



COMPARATIVE STUDY ON URBAN TRANSPORT AND THE ENVIRONMENT (CUTE) FRAMEWORK AS STRATEGY FOR THE REDUCTION OF CARBON DIOXIDE EMISSIONS OF ROAD VEHICLES AT ZAPOTE STREET

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Abstract

Carbon emissions from vehicles contribute significantly to carbon footprint production, which is one of the primary causes of climate change. In Caloocan City, increasing air pollution is observed despite the drastic decrease in air pollutants in major Metro Manila cities. This study primarily aims to provide strategies to reduce carbon dioxide emissions in Zapote St., Caloocan City, through a Comparative study on Urban Transport and the Environment (CUTE) Framework. The study identified that the hourly average carbon footprint contributed by private and public vehicles along Zapote Street is 686.27 and 243.71 kg CO₂e on weekdays and 634.65 and 212.97 kg CO₂e on weekends. The exploratory data analysis via Python shows that only the vehicle and fuel types affect the emissions volume. Accordingly, the Unified Vehicular Volume Reduction Program (UVVRP) was ineffective. It only resulted in additional private vehicles and increased congestion, indicating the need for an improved public transport system to encourage Filipinos to shift to public transport. Furthermore, the Traffic Volume Emission Projection (TVEP) model projects a decrease of 87.19 kg CO₂e per hour in 2023 and 164.72 kg CO₂e per hour by 2052, resulting from the 20% reduction in volume upon the implementation of the "no exemption of motorcycles" in the number coding scheme of Caloocan city.

Keywords: Carbon Footprint, Traffic Volume Projections, Traffic Policies, Transport Emission Model, Sustainable Transportation

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INTRODUCTION

Carbon emission is one of the leading causes of climate change and the increasing amount of carbon emissions from vehicles significantly contribute to global carbon footprint production (Ritchie, 2021). The accumulated amount of *carbon footprint* raises the global temperature and results in global warming and climate change, consequently affecting the environment and public health.

In a special report by the Center for Research and Energy on Clean Air (2020), a drastic decrease in NO_2 and $\text{PM}_{2.5}$ levels is seen in major Metro Manila cities during the Enhanced Community Quarantine (ECQ). However, there was no sustained decrease in $\text{PM}_{2.5}$ in Caloocan City. Instead, pollution increased throughout April and saw the slightest improvement in overall concentrations of the two pollutants. Due to this, the study takes place on Zapote Street, a four-lane 1.41-kilometer collector road in North Caloocan City, Philippines as shown in **Figure 1**. It is one of the routes leading to well-known malls like Ayala Fairview Terraces and SM Fairview, and along this road is the Caloocan City Hall North. Thus, public utility vehicles (PUVs) and private vehicles commonly traverse this road.

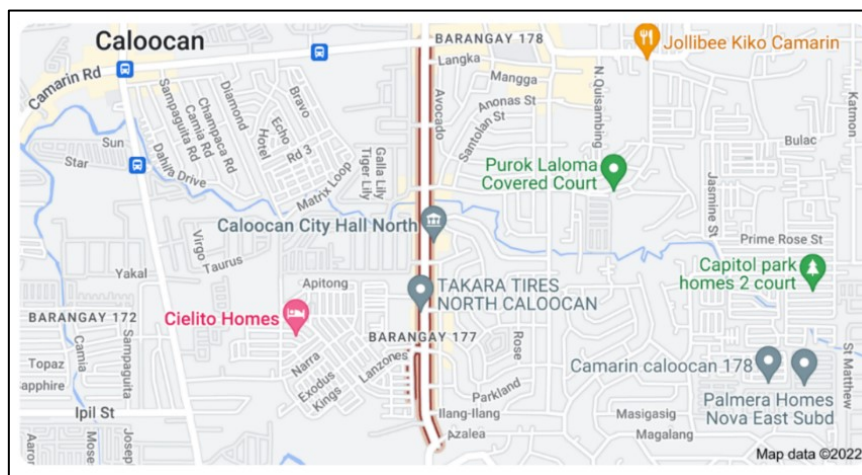


Figure 1: Map of Zapote Street (Google, 2022)

