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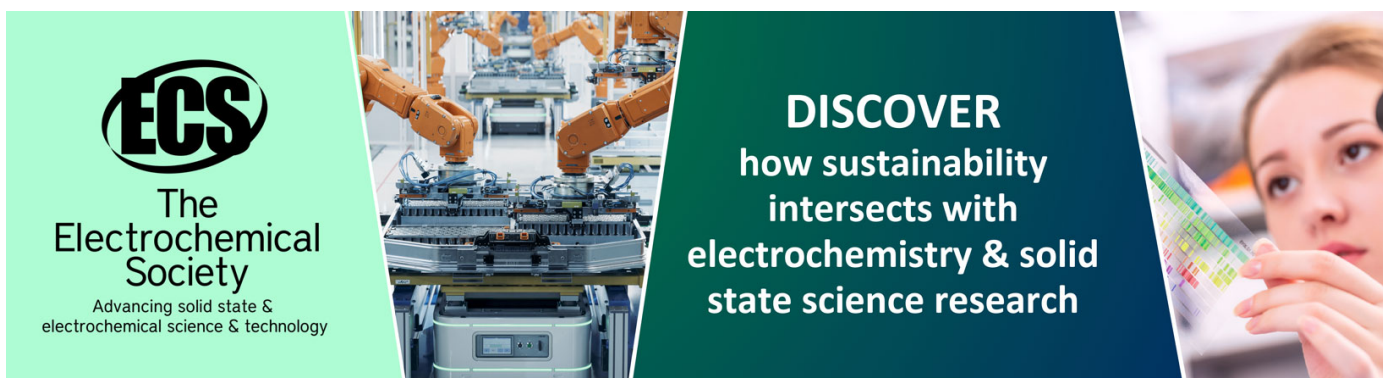
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Quantifying Carbon Emission from Campus Transportation: A Case Study in Universiti Kebangsaan Malaysia

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Abstract. Carbon footprint is a global concern discussed throughout the globe. The daily activities on university campuses cause emission of greenhouse gases that contribute to the increasing amount of carbon dioxide (CO₂) in the atmosphere. This research seeks to determine the CO₂ emissions by members of the campus community of Universiti Kebangsaan Malaysia (UKM), Bangi Campus. This study will also analyse the factors influencing CO₂ emission from the vehicles used on the campus. The findings of this study will serve as a basis to propose methods for reducing carbon footprint, especially from the transportation used on the campus. The study is carried out on the UKM campus to gather the data on the travel activity on the campus, where the members of the campus community serve as the study population. The DEFRA Model is used to calculate the CO₂ emission and the multivariable linear regression model is used to identify the factors influencing CO₂ emission. In the car category, petrol cars with 2.0L engine have the highest mean CO₂ emission of 1181.0932 kg CO₂/year/capita. In the motorcycle category, petrol motorcycles with engine capacity larger than 500cc recorded the highest emission of 999.1072 kg CO₂/year/capita. The CO₂ emissions by both categories are below the national mean carbon dioxide emission value of 7900 kg CO₂/year/capita recorded by the 2019 National Transport Policy and the mean carbon dioxide emissions of 5400 kg CO₂/year/capita in high-income countries. In this study, the critical factors influencing the daily and annual CO₂ emissions are the mode of transportation, type of fuel, and travel distance

1. Introduction

The recent years have seen an increasing concern regarding the harmful effect of carbon footprint on the community and environmental sustainability. According to Abdul-Azeez & Ho [1], the use of fossil fuels in the daily activities of humans have resulted in the release of an excessive amount of carbon dioxide (CO₂). Since CO₂ is one of the components of greenhouse gases (GHGs), the consumption of a higher amount of fossil fuels contributes significantly to global warming and climate change, which hampers the effort to achieve sustainable development. Besides contributing to global warming, other adverse effects of transportation on the environment include the production of harmful pollutants such as sulphur dioxide, nitrogen oxide, lead, hydrocarbon, carbon monoxide, and other harmful particles.



