Road Transportation Program: A Proposed Urban Heat Mitigation Strategy in Angeles City, Pampanga

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Abstract: - Escalating temperatures and the rising heat index have induced implications in urban regions and their occupants. There is a global action to limit the increase of temperature by 1.5° C and in line with this is to cut the gas emission. Thus, this study was conducted entitled "Road Transportation Program: A Proposed Urban Heat Mitigation Strategy in Angeles City, Pampanga". The researchers aimed to propose a heat reduction strategy through road transportation solutions by assessing the heat perception of road users as well as determining and projecting the amount of carbon dioxide (CO_2) tailpipe emissions from road vehicles in different scenarios. The research design was mixed-method research to obtain qualitative and quantitative data. 100 road users which consist of passengers, drivers, and pedestrians in MacArthur Highway, Angeles City responded to the survey, while engineers from Angeles City Hall and the Department of Environment and Natural Resources were interviewed. The qualitative data were transcribed and analyzed. The researchers utilized the Likert scale, average mean, CO_2 emissions formula, and relative change to treat the quantitative data. Accordingly, results indicated that road users felt warm when taking the highway. Moreover, projecting CO_2 emissions from road vehicles reveals that the shifting of passengers to zero-emission modes of transportation has the highest percentage decrease in emissions with 83.92%, followed by shifting of public transportation with 18.37%. Vehicle volume reduction shows a notably lower impact on reducing emissions. This is the first phase of the program and future researchers could study the viability of implementing the proposal.

Key Words: — *Road Transportation Program, Urban Heat Mitigation Strategy, Heat Perception, CO_2 Tailpipe Emission, Mixed Method Research, Vehicle Volume Reduction.*

I. INTRODUCTION

Global warming is a hiking atmospheric predicament caused by the accumulation of high concentrations of greenhouse gasses (GHG) and other air pollutants. It raises the temperature and intensifies the heat index in the local setting. This affects the thermal comfort of dwellers and challenges the institution's resiliency to the implications of this phenomenon. Different parameters of the contributions to rising atmospheric temperature were assessed and recent reports are primarily focused on urban regions where mainstream anthropogenic activities occur.

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Thus, it outreaches the perspective of the transportation sector associated with the causes and reducing factors of global overheating.

Due to the continuous production of different types of atmospheric pollution, adverse changes in climatic conditions became a paramount challenge. The average global temperature has increased by 0.85 °C since the early 20th century (Stocker, 2013). Relative to the annual heat emission, the future trend in global temperature by the end of the 21st century is projected to reach at least 1.1 °C up to 5.4 °C warmer than the average temperature of the past century as stated by the United States Global Change Research Program (USGCRP, 2017). Evidently, rapid urbanization has contributed to the intensive warming of the atmosphere due to the exertion of multiple anthropogenic activities. Its significant effect is the formation of Urban Heat Island (UHI), defined as cities that experience warmer temperatures than their surrounding areas. The future trends in static air temperature (SAT) in metropolitan areas will further exacerbate the implications of health risks (IPCC, 2014). As a consequence, these implications of heat waves in human health and the environment have an equivalent value of cost (Tong et al., 2021). According to the study by Wade and Jennings (2016), global warming would increase operational expenses, which would impede the global economy and might result in a 1% decline in GDP growth annually in the worst-case scenario. These require actions to reduce the heat induced by human activities. In due course, the United Nations announced their 17 Sustainable Development Goals (SDG) that incorporate all their plans needed to be established and addressed by 2030. Climate action is listed, and it includes interventions to reduce carbon dioxide (CO2) emissions and global warming. In addition to this, 196 countries signed a treaty called the Paris Agreement in 2015 to collectively reduce the emission of GHG and limit the increase of temperature in 2030 by 1.5 °C (UNFCCC, 2022).

Undoubtedly, one of the apparent contributors to releasing a large amount of GHG is the transportation sector which accounts for 24% of global emissions (Ritchie, 2020). Furthermore, increasing demand for transportation consequently raises the temperature through using natural gas vehicles. The combustion of gasoline and diesel in vehicles produces toxic pollutants. The most prevalent GHG released by vehicles is carbon dioxide; about 95-99% of the emission is composed of CO2 (USEPA, 2018). According to the data gathered by Tiseo (2022), transportation accounted for about 8.43 billion metric tons of global CO2 emissions in 2019, out of the types of transportation, road vehicles have the largest share in generating CO2. Heat mitigation actions in the field of transportation are usually applied on a city scale where mobility is higher and traffic congestion exists (Ivanchev, 2017).

In the Philippines, the transportation sector produced 32 million metric tons of CO2 in 2021 (Knoema, 2022). Considering the increasing demand for transportation, the expected range of CO2 emissions from road vehicles in the country for the years 2025 to 2034 will be 55 to 90 metric tons (Fabian & Gota, 2014). This contributes to the increase in local temperature. Currently, UHI has been detected in Metro Manila, the most urbanized area in the country (Oliveros et al., 2019). As an action to this, the government has been planning to decentralize Metro Manila and targeting to develop centers in other metropolitan areas. As per the National Economic and Development Authority (NEDA), one of the primary considerations of urban development in the country is Angeles City located within the province of Pampanga.

Angeles City is considered a highly urbanized area and it administered various modes of mobility. In 2019, the average daily traffic volume of motor carriers or motor vehicles in Angeles City, Pampanga amounted to approximately 371, 434 vehicles. As stated by the UN-Habitat (2022), 18.37% of the greenhouse gas emissions in the city are reported to originate from internal combustion engines in 2017. Moreover, altering the natural setting in the city to infrastructure has led to warming temperatures perceived in the area. As per Philippine Atmospheric, Geophysical Astronomical Services Administration (PAGASA), the highest recorded heat index in 2023 in the city is 43 °C which is classified as a dangerous level. The study of Estoque et al. (2020) examined the heat health risk index (HHRI) of 139 cities in the Philippines and the data shows that twenty-five (25) cities, including Angeles City, are at high to very high risk.

It is known that global warming and UHI are adverse events that concern the inhabitants and urban conditions. These phenomena should be addressed to limit their detrimental impacts. As a result, the researchers intend to participate in the heat mitigation action of local government units to sustain the resiliency of Angeles City in urban heating. The researchers aim to provide data and propose a road transportation program as a possible solution to mitigating the warming of the city by assessing the heat perception of locals and estimating the CO2 emissions from road vehicles in the city.