The main objective of this study is to provide strategies to reduce carbon dioxide emissions in Zapote St., Caloocan City, through the development of a Comparative study on Urban Transport and the Environment (CUTE) Framework and Traffic Volume Emission Projection (TVEP) Model. Specifically, it aims to: (1) determine the average amount of carbon footprint emissions per hour by private and public vehicles during a weekday and a weekend, (2) analyze the amount of carbon footprint emissions by motor vehicles, and (3) formulate

recommendations to existing traffic and environmental laws and ordinances and design a structure as solutions to reduce carbon emissions. The outcome of this study will help determine whether the existing laws and policies implemented to reduce carbon footprint in Zapote St., Caloocan City is effective.

LITERATURE REVIEW

Transportation

Transportation is one of the driving forces behind economic and social development (Gnap et al., 2020), but also one of the significant contributors to greenhouse gases and CO₂ emissions (Andong & Sajor, 2015). In the Philippines, road transport is the most dominant mode of transportation primarily served by private vehicles and PUVs such as jeepneys, buses, taxis, pedicabs, and tricycles.

Zapote Street, Caloocan City

Caloocan City, located in the northern part of the National Capital Region is divided into North and South Caloocan. Zapote Street is a 1.41 km road located in North Caloocan where the city hall complex is located, attracting investments in the area for future developments. Furthermore, it is part of the growth corridors of the comprehensive land use plan based on the increasing rate of economic and business transactions thriving in the road right-of-way.

Carbon Emissions of Vehicles

The principal greenhouse gas (GHG) emitted by vehicles is CO₂. The level of this emission is associated with the amount and type of fuel vehicles consume. Fuel consumption is directly proportional to the production of pollutants (Gnap et al., 2020). In 2018, the entire transport sector accounted for 21% of global CO₂ emissions. Road transport alone accounts for 75% of this emission corresponding to 15% of global CO₂ emissions (Ritchie, 2020). In the Philippines, the Climate Transparency (2020) report shows that transport emissions represent 26% of direct CO₂ emissions.

Impact of Carbon Emissions and Climate Change

EcoLife Dictionary defines *carbon emissions* as the release of carbon into the atmosphere. The increase in GHGs and atmospheric concentrations over the past 150 years warms the planet, contributing to changes in precipitation patterns, storm severity, and sea level and causing climate change (United States Energy Information Agency, 2021). In 2018, transportation sector emissions were the second largest contributor to global CO₂ emissions, next to the energy sector. In the Philippines, the transportation sector contributes to 34% of the total emissions, where 80% of it comes from road transport (TRANSfer, n.d.).

The Philippines, highly vulnerable to climate change and its impacts, is struck by around 20 tropical cyclones yearly and experiences daily seismic shocks and extreme flooding (Monjardin et al, 2019), affecting resources and livelihoods of many. These climate-related hazards had incurred an estimated USD 10 billion of losses from year 2010 to 2020 despite contributing only 0.3% of the total global GHG emissions (Philippine News Agency, 2021). A flood risk assessment focusing to both people (Gacu et al, 2022) and structures (Gacu et al, 2023) shows how vulnerable we are in the effect of climate change. Another study of (Realo et al, 2021) presented a lifeloss analysis during extreme weather events in a rural community which is basically a result of the effect of climate change.

Reducing Transportation Carbon Footprint

Local Sustainable Transportation and Modification of Vehicles

Metro Manila, one of the busiest regions in the country, corresponds to high carbon footprint production coming from the countless vehicles traversing the region. Effective land-use city planning should promote the use of public transit with more direct routes through common public destinations to allow less reliance on private vehicles. Creating transport infrastructure and implementing carbon dioxide standards in vehicles can improve fuel efficiency and mitigate more than half of transportation emissions. An alternative is substituting electric or biofuel-running vehicles for vehicular movement.

