IJAAR PUBLISHING®

Global Journal of Artificial Intelligence and Technology Development | ISSN: 3027-0502
Vol. 2, Issue 3 (July-September, 2024) | www.ijaar.org

CARBON FOOTPRINT PROGNOSIS IN NIGERIA'S KEY STATES: A SUPPORT VECTOR MACHINE-BASED APPROACH

[1*]**Ibrahim Usman Haruna and [1]Cosmas Tizhe**

[1.] Department of Mechanical Engineering Technology, Federal Polytechnic Mubi, Adamawa State, Nigeria

* Corresponding Author Email Address: heldabuk@yahoo.com

Abstract

The number of motor vehicles in Nigeria is increasing rapidly, and this trend contributes immensely to global warming as a result of the corresponding increase in carbon emissions pumping into the atmosphere. Therefore, the estimation of the carbon footprint produced by motor vehicles in Nigeria is imperative. This study attempts to predict the carbon footprint produced by cars in the Nigerian major states: Lagos, Kano, Rivers, and the FCT. The number of registered private and commercial cars in these states from 2018 to 2022 was obtained from the National Bureau of Statistics. The prediction of the number of cars from 2023 to 2050 was done with the aid of a prediction code developed using the Support Vector Machine algorithm in Matlab programming. The code developed was verified using a regression model. The predicted results showed that Lagos State has the highest number of registered cars, which represents 60.4% and 54.2% in 2030 and 2050, respectively. The percentage increase in registered cars in these states rises from 27.5% between 2023 and 2030 to 47.5% between 2030 and 2050. The total predicted carbon footprint produced by the cars in 2030, 2040, and 2050 was 30.184 $MtCO_2e$, 42.622 $MtCO_2e$, and 55.284 $MtCO_2e$, respectively. This result indicates that the transport sector needs to be given adequate attention by policymakers in order to mitigate and forestall the catastrophic effect of pumping carbon emissions into the atmosphere.

Keywords: Carbon footprint, Prediction, Algorithm, Programming, Nigeria

Haruna, I.U. & Tizhe, C. (2024). Carbon Footprint Prognosis in Nigeria's Key States: A Support Vector Machine-Based Approach. *Global Journal of Artificial Intelligence and Technology Development, 2*(3), 22-35. DOI: 10.5281/zenodo.13847802

INTRODUCTION

Anthropogenic emissions of greenhouse gas (GHG) into the atmosphere have been on the rise since the discovery of oil. This increase in the amount of GHGs in the atmosphere has been identified as the major reason for rise in the average global temperature and the accelerated change in the world's climate (Ulker *et al*., 2020; Mersin *et al*., 2020). Climate change is an issue that has gained global attention. Excessive carbon emissions are not only the cause of global warming but also a threat to human survival by causing natural and social problems such as enhanced radiation, rising sea levels, glacial melting, decreasing snow cover, and biodiversity destruction (Tan *et al*., 2021). Global warming not only affects the balance of the ecosystem, but also brings irreversible damage to the development of human society and the economy. This climate change is a thing of concern for right-thinking Nigerian because the country is among those vulnerable.

Globally, the transport sector is a major source of CO_2 pollution in the atmosphere, with global contribution of about 7.3 billion metric tons of carbon dioxide emission in 2020. About 20% of the global CO_2 emission is contributed by road transport (Ulker *et al*., 2020).Developing countries are responsible for an increasing proportion of CO_2 emissions which might be attributed to rapid motorization (Wang, 2010). In Nigeria, road transport is predominant in the transport sector. This entails an excessive of internal combustion engine vehicles, hence, an immense contributor of carbon emission through the combustion of petroleum-based products like PMS, AGO and ATK, although, relatively small amounts of methane (CH_4) and nitrous oxide (N_2O) are emitted during combustion (Ziady, 2021).