II. METHODOLOGY

The mixed method was used as the study's research design. Additionally, the strategy aforementioned assisted researchers in studying transportation solutions and measuring the parameters in heat reduction strategies. The quantitative aspect was used to determine road users' standpoints in terms of their heat perception. The outcomes were on a scale and close-ended questions, allowing the researchers to obtain statistical data. With this approach, the CO_2 emissions of road vehicles in the city were also determined. On the other hand, the qualitative approach was utilized in the critical analysis of existing studies about transportation solutions that were used in projecting carbon emissions in the city. Likewise, it constitutes a semi-structured interview with the credible city's local government officials. Semi-structured interviews collected data by utilizing predetermined questions that could be adjusted based on the flow of the conversation.

Moreover, the study was conducted in Angeles City, Pampanga, Philippines. This city has been reported to experience the UHI phenomenon (Dumalingan, 2019). It has a total area of 60.27 square kilometers that consists of thirty-three (33) barangays. It has road networks linking intra-city and inter-city regions. However, the main study area where data was collected is along the road of MacArthur Highway (R-9), Angeles City, Pampanga. It is also called Manila North Road and has an approximately 5.485 km road length which links inter and intra-city regions. To illustrate, two sections of the highway were determined by the researchers based on the traffic count data of the road. Section A is from K0082 + (-751) to K0083 + 605 which has a total of 2.264 km, while Section B has a road length of 3.221 km and is from K0083 + 605 to K0086 + 740. As reported by the 2021 traffic counting of DPWH, the road tallies an annual average daily traffic (AADT) of 24, 646 on the first sections of the road (section A) and 45, 912 on the latter sections (section B).

Fig.1. MacArthur Highway, Angeles City, Pampanga
Source: Google. (2023). Google My Maps [Web application]. Retrieved May 05, 2023.

The road users along MacArthur Highway were assessed regarding their heat perception when taking the road in the said area. Subsequently, with an unknown population, the sample size was computed through the use of G*Power software. It is a credible software used for computing statistical data and is known for estimating sample size (Kang, 2021).

Whereas:

Test Family = t-test
Significance level (α) = 1%
Effect size (d) = Medium
Power (1-β) = 95%

The sample size of 100 was calculated as the number of needed participants in the survey. Stratified random sampling was used to select respondents from the sample size, and they were divided into groups based on certain characteristics. The groups were classified as passengers, pedestrians (including cyclists), and drivers. To ensure an equal number of participants in each stratum, the sample size was equally divided: thirty-four (34) passengers, 33 drivers, and 33 pedestrians.

Concurrently, the researchers used a survey checklist to assess the heat perception of road users along MacArthur Highway. For this purpose, topics of the questions are about how the participant experienced the temperature with their daily trip and mobility in the study area. The survey form consisted of questionnaires regarding the perceived heat of road users in terms of walking on the sidewalks, cycling, and riding a vehicle. Furthermore, the researchers performed a one-on-one interview with the CPDO and EMB officers to gather information about the climate condition and transportation solutions. Whereas, the interview questions consisted of open-ended questions that were created prior to the interview but could still be modified during the interview. The questions were about climate conditions and action, cooperation with other government agencies/units, and feedback on the proposed transportation program.

On the other hand, the Likert scale was a scale used to rank the response of participants from the given questionnaire. As a result, the Likert Scale offered five potential responses to a statement and was utilized in the questionnaire. Furthermore, the Bedford scale (Table 2) is adapted in this paper to interpret the data computed from the responses in the survey.

Table.1. The Heat Perception Level of Road Users

Rating	Descriptive Level
5	Strongly Agree
4	Agree
3	Neutral
2	Disagree
1	Strongly Disagree

Table.2. Interpretation of the Heat Perception

Range of Mean	Interpretation
4.51-5.00	Strongly Agree
3.51-4.50	Agree
2.51-3.50	Neutral
1.51-2.50	Disagree
1.00-1.50	Strongly Disagree

Table.3. The Scale of the Heat Perception of Road Users

Scales	Weighted Mean	Remarks
5	4.21 – 5.00	Hot
4	3.41 – 4.20	Warm
3	2.60 – 3.40	Neutral
2	1.81 – 2.60	Cool
1	1.00 – 1.80	Cold

To get the average rating from the quantified responses of the participants, the researchers used the formula for mean. According to Bhandari, P. (2022) the mean is the sum of all the values divided by their total, and it is commonly used to measure the central tendency of the data set.

Formula:

$$\bar{x} = \frac{\Sigma X}{N}$$

Where:

x = Mean
ΣX = summation of all data values
N = total number of populations

2.1 Carbon Dioxide Emissions Formula

It was used to calculate the amount of tailpipe carbon dioxide emitted from the vehicles. An average standard value required in the formula was used. USEPA (2022) presented a formula to estimate the carbon dioxide emitted using the consumed fuel of the vehicle.

2.2 Formula for Passenger Vehicles:

$$ECO_2 = \sum (\frac{EF}{MPG} \times D)$$

Where:

$E\ CO_2$ = carbon dioxide emissions equivalent (grams)
EF= emission factor (grams CO_2 / gallon)
MPG= miles travelled by vehicle per gallon of fuel
D= distance traveled (miles)

Formula for Freight Vehicles:

$$E\ CO_2 = \sum (EF \times D \times W)$$

Where:

EF= emission factor (grams CO_2 / miles)
D= distance traveled (miles)
W= weight (pounds, kg, or tons)

The emission factors (EF) are from USEPA National Program Fuel economy standards that indicate the emission based on the activity of vehicles. It is categorized based on the type of fuel used that is burned when using vehicles. The passenger vehicle consists of a 2-axle and 4-tire. Meanwhile, trucks are considered freight vehicles for road transportation.

Table.4. Emission Factor for Passenger Vehicles

Fuel Type	Emission Factor (grams CO_2/ gallon)
Gasoline	8, 887
Diesel	10, 180

Note. Reprinted from *Greenhouse Gas Emissions from a Typical Passenger Vehicle* (p1), by U.S. Environmental Protection Agency, 2018.

Table.5. Emission Factor for Freight Vehicles (Trucks)

Category	Functional Unit		Emission Factor	GHG Included
All	grams per mile	Distance	1, 700	CO_2
Dray	grams per mile	Distance	1, 750	CO_2
Expedited	grams per mile	Distance	1, 200	CO_2
Flatbed	grams per mile	Distance	1, 800	CO_2
Heavy Bulk	grams per mile	Distance	2, 000	CO_2
LTL Dry Vans	grams per mile	Distance	1, 625	CO_2
Mixed	grams per mile	Distance	1, 700	CO_2
Refrigerated	grams per mile	Distance	1, 750	CO_2
Tanker	grams per mile	Distance	1, 750	CO_2
Truck-load Dry Vans	grams per mile	Distance	1, 700	CO_2

Note. Reprinted from *The Green Freight Handbook* (p 11), by Mathers et al., n.d.