The Philippine government implemented the PUV Modernization Program (PUVMP), which replaces the old combustion public vehicles that contribute to around 94% of the soot particle mass, with electric-powered vehicles for sustainable emissions in the country's transport sector and to mitigate the poor air quality and reduce GHGs (Guno et al., 2021). The Department of Transportation (DOTr) also issued a project to convert old jeepneys into minibuses as part of the modernization program for better efficiency and model in the transport sector (Climate Action Tracker, 2019). Electric tricycle was also implemented in General Santos city to reduce gas emission which have been very effective in the region (Cueto et al, 2022).

The Paris Agreement

On December 12, 2015, the 21st Conference of the Parties (COP21) in Paris was held to reach a planned action to combat climate change. The United Nations Framework Convention on Climate Change (UNFCCC) Parties agree to invest in mitigations and projects for a sustainable low-carbon future. Its main goal is to prevent the irreversible consequences of the increasing global temperature by keeping the global temperature rise below 2°C above the pre-industrial levels.

United Nations Sustainable Development Goals

The United Nations (UN) has listed 17 Sustainable Developments Goals (SDGs). The goals were adopted during the UN's general assembly in 2015 as a call to action to end poverty, protect the planet, and achieve peace and prosperity by 2030. Specifically, SDG 13, "Climate Action," focuses on combatting climate change and its impact on the planet.

RESEARCH METHODOLOGY

This study is divided into five phases. Phase 1 accounts for the 12-hour traffic count at three stations along Zapote Street, Caloocan. The gathered data is then classified according to their purpose (public/private transport) and fuel type (gasoline/diesel). Phase 2 accounts for quantifying the average daily amount of carbon emissions of public and private transport using Equations 1 and 2 (Climate Change Commission, 2017).

$$\text{Part 1: Activity data} \times \text{Emission Factor} = \text{Tons of Emissions} \quad (1)$$

$$\text{Part 2: Tons of Emissions} \times \text{GWP} = \text{CO}_2 \text{ emissions} \quad (2)$$

The activity data is measured in terms of the liters (L) of fuel used, whereas fuel efficiency rates of 5 km/L of diesel and 8 km/L of gasoline were utilized. The study used 2.27 kg CO₂e/L of gasoline and 2.63 kg CO₂e/L of diesel (Cueto et al., 2022) as the emission factors and 1 as the global warming potential value of CO₂ based on the Intergovernmental Panel on Climate Change (IPCC).

Phase 3 accounts for analyzing the amount of carbon footprint emitted by vehicles through exploratory data analysis using Python. Multiple regression and correlation analysis is performed to investigate the relationship of the volume of emissions with the vehicle type, fuel type, and time of the day and how these predictor variables affect the volume of emissions. For multiple regression analysis, the study used the following null and alternative hypotheses:

H₀: The predictor variables (vehicle type, fuel type, and time of the day) do not affect the volume of emissions emitted into the atmosphere.

H_A: The predictor variables (vehicle type, fuel type, and time of the day) affect the volume of emissions emitted in the atmosphere.

Phase 4 accounts for formulating recommendations to reduce carbon emissions and integrate a sustainable transportation system in Zapote Street. CUTE framework describes different strategies and policies and determines the best action to reduce carbon emissions. It consists of three strategies: 1) reducing unnecessary trip demand (AVOID); 2) shifting travel to low-carbon modes of

transport (SHIFT); 3) improving the intensity of carbon-based transport (IMPROVE) (Nakamura & Hayashi, 2013). Existing transportation laws and policies for carbon emission reduction were reviewed and analyzed to design sustainable transport solutions that are more effective for the current environmental situation in Caloocan City.

Phase 5 then accounts for modeling transport emissions to assess the validity and efficiency of the formulated recommendations from Phase 4. The transport emission model was integrated with various frameworks that accounted for variable and policy changes for long-term forecasting.

ANALYSIS AND DISCUSSION

Classified Traffic Count

The accumulated traffic count in Zapote Street on a weekday and a weekend are shown in **Figures 2a** and **2b**. As seen in both figures, motorcycles account for the highest traffic count, followed by passenger cars and by jeepneys. Meanwhile, heavy trucks have the lowest traffic count, followed by UV Express and by bus.

