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UNVEILING THE NEXUS BETWEEN FUEL CONSUMPTION, VEHICLE REGISTRATION, POPULATION AND GDP OF NEPAL

***Niraj Bohara[1], and Hemant Tiwari[2]**

[1]Lecturer/ Executive Member, Department of Civil Engineering, United Technical College/Safe and Sustainable Travel Nepal, Bharatpur -11, Chitwan, Nepal.
[2]General Secretary, Society of Transportation Engineers of Nepal, Kathmandu, Nepal

[1] http://orcid.org/0009-0002-0948-4956, [2] http://orcid.org/0000-0003-4409-1787,

Email: *nbohara@unitedtechnicalcollege.edu.np1, hemu.ioe.edu.np2

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ABSTRACT

Vehicle numbers soar with the increase in travel demand, thus increasing petroleum consumption, one of the extensive non-renewable resources. The increased demand for travel is also linked to Gross Domestic Product (GDP). However, due to the rise in fuel standards and higher fuel efficiency vehicles, the fuel consumption per vehicle is following the decreasing patterns. Thus, this study is about the relationship between petroleum consumption, vehicle registration and GDP of Nepal using regression analysis. Data for analysis were between 1994 and 2022 for registered vehicles, petroleum consumption and GDP whereas population data were collected from 1930 to 2021. The linear regression model came to be statistically significant between variables, (a) vehicles registered and petroleum consumption (diesel and petrol sales); (b) operating vehicles and petroleum consumption; and (c) operating light vehicles and petrol consumption. Similarly, significant exponential regression models were observed between (a) GDP and operating vehicles; and (b) GDP and petroleum consumption. Additionally, the study presented a logistic population growth model and vehicle growth model as significant models to put forth predicted population and vehicles in 2030 and 2040. These models were used to estimate the possible petroleum consumption in 2030 and 2040. Alongside, a situation, where high electric vehicle penetration might be observed, was also taken to predict the possible petroleum consumption. Rising petroleum consumption can be curbed to a certain limit with proper policy interventions and research and development in electric vehicles.

I. INTRODUCTION

The burning of fuels generates locomotive power for internal combustion engines. In the present world, diesel, petrol (gasoline), and natural gases are being used widely for light vehicles and heavy vehicles movement. Light fuels are generally used for lighter vehicles generating higher fuel efficiency movements whereas heavy fuels such as diesel are being used for heavy duty operations. There have been studies on the use of biofuels and additives to increase efficiency and control pollution, however, the use of these non-renewable sources hasn't stopped petroleum product sales from soaring.

Internal combustion engines, though have improved their efficiency in terms of km per litre consumption and even in terms of emission, as per the study by Yeu and Liu. They forecasted that internal combustion engine technology in future continually would dominate other vehicles. This in turn would increase demand for more petroleum consumptions. The study also stated that increased efficiency is the main reason behind the popularity of IC engine technology [1].

The study "The Role of Regulations, Gasoline Taxes and Autonomous Technical Change" cited that EU and US standards for vehicles have increased the fuel efficiency standards between 2015 and 2020. EU raised the standard limit of mileage from 17.85

km/lit in 2015 to 24.21 km/lit in 2020 AD while in the US, as per the Mandatory fuel efficiency standards, the fuel efficiency was increased from 15 km/lit to 20 km/lit in 2020 for light trucks and cars operating with gasoline (petrol). This also shows the demand for higher fuel-efficient vehicles. As per the same study, the improvement in fuel efficiency is also induced because of increased standards [2].

In addition, standards are introduced to control the emissions and to sustain the engine efficiency. Standard in Europe started in the 70's and was mostly focused on the reduction of lead, benzene, sulfur, polyaromatic hydrocarbons, manganese, and volatile organic components. The main reasons these components were regarded as pollutants were because of their incomplete combusting nature, and volatility, which were specifically harmful to humans [3].

To predict the condition of Nepal regarding emission and energy consumption Bajracharya in 2013 produced a relation between vehicle population and different variables such as population, and the Gross Domestic Product. The relationship observed had an excellent correlation for Minibus and population, motorcycle (2-wheeler), and urban population whereas those associated with GDP had only a strong correlation. The relation was best fit by a logarithmic function. The study also suggested the diminishing vehicle km travelled with the increased age of vehicles [4].

A study by Bajracharya and Bhattarai in 2016, studied the vehicle and energy consumption in Kathmandu Valley and predicted different scenarios in 2030. The study incorporated the estimation of the vehicle fleet using the equation $N_{i,y} = 0.5 * D_{i,y} + \sum_{x=1990}^{y-1} D_{i.y} * \phi_i(y - x)$. The study was conducted with the base year data of 1990 as x and for y year where ϕ represents the survival probability of that particular group of vehicles. The other data estimated in the study were annual mileage and emissions. The study predicted that the vehicle population will reach 1 million in the year 2030 where the highest proportions would be covered by light vehicles whereas the petrol demand is to soar to 257,000 kL in 2030 while the model predicted that diesel consumption is going to boom to 135,000 kL in Kathmandu Valley alone [5].

II. VEHICLE REGISTRATION, PETROLEUM CONSUMPTION AND GDP STATUS

In reference to the Department of Transport Management [6] and the economic survey data of 2023 [7]The registered vehicles, after reducing the number of e-rickshaws (electric vehicles) when plotted against the year (1990 -2022), depict a vehicle trend with three different growth rates. It ranges from a low to a high rate of growth. A low growth rate was seen between 1990 and 2007, a mild growth rate was seen between 2007 and 2016, whereas a steep growth rate (high) was seen after 2016. The vehicle growth is continuous and follows a smooth curve with year as shown in the Fig. 1. The total vehicle registration observed in the year 1994 was 139,858 which later rose uninterruptedly to 5,032,666 registered vehicles in 2022.