The miles traveled by vehicles for every 1 gallon of fuel were computed using the average fuel consumption data from Clean Air Asia (2012, 2015). Presented in Table 6 is the fuel economy in the Philippines. From this, the values were converted into miles per gallon.

Table.6. Fuel Economy of Road Vehicles

Vehicle-Fuel Type	Fuel Economy (L/100 km)	Fuel Economy (mi/ gal)
Passenger Cars		
Diesel	9.9	23.76
Gasoline	6.2	37.94
Light Commercial Vehicles		
Diesel	11.2	21.00
Gasoline	9.4	25.02
Bus (Diesel)	27.8	8.47

Note. Presented in the table is the fuel economy that is rounded to the nearest hundredths. The values used in CO_2 estimation are the exact values of fuel economy in mi/gal.

Table.7. Annual Average Daily Traffic of MacArthur Highway, Angeles City, Pampanga

Vehicle Type	AADT (No. of Vehicles)
Section A	
Motor-tricycle	6 377
Passenger Car	10 997
Passenger Utility	1 199
Small Bus	174
Large Bus	102
Goods Utility	5 580
Rigid Truck	112
Truck Semi-Trailer	105
Sub-total	24, 646
Section B	
Motor-tricycle	5 232
Passenger Car	39 009
Passenger Utility	347
Small Bus	264
Large Bus	233
Goods Utility	639

Rigid Truck	141
Truck Semi-Trailer	47
Sub-total	45, 912

Table 7 displays the recent DPWH report, which shows the annual average daily traffic data for the year 2021. This data is used for calculating the carbon dioxide emissions of vehicles driving down the roadway. It was used for determining the amount of carbon dioxide emissions created depending on the reported traffic volume.

2.3 Relative Change

The relative change formula was used to determine the increase or decrease of a specific value. It shows the change between the initial quantities and to the projected quantity and was used to compare two data sets. This was used to determine the change in carbon dioxide emission after projecting it with the transportation solutions.

Formula:

$$C = \frac{B-A}{A} \times 100$$

Where:

C= relative change
A= quantity of first value
B= quantity of final value

2.4 Critical Analysis

The researchers utilized critical analysis for examining the existing studies. This was a method used for gathering evidence from secondary data (Open University, 2017). It was used in investigating the mitigation measures of transportation-related factors that are proven by other academic research.

III. Results And Discussion

The study gathered one hundred (100) responses from MacArthur Highway, Angeles City, Pampanga. Road users are the survey respondents, classified into three: drivers, passengers, and pedestrians. The researchers conducted semi-structured interviews with one engineer from the Angeles City Planning and Development Office (R1) and one from the DENR Region III Environmental Management Bureau (R2). Both respondents responded that global warming affects the weather condition in the city since it can modify the city's regular weather conditions. Unpredictable weather conditions have occurred, with variations between dry and wet days. Consequently, human health is susceptible to heat hazards brought on by weather conditions.

The statement (S) included in the questionnaire are the following questions: S1- I feel uncomfortably hot when passing by MacArthur Highway; S2 - I feel thirsty when passing by MacArthur Highway; S3 - I feel the need to find a shaded place when passing by MacArthur Highway; S4 - When passing by MacArthur Highway, I ought to have a cooling product/ device with me; S5 - I feel uncomfortable during summer days when passing by MacArthur highway; S6 - During cooler days, I still feel hot when passing MacArthur Highway; S7 - I usually feel exhausted or stressed due to the heat in MacArthur Highway; S8 - The weather /heat in the highway interferes with my day-to-day travel experience; S9 - MacArthur Highway is hotter than other places I am passing by; S10 - I prefer cooler roads to pass by; and S11 - I feel that there is a need to address the heat experienced when passing MacArthur Highway.

Table.8. Road Users' Frequency Level of Heat Perception along MacArthur Highway

S	SD	D	N	A	SA	T	
S1	4	6	30	43	17	100	3.630
S2	5	20	36	29	10	100	3.190
S3	4	5	22	28	41	100	3.970
S4	10	12	22	36	20	100	3.440
S5	3	4	19	37	37	100	4.010
S6	11	26	48	13	2	100	2.690
S7	2	9	23	41	25	100	3.780
S8	3	9	28	42	18	100	3.630
S9	3	17	48	23	9	100	3.180
S10	3	5	13	20	59	100	4.270
S11	2	3	21	38	36	100	4.030
Remarks	Cold	Cool	Neutral	Warm	Hot		
	4.545	10.545	28.182	31.818	24.909	100	**3.620**
%	4.55	10.55	28.18	31.82	24.91	100	

Note. **S**, Statement; **SD**, Strongly Disagree; **D**, disagree; **N**, Neutral; **SA**, Strongly Agree; **A**, Agree

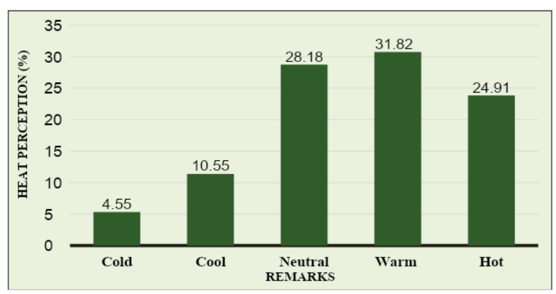


Fig.2. Summary of Road Users' Frequency Level of Heat Perception along MacArthur Highway

Based on the results in Table 8, 4.55% of the respondents felt cold when passing by on the highway and 10.55% of the respondents felt cool. The other 28% of respondents felt neutral as reflected in their responses in the questionnaires. The highest percentage of the respondents (31.82%) feels warm when passing the MacArthur Highway and the remaining 24.9% feels hot when passing by the said highway. As reflected in the table, the average responses in the statements are "agree" and "neutral". With an average mean of 3.62, the road users on the highway felt warm as they take the roadway.

Both respondents from the qualitative approach agreed that the transportation sector is the major source of GHG emissions in Angeles City. Where people are more likely to use roads than pathways as the city routes prioritize to cater vehicles rather than pedestrians, resulting in higher gas emissions. In comparison to other nations, pedestrians, sidewalks, and bike lanes are often used and highlighted.