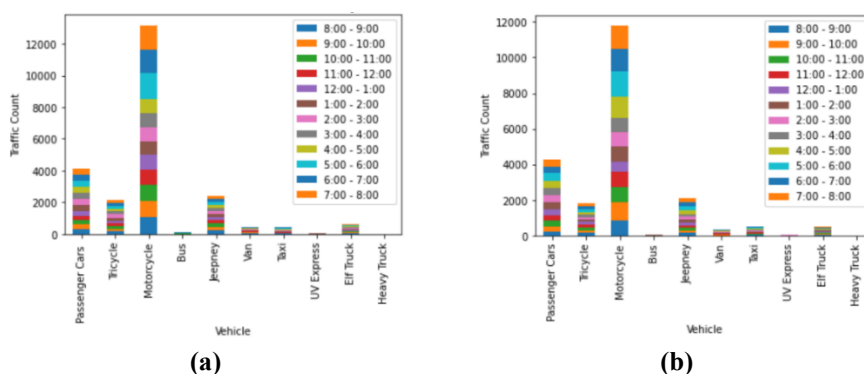


Figure 2: 12hr-Accumulated Traffic Count for a Weekday (a) and a Weekend (b)

Carbon Footprint of Vehicles

The 12-hr accumulated CO₂e emissions from private and public vehicles on a weekday and a weekend are shown in **Figures 3a** and **3b**. On weekdays, private vehicles contribute 686.27kg CO₂e per hour while public vehicles only contribute 243.71kg CO₂e. On weekends, private vehicles contribute 634.65kg CO₂e per hour while public vehicles only contribute 212.97 kg CO₂e. This depicts a vast difference between the emissions by private and public vehicles. Specifically, emissions from private vehicles are 281.59% and 298% higher than public vehicles' emissions on weekdays and weekends, respectively.

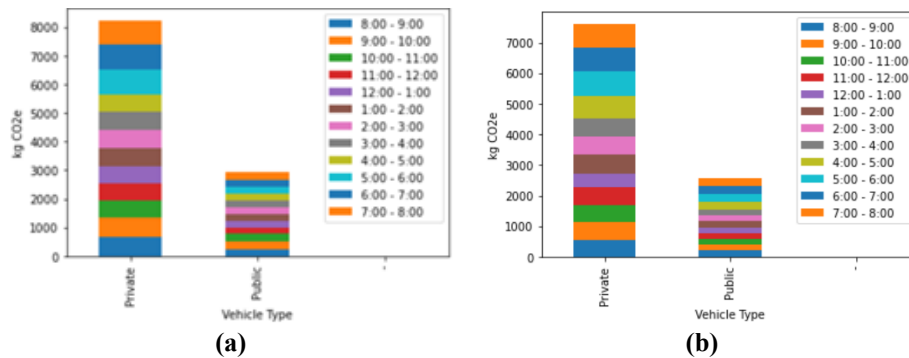


Figure 3: 12hr-Accumulated CO₂e Emissions on a Weekday (a) and on a Weekend (b)

Multiple Regression Analysis

To model transport emissions, the vehicle type, fuel type, and time of the day are used as predictors. Results of multiple regression analysis show that the Total Emissions can be predicted using Equation 3 and 4 for weekdays and weekends.

$$\text{Total Emission} = (203.1260) - (222.8488)X_{\text{Vehicle Type}} + (140.8395)X_{\text{Fuel Type}} + (4.7675)X_{\text{Time of the Day}} \quad (3)$$

$$\text{Total Emission} = (148.7002) - (210.2552)X_{\text{Vehicle Type}} + (134.3197)X_{\text{Fuel Type}} + (7.1682)X_{\text{Time of the Day}} \quad (4)$$

For both the weekday and the weekend, the vehicle type and fuel type have p-values less than 0.05 indicating that they affect the volume of emissions. Most vehicles passing through Zapote Street are private vehicles constituting approximately 78% of the total traffic count on both weekdays and weekends. Along with this, 77% of the vehicles passing the street are gas-powered vehicles. In contrast, the time of the day does not affect the volume of emissions.