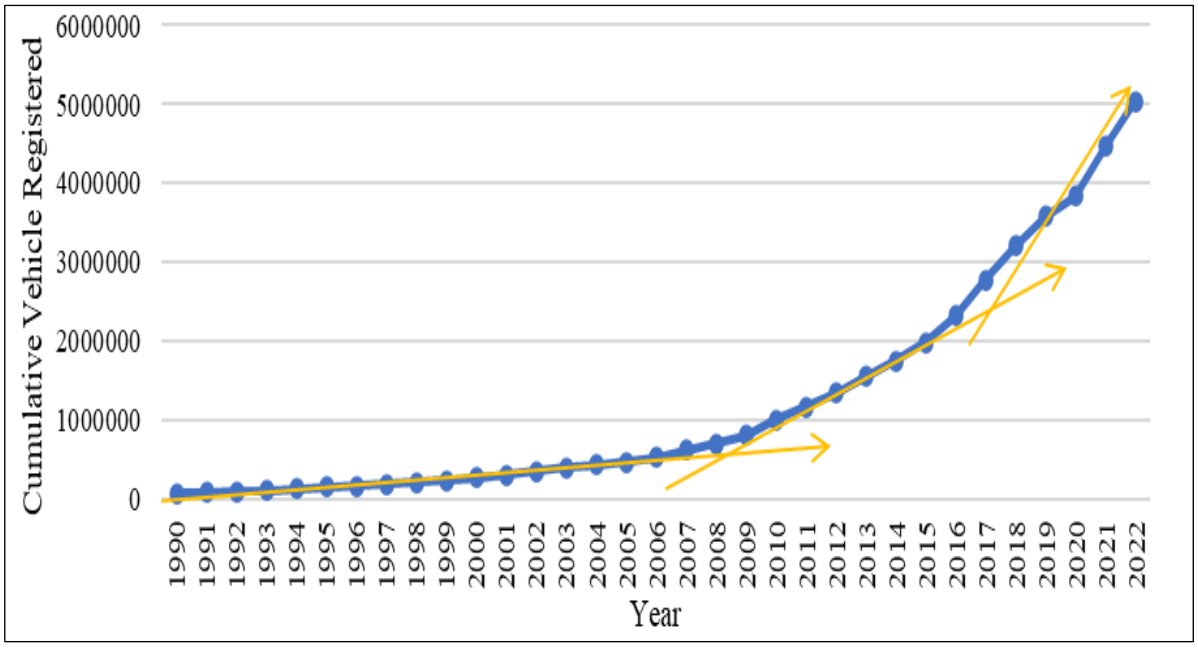

Figure 1: Growth trend of cumulative vehicles registered in Nepal (1990 – 2022).
Source: [7].

According to the database of Nepal Oil Corporation, the only fuel importer of Nepal, fuel consumption has been ever-increasing. Diesel sales and petrol sales in kL are taken as the fuel consumption for the study. There are two distinct drops in petroleum consumption as seen, in 2016 and 2020 which is due to the blockade in 2015 and COVID-19 in 2020. Thus. collected data were arranged chronologically from 1994 to 2022. The trend in fuel consumption suggests that from 1994 till 2008, the growth rate was low, from 2008 till 2016, the growth rate was medium whereas the growth rate after 2016 seems to have risen steeply as shown in Figure. 1, which follows a similar trend as registered vehicles. This displays, there exists a close relationship between fuel sales and the vehicle number. The total petroleum consumption (diesel + petrol) seems to be 226,750 kL in 1994 which rose to 2,460,408 kL in 2022. Similarly, the petrol consumption in 1994 was 31,061 kL which was 732,837 kL in 2022. While for diesel, the consumption of 195,689 kL in 1994 is seemed to increase to 1,727,571 kL in 2022 [8].

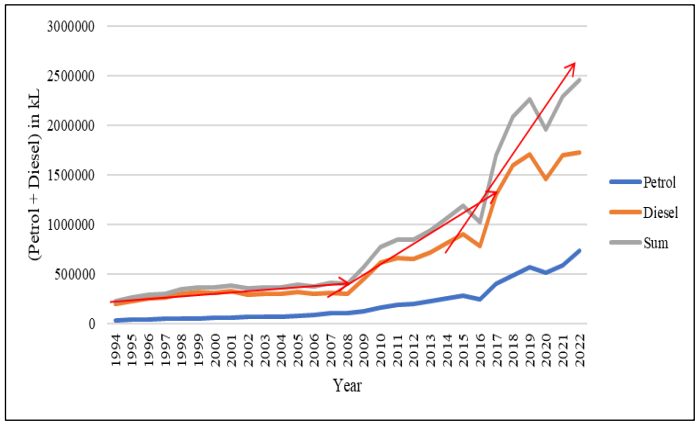

Figure. 1: Growth trend of petroleum consumption in Nepal (1994 – 2022).
Source: [8].

For Gross Domestic Product, the World Bank Global Outlook (indicator) has been taken GDP (constant 2015 US$). The trend is similar to that of vehicle growth and petroleum product sales but not on a similar scale. The three trends/growth rates are seen between 1991 and 2004, 2004 to 2015 and 2015 to 2022 in Figure 2. The GDP is observed to be 8,779 million US$, 10,271 million US$ and 33,084 million US$ in 1991, 1994 and 2022 which demonstrates the progressive trend of GDP (constant 2015 US$) [9]. So, this study is focused on finding out the relationship between vehicle numbers, petroleum product sales (petroleum consumption) and gross domestic product of the country.

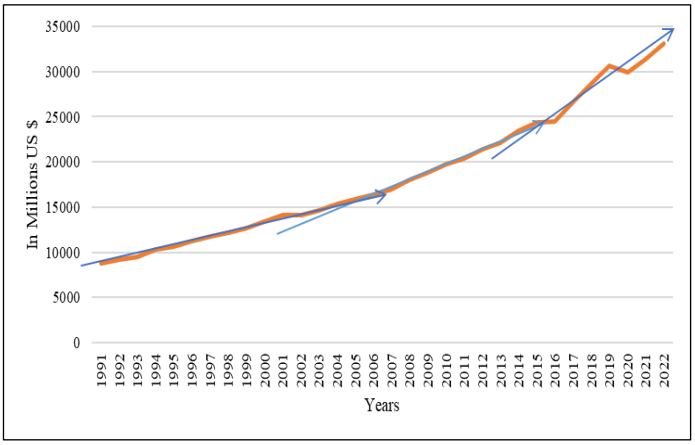

Figure 2: Growth trend of GDP (constant 2015 US$) of Nepal (1991 – 2022).
Source: [9].

III. LIMITATIONS OF THE STUDY

The study is only limited to the relationship between vehicles, fuel consumption, population and GDP based on the available data from government sources and the World Bank. Electric vehicles (cars and motorcycles) have been introduced to the Nepali market since mid-2010, but it only started rising in early 2020. Thus, the proper data set for electric vehicles except for e-rickshaws hasn't been available in the records. So, petroleum-consuming vehicles were computed by only reducing the e-rickshaws number. Likewise, all the registered vehicles for various reasons, do not get to ply on roads. Because of the unavailability of provisions for de-registration of these vehicles, the exact number of vehicles plying on the road could not be extracted. Thus, for computing the operating vehicles, an approach with the consideration of phased-out vehicles has been made in this study. Phased-out vehicles were considered The cabinet in January 2015 and February 2017 decided to ban vehicles older than 20 years operating on roads in Nepal [10]. The construction industry is another component responsible for fuel consumption and increased fuel sales, but the unavailability of this specific data led to ignoring this aspect during the study.