Table.9. Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Passenger Vehicles and Goods Utility on MacArthur Highway

Vehicle Type	Fuel Type	No. Of Vehicles	Ef (G/Gal)	Mp (Mi/Gal)	Distance (Mi)	E_{co2} (G)	E_{co2} (Ton)
Section A							
Motor-tricycle	Gasoline	6 377	8 887	37.94	1.41	2.10E+06	2.32
Passenger Car	Gasoline	10 997	8 887	37.94	1.41	3.62E+06	3.99
Passenger Utility	Diesel	1 199	10 180	23.76	1.41	7.23E+05	0.80
Small Bus	Diesel	174	10 180	8.47	1.41	2.94E+05	0.32
Large Bus	Diesel	102	10 180	8.47	1.41	1.73E+05	0.19
Goods Utility	Diesel	5 580	10 180	21.00	1.41	3.81E+06	4.19
Sub-total						1.07E+07	11.82
Section B							
Motor-tricycle	Gasoline	5 232	8 887	37.94	2.00	2.45E+06	2.70
Passenger Car	Gasoline	39 009	8 887	37.94	2.00	1.83E+07	20.16
Passenger Utility	Diesel	347	10 180	23.76	2.00	2.98E+05	0.33
Small Bus	Diesel	264	10 180	8.47	2.00	6.35E+05	0.70
Large Bus	Diesel	233	10 180	8.47	2.00	5.61E+05	0.62
Goods Utility	Diesel	639	10 180	21.00	2.00	6.20E+05	0.68
Sub-total						2.29E+07	25.19
Total						3.36E+07	37.01

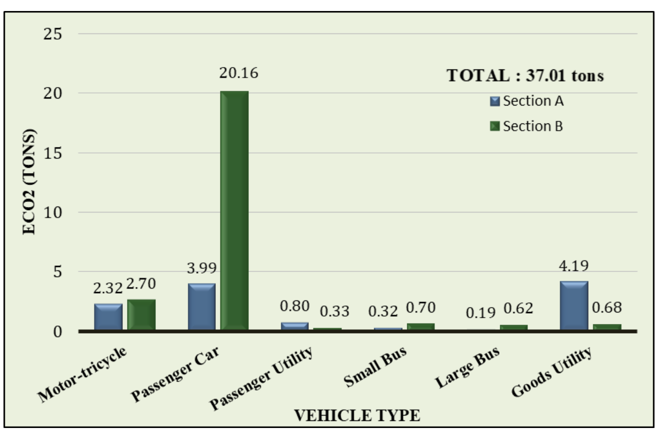


Fig.3. Summary of Carbon Dioxide Emissions from Passenger Vehicles and Goods Utility of MacArthur Highway

As shown in Figure 3, the daily average carbon dioxide emitted by the vehicles passing by MacArthur Highway is 37.01 tons. Most vehicles passing by the highway consist of passenger vehicles. With 10 997 and 39 009 passenger vehicles passing by sections A and B of the highway, carbon dioxide emissions are significantly higher than the other types of cars which are 3.99 and 20.16 tons respectively. Moreover, motor tricycles share a high amount of CO_2 in the total emissions of the highway. It generates 2.32 and 2.70 tons of CO_2 for both sections A and B. Also, having 4.19 tons of CO_2, goods utilities generate the second highest emission in section A even though the number of units is lesser than motor-tricycles. Passenger utilities, small buses, and large buses have lower emissions compared to other vehicles which are reflected in having a lower number of units on the road.

Table.10. Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Trucks on MacArthur Highway

Vehicle Type	Category	No. Of Vehicles	EF (G/Mi)	Weight	Distance (Mi)	E_{co2} (G)	E_{co2} (Ton)
Section A							
Rigid Truck	All	112	1 700	N/A	1.41	2.68E+05	0.30
Truck Semi-Trailer	All	105	1 700	N/A	1.41	2.51E+05	0.28
Sub-total						5.19E+05	0.57
Section B							
Rigid Truck	All	141	1 700	N/A	2.00	4.80E+05	0.53
Truck Semi-Trailer	All	47	1 700	N/A	2.00	1.60E+05	0.18
Sub-total						6.40E+05	0.71
Total						1.16E+06	1.28

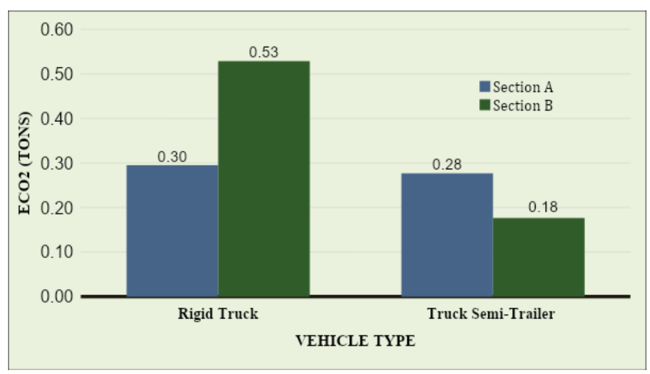
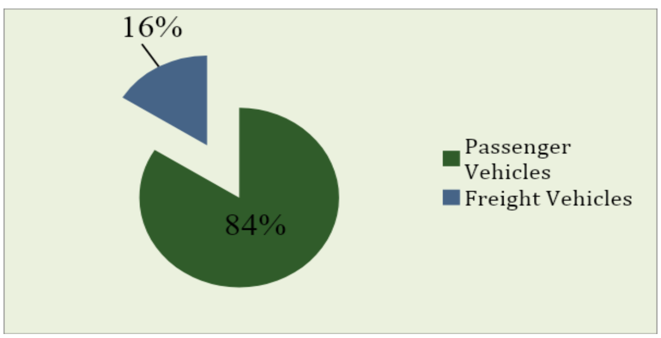


Fig.4. Summary of Carbon Dioxide Emissions from Trucks on MacArthur Highway

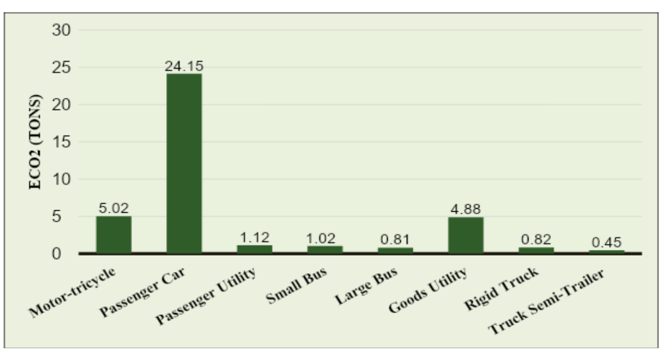
On the other hand, Figure 4 shows the total CO_2 emitted by trucks. The overall emission from trucks on MacArthur Highway is 1.28 tons. The table shows that semi-trailer trucks accumulate lower emissions than rigid trucks. It has 0.28 and 0.18 CO_2 emissions in section A and section B, respectively. Meanwhile, the rigid truck has accumulated a higher release of carbon dioxide since it has a higher number of reported units passing by the highway. It has 0.30 and 0.53 tons of carbon dioxide emissions daily.