Information on the level of greenhouse gases emissions and the impact measurement of carbon footprint is critical in the effort to reduce the impact of GHG emissions [2]. Reduced carbon footprint contributes to the mitigation of global climate change. Carbon footprint is a measure of the carbon emission associated with a person, institution, or country. Knowing the carbon footprint of a person can contribute to increasing the awareness of the impact of global problems and climate change on the life of an individual [3]. The population of a university comprises the members of the staff, students, and the public that commute within the campus either using private vehicles or the transportation provided by the university, where each person has their own carbon footprint. A large university campus has a greater carbon footprint.

Abdul-Azeez & Ho [1] discovered that the highest source of CO₂ emissions is from the vehicles used for commuting on the campus and delivering goods and equipment, where the carbon emission from these vehicles is equivalent to that of the national average. The key factor hindering the achievement of the sustainability goals of a university is the vehicles used by the campus community. The strategic plan to achieve campus sustainability must take into account the extended daily use of vehicles, travel distance, and the use of private and heavy vehicles. A study conducted at Universiti Kebangsaan Malaysia in 2011 discovered that about 18% of the members of campus community preferred to walk, 32% preferred to take the campus bus, and the remaining 50% preferred to use their private vehicle [4]. This research measured the CO₂ emissions from the vehicles used by the members of the campus community and identified the key factors influencing CO₂ emissions

2. Methodology

The research methodology is a critical component of research and is an approach adopted to achieve the key research objectives.

2.1. Research instrument

The research instrument in this study is a questionnaire comprising two sections. Section A gathers the demographic data of the respondents, including gender, age, race, occupation, and if the respondents are students, their study level, faculty, and college of residence. Section B gathers the information on the vehicles used on the campus, including the type of vehicle, type of fuel used, engine capacity, daily travel distance, and weekly travel frequency. The questionnaires were distributed to the respondents on the campus. The researcher gave a brief explanation of the survey to the respondents to ensure that they understand all items in the questionnaire.

2.2. Study area and sample size

The target population in this study is the campus community of Universiti Kebangsaan Malaysia (UKM), Bangi Campus. The 2019 population data provided by the Centre for Academic Management, UKM showed that the total number of staff and registered students at the UKM Bangi Campus is 26,601. This study adopted the method recommended by Burmeister and M. Aitken [5] for determining the sample size for studies that use regression analysis, where the sample size is obtained using the formula $N \geq 50 + 8P$ (where p is the total number of variables). This study considered 18 variables, namely method of commuting (car, motorcycle, bus, and walking), type of fuel (petrol or diesel), engine capacity (cars with 1.4L, 1.4-2.0L and 2.0L petrol engines, cars with 1.7L, 1.7-2.0L and 2.0L diesel engines, motorcycles with 125 cc, 125-500 cc, and 500 cc petrol engines, and diesel bus), and the daily and annual travel distance. Even though the formula gave a sample size of 194 respondents, 375 respondents participated in this study.

2.3. Calculation of CO₂ emissions

There are two methods for calculating carbon dioxide emissions. The straightforward and frequently used method to calculate CO₂ emissions multiplies the travel distance with the CO₂ emission factor for each vehicle [6]. The second method multiplies the amount of energy consumed during the travel with the emission factor of CO₂ of the energy. This study calculated the total CO₂ emissions by multiplying

the travel distance with DEFRA emission factor for each type of vehicle. Azliyana Azhari et al. [8] used the DEFRA model to analyze the carbon emission from a vehicular source in selected industrial areas in Malaysia. This study used 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) [9] to calculate CO₂ emissions by using equation 1.

$$\text{Total Carbon Footprint (kg CO}_2\text{ eq)} = \text{Travel distance (km)} \times \text{Emission Factor (kg CO}_2\text{ eq/ km)} \quad (1)$$

The data for the travel distance gathered through the questionnaire was multiplied with the emission factor to obtain the estimated daily and annual CO₂ emissions. In the case of a bus, this study assumed that the bus operated at a full capacity of 52 passengers (40 sitting and 12 standing passengers) and the emission factor was divided by 52 people to obtain the emission factor per person. Table 1 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 1. Emission Factor for each mode of transportation.