IV. METHOD OF STUDY

For the study, the majority of the data were collected from secondary sources, i.e. published databases from respective government organizations summarized in Table 1. The annual petroleum consumption was considered to be equal to the annual sales. With all the data collected, the analysis period was taken between 1994 and 2022. To establish the relationship between various variables, various regression models were used, and the significance of such relationships was accessed by Coefficient of Determination (R^2) and P-values. The regression analysis were performed using MS Excel.

Linear Regression models were developed for the following set of variables.

a. Vehicle number and Petroleum Consumption
b. Operating vehicles and petroleum consumption
c. Light vehicles and petroleum consumption

Exponential Regression models

a. GDP and Operating vehicles
b. GDP and Petroleum Consumption

Logistic models

a. Population and t – years
b. Vehicle/1000 population and t-years

Table 1: Basic document specifications.

Year	Cum. Vehicles ('00,000)	Petroleum Consumption ('00,000 kL)	Population (in millions)	GDP in Million $ (Constant 2015)
94	1.40	2.27	19.78	8,779.12
95	1.59	2.62	20.23	9,139.62
96	1.80	2.92	20.69	9,491.48
97	2.03	3.03	21.16	10,271.31
98	2.24	3.48	21.64	10,627.56
99	2.48	3.66	22.13	11,193.83
00	2.76	3.66	22.64	11,758.96
01	3.17	3.85	23.15	12,113.66
02	3.64	3.50	23.47	12,648.18
03	4.02	3.67	23.78	13,432.37
04	4.42	3.67	24.11	14,077.11

05	4.82	3.91	24.43	14,094.02
06	5.37	3.75	24.77	14,650.03
07	6.26	4.09	25.10	15,336.04
08	7.11	4.04	25.44	15,869.60
09	8.13	5.71	25.79	16,403.56
10	9.39	7.75	26.14	16,963.17
11	10.89	8.43	26.49	17,998.71
12	12.42	8.48	26.75	18,814.61
13	14.36	9.38	27.01	19,720.80
14	16.16	10.63	27.27	20,395.61
15	18.36	11.85	27.53	21,348.11
16	21.48	10.21	27.80	22,100.66
17	25.78	16.99	28.07	23,429.24
18	29.85	20.82	28.34	24,360.80
19	33.34	22.65	28.61	24,466.31
20	35.59	19.61	28.89	26,662.72
21	41.45	22.86	29.16	28,695.05
22	46.68	24.60	29.54	30,605.30

Source: Authors, (2024)

The study also computed the fuel consumption per vehicle in a year and the trend of the consumption set throughout the study period.

To add up, a scenario analysis was performed to predict petroleum consumption in the years 2030 and 2040 AD. For this, logistic models for population prediction of Nepal and vehicle prediction were prepared and used.

IV.1 LOGISTIC MODEL

This model is used for those growing variables which reach a constant saturation limit at a certain point. D. Das et al in 2009 [11] used this equation to model the vehicle per population whereas a similar equation was also used to model the population in Uganda and Nepal [12],[13]. In this model, the rate of increment of the variable is slow at first whereas becomes rapid when it reaches near saturation.

The logistic model is represented as

$$Y_t=\frac{S}{1+ce^{-\alpha t}} \quad (1)$$

Where,

S represents the saturation

α is the Malthusian Factor, represents the shape of the curve and growth factor

whereas c represents the constant, which represents the start of the curve

t represents the time where t = 0, 1…. Years for consecutive years

The work also involves the estimation of the saturation for population and vehicle population. A methodology adopted by Wali, Kagoyire and Icyingeneye in 2012 [13] of modelling Uganda's Population and work by Adhikari and Raya in 2018 [12] where the population of Nepal was modelled is used to estimate the saturation limit.

Where,

In the exponential growth law,

$$\frac{dY_t}{dt}=\alpha y_t \quad (2)$$

Whose solution would be as:

$$Y_t=Y_o e^{\alpha t} \quad (3)$$

This represents that the growth rate keeps increasing with time without the consideration of the saturation period. To correct this nature, to understand the growth rate, the correction is applied with coefficients α and β which represent the position of the variable near the saturation such that:

$$\frac{dY_t}{dt}=\alpha Y_t\frac{(\alpha-\beta Y_t)}{\alpha} \quad (4)$$

If the variable reaches near saturation represented by $Y_t = S = \frac{\alpha}{\beta}$, then the growth rate reaches zero at this stage which signifies the saturation state. The solution to this equation is as:

$$Y_t=\frac{\frac{\alpha}{\beta}}{1+\left(\frac{\frac{\alpha}{\beta}}{Y_o}-1\right)e^{-\alpha t}} \quad (5)$$

If t_k is the time of inflection and S is the saturation, when $\left(\frac{\frac{\alpha}{\beta}}{Y_o}-1\right) = e^{\alpha t}$ and $Y_t = \frac{S}{2} = \frac{\alpha}{2\beta}$, the point of inflection occurs when the rate of growth is maximum.

The equation (Eq. 5) is redefined as:

$$Y_t = \frac{S}{1+e^{-\alpha(t-t_k)}} \quad (6)$$

Least square error is computed to estimate saturation where:

$$e = \sum\left(Y_i-y_i\right)^2 \quad (7)$$

For this,

$$y_i=\text{predicted value at } i^{th}\text{year}=S*h_i \quad (8)$$

Where,

$$H_i=\frac{1}{1+e^{-\alpha(t_i-t_k)}} \quad (9)$$

Thus,

$$e=\sum(Y_i-S*hi)^2$$

For minimum e, differentiating with respect to S,

$$\frac{de}{dS}=0=-2\sum(y_i*h_i)+2S\sum(h_i^2)$$

And, thus, saturation can be estimated as:

$$S=\frac{\sum h_i * Y_i}{\sum(h_i * h_i)} \quad (10)$$

The value of error is minimized with t_k and α value iterated multiple times with the help of the MS Excel Solver tool.

$$e = \sum(Y_i*Y_i)-\frac{(\sum(Y_i*h_i))^2}{\sum(h_i*h_i)} \quad (11)$$

To, measure the goodness of fit, R^2 is computed for the developed model as

$$R^2=1-\frac{\sum(Yi-y_i)^2}{\sum(Y_i-\overline{Y_i})^2} \quad (12)$$

Where, $\overline{Y_t}$ is the mean of the variable

This method of saturation estimation and model fitting is performed only with population data collected from the census years between 1930 and 2021. In Nepal, census is taken every 10 years. [14]. Thus, intermediate data are interpolated considering exponential growth between two points of the census ($P = \beta e^{\alpha t}$). Adhikari also did this practice [12].