Table.11. Summary of Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on Vehicle Types

Vehicle Type	ECO_2 (ton)		Total	Percentage %
	Section A	Section B		
Passenger Vehicles				
Motor-tricycle	2.32	2.70	5.02	13.11
Passenger Car	3.99	20.16	24.15	63.09
Passenger Utility	0.80	0.33	1.12	2.94
Small Bus	0.32	0.70	1.02	2.68
Large Bus	0.19	0.62	0.81	2.11
Sub Total			32.13	83.92
Freight Vehicles				
Goods Utility	4.19	0.68	4.88	12.74
Rigid Truck	0.30	0.53	0.82	2.15
Truck Semi-Trailer	0.28	0.18	0.45	1.18
Sub Total			6.15	16.08
Total			38.29	100.00



(a)



(b)

Fig.5. Summary of Carbon Dioxide Emissions from Road Vehicles on MacArthur Highway

The CO_2 emissions per vehicle type traveling through MacArthur Highway are summarized in Table 11. Passenger vehicles produced the highest tailpipe emissions on MacArthur Highway, accounting for 83.92% of total emissions. It emits a total of 32.13 tons of CO_2. Meanwhile, freight vehicles emit 6.15 tons which accounts for the remaining 16.08%. Passenger cars account for 63.09% of total highway emissions and have the highest emissions among all the vehicle types. Secondly, motor tricycles account for 13.11% of CO_2 emissions. The third vehicle that has the highest share in the CO_2 emissions of the highway is the goods utilities, accounting for 12.74% of the accumulated emissions which is equivalent to 4.88 tons. Passenger utility, small buses, large buses, and rigid trucks emit relatively similar amounts of CO_2 which are 1.12, 1.02, 0.81, and 0.82 tons respectively.

Determining the emissions of carbon dioxide in a region could help policymakers in planning solutions. Identifying which are the major contributors could lead to where efficient reduction measures would be more efficient and could be prioritized. Carbon dioxide reduction measures often apply to its primary source. To model a scenario based on evidence that has been proven by other studies, the table below presents the summary of reviewed materials by the researchers. As per Morrison (2017), examining studies allows researchers to acquire reliable claims from relevant papers. It would support the content of the programs proposed in this paper.

Table.12. Summary of Transportation Solutions for Reducing CO2 Studies

Vehicle Volume Reduction	
Tang, Ceder, and Ge (2018)	Harmful emissions were decreased due to reducing of the numbers of vehicle.
Velez and Plepys (2021)	Car sharing strategy has the highest GHG emission reduction at city levels.
Migliore, D'Orso, and Caminiti (2020)	CO2 emissions will be decreased by 38% by implementing car sharing.
Cavallaro, Giaretta, Nocera (2017)	Road pricing can significantly reduce the carbon emission when enforced.
Asian Development Bank (2021)	Higher carbon tax rates may force the facilities and individuals to consider ways to stop using carbon.
Boarnet (2014)	Congestion tolls and cordon pricing could reduce greenhouse gas emission from vehicles.
Modal Shift	
Zamasz et al. (2021)	Full fleet electrification transition will reduce carbon emission by 24%.

Raugei (2022)	Hybrid electric vehicles is the most effective strategy to decrease the emissions of vehicles.
Vega-Perkins, Newell, and Keoleian (2023)	More than 2.3 metric tons of CO2 will be reduced to households when they shift to electric vehicles
Bieker 2021	Using battery and hydrogen fuel cell electric vehicles are the only potential solution for GHG emission reduction.
Brand (2021)	Cycling for mobility have 84% lower life cycle CO2 than those who do not.
Hong (2018)	Active transportation has more environmental benefits than negatives when compared to fuel powered vehicles.
Alessio et al. (2021)	Active mobility is a vital mitigating strategy to reduce GHG emissions.

To analyze the future trends in the CO_2 tailpipe emissions of the vehicles within the MacArthur Highway, different scenarios were formulated based on the given transportation solutions. These also served as the adapted transportation program of the study.

a. Vehicular Volume Reduction Scenario (VVRS)

In this scenario, private vehicle ownership will be reduced by 10% and 20%, whereas the quantity of public transportation will remain. It was assumed that public transportation will carry the maximum capacity of passengers. Consequently, with the support of car-sharing and the application of pricing schemes, the mobiles on the road could accommodate all the passengers on the highway. In this setting, the characteristics of vehicles are unchanged.

b. Modal Shift Scenario (MSS)

This scenario focuses on shifting to zero-emission mobility. Rather than using motorized vehicles, walking and cycling is a preferred choice for short-distance travel. Moreover, shifting to electric vehicles is adapted for zero-emission from mobile combustion which offers faster mobilization than active transportation. This scenario is divided into two settings:

c. Zero-emission for Public transportation (MSS-A)

This includes fleet electrification of public vehicles. Along with this is an encouragement to public transportation users to shift to active transportation. Hence, the emission factor for the public passenger vehicles along MacArthur Highway which includes motor tricycles, utility vehicles, and small buses has zero emission factors.

d. Zero-emission for Passenger Vehicles (MSS-B)

In this setting, it covers full fleet electrification of passenger vehicles. The emission factor for all passenger vehicles is zero. This includes motor tricycles, passenger cars, passenger utilities, small buses, and large buses.