According to data from the National Bureau of Statistics (NBS), there were about 11.8 million vehicles in Nigeria in 2018, which were made up of commercial (57.70%), private (40.98%), and government and diplomatic (1.32%) vehicles (NBS, 2018). The number of vehicles increased to 13 million by April 2021 (Iwunze, 2022). The 2020 annual statistical bulletin by the Nigerian National Petroleum Commission (NNPC) showed a persistent increase in the daily consumption of petroleum products, with PMS being the most consumed (NNPC, 2020). The expansion of the nations road transport sub-sector and its sole dependence on fossil fuels is pivotal to such increment, hence a major contributor to the nation's carbon footprint. Carbon footprint can be defined as the total emission of greenhouse gases expressed in carbon dioxide equivalent (CO_2e) (Naderipour *et al*., 2021).

The importance of studying the carbon footprint has stimulated the interest of many researchers to develop mathematical models to predict the carbon footprint for the purpose of finding ways of forestalling further catastrophic effects of pumping carbon emission into the atmosphere. Thus, predicting carbon emissions especially based on the influencing factors is now a hot research topic in the field of carbon emission. The establishment of carbon emission prediction models can provide technical support for decision makers to formulate emission reduction plans and help reduce carbon emissions. Chairul *et al*. (2015) developed a model for the prediction of carbon dioxide emission from electrical energy consumption and coal prediction using support vector machine. An adaptive neuro-fuzzy interference system (ANFIS) and multi-layer perceptron artificial neural network (MLP-ANN) have been developed to estimate CO_2. The proposed model of ANFIS and MLP-ANN demonstrates that both methods can solve CO_2 prediction problem (Kainuma *et al*., 2000). Ge *et al*. (2017) developed a prediction model for industrial carbon emissions in Tianjin based on industrial carbon emissions data from 2003-2012 using the logistics model and the STIRPAT model, and compared the results. Perez-Suarez and Lopez-Mendendez (2015) predicted carbon emissions for several countries using the extended environmental Kuznets curve and

environmental logistic curve, and the percentage error of their proposed model fluctuated between 2.5 and 6.8 per cent.

Machine learning outperforms traditional statistical methods in many problems and has high prediction accuracy and robustness (Deng *et al*., 2020). This might be attributed to the non-linearity of carbon emissions released from various sources. Javanmard et al. (2021) employed 12 favorite machine learning algorithms used by recent studies for prediction in the building, energy, and water domain to predict the costs and carbon emission in an integrated energy-optimization model in buildings. Chai *et al*. (2022) used Genetic Algorithm (GA) combined with neural network to establish a carbon emissions prediction model for Xinjiang. Li *et al*. (2018) used the SVM-ELM model to predict the carbon emissions in some regions. Liu et al. (2018) identified the key factors affecting carbon emissions and constructed a BP neural network model to predict the carbon emissions for Beijing in the next five years under different development scenarios. Ahmadi *et al*. (2019) used artificial neural network (ANN) approach to predict CO_2 emissions for five countries in the Middle East. Ning *et al*. (2021) forecast China's carbon emission based on ARIMA method.

Although many prediction models were developed to predict the carbon emissions from various sources in many parts of the world, research is missing in the development of prediction models for the prediction of carbon footprint produced by both private and commercial cars in Nigeria. This work is an attempt to predict the carbon footprint produce by private and commercial cars in the major states of Nigeria: Lagos, Kano, Rivers, and FCT using machine learning- support vector machine (SVM) algorithm.

STUDY AREA

Nigeria lies along the western coast of the second largest continent in the world, with a land mass of 910768km^2 and water body of 13000 km^2, totaling an area of 923766 km^2, with a population of about 211400708 (Li *et al*., 2018). This entire population is directly or indirectly served by the road transport sector. Nigeria has about 195000km road network; 36182 km of this network is Federal while the rest are state and local roads (Akujor *et al*., 2022).

Passenger transport involves a variety of transport modes, vehicle types, vehicle owners (individuals or organizations), and varying ranges in terms of administrative areas covered by different vehicle types. This results in a large body of statistical data. In addition, the variety of statistical standards and the imperfect traffic statistics in Nigeria make things difficult. All these factors combined to make carbon emission estimation and prediction difficult. Calculation should be based on data availability and calculation scope which should be determined based on acceptable accuracy.

Calculation Scope Description

The calculation scope was defined based on:

i. Only cars registered in Lagos state, Kano state, Rivers state, and the FCT were considered for the study.
ii. Only private and commercial cars were considered in this study
iii. Only direct emissions were considered for the cars
iv. Petrol was the fuel considered for private cars while both petrol and diesel were the fuel considered for the commercial cars.

v. The average daily distance travelled by private cars was 10 km while that of commercial cars was 40 km.

