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Original Article

개발도상국의 교통수단이 대기 질 및 탄소배출에 미치는 영향: 미얀마를 중심으로

Impact of Transportation on Air Quality and Carbon Emissions in Developing Countries: A Case of Myanmar

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ABSTRACT

Purpose: The purpose of this study is to analyze air quality and carbon emissions in developing countries, particularly Myanmar, and explore the impact of transportation on CO2 emissions during peak hours relative to free-flow conditions. **Method:** This study conducted a traffic survey in two major cities in Myanmar to quantify carbon dioxide emissions from the transportation sector, using IPCC's tier 1 and tier 2 approaches, with statistical analysis performed using Python 3 and Microsoft Excel for comparative analysis of critical factors in CO2 emissions. **Result:** The result of this study is an estimate of the vehicle kilometers traveled (VKT) and fuel consumption in Yangon city for the year 2019, based on data from various sources including the Myanmar Statistical data base, YUTRA project survey, and Ministry of Electric and Energy. The study also analyzes the average travel time index (TTI) for the four roads in Yangon, which indicates the impact of congestion on vehicle travel time and CO2 emissions. Overall, the study provides important insights into the transport sector in Yangon city and can be used to inform policies aimed at reducing greenhouse gas emissions and improving traffic conditions. **Conclusion:** The study concludes that congestion plays a significant role in increasing fuel use and emission levels in the road transport sector in Myanmar. The analysis provides valuable insights into the impact of the sector on the environment and emphasizes the importance of addressing congestion to reduce fuel use and emissions. However, the study's scope is limited to Yangon city and Mandalay city, and some mean values may not accurately represent the entire country and other developing countries.

Keywords: Public Transportation, Air Pollution, Myanmar, Traffic Data, Developing Countries, Sustainable Development, Policy Makers

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Introduction

The transportation sector is a significant contributor to air pollution and greenhouse gas emissions, particularly in developing countries where there is a high dependency on private modes of transportation such as cars and motorcycles. Despite this, public transportation is not popular in many developing countries, leading to traffic congestion and further exacerbating air pollution. This study aims to analyze the air quality and carbon emissions in developing countries, with a particular focus on Myanmar. As a country with a moderate Human Development Index, Myanmar presents a unique case for examining the impact of transportation on air quality.

Myanmar is the second largest country in Southeast Asia after Indonesia, with a total land area of 261,228 square miles (677,000 square kilometers). Most of these areas in Myanmar are mountain ranges, hills, and valleys. As a result, it is difficult to travel, and the infrastructure, including transportation, remains poor. Myanmar has about 55 million people racially. Among them, 10% of Myanmar's population lives in Yangon. Air pollution is a serious issue in many urban areas, including Myanmar's urban areas where infrastructure is coarse due to rapid urbanization. Public transportation, including buses, trains and other public transportation, is an essential part of many urban transportation systems. But it is not always clear how public transportation affects air pollution levels.

This study investigates the levels of carbon emissions from both the private and public sectors in Myanmar, and also analyze the effect of traffic congestion on CO2 emissions during peak hours compared to free flow conditions. The findings of this study will contribute to the understanding of the relationship between transportation and air quality in developing countries and can be used by policymakers to reduce carbon emissions and improving air quality.

Literature Review

Various studies have explored the negative impact of private transportation modes on traffic congestion and air pollution in developing countries. For example, a study by Nsowah-Nuamah et al.(2021) analyzed the relationship between car ownership and air pollution in Ghana, a developing country in West Africa. The study found that the increase in the number of cars on the road significantly contributed to air pollution in Ghana. Similarly, another study by Saqib et al.(2021) explored the use of motorcycles in Pakistan, a developing country in South Asia, and its impact on traffic congestion and air pollution. The study found that the increase in the number of motorcycles on the roads significantly contributed to traffic congestion and air pollution in Pakistan. In terms of public transportation, a study by Chaurey et al.(2018) explored the use of electric buses in India, a developing country in South Asia, and their impact on reducing carbon emissions. The study found that the use of electric buses significantly reduced carbon emissions and could be a sustainable transportation option for developing countries. Another study by Yang et al.(2019) analyzed the use of bus rapid transit (BRT) systems in China, a developing country in East Asia, and their impact on reduction of traffic congestion and air pollution. The study found that the implementation of BRT systems significantly reduced traffic congestion and air pollution in Chinese cities. However, despite the availability of public transportation options, people in developing countries tend to avoid them due to various reasons such as inconvenience, unreliability, and safety concerns. Thus, policymakers in these countries need to address these issues to encourage the use of public transportation and reduce the reliance on private modes of transportation.