Table.13. Average Daily Carbon Dioxide Inventory from Tailpipe Emission of Passenger Vehicles in MacArthur Highway Based on (10%) VVRS

Vehicle Type	Fuel Type	No. Of Vehicles	EF (G/Gal)	MPG (mi/ gal)	DISTANCE (mi)	E_{CO2} (ton)
SECTION A *Private Vehicles*						
Passenger Car	Gasoline	9 898	8 887	37.94	1.41	3.60
Large Bus	Diesel	92	10 180	8.47	1.41	0.17
Public Vehicles						
Motor-tricycle	Gasoline	6 377	8 887	37.94	1.41	2.32
Passenger Utility	Diesel	1 199	10 180	23.76	1.41	0.80
Small Bus	Diesel	174	10 180	8.47	1.41	0.32
SECTION B *Private Vehicles*						
Passenger Car	Gasoline	35 109	8 887	37.94	2.00	18.14
Large Bus	Diesel	210	10 180	8.47	2.00	0.56
Public Vehicles						
Motor-tricycle	Gasoline	5 232	8 887	37.94	2.00	2.70
Passenger Utility	Diesel	347	10 180	23.76	2.00	0.33
Small Bus	Diesel	264	10 180	8.47	2.00	0.70
Total						**29.64**

Table.14. Summary of Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on (10%) VVRS

Vehicle Type	ECO_2 (ton)		Total
	Section A	Section B	
Passenger Car	3.60	18.14	21.74
Large Bus	0.17	0.56	0.73
Motor-tricycle	2.32	2.70	5.02
Passenger Utility	0.80	0.33	1.12
Small Bus	0.32	0.70	1.02
Goods Utility	4.19	0.68	4.88
Rigid Truck	0.30	0.53	0.82
Truck Semi-Trailer	0.28	0.18	0.45
Total			35.79

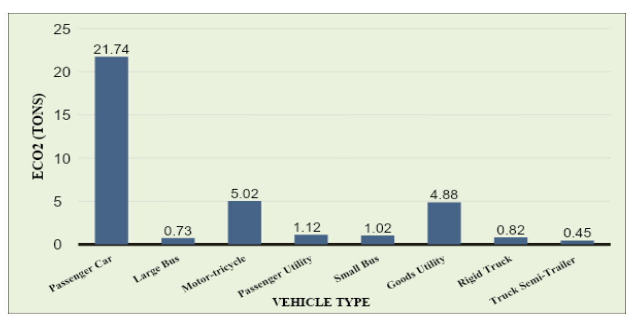


Fig.6. Summary of Carbon Dioxide Emissions from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on (10%) VVRS

Shown in Table 14 is the carbon dioxide emitted by the vehicles in (10%) VVRS. As the quantity of private passenger vehicles decreases by 10%, the new computed emissions of passenger cars and large buses are 21.74 and 0.73 tons respectively. In section B, the amount of CO_2 emissions is 2.70 tons for motor-tricycle, 0.33 tons for passenger utility, and 0.70 tons for small buses. In the setting of (10%) VVRS, road vehicles released a total of 35.79 tons of CO_2 daily.

Table.15. Average Daily Carbon Dioxide Inventory from Tailpipe Emission of Passenger Vehicles in MacArthur Highway Based on (20%) VVRS

Vehicle Type	Fuel Type	No. Of Vehicles	EF (g/gal)	MPG (mi/ gal)	DISTANCE (Mi)	E_{CO2} (ton)
Section A *Private Vehicles*						
Passenger Car	Gasoline	8 798	8 887	37.94	1.41	3.20
Large Bus	Diesel	82	10 180	8.47	1.41	0.15
Public Vehicles						
Motor-tricycle	Gasoline	6 377	8 887	37.94	1.41	2.32
Passenger Utility	Diesel	1 199	10 180	23.76	1.41	0.80
Small Bus	Diesel	174	10 180	8.47	1.41	0.32
Section B *Private Vehicles*						
Passenger Car	Gasoline	31 208	8 887	37.94	2.00	16.13
Large Bus	Diesel	187	10 180	8.47	2.00	0.50
Public Vehicles						
Motor-tricycle	Gasoline	5 232	8 887	37.94	2.00	2.70
Passenger Utility	Diesel	347	10 180	23.76	2.00	0.33
Small Bus	Diesel	264	10 180	8.47	2.00	0.70
Total						27.14

Table.16. Summary of Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on (20%) VVRS

Vehicle Type	ECO_2 (ton)		Total
	Section A	Section B	
Passenger Car	3.20	16.13	19.32
Large Bus	0.15	0.50	0.65
Motor-tricycle	2.32	2.70	5.02
Passenger Utility	0.80	0.33	1.12
Small Bus	0.32	0.70	1.02
Goods Utility	4.19	0.68	4.88
Rigid Truck	0.30	0.53	0.82
Truck Semi-Trailer	0.28	0.18	0.45
			33.30

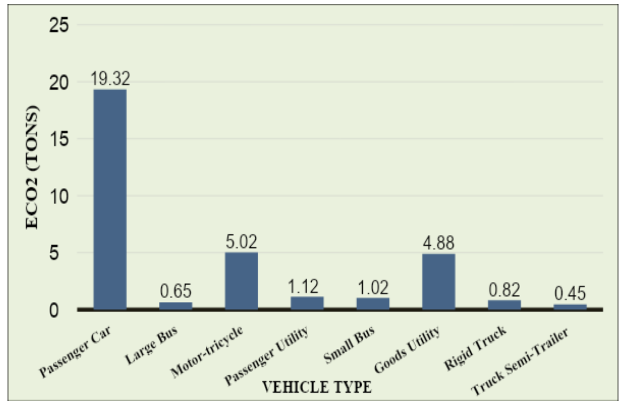


Fig.7. Summary of Carbon Dioxide Emissions from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on (20%) VVRS

Table 15 shows the total carbon dioxide emissions of (20%) VVRS. In this scenario, the overall CO_2 released by road vehicles is 33.30 tons. The change in the emissions of private vehicles is equal to 19.32 and 0.65 tons on passenger cars and large buses, respectively. Hence, the value for private and freight vehicles remains.