Data Availability

In the absence of official data in Nigeria on the carbon emission factors of fuels, the values used in this study were obtained from the Intergovernmental Panel on Climate Change (IPCC, 2006). The number of registered cars (private and commercial) was obtained from the database of National Bureau of Statistics.

METHODOLOGY

The methodology followed was logically highlighted hereunder.

Data Collection

The registered private and commercial cars for the Nigerian major states: Lagos state, Kano state, Rivers state, and FCT were obtained from National Bureau of Statistics (NBS) for the period of five years (2018-2022). This information is presented in Table 1.

Table 1: Registered Cars in Nigeria's Major States (2018-2022)

S/N	State	Car Type	2018	2019	2020	2021	2022
1	Lagos	Private	2242885	2324023	2405161	2486300	2567439
		Commercial	1802501	1874788	1947076	2019364	2091653
2	Kano	Private	646685	671360	696035	720710	745385
		Commercial	566268	591053	615848	640643	665438
6	Rivers	Private	311684	323604	335524	347444	360364
		Commercial	387900	400720	413540	426360	439180
10	FCT	Private	247957	262790	275841	286891	299931
		Commercial	322746	335781	348721	361661	374601

Development of the Support Vector Machine (SVM) Model

SVM model was developed using Matlab programming to predict the number of registered cars (private and commercial) in years 2023 – 2030, 2040, 2045, and 2050 for the states under study. In developing the code, Lagos state, Kano state, Rivers state, and the FCT are represented by the letters L, K, R, and F respectively. The SVM model developed for both private and commercial cars using the Matlab programming is presented in Appendices A and B respectively. The predicted values for both private and commercial cars are presented in Table 2.

Model Verification

The verification of the SVM model is essential to determine the correctness of the model. Based on the code developed, the predicted values of L, K, R and F using the SVM model were compared with the corresponding predicted values using the regression model. The RMSE between the values obtained from the two models is 0.13.

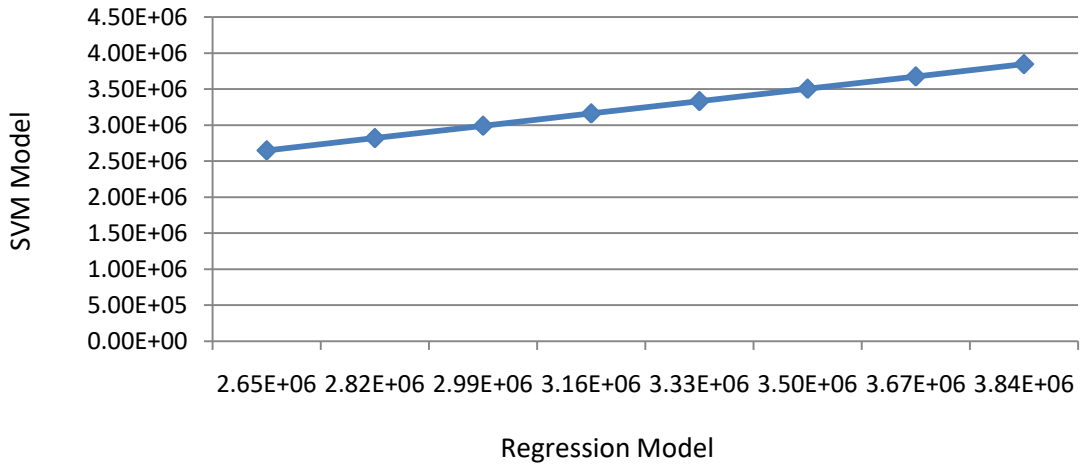


Fig. 1: SVM Model VS Regression Model

Estimation of Registered Cars on Fuel-type Basis

The two major fuel types used by most Nigerian cars are petrol and diesel (NNPC, 2020). Study has shown that almost all Nigerian private cars on our roads use petrol while in the case of commercial vehicles, some use petrol while others use diesel. Assuming 20% of the commercial cars use diesel, then the annually predicted cars that use diesel as well as petrol for the states under study are presented in Table 3.