Mode of Transportation	Type of Fossil Fuel	Engine Size Capacity	Emission Factor (kg CO ₂ eq/km)
Car	Petrol	1.4 L	0.17985
		1.4 L-2.0 L	0.21280
		2.0 L above	0.29549
	Diesel	1.7 L	0.15095
		1.7 L-2.0 L	0.18757
		2.0 L above	0.25580
Motorcycle	Petrol	125 cc	0.08499
		125-500cc	0.10316
		500 cc above	0.13724
Bus	Diesel	-	0.10351

Source: DEFRA [9]

2.4. Data analysis

This study used the Statistical Package for Social Sciences (SPSS) to analyze the data and obtain daily and annual mean emission for each method of commuting. The mean annual emission of each vehicle was compared with those of the national emissions and emissions in high-income countries. The study used the multivariate linear regression model to determine the critical factors in CO₂ emissions. The independent variables are the demographic factors, namely gender, age, occupation, mode of commuting, type of fossil fuel, engine capacity, and the travel distance. The dependent variables, namely the respondent's daily and annual CO₂ emissions, were calculated using the DEFRA model.

3. Result and Discussion

3.1. Carbon dioxide emissions

The first step in the analysis of carbon dioxide emissions is identifying the method of commuting on the campus.

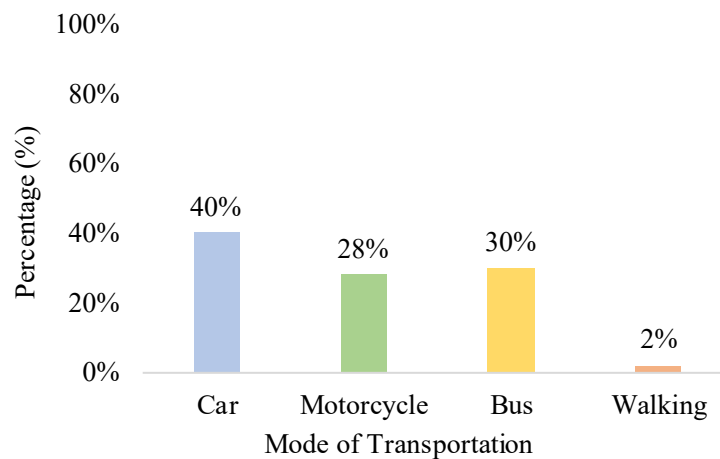


Figure 1 Graph of percentage of Mode of Transportation by respondent.

The bar chart in Figure 1 shows that 40% (152) of the respondents drove their cars, while 28% (104) preferred to commute by motorcycles. The remaining 30% (112) preferred to take the bus, and only 2% (7) chose to walk.

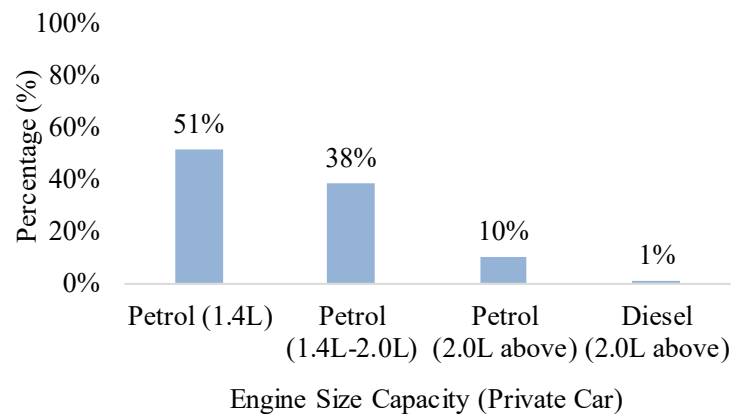


Figure 2 Graph of percentage of Engine Size Capacity (Private Car).

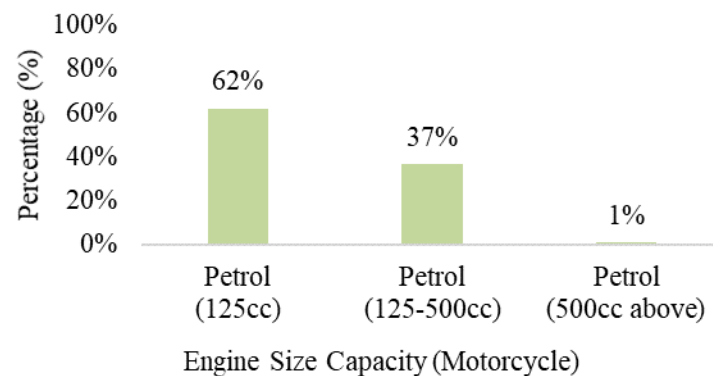


Figure 3 Graph of percentage of Engine Size Capacity (Motorcycle).