Table.17. Average Daily Carbon Dioxide Inventory from Tailpipe Emission of Passenger Vehicles in MacArthur Highway Based on MSS-a

Vehicle Type	Fuel Type	No. Of Vehicles	Ef (G/Gal)	Mpg (Mi/ Gal)	Distance (Mi)	E_{co2} (Ton)
Section A *Private Vehicles*						
Passenger Car	Gasoline	10 997	8 887	37.94	1.41	3.99
Large Bus	Diesel	102	10 180	8.47	1.41	0.19
Public Vehicles						
Motor-tricycle	N/A	6 377	0	N/A	1.41	0.00
Passenger Utility	N/A	1 199	0	N/A	1.41	0.00
Small Bus	N/A	174	0	N/A	1.41	0.00
Section B *Private Vehicles*						
Passenger Car	Gasoline	39 009	8 887	37.94	2.00	20.16
Large Bus	Diesel	233	10 180	8.47	2.00	0.62
Public Vehicles						
Motor-tricycle	N/A	5 232	0	N/A	2.00	0.00
Passenger Utility	N/A	347	0	N/A	2.00	0.00
Small Bus	N/A	264	0	N/A	2.00	0.00
Total						24.96

Table.18. Summary of Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on MSS-A

Vehicle Type	Eco_2 (Ton)		Total
	Section A	Section B	
Passenger Car	3.99	20.16	24.15
Large Bus	0.19	0.62	0.81
Motor-tricycle	0.00	0.00	0.00
Passenger Utility	0.00	0.00	0.00

Small Bus	0.00	0.00	0.00
Goods Utility	4.19	0.68	4.88
Rigid Truck	0.30	0.53	0.82
Truck Semi-Trailer	0.28	0.18	0.45
			31.12

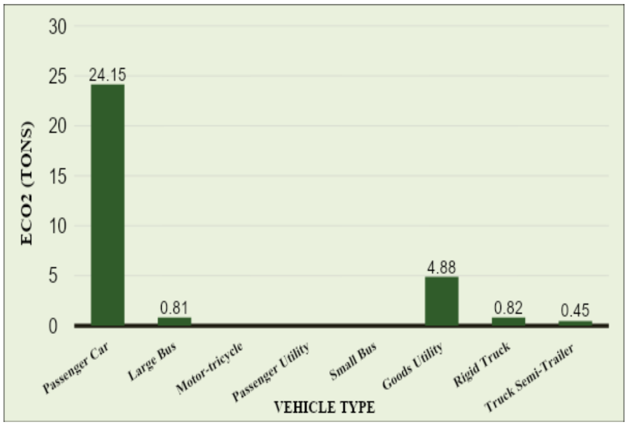


Fig.8. Summary of Carbon Dioxide Emissions from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on MSS-A

Presented in Tables 16 is the carbon dioxide emissions based on MSS-A. The total carbon dioxide emitted by the road vehicle on the highway is 31.12 tons. The highest contribution is from passenger cars which emitted 24.15 tons. And following this is the good utilities having 4.88 tons of CO_2 emission. Large buses, rigid trucks, and truck semi-trailers emitted 0.81, 0.82, and 0.45 tons respectively which are significantly lower than passenger cars and goods utility. As for having zero emissions from public vehicles such as motor tricycles, passenger utility, and small buses, the generated carbon dioxide of passenger vehicles on the highway is 24.15 tons.

Table.19. Summary of Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on MSS-B

Vehicle Type	Eco_2 (Ton)		Total
	Section A	Section B	
Passenger Car	0.00	0.00	0.00
Large Bus	0.00	0.00	0.00
Motor-tricycle	0.00	0.00	0.00
Passenger Utility	0.00	0.00	0.00
Small Bus	0.00	0.00	0.00
Goods Utility	4.19	0.68	4.88
Rigid Truck	0.30	0.53	0.82
Truck Semi-Trailer	0.28	0.18	0.45
			6.15

Table 17 shows the total CO_2 emissions on MacArthur Highway based on MSS-B. All of the computed emissions are from freight vehicles as it is stated that full fleet electrification of passenger vehicles will occur.

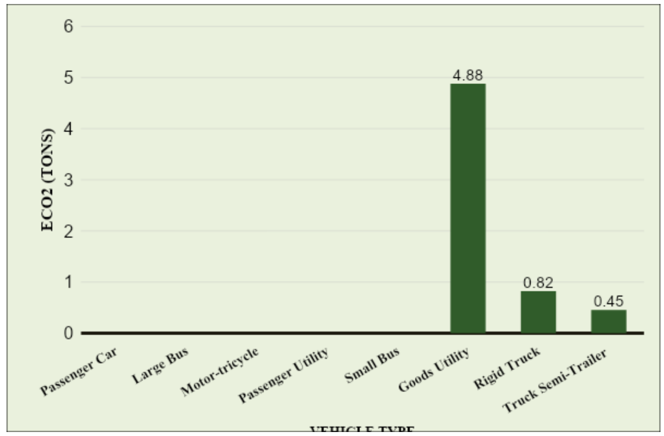


Fig.9. Summary of Daily Carbon Dioxide Emissions from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on MSS-B

All passenger vehicles accumulated zero carbon dioxide emissions from the tailpipes of mobiles. The CO_2 released by the freight vehicles is 6.15 tons and the majority of it comes from goods utilities. Rigid trucks emitted 0.82 tons and 0.45 tons from semi-trailer trucks.

Table.20. Summary of Average Daily Carbon Dioxide Inventory from Tailpipe Emissions of Road Vehicles in MacArthur Highway Based on Primary and Simulating Scenarios

Scenario	Co_2 Emission		Relative Change
	Primary	Scenario-Based	
VVRS			
10%	38.29	35.79	-6.51%
20%	38.29	33.30	-13.03%
MSS			
A	38.29	31.12	-18.73%
B	38.29	6.15	-83.92%

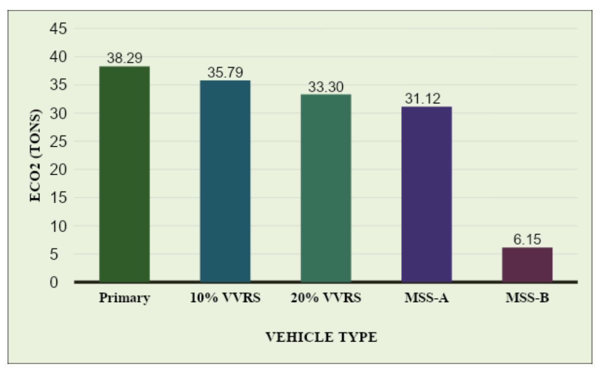


Fig.10. Summary of Carbon Dioxide Emissions from Road Vehicles in MacArthur Highway Based on Primary and Simulated Scenarios

Shown in Table 18 are the differences in CO_2 emissions by the city based on the current setting and four simulated scenarios. It shows that MSS-B has the highest percentage decreased in the emissions of the city with 83.92%. Following this is MSS-A which has an 18.73% reduction in CO_2 emissions. VVRS has an accumulated change of -6.51% and

-13.03% in CO_2 emissions of road vehicles in MacArthur Highway.