However, the vehicle fleet saturation is estimated through literature. From the literature, it is found that saturation vehicle fleet varies with per capita GDP of that country. A study performed by Huo et al, 2007, studied the saturation point of highway vehicle registration for 18 countries. The higher the per capita income, the greater the saturation vehicle fleet. The study suggested that the saturation point for different countries looks different. Vehicles per thousand people in Asian countries were predicted smaller even with similar GDP per capita when compared to European and North American Countries. The study depicted that for densely populated countries, the value of saturation doesn't reach very high. A high degree of saturation can be assumed up to 850 vehicles per 1000 people whereas for China it can be assumed to be 600 vehicles for a high growth scenario [15]. A similar result was also observed in the work of Dargay et al, 2007 where different vehicle models with their coefficients and saturation were explained [16]. Another study performed by Bottiny, an economist, in 1966, emphasized the importance of understanding saturation in vehicle ownership which is eventual. However, the successful prediction, as per the study, is difficult. 2 passenger cars per household, or 1 and 7/10th persons per passenger cars, registered vehicle per 2 and 2/10th of residents, and ownership of one car for every 2.5 persons were some of the saturation points estimated through literature reviews in that study [17]. In a work of Singh in 2019, where a projection of vehicles was made for 2050, two different saturation points were taken for modelling. One was a conservative approach and the other was an aggressive growth approach for two-wheelers and cars as 250 and 350 two-wheelers per 1000 persons and 150 and 250 cars per 1000 persons [18].

For this study, to estimate the future vehicle fleet in similar growth conditions, a logistic model is being used. As suggested by the works of literature, sighting to difficulty in proper estimation, two growth models have been generated with 400 vehicles per 1000 persons and 550 vehicles per 1000 persons have been taken and the least square method, with Excel regression tool, has been used to model the vehicle fleet per 1000 persons. To explain the significance of the model, the coefficient of determination R^2 and p-value are used.

V RESULTS AND DISCUSSION

V.1 VEHICLE FUEL CONSUMPTION PER YEAR

As per the study, the fuel consumption per vehicle even with the increase in the number of vehicles is decreasing which can be seen in Figure 3.

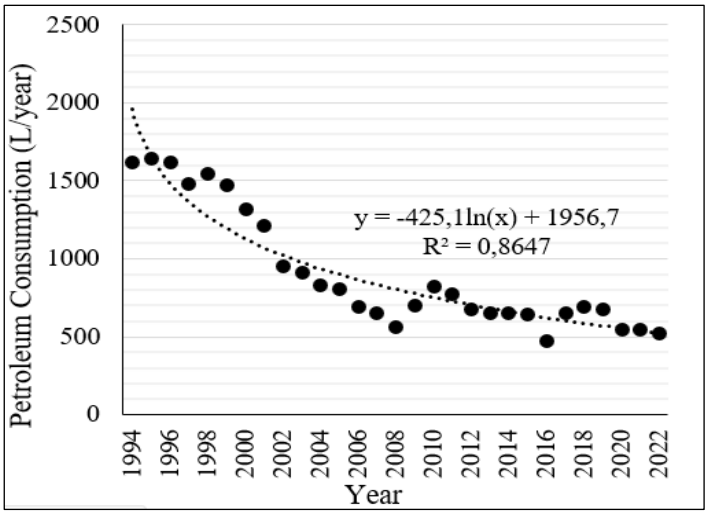

Figure 3: Trend of Diminishing per Vehicle Annual Petroleum Consumption (litre).
Source: Authors, (2024).

The figure shows the diminishing annual petroleum consumption per vehicle. This shows the increment of higher fuel-efficient vehicles in the context of Nepal. A similar trend of fuel consumption per year is even seen in the United States as per the Bureau of Transportation Statistics [19]. While observing the data of 1998 and 2020 of fuel consumption per vehicle in a year, the fuel consumption reduced from 2729.097 litres to 2183.617 litres which means a reduction of 19.987% within this period in the United States. With Nepal currently importing Euro 6 standard fuel from India and sooner applying the same to the vehicles, a greater decrease in fuel consumption is to be expected. This is further supported by the policy of the current global leaders and the Nepalese government to promote electric vehicles. The trend of the reduced petroleum consumption in litre/year/vehicle can be seen in the figure which seems to follow the logarithmic curve with an R^2 value of 0.864.

V.2 PETROLEUM CONSUMPTION AND THE REGISTERED VEHICLES

With the regression analysis between the vehicle population (registered) and the petroleum sales (Diesel and petrol), an excellent correlation was observed with R^2 of 0.969 and with the P value of 5.22 *10^{-6} for the intercept and 6.32*10^{-6} for the vehicle number. The P values suggest the significant characteristics of the variables in the regression equation. Thus, a usable regression equation based on the analysis is given:

"Petroleum Consumption (in '00,000 kL) = 0.491* Cum. Vehicle ('00,000) + 1.88," (13)

Thus, the relationship suggests that there is a positive and significant relationship between the annual petroleum consumption and the cumulative number of registered vehicles. This trend is set to go further with time since the demand for the vehicles is still on rise. A scatter plot is shown in Figure 4.

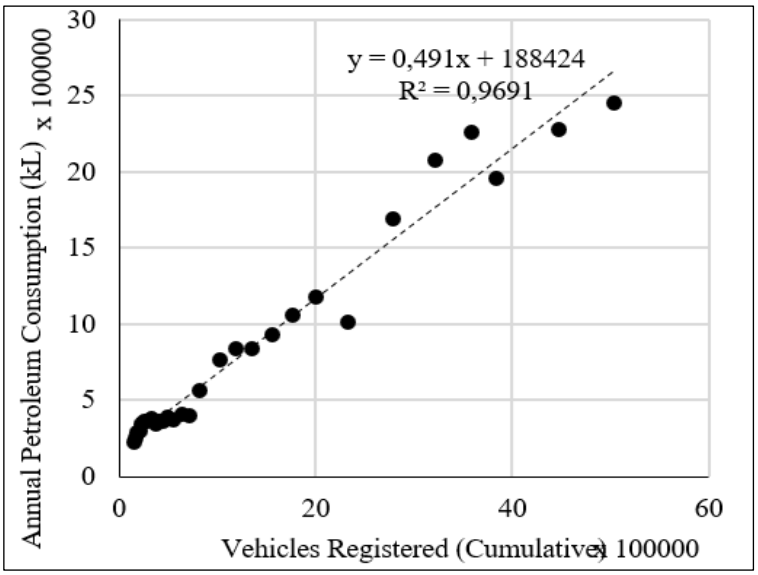

Figure 4: Scatter plot between Annual Petroleum Consumption and Vehicles Registered
Source: Authors, (2024)

Figure 5 above shows that the rise in petroleum consumption and the rise in vehicle numbers in Nepal are inevitable irrespective of the time. Another thing evident from the graph is the higher growth in the later period compared to the initial period of the study. This can be due to the fact that the country entered into a period of stability after a long era of insurgency.