Multiple Correlation Analysis

The correlation matrix of all the variables in the study is shown in **Figure 4**. This shows a strong association between the total emissions and vehicle type on a weekday and a weekend indicating that the rise in total emissions is strongly associated with the dependence on private vehicles. Moreover, a moderate and weak association is observed between the total emissions and fuel type on a weekend and a weekday respectively indicating that the number of total emissions is associated with using gas-powered vehicles. In contrast, a very weak to no association is observed in all other variables.

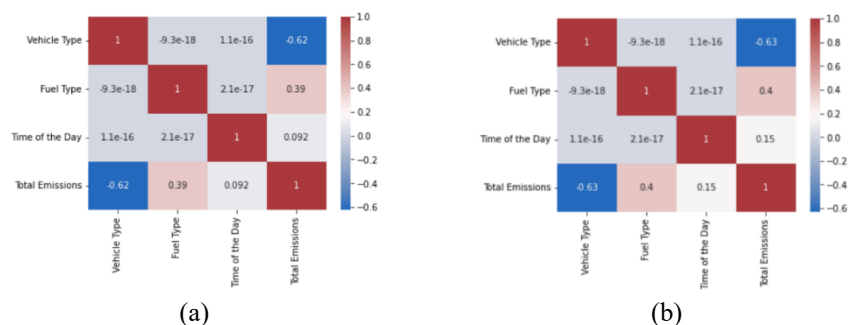


Figure 4: Correlation Matrix of Predictors for a Weekday (a) and Weekend (b)

Comparative study on Urban Transport and the Environment (CUTE) Framework

Table 1 shows the CUTE Framework, a review, analysis, and formulated recommendations for the existing traffic and environmental laws and ordinances in the Philippines.

Table 1: CUTE Framework

Existing Ordinance/Law	Flaws/Remarks	Recommendations
Section 141, Prohibited License Plate Ending under Article XXIV and Section 44, Vehicles Not to Be in Certain Areas under Article X of Ordinance No. 0391, s. 2005 – An Ordinance Providing for the Adoption of the New Traffic Management Code (North Caloocan City Hall, n.d.)	Adoption of Vehicular Volume Reduction Scheme was deemed ineffective in easing the traffic flow in Caloocan City as it only resulted in the addition of more private-owned cars on the road, contributing even more to the congestion. As for stopping and parking of vehicles, some PUVs take their time unloading, especially when not caught by the traffic enforcer, taking advantage of the situation, to wait and board more passengers. Private vehicles sometimes take their time also to unload passengers at <i>palengke</i> (wet market) and stores along the streets/roads that usually do not have parking spaces. Hence, disrupting the vehicular flow, leading to delays and traffic congestion.	Encourage the use of public and active transportation by i. including motorcycles in the implementation of the vehicular volume reduction scheme; ii. considering initiatives that will discourage Filipinos from purchasing private vehicles; iii. assigning specific roads/streets exclusive for public and active transport during peak hours; iv. integrating Intelligent Transport Systems for bus operations; v. building train infrastructure; vi. applying road congestion charging on major roads; vii. ensuring sufficient and well-designed loading/unloading stops, and viii. observing strict implementation of loading/unloading at designated stops.

Existing Ordinance/Law	Flaws/Remarks	Recommendations
RA 8749 – The Philippine Clean Air Act (DENR-EMB, 1999)	RA 8749 penalizes drivers violating the anti-smoke belching act by imposing fines ranging from Php 2,000 to Php 6,000. Still, 72.7% of the 282 vehicle emission standard violations from 2018 to 2019 were recorded by the Land Transportation Office (Lu, 2022). 88.3% of the apprehended drivers fell under the driving professional license category and violated the anti-smoke belching during daytime working and rush hours between 6 a.m. to 5 p.m.; In Cagayan de Oro City, reports state that more than 50% are non-compliant with the anti-smoke belching requirements (Philippine News.net, 2022)	Reduce the amount of smoke emitted by motor vehicles through regular maintenance and smoke emission tests. Since maintenance costs and other unexpected expenses can be financially burdensome for PUV drivers and operators, the government might consider providing financial aid for jeepney and bus operations (e.g., allowance for fuel and vehicle maintenance) Regarding penalties, impose progressive punishment and penalties by setting fines relative to the net worth of the offender and the severity of the offense committed.