Materials and Method

The aim of this study at quantifying greenhouse gases, especially carbon dioxide from the transport sector in two major cities of Myanmar. Other GHGs such as methane and nitrous oxide have not been considered in this study, as their contribution has been observed to be less than 2% of global GHG emission from the road from the road and transport sector. IPCC suggests two standard approaches for calculate of CO2 emission from transportation .i.e tier 1 which is a fuel consumption based approach and tier 2 which depends upon vehicle kilometer travelled by each category of vehicle. Data was gathered through a traffic survey within the selected . Statistical analysis of the data was performed using Python 3 (ipykernal) and presented on Microsoft Excel. The comparative analysis to determine the critical factors in CO2 emissions.

Congestion Survey on Pyay Road in Yangon and 26th Road in Mandalay

The parameter used in this study to quantify congestion is travel time index (TTI). This parameter depends on the time required for a vehicle to cross a given section of road during peak traffic hours. In this study, the most useful and main road in Yangon, it is Pyay road, as well as along the 26th Road in Mandalay are selected as case study. Pyay road is a major thoroughfare of Yangon. It crosses the western-central side of the city in a north–south direction. It contains many important buildings, including banks, hospitals, several government buildings, various television and radio stations, including the National Museum, the old National Parliament building, People's Square and Park, Myanmar Radio and Television Building, Junction Square, Yangon University, and leads up to Inya Lake. This road carry significant traffic load through CBD and experience frequent visible traffic congestion and jams. The selected road has 3 or more lanes in each direction. Motorcycle banned by government in CBD since 2003. Most of the traffic comprised of passenger cars and public buses. Owing to availability and afford ability, the modes of transport chosen to estimate the TTI were private car and public bus.

Origin and destination points were kept as bus stops to allow for exact time and distance measurement even when travelling by public bus. Private car’s calibrated electronic meter was used to measure the distance between the origin and destination points which was further verified using Google maps. The time of survey for the roads was chosen so as to coincide with their peak and off-peak time flow which was identified based on the traffic count data from the YUTRA 2015 report. Table 1 shows name of road with are intersection to Pyay road.

Table 1. Origin and destination points chosen for traffic survey trips in Yangon

Name of Road	Origin	Destination	Distance travelled(km)
Pyay Road	KhayaePin Junction	SawByarGyi Junction	4.46
	SawByarGyi Junction	8mile Junction	3.51
	8mile Junction	Hledan Junction	4.76
	Hledan Junction	BoGyoke Junction	5.29

For each mode, two trips each were made during the peak and off-peak time. The peak hour data was collected on working days while the off-peak data was collected on weekends. The travel time index was calculated as the ratio of peak to off-peak time taken to travel the given section of the road. Fig. 1 and Fig. 2 show the case study area by map.

For the case study, the traffic volume survey is taken from Civil Engineering Department of Mandalay Technological University in 2019 by manually counting method at the main junction along 26th road. According to city characteristics of Myanmar policy, the designed speed of road is assumed to be 48 kilometre per hour.