V.3 PETROLEUM CONSUMPTION AND OPERATING VEHICLES

Vehicles due to various reasons are taken out of the road and do not consume petroleum products. Thus, the study presents the correlation between the number of vehicles after deducting the phased-out vehicles (20-year-old vehicles) and petroleum consumption. The regression analysis observed a similar result with the R^2 of 0.968 and P values of $1.78*10^{-5}$ for intercept and $8.5*10^{-22}$ for variable operating vehicles. Thus, a significant regression equation, of linear type, formed as:

Fuel consumption (in '00,000 kL) = 0.532 * Cum. Veh. ('00,000) + 1.765 (14)

The scatter plot between these variables is shown in Figure 5.

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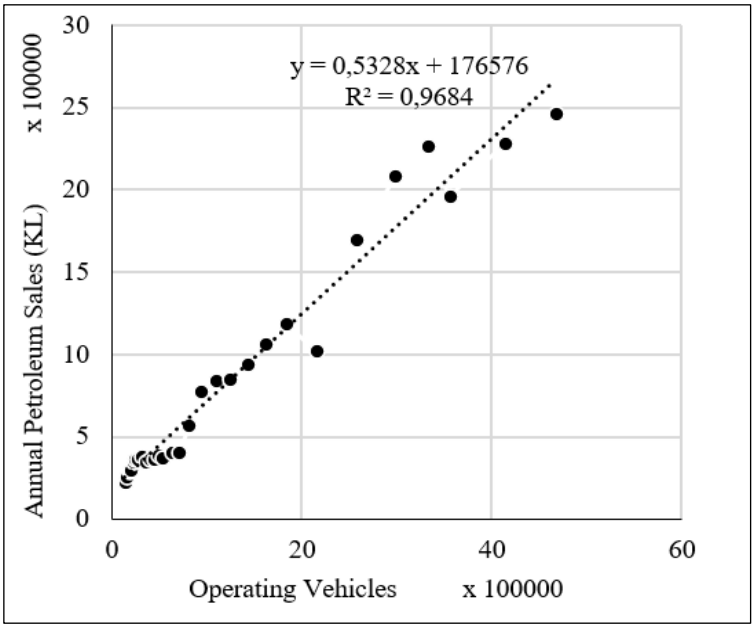

Figure 5: Scatter plot between Annual Petroleum Consumption (kL) and Operating Vehicles.
Source: Authors, (2024).

V.4 PETROL CONSUMPTION AND LIGHT VEHICLES

With the advent of light vehicles, lighter fuels (petrol) with high efficiency resulting in lower consumption of fuel have been in use. Because of the lower cost of these vehicles and preference for personal use, the proportions of light vehicles have increased significantly in these years. An 87% proportion is covered by these vehicles which can be seen in the Figure 6.

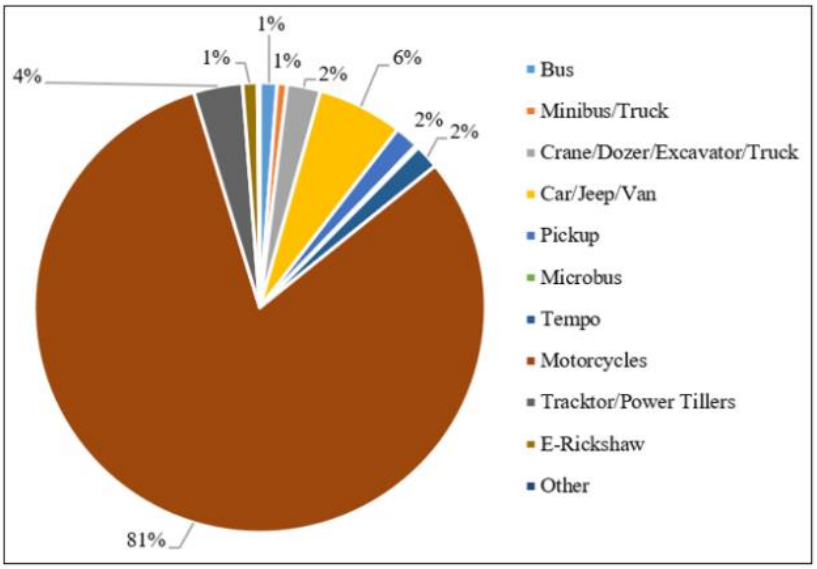

Figure 6: Distribution of Different Category of Vehicles in Nepal.
Source: [7].

Upon, model fitting, linear regression, there existed a significant relationship between petrol sales (kL) and the light vehicle numbers with an R^2 value of 0.983 and P values 0.019 between intercept and variable petrol consumption and $1.1*10^{-25}$ between the variable and number of light vehicles. The usable linear regression equation is as:

$$\text{Petrol consumption ('00,000 kL per annum)} = 0.157*\text{Light vehicles ('00,000)} + 1.642 \quad (15)$$

The scatter plot between annual petrol sales and operating light vehicles is shown in the Figure 7.

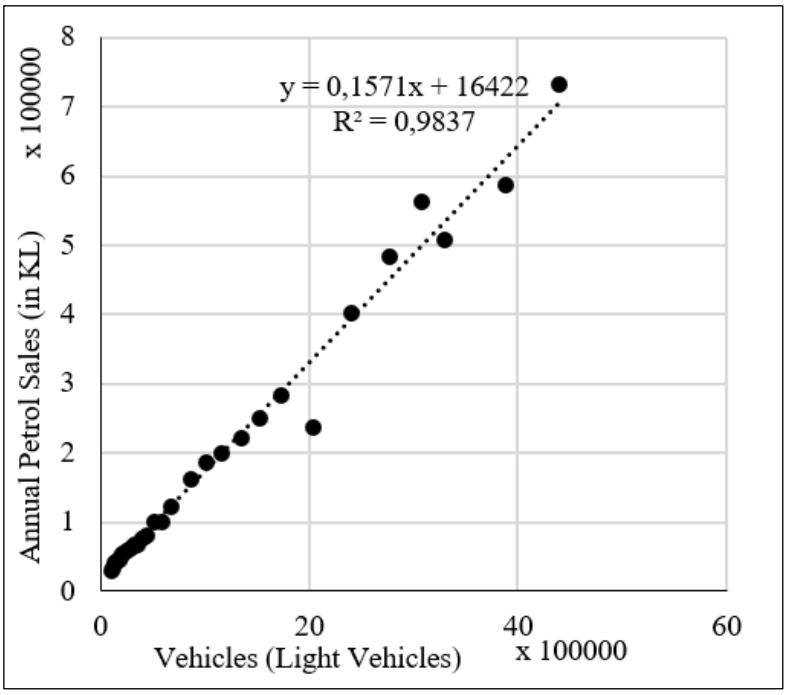

Figure 7: Scatter Plot between Annual Petrol Consumption and Operating Light Vehicles.
Source: Authors, (2024).