Figure 2 shows the breakdown of the cars driven by the respondents, where 51% are petrol cars with 1.4L engine, 38% are petrol cars with 1.4-2L engine, 10% are petrol cars with 2.0L engine, and 1% are diesel cars with 2.0L engine. Figure 3 shows the breakdown of the motorcycle used by 104 respondents, where 62% are petrol motorcycles with 125cc engine, 37% are petrol motorcycle 125-500cc engine, and 1% is petrol motorcycles with 500cc engine. The DEFRA model was used to calculate the daily and annual carbon dioxide (CO₂) emission from each vehicle.

Figure 4 shows that petrol cars with 1.4-2L engine released the highest amount of carbon dioxide annually (38607.8784 kg CO₂ or 33.23%), followed by petrol cars with a 1.4L engine, which released 30.33% or 35239.09 kg CO₂ annually. Cars with the highest engine capacity released the highest amount of carbon dioxide annually compared to other types of vehicles. Petrol and diesel cars with an engine capacity larger than 2L contributed 15.25% and 0.34% of the annual carbon dioxide emissions, respectively. The low percentage of CO₂ emission from cars with large engine capacity is because only a small proportion of respondents commute by this type of car. Petrol motorcycles with 125-500 cc engine released the highest amount of carbon dioxide (11694.22 kg CO₂ or 10.06%) compared to 125 cc petrol motorcycles (9.69%) and 500 cc petrol motorcycles (0.86%). Bus passengers contributed the least to CO₂ emissions, where each passenger contributed about 0.24% (276.9653 kg CO₂) of the annual carbon dioxide emissions. Walking is the most sustainable way for commuting since there is no carbon dioxide emission.

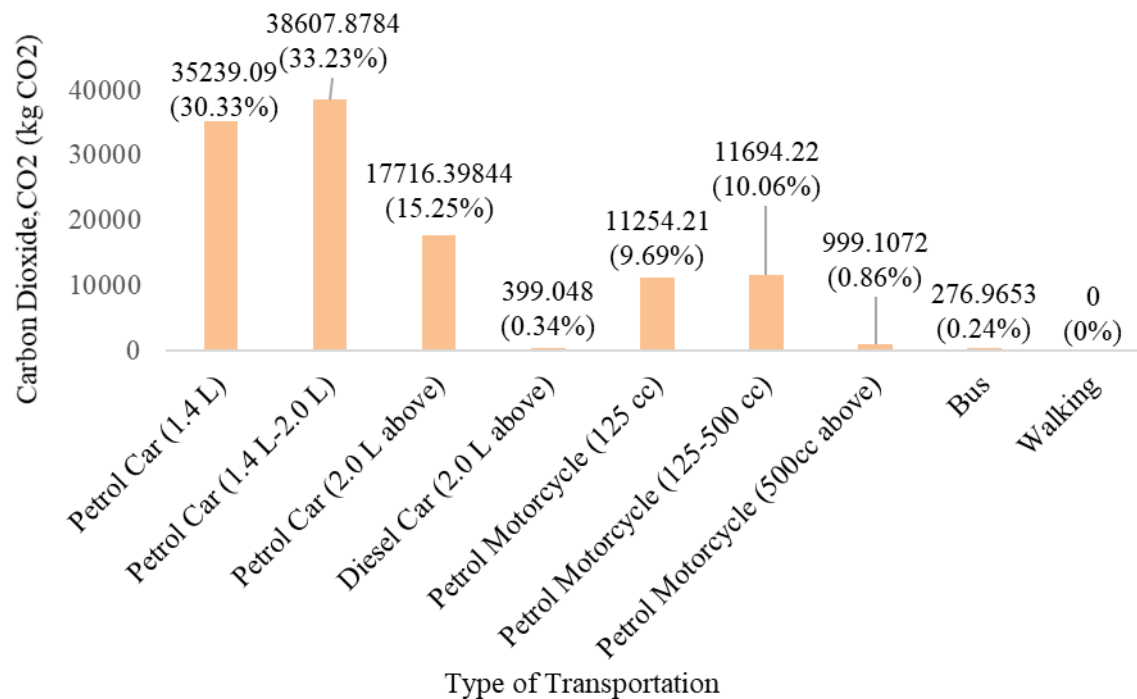


Figure 4 Graph of total annual emissions of Carbon Dioxide (kg CO₂/ year).