Fig. 1. Pyay road in Yangon

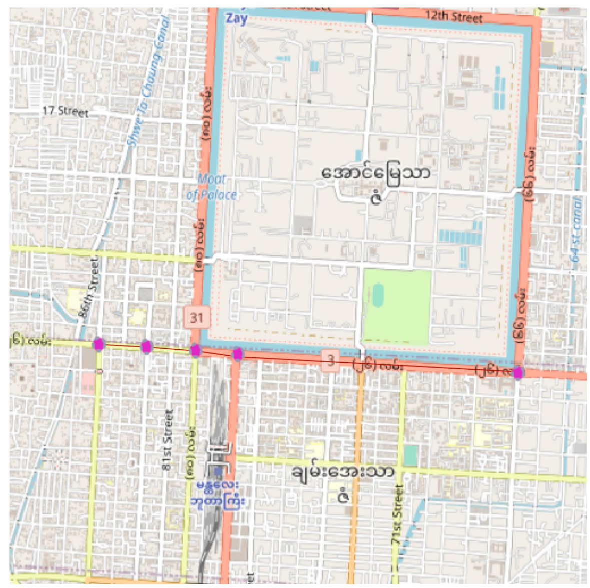

Fig. 2. The 26th road in Mandalay

Results

Vehicle population data for Yangon in (Fig. 3) obtained from Myanmar Statistical data base (MMSIS). Then, the average trip length of vehicles per day for the year 2010 for each category of vehicle was obtained from the Comprehensive Transportation Study report for Yangon city or YUTRA project survey 2015 report. The average trip length of vehicles per day for the year 2019 was assumed same as that in 2015, as no major land-use changes had been made for Yangon during this time period.

Further, it was assumed that number of trips (vehicle category-wise) made per day was proportional to the vehicle population in the region. The vehicle population and number of trips in Yangon made in the year 2011 were obtained from the YUTRA report. This was then used to arrive at the number of trips made in 2015 (Table 2)based on the proportion of vehicle population in 2011 and 2019(Table 3) and then multiplied with the average trip length to arrive at the VKM for the year 2019 for Yangon.

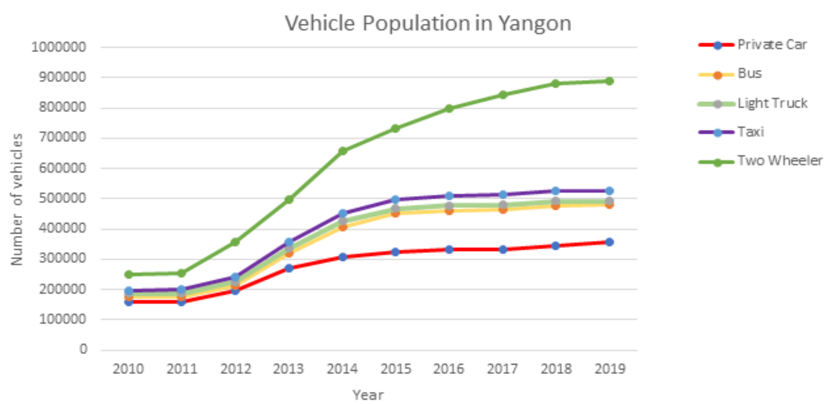

Fig. 3. Vehicle in Yangon from 2010-2019

Table 2. Average trip length of vehicle in 2010

Type of Vehicle	Average trip length in km per day
Private car	8.9
Bus	12
Two wheeler	4.3
Truck	6
Taxi	7.1

Source: YUTRA project report

Table 3. Vehicle kilometre travelled data of each category of vehicle for the year 2015 in Yangon

Mode of transport	Vehicle kilometre travelled for the year 2015
Private car	4713832
Bus	38742384
Two wheeler	2026959
Truck	529194
Taxi	3561992

Source: YUTRA project report

Fuel consumption

Data for fuel consumption in Yangon has been obtained from Ministry of Electric and Energy (MOEE) (Table 4). In Yangon city, there were 5,533,776 registered motor vehicles in 2019. Motors are operated with Premium Diesel, Diesel, Octane 92 Rom, Octane 95 Rom, Gasoline and natural gas (CNG). In Yangon city fossil fuels are imported and compressed natural gas (CNG) is obtained from local resources.

Table 4. Fuel consumption based emission factors for each type of fuel at Yangon Region,2019

Fuel Type	Net Calorific Value (Liter or cu ft)	CO2 (kg/l or kg/cu ft)
Gasoline/Petrol	559953079	2.272
Diesel	360764214	2.676
CNG	8302998048	0.053

Source: Myanmar Oil and Gas Enterprise data

This vehicle category- wise emissions factors(gm/km) calculated the total CO2 emissions by multiplying the travel distance with DEFRA emission factor for each type of vehicle. The guidelines developed by the United Kingdom Agricultural Engineers Association for the Department of Energy and Climate Change (DECC) and the Department of Environment, Food and Rural Affairs, United Kingdom (DEFRA) to calculate CO2 emissions by using equation (1).

$$Total\ Carbon\ Emission\ (kg\ CO_2 eq) = \ Travel\ Distance\ (km) \times Emission\ Factor\ (kg\ CO_2 eq/km) \quad (1)$$

Table 4 shows the emission factor for vehicles with different engine capacities and fuel types. As an example, the emission factor for a respondent commuting with a petrol car with a 1.6L engine is 0.21280 kg CO2 eq/km.