From the equation, it can be seen that the coefficient is lower for petrol consumption than that for the equation between vehicles and total petroleum consumption, i.e., 0.157 compared to that of 0.532. This can be supported by the nature of these vehicles i.e., being light and easy to propel. This is also observed in the total annual petrol consumption whose average sales are comparatively lower than the total annual diesel sales.

V.5 RELATIONSHIP WITH GROSS DEVELOPMENT PRODUCT

The need for travel rises with the increased income of an individual. Thus, there is the existence of a relationship between the number of vehicles and the GDP (constant 2015 US$) of the country and consequently with petroleum consumption. The regression equation formed between operating vehicles and the GDP is as:

$$\text{Cum Vehicles ('00,000)} = 0.381 * e^{0.000153 * \text{GDP (in millions)}} \quad (16)$$

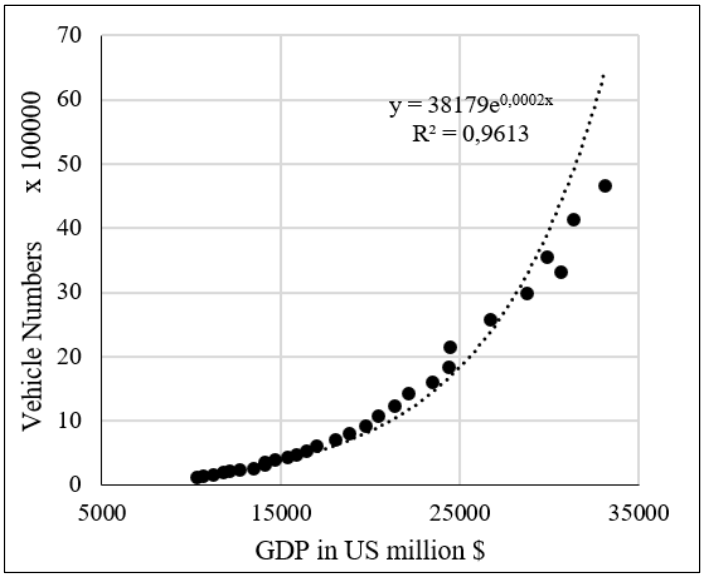

Figure 8 a): A Scatter Plot Between Operating Vehicles and GDP (in million $).
Source: Authors, (2024).

With the p-value near zero and the coefficient of determination (R^2) 0.961, the relationship between the vehicle and the GDP proves to be significant in the context.

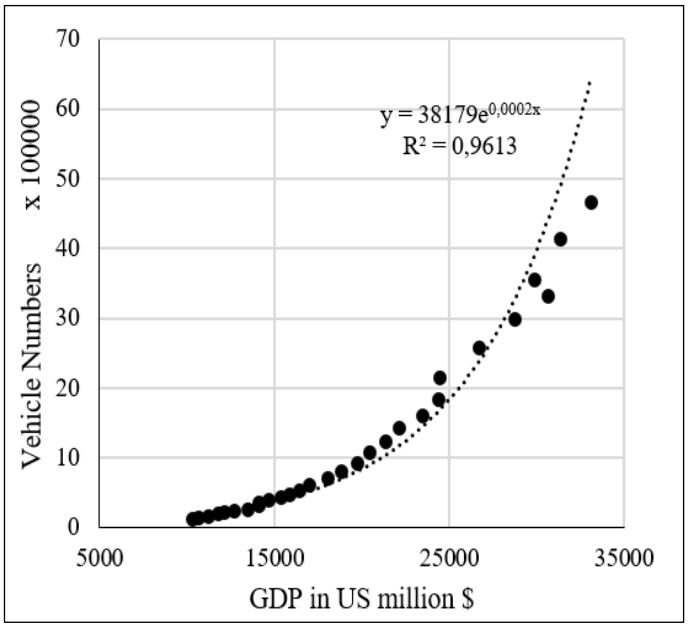

Figure 8 b): illustrates the scatter plot between these two variables along with the exponential trendline.
Source: Authors, (2024).

Taking exponential expression for regression again between petroleum consumption and gross domestic product in million US $ led to the following equation with the significant relationship with near to zero P value and R^2 of 0.971:

$$\text{Petroleum Consumption (kL)} = 0.793 * e^{0.00011 * \text{GDP (in millions)}} \quad (16)$$

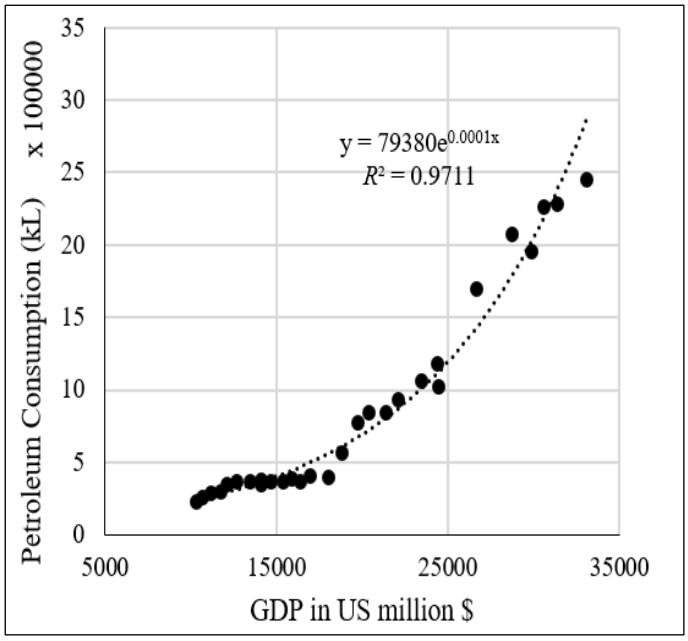

Figure 9: A Scatter Plot Between Petroleum Consumption (kL) and GDP (million $).
Source: Authors, (2024)

VI FORECAST MODEL

VI.1 POPULATION FORECAST MODEL

As the growth rate hovers around 3%, the iteration started $\alpha = 0.03$ and $t_k = 2100$. Special care was taken to take this point such that the saturation population is believable After minimizing the error function with α and t_k, the saturation population computed was 58,783,356 with $\alpha = 0.027$ and $t_k = 2019$, year of inflection with the highest growth rate of population.