Estimation of Carbon Footprint Produced by Cars

The average distance moved by private cars on a daily basis ranges from 8 km to 12 km, and for commercial cars, it ranges from 35 km to 45 km (Naderipour *et al*., 2021). Assuming the daily average distance moved by private cars is 10 km and that of commercial cars is 40 km, the carbon footprint produced by private cars can be determined from equation 1 (Mshelia, 2021). The annually estimated carbon footprints of the private cars for the states under study are presented in Table 4.

$$AE = NV \times ATD \times EF \times 365 \quad (1)$$

Where:

AE = Annual Emission

NV = Number of cars based on the type of fuel considered

ATD = Average Travel Distance

EF = Emission Factor based on the type of fuel considered

Since it was assumed that 20% of the commercial cars used diesel, the annual carbon footprint produced by the cars that used diesel for the states under study can also be calculated using equation 1. The annual predicted values of the carbon footprint produced by these cars are presented in Table 4. Similarly, the carbon footprint produced by the 80% of the commercial cars that used petrol was also estimated using equation 1. The annual

predicted carbon footprint produced by the commercial cars that used petrol for the states under study are presented in Table 5.

RESULTS AND DISCUSSION

Figure 1 shows the percentage of registered cars in Nigerian major states.

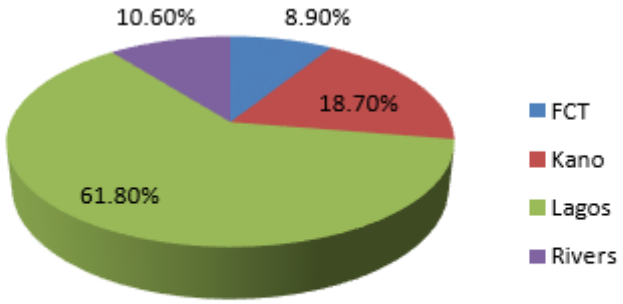


Figure 1: Percentage of Registered Cars of Nigerian Major States

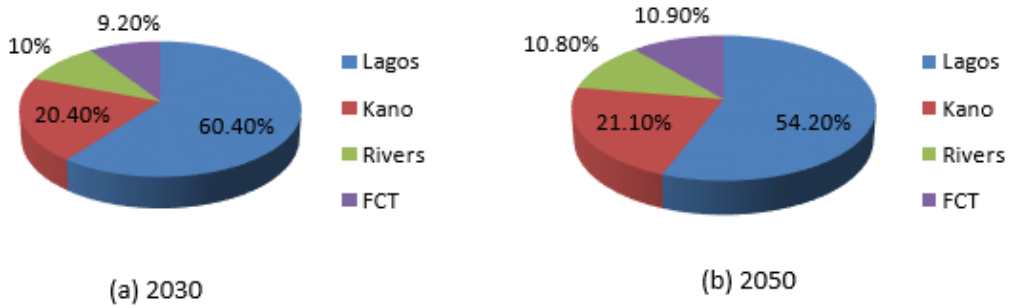
From the data collected for the registered cars in Nigerian Major states: Lagos state, Kano state, Rivers state, and the FCT, it can be seen that Lagos state registered about 61.8% of the cars within the period under study, followed by Kano state, Rivers state, and FCT with 18.7%, 10.6%, and 8.9% of the registered vehicles respectively. This clearly shows that Lagos state with the highest percentage of registered cars should be the focal point to be considered for the mitigation of the carbon footprint in Nigeria.

The annually predicted numbers of registered cars, both private and commercial, for the Nigerian major states are presented in Table 2.