IV. Summary, Conclusion, and Recommendations

4.1 Summary

Based on the results, the road users perceived warm temperatures on the highway. They feel exhausted when they use the highway garnering 3.62 as the average mean which denotes a warm rating. According to Posten and Steinmetz (2016), the more the physical temperature of a person increases, the more it affects their psychological process. Respondents consider the weather or heat on the highway interferes with their day-to-day travel as it reflects with 3.60 mean which has a rating of warm. The heat felt by the road users is caused by the escalating temperature in the area and this interferes with their daily activities. Comfortability of the people was affected by the perceived heat in the area therefore it is imperative to investigate the reduction measures that aid the experienced heat. It was also reflected in the answers of the participant who endorsed the notion of addressing the heat on the roadway, with a mean of 4.03.

The estimated daily CO_2 emissions of the city from the tailpipe of road vehicles is 38.92 tons. Macarthur Highway comprises only 0.002% of the total road length in the Philippines. However, vehicles in this fragment of road emit 0.004% of the daily CO_2 emission on a national level. The ratio of CO_2 it emitted is higher than its supposed ratio based on its road length.

Due to city-scale demand for transport, vehicular traffic counts are higher in this road network. The majority of the CO_2 emissions on the said highway came from passenger vehicles (83.92%) and there is only a small percentage that is contributed by freight vehicles (16.08%) on the highway. Based on these results, it is clear that unit count is a significant factor in accumulating a high amount of carbon dioxide emissions since the majority of vehicles passing by the highway are passenger vehicles.

As indicated in the results from estimating CO_2 emissions that were set on the vehicle volume reduction scenario, only a small amount of CO_2 was reduced. For 10% VVRS, 35.79 tons are computed which results in a -6.51% change. The 10% reduction in private vehicle ownership has a small impact as compared to the computed reduction of other studies presented in Table 09. However, this action adheres to the plan of Angeles City to gradually decrease the vehicle units. Meanwhile, in 20% VVRS, the emissions are decreased by 13.03% which accumulates a daily release of 36.86 tons of CO_2 coming from internal combustion engines of vehicles. Reducing 20% of the private vehicles shows that the change in carbon dioxide emissions on the highway is relatively similar to the claims of the reviewed studies. Since only private passenger vehicles are affected in these settings, it reflects a low-emission change. On top of that, this was also mentioned by the respondents of the interview. Vehicle volume reduction would be harder to achieve as the city continuously urbanizes and the demand will rise accordingly.

On the other hand, modal shift scenarios presented a higher relative change in the estimated CO_2 emissions. The zero-emission of public passenger vehicles (MSS-A) has resulted in 31.12 tons of CO_2 released and that has a -18.73% change in carbon dioxide emissions. Based on the reviewed studies, the computed change of CO_2 emissions in MSS-A has a lower impact than those results from the said studies. Garnering the highest change in CO_2 emissions and having the lowest emission among all the scenarios is the MSS-B. There is an 83.92% decrease in CO_2 emissions which only produced 6.15 tons of CO_2. Passenger vehicles make up the majority of the vehicles on the highway and it is the primary component with CO_2 emissions modifications. Since full fleet changes in the emissions were simulated in these vehicles, higher relative change was observed.

Align with heat reduction strategies proposed by USEPA (2022) is cutting CO_2 emissions. Net-zero emissions are the ultimate goal. In line with this, the Philippines has announced that 70% of carbon emissions must be reduced by 2030 (Philippines - TRANSfer, 2018). From the solutions presented in the paper, full-fleet electrification of passenger vehicles is an ideal action for supporting this goal.

4.2 Conclusion

Overall, the researchers have concluded that the heat mitigation action of a city must include reduction measures in the transportation aspect which specifically inclined to the mobility demand of the dwellers and CO_2 emissions of the vehicular modes. This sustains the heat resiliency of the city and could also amend sufficient transportation plans for road users and lawmakers. Modal shift and vehicle volume reduction are programs wherein proven to have a positive impact on aiming a lower emissions and heat production. The researchers determined that the road users on MacArthur Highway felt warm as they passed by the roadway. Warmer temperatures in the area induced discomfort for the users. As they suggest, the heat experienced on the highway must be elevated.

Additionally, it was observed that carbon dioxide emissions from road vehicles on the highway are influenced by the number of vehicle units. Passenger vehicles are the primary source of carbon dioxide emissions on MacArthur Highway. Since the highway caters larger volume of these type of vehicles, higher emissions are released by this type of mobility. Consequently, transportation solutions apply to passenger vehicles.

Mobility alternatives such as the Vehicular Volume Reduction Scenario (VVRS) and the Modal Shift Scenario (MSS) were seen to cut emissions, but their effectiveness is dependent on the vehicle and scenario. These programs were mainly applied to passenger vehicles rather than freight. Electrification of passenger vehicles shows the highest potential of reducing carbon dioxide emissions from road vehicles. However, implementation of this is highly challenging as it could result in job losses for public transportation operators. While reducing vehicular units shows significantly lower impacts.

Meanwhile, according to both respondents, the transportation industry is the main contributor to GHG emissions in Angeles City. Whereas the City of Angeles is becoming more vehicle-centric, resulting in higher gas emissions, individuals are more likely to use roads than sidewalks, bike lanes, and walkways. Thus, it was also discussed that the officials are considering cooperating with DPWH regarding the walkability of the roadways. As the researchers mentioned the transportation solutions proposed in the study regarding lowering carbon emissions from road vehicles, both respondents agreed that this is ideal for acquiring lower temperatures.

4.3 Recommendations

The following recommendations are offered based on the work accomplished during this study:

a. Further research might consider studying the viability of executing the program, as well as identifying possible obstacles and solutions for effective implementation. To establish the program's sustainability and build a detailed implementation strategy, the research should incorporate a variety of variables such as financial resources, technical requirements, and potential risks.

b. Other transportation solutions, such as re-routing and centralized routing systems, may be investigated which may provide more comprehensive and efficient traffic congestion solutions and reduce distance travel. By adding these extra variables, researchers can gain a more comprehensive understanding of transportation planning and design more efficient solutions to decrease the heat by alleviating traffic congestion.

c. Reliable greenhouse gas emissions measurement and reporting are critical for designing effective climate change policies and strategies. More precise and comprehensive measurement methodologies are suggested to be utilized. Future researchers must improve data collection and analysis methods, and the inclusion of estimating other greenhouse gasses.

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