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 National Transportation Policy, Malaysia and the mean emissions in high-income countries [10].

Table 2. Mean annual emissions of Carbon Dioxide (CO₂).

Transportation	Fuel type	Engine size capacity	Mean Carbon Dioxide (CO ₂) annual (Kg CO ₂ / km)
Car	Petrol	1.4 L	451.7832
		1.4 L-2.0 L	665.6531
		2.0 L above	1181.0932
Motorcycle	Diesel	2.0 L above	399.048
		Petrol	173.1416
	Petrol	125 cc	307.7426
		125-500cc	999.1072
Bus	Diesel	-	2.4729
Walking	-	-	0
Mean CO ₂ emission Malaysia =7900kg CO ₂ /km			
Mean CO ₂ emission for high income country =5400kg CO ₂ /km			

Table 2 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 countries. Petrol cars with engine capacity larger than 2.0L have the highest mean annual emission (1181.0932 kg CO₂/ year/capita), followed by petrol motorcycle with engine capacity larger than 500cc (999.1072 kg CO₂/ year/capita). It is worth noting that the high mean values both

transportation modes may not be accurate because of the small number of respondents using these vehicles to commute. Relative to other categories of cars, petrol cars with 1.4L-2.0L engine have the second-highest mean emissions of 665.6531 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 307.7426 kg CO₂/year/capita. Bus passengers emitted only 2.4729 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 (7900 kgCO₂/year/capita) and the mean carbon dioxide emission in high-income countries (5400 kg CO₂/year/capita).

3.2. Multivariate linear regression model

This study used multivariate linear regression model in SPSS software to identify the critical factors influencing carbon dioxide (CO₂) emissions from the vehicles. These factors were evaluated using p-values, which indicate the significance of the factors in CO₂ emissions. Factors with p-value <0.05 shows are significant, while those with p-value >0.05 are not significant. Table 3 presents the p-values of factors in daily and annual carbon dioxide emissions.

Table 3. Influenced Factor.

Factor	Daily			Annually		
	Unstandardized Coefficient	Standard Coefficient	Sig (p-value)	Unstandardized Coefficient	Standard Coefficient	Sig (p-value)
	B	Beta		B	Beta	
Gender	0.017	-0.005	0.869	4.417	0.005	0.883
Age	0.242	0.108	0.034	54.068	0.087	0.105
Occupation	0.089	0.022	0.671	44.665	0.039	0.464
Mode of Transportation	-1.537	-0.815	0.000	-433.949	-0.827	0.000
Fossil Fuel	0.525	0.298	0.000	133.450	0.272	0.000
Engine Size Capacity	0.131	0.225	0.073	40.353	0.249	0.059
Distance Travelled	2.679	0.672	0.000	696.784	0.652	0.000
Gender: Male	0.108	0.032	0.486	38.805	0.041	0.371
Occupation: Staff	1.954	0.478	0.000	528.685	0.465	0.000
Car	2.156	0.645	0.000	605.016	0.650	0.000
Motorcycle	0.797	0.217	0.136	230.265	0.226	0.120
Bus	0.009	0.002	0.987	2.473	0.002	0.987
Petrol Car (1.4L)	1.646	0.407	0.001	451.783	0.401	0.001
Petrol Car (1.4L-2L)	2.320	0.511	0.000	665.653	0.527	0.000
Petrol Car (2L)	4.216	0.503	0.000	1181.093	0.506	0.000
Diesel Car (2L)	1.535	0.048	0.260	399.048	0.045	0.288
Petrol Motorcycle (125cc)	0.575	0.133	0.257	173.142	0.143	0.216
Petrol Motorcycle (125-500cc)	1.124	0.207	0.033	307.743	0.203	0.034
Petrol Motorcycle (500cc above)	2.745	0.086	0.044	999.107	0.113	0.008
Bus	0.009	0.002	0.986	2.473	0.002	0.986