Table 5. Emission factor for each mode of transportation

Mode of Transportation	Type of Fossil Fuel	Engine Size Capacity	Emission Factor (kg CO2 eq/km)
Car	Petrol	1.4L	0.17985
		1.4L-2.0L	0.21280
		2.0L above	0.29549
	Diesel	1.7L	0.15095
		1.7L-2.0L	0.18757
		2.0L above	0.25580
Motorcyle	Petrol	125cc	0.08499
		125-500cc	0.10316
		500cc above	0.13724
Bus	Disel	-	0.10351

Source: DEFRA

Carbon dioxide emissions from private and public transport sector

The study aims at quantifying greenhouse gases, especially carbon dioxide, from the transport sector in Yangon. Following Table were the CO2 emissions obtained for the road transport sector in Yangon from the descriptive analysis identified low carbon dioxide emissions per capita by each vehicle. The mean annual emission was compared with the national emission provided the Ministry of Electric and Energy (MOEE), Myanmar and the mean emission in high-income countries.

Table 6 shows the mean annual carbon dioxide emissions (Kg CO2/year/capita)for each type of vehicle relative to those of the mean national carbon dioxide emission and the mean value for high income country. Petrol cars with engine capacity larger than 2.0Lhave the highest mean annual emission, (1269.0932 kg CO2/ year /capita), followed by petrol motorcycle with the engine capacity larger than 500cc (967.1072 kg CO2/year/capita). It is worth noting that the high mean values both transportation modes may not be accurate and not represent the whole country of Myanmar because the designed location is Yangon city which has banned law of motor cycle. Relative to other categories of cars, petrol cars with 1.4L- 2.0L engine have the second-highest mean emissions of 754.6531 kg CO2/year/capita. In the case of petrol motorcycles, those with 125-500 cc engine emitted the second-highest amount of carbon dioxide of 340.5421 kg CO2/year/capita. Bus passengers emitted only 4.5806 kg CO2/year/capita. Generally, the mean annual CO2 emissions (kg CO2/year/capita) for all vehicles are lower than the national mean carbon dioxide emissions (8000 kgCO2/year/capita) and the mean carbon dioxide emission in high-income countries (5400 kg CO2/year/capita).

Table 6. Mean annual emissions of Carbon dioxide by mode

Transportation	Fuel type	Engine size capacity	Mean Carbon Dioxide (CO2) annual (kg CO2/km)
Car	Petrol	1.4L	553.6632
		1.4L-2.0L	754.6531
		2.0L above	1269.0932
	Diesel	2.0L above	409.048
Motorcyle	Petrol	125cc	193.1416
		125-500cc	340.5421
		500cc above	967.1072
Bus	Disel	-	4.5806

Mean CO2 emission Myanmar= 8000kg/CO2/km

Mean CO2 emission for high income country= 5400kg CO2/km

Carbon dioxide emissions during peak hours and traffic congestion.

Pyay Road in Yangon

The average travel time index (TTI) for the four roads in Yangon Table (7,8,9,10) was found to be 1.58, 1.5, 1.865, and 1.19, with an overall average of 1.53 for Pyay Road. This indicates that vehicles take approximately 51% more time to complete their trips in congested conditions than in free-flow conditions. Additionally, the CO2 emissions calculated using the fuel consumption method were found to be approximately 53% higher than those calculated using the vehicle kilometer traveled (VKT) method. Therefore, the TTI provides a reasonable indication of the share of CO2 emissions from the transport sector due to congestion, as congestion represents a situation where fuel combustion occurs without a significant increase in VKT. Based on these observations, it can be inferred that the above statement is roughly correct.