Transport Emissions Model

The 'Traffic Volume Emission Projection' (TVEP) is a static transport emission model system with a top-down emission structure that strategically projects the estimated amount of CO₂e emission to determine the efficiency of implemented local laws and policies in reducing the CO₂e emission in the area. It relies on adjustment parameters and only covers motor land vehicles running on fuel. It also projects the average kg CO₂e per hour emission from the given traffic count data and uses user-supplied inputs depending on the mitigations and changes to be applied for the projections. Furthermore, the transport model can be adapted nationally to project future conditions onto a larger area.

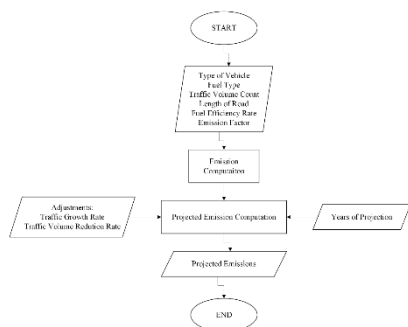


Figure 5: Traffic Volume Emission Projection (TVEP) Algorithm

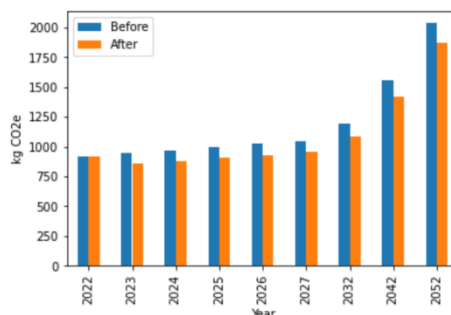


Figure 6: Projected CO₂e Emission in Zapote Street Before and After Implementing the Recommendation of No Exemption of Motorcycles in the Number Coding of Caloocan

Figure 5 shows the algorithm of TVEP and accordingly, the amount of CO₂e emission before and after implementing the recommendation of “no exemption of motorcycles in Caloocan” in the number coding scheme is projected. As shown in **Figure 6**, there will be a decrease of 87.19, 106.34, 132.59, and 164.72 kg CO₂e per hour corresponding to 9.68, 9.33, 8.91, and 8.43 percentage difference in 2023, 2032, 2042, and 2052 respectively, after implementing the recommended policy changes.

CONCLUSION

This study was able to determine the average hourly amount of carbon footprint contributed by private and public vehicles along Zapote Street to be 686.27 and 243.71 kg CO₂e, respectively, on weekdays, and 634.65 and 212.97 kg CO₂e respectively on weekends through a 12-hr traffic count and carbon footprint calculation. Accordingly, exploratory data analysis showed that only the vehicle type and fuel type affect the volume of emissions, and that there is a strong association between the total emissions and vehicle type and a moderate to weak association between the total emissions and fuel type. Through the CUTE Framework the UVVRP in Caloocan City was deemed ineffective as it only resulted in additional private vehicles on the road and increased road congestion. This raises a great need for an improved public transport system to encourage Filipinos to shift to using public transportation services. Furthermore, the Traffic Volume Emission Projection model projects a decrease of 87.19 kg CO₂e per hour in 2023 and 164.72 kg CO₂e per hour by 2052 resulting from the 20% reduction in volume upon the implementation of the "no exemption of motorcycles" in the number coding scheme of Caloocan city.

From the conclusions drawn, future researchers are recommended to conduct air quality testing or choose a location where a CO₂ analyzer is available to provide supplementary data. Moreover, for easy and efficient data gathering, the researchers recommend using or developing a program that enables the determination of the age and model of the vehicles for fuel type classification, and whether they follow Euro 4 standards.

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