Table 2: Annually Predicted Private and Commercial Cars for Nigerian Major States

	Year	Car Type	Fuel Type	State			
				Lagos	Kano	Rivers	FCT
1	2023	Private	Petrol	2.6509e+06	7.8877e+05	3.3678e+05	3.1760e+05
		Commercial	Diesel	2.1739e+06	6.8916e+05	4.4971e+05	3.8706e+05
2	2024	Private	Petrol	2.8228e+06	8.6734e+05	3.6286e+05	3.4647e+05
		Commercial	Diesel	2.2520e+06	7.1315e+05	4.6261e+05	3.9965e+05
3	2025	Private	Petrol	2.9918e+06	9.4590e+05	3.8952e+05	3.7494e+05
		Commercial	Diesel	2.3301e+06	7.3762e+05	4.7556e+05	4.1222e+05
4	2026	Private	Petrol	3.1568e+06	1.0241e+06	4.1677e+05	4.0305e+05
		Commercial	Diesel	2.4082e+06	7.6258e+05	4.8856e+05	4.2479e+05
5	2027	Private	Petrol	3.3168e+06	1.1023e+06	4.4460e+05	4.3087e+05
		Commercial	Diesel	2.4863e+06	7.8804e+05	5.0161e+05	4.3735e+05
6	2028	Private	Petrol	3.4720e+06	1.1791e+06	4.7299e+05	4.5845e+05
		Commercial	Diesel	2.5645e+06	8.1400e+05	5.1471e+05	4.4990e+05
7	2029	Private	Petrol	3.6223e+06	1.2545e+06	5.0197e+05	4.8585e+05
		Commercial	Diesel	2.6427e+06	8.4048e+05	5.2786e+05	4.6244e+05
8	2030	Private	Petrol	3.7679e+06	1.3285e+06	5.3156e+05	5.1311e+05
		Commercial	Diesel	2.7209e+06	8.6746e+05	5.4106e+05	4.7496e+05
9	2035	Private	Petrol	4.5130e+06	1.7987e+06	7.1885e+05	7.1745e+05
		Commercial	Diesel	3.1314e+06	1.0784e+06	6.3464e+05	5.7920e+05
10	2040	Private	Petrol	5.2581e+06	2.2689e+06	9.0615e+05	9.2178e+05
		Commercial	Diesel	3.5423e+06	1.2902e+06	7.3004e+05	6.8602e+05
11	2045	Private	Petrol	6.0042e+06	2.7390e+06	1.0934e+06	1.1260e+06
		Commercial	Diesel	3.9536e+06	1.5027e+06	8.2725e+05	7.9551e+05
12	2050	Private	Petrol	6.7494e+06	3.2092e+06	1.2807e+06	1.3303e+06
		Commercial	Diesel	4.3651e+06	1.7159e+06	9.2629e+05	9.0767e+05

From Table 2, the predicted percentage of the registered cars in the major Nigerian states in 2030 and 2050 is shown in Figures 2a and 2b respectively.



(a) 2030 (b) 2050

Figure 2 (a and b): Predicted Percentage of Registered Cars in Nigerian Major States in 2030 and 2050

It can be seen that Lagos state has the largest predicted number of registered cars with 60.4% in 2030 and 54.2% in 2050 followed by Kano state with predicted registered cars of 20.4% and 21.1% in the years 2030 and 2050 respectively. Rivers state and the FCT have predicted registered cars of 10% and 10.8% in 2030 and 9.2% and 10.9% in 2050 respectively. From this information, it can be seen that FCT has the highest percentage increase of the registered cars by 2050 followed by Kano state, Rivers state and Lagos state. Overall, the predicted percentage increase in the number of registered cars increases from 2030 to 2050 by about 47.5%. The increase in the number of registered cars might be attributed to factors such as rural urban migration and the improvement in the standard of living,

The numbers of private and commercial cars with their fuel type in the major states are presented in Table 3, while Table 4 presents the number of registered cars based on the fuel type used.

Table 3: Number of Private and Commercial Cars with their Fuel Type of the Major States