Table 7. Travel time in peak and off peak hour and corresponding travel time index first road

Trip Number	mode of travel	Distance travelled (km)	Time taken durning peak hour (minute)	Time taken durning off peak hour (minute)	Average travel time distance
Trip 1	Private Car	4.46	15.0	11.0	1.36
Trip 2	Car	4.46	15.0	7.0	
Trip 3	Bus	4.46	27.0	15.0	1.8
Trip 4	Bus	4.46	27.0	12.0	

Table 8. Travel time in peak and off peak hour and corresponding travel time index in second road

Trip Number	mode of travel	Distance travelled (km)	Time taken durning peak hour (minute)	Time taken durning off peak hour (minute)	Average travel time distance
Trip 1	Private Car	3.51	17.0	10.0	1.7
Trip 2	Car	3.51	15.0	10.0	
Trip 3	Bus	3.51	26.0	20.0	1.3
Trip 4	Bus	3.51	25.0	19.0	

Table 9. Travel time in peak and off peak hour and corresponding travel time index in third road

Trip Number	mode of travel	Distance travelled (km)	Time taken durning peak hour (minute)	Time taken durning off peak hour (minute)	Average travel time distance
Trip 1	Private Car	4.76	25.0	10.0	2.5
Trip 2	Car	4.76	20.0	10.0	
Trip 3	Bus	4.76	37.0	30.0	1.23
Trip 4	Bus	4.76	28.0	25.0	

Table 10. Travel time in peak and off peak hour and corresponding travel time index in last road

Trip Number	mode of travel	Distance travelled (km)	Time taken durning peak hour (minute)	Time taken durning off peak hour (minute)	Average travel time distance
Trip 1	Private Car	5.29	20.0	15.0	1.3
Trip 2	Car	5.29	17.0	13.0	
Trip 3	Bus	5.29	37.0	34.0	1.08
Trip 4	Bus	5.29	35.0	33.0	

The 26th road in Mandalay

The study area is downtown area having moats, shopping centers, hotels and banks along the 26th road. These junctions are the 26th x the 66th, the 26th x the 78th, the 26th x 80th, the 26th x the 82nd and the 26th x the 84th. The traffic volumes are counted for eight hour periods of 7:00 AM to 11:00 AM and 3:00 PM to 7:00 PM. From this study, it is found that peak traffic volume is occurred at the period of 8:00 AM to 9:00. This peak volume is used to design the signal timing. Actual cycle length of designed junctions are obtained as 83 seconds, 77 seconds ,122 seconds, 76 seconds, 75 seconds respectively. Table 11 is Traffic Survey on 26th Road in Mandalay.

Table 11. Traffic volume of survey on 26th road mandalay

Type of vehicle	Junction	Traffic Volume							
		7:00-8:00	8:00- 9:00	9:00-10:00	10:00-11:00	3:00-4:00	4:00-5:00	5:00-6:00	6:00-7:00
Car	26th x 66th	3317	3984	3488	3313	3289	3100	3360	3332
	26th x 78th	3362	4094	4049	3494	3269	3569	3402	2992
	26th x 80th	4267	5273	4472	4672	3289	4250	4609	4165
	26th x 82nd	2900	4087	2814	2972	2846	3027	3066	2435
	26th x 84th	3320	4087	3307	3205	2958	3258	2776	2293
Motorbike	26th x 66th	8313	9365	7604	7110	6782	6488	7057	6721
	26th x 78th	3874	4482	3627	3986	3491	3888	3519	2659
	26th x 80th	912	11528	6992	7543	6782	6673	8444	15
	26th x 82nd	4807	6104	5269	5053	4279	4736	4230	3989
	26th x 84th	5880	6319	5659	5042	4873	5499	5640	5082

Conclusion

The study examines the energy consumption and greenhouse gas emissions from the road transport sector in Myanmar. The study also highlights the significant role played by congestion in increasing fuel use and emission levels. The travel time index, which is a reasonable indicator of congestion, was found to be 1.51 for Yangon. The scope of this analysis is limited to the mean annual carbon dioxide emissions for each type of vehicle in Yangon, Myanmar. The analysis compares the mean emissions of each vehicle category with the mean national carbon dioxide emission and the mean value for high-income countries. However, it is worth noting that the high mean values for petrol cars with an engine capacity larger than 2.0L and petrol motorcycles with an engine capacity larger than 500cc may not accurately represent the whole country of Myanmar because the study location is limited to Yangon city, which has a ban on motorcycles. Nonetheless, the study provides valuable insights into the road transport sector's impact on the environment and highlights the importance of addressing congestion to reduce fuel use and emissions.

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