicles, could offer effective measures in curbing carbon emissions from motor vehicles. Integrating these diverse carbon reduction strategies is expected to yield holistic and effective solutions to address the issue of CO emissions along the Eastern Crossroad of Jambi, while ensuring the welfare of the local community.

4. Conclusions

Based on the research findings, Tuesday mornings have emerged as a critical temporal juncture characterized by the highest vehicular density at observation points I, II, and III along the Mendalo Darat as part of the Eastern Crossroad of Jambi. The recorded volume of vehicles during this peak period reached a staggering 17,954 units, accompanied by an emission rate of 114,290 μg/m.s. This intriguing revelation is inherently tied to the heightened level of community activities on that specific day, providing a compelling insight into the intricate interplay between daily routines and vehicular traffic. The discernible pattern in the research data paints a vivid picture of the dynamic fluctuations in vehicle volume over time. Furthermore, meteorological parameters such as air humidity, air pressure, wind speed, and wind direction significantly affect the concentration of CO in the air. This temporal ebb and flow are intricately linked to the pivotal role played by the National Crossroad, serving not only as a crucial link between the District and the City, but also as a primary provincial thoroughfare.

The measured CO concentrations tended to surpass the quality standards stipulated by government regulations. A notable concentration peak occurs on Tuesday evenings at point I, soaring to 38,536.44 μg/Nm3. This alarming elevation has prompted a closer examination of the potential environmental and health implications associated with such heightened CO levels. This observation underscores the direct correlation between daily human activities, vehicular mobility, and air quality, offering valuable insights into potential mitigation strategies during high-activity periods.

This research identifies a notable trend wherein the CO concentration tends to spike during the evening hours. This diurnal fluctuation is attributed to the escalated activity of motor vehicles on the national highways. The exacerbation of this phenomenon is evident in the form of vehicle stops at traffic signal lights. These intermittent halts result in a discernible increase in CO concentration, emphasizing the impact of traffic management infrastructure on air quality dynamics.

The research findings shed light on the intricate relationship between temporal dynamics, vehicular density, and CO concentrations along the Mendalo Darat road. The identification of peak periods and their correlation with community activities underscores the need for targeted interventions to manage air quality during high-traffic periods. An effective scheme for reducing carbon dioxide emissions along the Eastern Crossroad in Jambi has been formulated. This involves traffic management with vehicle restrictions during peak hours, green infrastructure technologies, and environmental awareness campaigns. Thus, these strategies are expected to address the carbon dioxide emissions issue in the area.

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