Year	Car Type	Fuel Type	State			
			L	K	R	F
2023	Private	Petrol	2.6509e+06	7.8877e+05	3.3678e+05	3.1760e+05
	Commercial	Diesel	4.35E+05	1.38E+05	8.99E+04	7.74E+04
		Petrol	1.74E+06	5.51E+05	3.60E+05	3.10E+05
2024	Private	Petrol	2.8228e+06	8.6734e+05	3.6286e+05	3.4647e+05
	Commercial	Diesel	4.50E+05	1.43E+05	9.25E+04	7.99E+04
		Petrol	1.80E+06	5.71E+05	3.70E+05	3.20E+05
2025	Private	Petrol	2.9918e+06	9.4590e+05	3.8952e+05	3.7494e+05
	Commercial	Diesel	4.66E+05	1.48E+05	9.51E+04	8.24E+04
		Petrol	1.86E+06	5.90E+05	3.80E+05	3.30E+05
2026	Private	Petrol	3.1568e+06	1.0241e+06	4.1677e+05	4.0305e+05
	Commercial	Diesel	4.82E+05	1.53E+05	9.77E+04	8.50E+04
		Petrol	1.93E+06	6.10E+05	3.91E+05	3.40E+05
2027	Private	Petrol	3.3168e+06	1.1023e+06	4.4460e+05	4.3087e+05
	Commercial	Diesel	4.97E+05	1.58E+05	1.00E+05	8.75E+04
		Petrol	1.99E+06	6.30E+05	4.01E+05	3.50E+05
2028	Private	Petrol	3.4720e+06	1.1791e+06	4.7299e+05	4.5845e+05
	Commercial	Diesel	5.13E+05	1.63E+05	1.03E+05	9.00E+04
		Petrol	2.05E+06	6.51E+05	4.12E+05	3.60E+05
2029	Private	Petrol	3.6223e+06	1.2545e+06	5.0197e+05	4.8585e+05
	Commercial	Diesel	5.29E+05	1.68E+05	1.06E+05	9.25E+04
		Petrol	2.11E+06	6.72E+05	4.22E+05	3.70E+05
2030	Private	Petrol	3.7679e+06	1.3285e+06	5.3156e+05	5.1311e+05
	Commercial	Diesel	5.44E+05	1.73E+05	1.08E+05	9.50E+04
		Petrol	2.18E+06	6.94E+05	4.33E+05	3.80E+05
2035	Private	Petrol	4.5130e+06	1.7987e+06	7.1885e+05	7.1745e+05
	Commercial	Diesel	6.26E+05	2.16E+05	1.27E+05	1.16E+05
		Petrol	2.51E+06	8.63E+05	5.08E+05	4.63E+05
2040	Private	Petrol	5.2581e+06	2.2689e+06	9.0615e+05	9.2178e+05
	Commercial	Diesel	7.08E+05	2.58E+05	1.46E+05	1.37E+05
		Petrol	2.83E+06	1.03E+06	5.84E+05	5.49E+05
2045	Private	Petrol	6.0042e+06	2.7390e+06	1.0934e+06	1.1260e+06
	Commercial	Diesel	7.91E+05	3.01E+05	1.65E+05	1.59E+05
		Petrol	3.16E+06	1.20E+06	6.62E+05	6.36E+05
2050	Private	Petrol	6.7494e+06	3.2092e+06	1.2807e+06	1.3303e+06
	Commercial	Diesel	8.73E+05	3.43E+05	1.85E+05	1.82E+05
		Petrol	3.49E+06	1.37E+06	7.41E+05	7.26E+05

Table 4: Number of Registered Cars Based on the Fuel Type Used

Year	Fuel Type	Total Number of Registered Cars on Fuel Type Basis
2023	Petrol	7.06E+06
	Diesel	7.40E+05
2024	Petrol	1.34E+08
	Diesel	7.65E+05
2025	Petrol	7.86E+06
	Diesel	7.92E+05
2026	Petrol	8.27E+06
	Diesel	8.18E+05
2027	Petrol	8.67E+06
	Diesel	8.43E+05
2028	Petrol	9.06E+06
	Diesel	8.69E+05
2029	Petrol	9.44E+06
	Diesel	8.96E+05
2030	Petrol	9.83E+06
	Diesel	9.20E+05
2035	Petrol	1.21E+07
	Diesel	1.09E+06
2040	Petrol	1.43E+07
	Diesel	1.25E+06
2045	Petrol	1.66E+07
	Diesel	1.42E+06
2050	Petrol	1.89E+07
	Diesel	1.58E+06

From Tables 3 and 4, it can be seen that the numbers of cars that used petrol are slightly more than those that used diesel. This might be attributed to the fact that many commercial cars also use petrol.

The annual predicted carbon footprint produced by the registered cars in the Nigerian major states is presented in Table 5.