Table 3 shows the key factors of the model. The model was run for overall factors to determine the effects of the independent factors, namely gender, age, occupation, type of vehicle, fossil fuel, engine capacity, and travel distance, on the daily and annual carbon dioxide emissions. Generally, the type of vehicle, type of fossil fuel, and travel distance are the critical factors influencing the daily and annual emission. The age factor is only influential in the model for daily carbon emissions because the p-values of all factors are less than 0.05, which means that any change in these factors will cause higher carbon dioxide emissions. Gender, occupation, and engine capacity did not influence the daily and annual carbon dioxide emissions. In conclusion, the type of vehicle, type of fossil fuel, and travel distance are the factors having the most influence on the daily and annual CO₂ emissions. The outcomes of this study are congruent with those obtained by Triantafyllidis et al. [11], which showed that different modes of transportation and travel distance influenced CO₂ emissions.

A detailed analysis showed that the total daily and annual carbon dioxide emission is not affected by gender. However, the occupation of the staff member influenced the daily and annual carbon emissions, indicating that greater participation of the staff members in the survey resulted in higher daily and annual carbon dioxide emissions. In this study, female respondents contributed to higher CO₂ emissions relative to male respondents. On the contrary, P. Wei and H. Pan [6] discovered that male respondents contributed to higher CO₂ emissions from transportation. The result of this study also showed that age and occupation are not critical factors in CO₂ emission, which is in line with the findings made by Y. Lee [12].

Further analysis of the type of vehicle showed that cars contribute to the daily and annual carbon emissions, where an increase in car usage will increase CO₂ emissions. In terms of engine capacity and type of fossil fuels, all petrol cars contribute significantly to the daily and annual carbon dioxide emissions, where both factors have a p-value of less than 0.05. The p-values for petrol motorcycles with engine capacities of 125-500cc and 500cc are less than 0.05, which means that these vehicles influenced the amount of daily and annual carbon dioxide emissions. S. Mustapa and H. Bekhet [13] have shown that petrol vehicles emitted a high amount of carbon dioxide. Given that 70% of the cars in Malaysia run on petrol, one effective way to reduce carbon emissions on the UKM campus is by providing an alternative commuting method that releases less carbon dioxide into the environment. In summary, an efficient method for reducing carbon emissions is by providing a viable travel alternative on campus.

4. Conclusion

This study used the DEFRA model to determine the CO₂ emissions of each type of vehicle used for commuting on the UKM Bangi campus. Petrol cars with engine capacity of between 1.4 to 2.0L emitted 33.33% or 38607.8784 kg CO₂ per year. Respondents who commuted by bus contributed the least to CO₂ emission (about 276.9653 kg CO₂ per year or 0.24%) and have the lowest emission rate per capita of 2.4729 kg CO₂. This low emission rate makes buses the most sustainable method for commuting. However, the mean annual CO₂ emissions of all types of vehicles used on the campus are lower than the 7900 kg CO₂ mean annual carbon emission in Malaysia and 5400 kg CO₂ mean annual emission in high-income countries.

The result of multivariate linear regression showed that, unlike the respondents who commute by bus and motorcycle, respondents who commute by car have a p-value of less than 0.05. Petrol cars with different engine capacities of 1.4L, 1.4-2.0L, and 2.0L and motorcycles with 125-500 and 500 cc engines have significant p-values. The type of vehicle, type of fuel, and distance travelled have significant p-values of less than 0.05 and are the critical factors influencing the daily and annual carbon dioxide emissions.

In conclusion, all members of the campus community, including the management, staff and students, must play a role in the effort to reduce CO₂ emissions by reducing the number of vehicles on the campus by taking the campus bus and carpooling and using vehicles with low carbon emissions. Another way to reduce carbon emissions is by providing bicycles or electric motorcycles at a low rental fee. These measures are critical in ensuring comprehensive and sustainable campus

transportation that would ultimately benefit the campus community and ensure environmental sustainability.

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