Here,

$$\beta = \frac{S}{\alpha} = 4.71 * 10^{-10}$$

Thus, the population model prepared is as:

$$P_t = \frac{58{,}783{,}356}{1 + 11.761 e^{-0.027t}} \quad (17)$$

Where,
P_t represents the population at t years
t years is $(Year - 1930)$

Upon computation of the coefficient of determination, an excellent fit has been observed. An R^2 of 0.995. Figure 10 shows the model fitting in actual data.

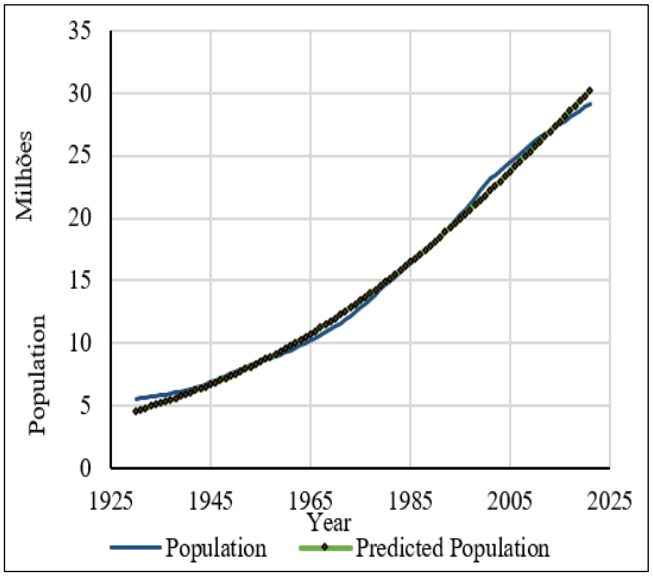

Figure 10: The resemblance between population model and the population through a scatter plot.
Source: Authors, (2024).

VI.2 CUMULATIVE VEHICLES PER 1000 POPULATIONS FORECAST MODEL

Two growth models have been computed with two saturation values using the least square method with Excel. Excellent goodness of fit for both the models have been observed for both the models.

For a Saturation of 400 cumulative vehicles per 1000 persons, where an assumption of 2.5 persons per vehicle is made, the medium growth model developed is as:

$$\text{Cum. Vehicles per 1000 persons} = \frac{400}{1+67.524e^{-0.127*t}} \quad (18)$$

With R^2 of 0.986, where the inflection year is 2027, and with p-values for both the coefficients negligible, shows the significant relationship of the equation.

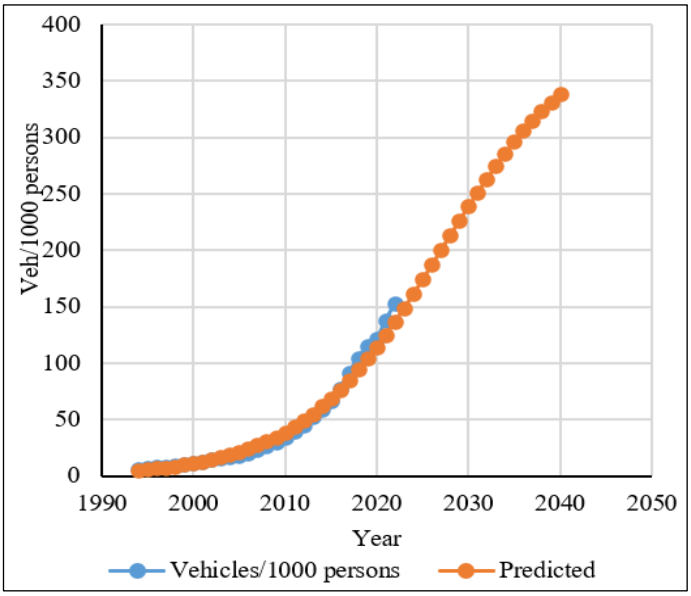

Figure 11: A plot of vehicle population model and vehicle population per 1000 persons in different years for medium growth.
Source: Authors, (2024).

While for saturation of 550 cum. Vehicles per 1000 persons for high growth:

$$\text{Cum. Vehicles per 1000 persons} = \frac{550}{1+90.78e^{-0.122*t}} \quad (19)$$

An R^2 of 0.9906 and p-values that tend to zero have been observed for this equation as well. This can also be observed in Figure 12.

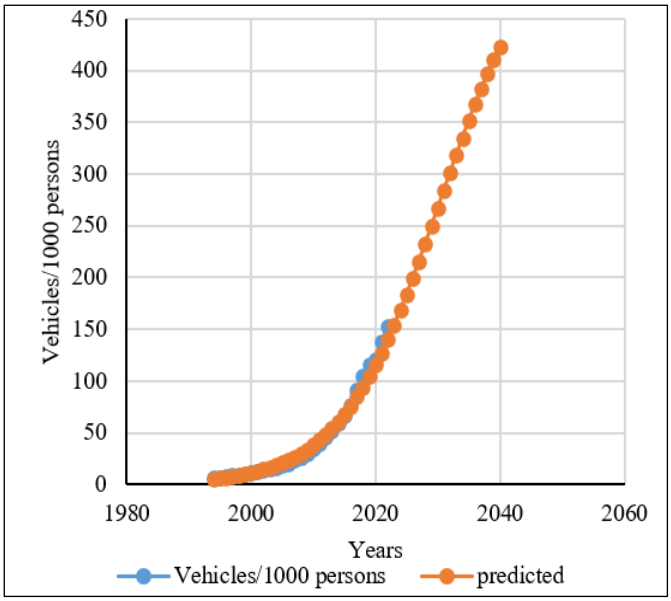

Figure 12: A plot of vehicle population model for high growth.
Source: Authors, (2024).

VI.3 PREDICTED SCENARIO

With the population model and vehicle population model, the predicted corresponding population and the vehicle fleet in year 2030 and 2040 is shown in Table 2

This prediction is based on the developed models of the study. The prediction shows that, while comparing to the situation of 2022, the vehicle fleet will almost double in 2030 while considering high growth and will almost three-fold in 2040. The vehicle fleet size seems to reach 76.65 (’00,000) as per the medium growth model in 2030 whereas seems to reach 119.80 lakhs in 2040. Similarly, for high growth, 46.68 (’00,000) vehicles would grow to 85.18 (’00,000) and 148.94 (’00,000) vehicles in 2030 and 2040 respectively. Apparently, a similar growth pattern is observed in fuel consumption in 2030 and 2040 which has been depicted in Table 3. A 24.61 (’00,000) kL fuel consumption in 2022 grows to 42.54 (’00,000) kL in 2030 and almost trebles to 65.5 (’00,000) kL in 2040 in the medium growth model. In high growth model of vehicle growth, fuel consumption rises 2 folds and 4 folds to 47.08 (’00,000) kL and 81 (’00,000) kL in 2030 and 2040 year respectively.