Table 5: Annually Predicted Carbon Footprint produced by Cars in Nigerian Major States

Year	Fuel Type	Total Number of Registered Cars on Fuel Type Basis	Carbon Footprint Produced by Cars on Fuel Type Basis ($MtCO_2e$)	Total Carbon Footprint Produced by the Cars ($MtCO_2e$)
2023	Petrol	7.06E+06	11.956378	22.72939753
	Diesel	7.40E+05	10.77301953	
2024	Petrol	1.34E+08	12.28879236	23.06181189
	Diesel	7.65E+05	11.13697289	
2025	Petrol	7.86E+06	13.42530444	24.95534696
	Diesel	7.92E+05	11.53004252	
2026	Petrol	8.27E+06	14.12560658	26.0341606
	Diesel	8.18E+05	11.90855402	
2027	Petrol	8.67E+06	14.80882818	27.08133556
	Diesel	8.43E+05	12.27250738	
2028	Petrol	9.06E+06	15.47496924	28.12598812
	Diesel	8.69E+05	12.65101888	
2029	Petrol	9.44E+06	16.12402976	29.16811827
	Diesel	8.96E+05	13.04408851	
2030	Petrol	9.83E+06	16.79017082	30.18365456
	Diesel	9.20E+05	13.39348374	
2035	Petrol	1.21E+07	20.6674534	36.53582001
	Diesel	1.09E+06	15.86836661	
2040	Petrol	1.43E+07	24.4251722	42.62284033
	Diesel	1.25E+06	18.19766813	
2045	Petrol	1.66E+07	32.1114152	52.78396619
	Diesel	1.42E+06	20.67255099	
2050	Petrol	1.89E+07	32.2822206	55.28407311
	Diesel	1.58E+06	23.00185251	

It can be seen from Table 5 that the carbon footprint produced by registered cars in Nigerian major states increases from 22.729 $MtCO_2e$ in 2023 to about 55.284 $MtCO_2e$ by the year 2050. This finding is in consonance with the work of Jena *et al.* (2021), who stated that there is a linear correlation between an increase in the number of vehicles and the production of carbon footprints.

CONCLUSION

It is impossible to overstate the importance of estimating the carbon footprint that the transportation industry produces. In this study, a support vector machine method was used to anticipate the carbon footprint that automobiles in the major states of Nigeria will produce between 2023 and 2050. In Lagos State, Kano State, Rivers State, and the Federal Capital Territory, the estimated total carbon footprint generated by automobiles in 2030, 2040, and 2050 is 30.184 $MtCO_2e$, 42.622 $MtCO_2e$, and 55.284 $MtCO_2e$, respectively. Despite the fact that these projections were comparatively smaller than those made by industrialized nations like the US and China, Nigeria's technological incapacity to adapt to climate change is concerning, as it may be directly linked to the enormous rise in the country's carbon footprint. This information may help policy makers to take necessary actions in order to mitigate such a large increase in carbon footprint for sustainable development.

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APPENDIX A: Development of the Code for the Prediction of Registered Private Cars in L, K, R, and F

To use the model to predict the values of L, K, R and F for the given input values, we can use the following code:

```matlab
% Create input values for prediction
X_pred = [2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2035, 2040, 2045, 2050]';

% Predict the values using the linear regression models
Y_pred_L = predict(mdl_L, X_pred);
Y_pred_K = predict(mdl_K, X_pred);
Y_pred_R = predict(mdl_R, X_pred);
Y_pred_F = predict(mdl_F, X_pred);

% Predict the values using the SVM models
Y_pred_L_svm = predict(mdl_L.Trained, X_pred);
Y_pred_K_svm = predict(mdl_K.Trained, X_pred);
Y_pred_R_svm = predict(mdl_R.Trained, X_pred);
Y_pred_F_svm = predict(mdl_F.Trained, X_pred);

% Display the predicted values
disp('Linear Regression Predictions')
disp(['L:', num2str(Y_pred_L')])
disp(['K:', num2str(Y_pred_K')])
disp(['R:', num2str(Y_pred_R')])
disp(['F:', num2str(Y_pred_F')])

disp('SVM Predictions')
disp(['L:', num2str(Y_pred_L_svm')])
disp(['K:', num2str(Y_pred_K_svm')])
disp(['R:', num2str(Y_pred_R_svm')])
disp(['F:', num2str(Y_pred_F_svm')])
```