VI.4 ELECTRIC VEHICLE PENETRATION

In the action plan for electric mobility for Nepal, targets have been set to gain 20% electric vehicle share and reduction of fossil fuel consumption by 50% as long-term target [20]. A scenario analysis performed by Andre et alin 2020 in France provided a scenario with more preferences for electric vehicles through policy, incentives and infrastructure, predicted that electric vehicles would penetrate 10.9%, 2.3%, 15% and 42% share of light duty vehicles, trucks, buses and two-wheelers in 2025 [21].

Lutsey, 2015 work suggested in future of the zero-emission vehicles, electric vehicles, and fuel cell electric, with policy support, research and development, and regulation that the share of these vehicles may reach up to 20% to more than 50% whereas also predicted that the share may also reach a value of only 5 to 10% in the time frame 2025-30 if not supported with policy and development [22].

Thus, in this study, a conservative approach with a 20% light vehicle share is assumed to be occupied by electric vehicles in 2030 and 2040 to predict the probable fuel consumption. 87% of the total vehicle share is covered by light vehicles in the context of Nepal which leads to our computation. In 2030 and 2040, a reduction of 17.4% in the total vehicle fleet is taken to estimate the fuel consumption and tabulated in Table 3. The comparative graphic representation has also been shown in Figure 13. The prediction suggests that there would be a reduction of around 7 (’00,000) kL and 11 (’00,000) kL consecutively, 7 (’00,000) kL and 14 (’00,000) kL with the consideration of replacement by electric vehicles for medium growth scenario and high growth scenario in 2030 and 2040 respectively.

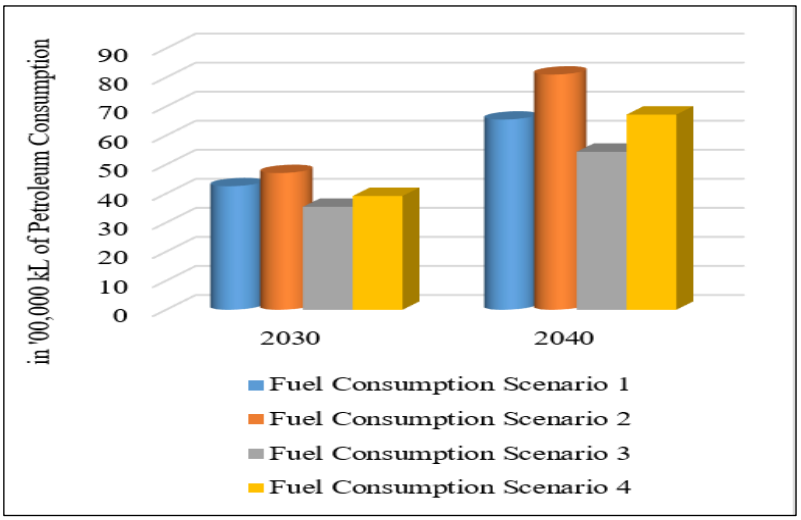

Figure 13: Comparative chart between Fuel Consumption in 4 different scenarios in year 2030 and 2040.
Source: Authors, (2024).

VII. CONCLUSION

The study explored a correlation between GDP, petroleum consumption, and vehicle population. The study showed that the significant linear regression model between petroleum consumption and the vehicle population, petroleum consumption and the operating vehicles population, and petrol consumption and the operating light vehicles are all statistically significant with a high coefficient of determination. Additionally, the relationship between GDP and petroleum consumption; and GDP and operating vehicles is also statistically significant in exponential regression form. The growth trend was observed in all the contexts, but in different scales, with three phases between 1994 to 2005, 2005 to 2016, and 2016 to 2022. Subsequently, logistic models to predict vehicle population and population with high coefficient of determinations and significant relations have been developed to predict the 2030 and 2040 vehicle fleet and population. Two scenarios for vehicle growth have been used to predict fuel consumption in those years. To address the current electrification in the transportation sector, adjustments have been made to the prediction which will yield lesser fuel consumption in the near future. However, this trend has to be supported by action plans, research and incentives. Two growth scenarios, medium and high growth of vehicle fleets, don’t make a high difference in the year 2030 while a huge difference is marked in 2040 in fuel consumption.

Table 1: Predicted Values of Year 2030 and 2040 and comparison with year 2022.

Attributes	**Existing**	**Prediction**		**Remarks**
	Year 2022	**Year 2030**	**Year 2040**	
Population	29,544,413	32,403,852	35,745,611	Logistic Model
Vehicle/1000 persons	158.01	236.55	335.15	Medium Growth
		262.87	416.68	High Growth
Vehicle Fleet in ’00,000‘	46.68	76.65	119.80	Medium Growth
		85.18	148.94	High Growth
Fuel Consumption in ’00,000 kL‘	24.61	42.54	65.5	Medium Growth (Scenario 1)
		47.08	81.00	High Growth (Scenario 2)

Source: Authors, (2024).

Table 2: Prediction of Petroleum Consumption with Considerable Electric Vehicle Share.

Attributes	Existing	Prediction		Remarks
	Year 2022	Year 2030	Year 2040	
Fuel Consumption in "00,000 kL"	24.61	35.45	54.41	Medium Growth (Scenario 3)
		39.19	67.21	High Growth (Scenario 4)

Source: Authors, (2024).

The study also found that there was an increase in fuel efficiency over time, which could be attributed to induced fuel standards and high-efficiency petrol-powered lighter vehicles. Finally, the study concludes with different regression equations that are statistically significant between variable vehicles, GDP, and petroleum consumption with the given sets of data between 1994 and 2022.

VIII. AUTHOR'S CONTRIBUTION

Conceptualization: Niraj Bohara and Hemant Tiwari.
Methodology: Niraj Bohara and Hemant Tiwari.
Investigation: Niraj Bohara and Hemant Tiwari.
Discussion of results: Niraj Bohara and Hemant Tiwari.
Writing – Original Draft: Niraj Bohara
Writing – Review and Editing: Niraj Bohara and Hemant Tiwari.
Resources: Niraj Bohara and Hemant Tiwari.
Supervision: Niraj Bohara and Hemant Tiwari.
Approval of the final text: Niraj Bohara and Hemant Tiwari.

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