The output of this code will display the predicted values for both the linear regression models and the SVM models:

```
Linear Regression Predictions
L:2.6486e+06 2.8194e+06 2.9902e+06 3.1609e+06 3.3317e+06 3.5025e+06 3.6733e+06
3.8441e+06 4.7054e+06 5.5668e+06 6.4281e+06 7.2895e+06
K:7.9381e+05 8.7186e+05 9.4992e+05 1.0270e+06 1.1041e+06 1.1802e+06 1.2553e+06
1.3295e+06 1.7896e+06 2.2496e+06 2.7097e+06 3.1697e+06
R:3.3163e+05 3.5757e+05 3.8404e+05 4.1099e+05 4.3840e+05 4.6624e+05 4.9448e+05
5.2311e+05 7.3243e+05 9.4175e+05 1.1511e+06 1.3604e+06
F:3.2017e+05 3.4879e+05 3.7703e+05 4.0493e+05 4.3252e+05 4.5982e+05 4.8684e+05
5.1361e+05 7.2665e+05 9.3970e+05 1.1527e+06 1.3651e+06

SVM Predictions
L:2.6509e+06 2.8228e+06 2.9918e+06 3.1568e+06 3.3168e+06 3.4720e+06 3.6223e+06
3.7679e+06 4.5130e+06 5.2581e+06 6.0042e+06 6.7494e+06
K:7.8877e+05 8.6734e+05 9.4590e+05 1.0241e+06 1.1023e+06 1.1791e+06 1.2545e+06
1.3285e+06 1.7987e+06 2.2689e+06 2.7390e+06 3.2092e+06
R:3.3678e+05 3.6286e+05 3.8952e+05 4.1677e+05 4.4460e+05 4.7299e+05 5.0197e+05
5.3156e+05 7.1885e+05 9.0615e+05 1.0934e+06 1.2807e+06
F:3.1760e+05 3.4647e+05 3.7494e+05 4.0305e+05 4.3087e+05 4.5845e+05 4.8585e+05
5.1311e+05 7.1745e+05 9.2178e+05 1.1260e+06 1.3303e+06
```

APPENDIX B: Development of the Code for the Prediction of Registered Commercial Cars in L, K, R, and F

The code to use the SVM models to predict the values of L, K, R, and F for a range of X values:

```matlab
% Define X values to predict for
X_pred = [2023:1:2050]';

% Predict target values using trained models
Y_pred_L = predict(L_model_svm, X_pred);
Y_pred_K = predict(K_model_svm, X_pred);
Y_pred_R = predict(R_model_svm, X_pred);
Y_pred_F = predict(F_model_svm, X_pred);

% Print the predicted values
fprintf("Predicted L values:\n");
fprintf("%.0f, ", Y_pred_L');
fprintf("\n\n");

fprintf("Predicted K values:\n");
fprintf("%.0f, ", Y_pred_K');
fprintf("\n\n");

fprintf("Predicted R values:\n");
fprintf("%.0f, ", Y_pred_R');
fprintf("\n\n");

fprintf("Predicted F values:\n");
fprintf("%.0f, ", Y_pred_F');
fprintf("\n\n");
```

This code predicts the target values for L, K, R, and F using the trained SVM models for a range of X values between 2023 and 2050 (inclusive). It then prints the predicted values for each target variable.

The output of this code will be:

```
Predicted L values:
2173941, 2251986, 2330059, 2408159, 2486291, 2564459, 2642669, 2720924, 3131497, 3542383, 3953586, 4365106

Predicted K values:
689160, 713152, 737625, 762584, 788036, 814000, 840475, 867469, 1078392, 1290221, 1502737, 1715939

Predicted R values:
449711, 462611, 475561, 488561, 501611, 514712, 527862, 541062, 634638, 730034, 827250, 926285

Predicted F values:
387055, 399646, 412225, 424793, 437351, 449899, 462436, 474964, 579195, 686023, 795512, 907670
```

These are the predicted target values for each target variable using the SVM models trained on the input-output data.