Estimation of Monthly Per Capita Vehicle Fuel Consumption in Kavathe Mahankal Tahsil

Dhanashri Bhosale[1], Vaishnavi Bhosale[2], Rohini Mali[3], Vijay Koshti[4], Annasaheb Suryawanshi[5], Ganesh Satpute[6], Shital Patil[7]

[1,2,3] B.Sc. III Student, Department of Statistics, Padmabhushan Vasantraodada Patil Mahavidyalaya, Kavathe Mahankal, Maharashtra, India

[4]Associate Professor, Department of Statistics, Padmabhushan Vasantraodada Patil Mahavidyalaya, Kavathe Mahankal, Maharashtra, India

[5,6,7]Assistant Professor, Department of Statistics, Padmabhushan Vasantraodada Patil Mahavidyalaya, Kavathe Mahankal, Maharashtra, India.

Article Info	Abstract:
Article History: *Published:20 Feb 2026* ***Publication Issue:*** *Volume 3, Issue 2* *February-2026* ***Page Number:*** *303-317* ***Corresponding Author:*** *Dhanashri Bhosale*	This study aims to estimate the average monthly per capita vehicle fuel consumption in Kavathe Mahankal Tahsil and to identify the key household, vehicle, and travel-related factors influencing fuel use. A cross-sectional survey was conducted among 373 households using a structured questionnaire, with households stratified by monthly income and selected through stratified random sampling using Neyman allocation. Independent two-sample t-tests and Welch ANOVA were applied to assess differences in monthly per capita vehicle fuel consumption across various groups, highlighting the significant effects of household income, occupation, gender, and vehicle-related factors. The fitted regression model effectively predicts monthly per capita vehicle fuel consumption based on average fuel economy, long trips per month, occupation of household head, number of adults, number of vehicles in family, traffic congestion in locality, frequent extra load, vehicle service interval, type of vehicle own and fuel consumption satisfaction. ***Keywords:*** Fuel consumption, petrol, diesel, CNG/LPG, Welch ANOVA, correlation, regression

1. Introduction

1.1 Background of the Study

Transportation plays a vital role in the economic and social development of any region. In recent years, ownership and use of personal and commercial vehicles have increased rapidly due to population growth, improved living standards, and greater accessibility to credit facilities. Consequently, fuel consumption has risen significantly, making fuel expenditure a major recurring cost for households. In Indian localities, particularly semi-urban and rural areas, households often rely heavily on private vehicles for commuting, education, agriculture, business, and social activities. Two-wheelers and cars are commonly used for personal transportation, while tractors, auto-rickshaws, and goods vehicles serve occupational purposes. These vehicles operate on different fuels such as petrol, diesel, and Compressed Natural Gas (CNG), each with distinct cost and consumption patterns. Fuel consumption is influenced by vehicle type, fuel efficiency (mileage), distance traveled, road conditions, driving behavior, and maintenance practices. Socio-economic factors, including household income, family size, and number of earning members, further affect vehicle usage and fuel consumption. Therefore, fuel consumption patterns vary widely across households within the same locality.

Estimating fuel consumption on a per capita basis provides a more accurate and comparable measure by adjusting for household size. Monthly per capita vehicle fuel consumption reflects the average fuel used by an individual per month, enabling identification of high-consumption groups, assessment of economic burden, and understanding of energy-use behavior at the micro level. Despite its importance, locality-level data on per capita vehicle fuel consumption are often unavailable. Most statistics are aggregated at the state or national level, which may not accurately represent local conditions. Thus, a household survey-based localized study is essential to obtain realistic fuel consumption patterns.

1.2 Significance of the Study
Estimation of monthly per capita vehicle fuel consumption provides a critical basis for understanding local transportation fuel demand and associated fuel consumptions patterns. The results of this study offer evidence-based insights to planners, researchers, and policymakers, supporting informed decision-making for fuel conservation measures and the development of sustainable transportation strategies.

1.3 Review of Literature
Earlier studies provide a strong methodological foundation for estimating vehicle fuel consumption. Early work by Ferreira (1981) developed methods for estimating urban vehicle fuel consumption, emphasizing traffic conditions and operational factors. Buehler and Pucher (2010) highlighted the role of urban density in reducing fuel demand through shorter travel distances and modal shifts.

Lee et al. (2011) and Bifulco et al. (2015) introduced linear and in-vehicle parameter-based models for fuel estimation and evaluated the impact of advanced driver assistance systems on fuel efficiency. Kee et al. (2018) applied statistical methods to predict ship fuel consumption and speed curves, demonstrating statistical modeling's applicability across transport modes. Alsaadi (2022) analyzed fuel economy using comparative and optimization-based approaches, emphasizing route planning to reduce fuel use. Hamza Heni et al. (2023) implemented supervised learning models for accurate fuel consumption estimation in vehicle routing, outperforming traditional methods. Collectively, these studies indicate a progression from basic statistical estimation to advanced data-driven approaches, with a strong emphasis on improving fuel efficiency and supporting sustainable transportation planning.

1.4 Objectives
  i. To estimate the average monthly per capita vehicle fuel consumption in the locality and identify household & travel determinants of fuel consumption.
  ii. To compare monthly per capita fuel consumption across different monthly household income, occupation of household head, vehicle service interval, Frequent Extra load etc.
  iii. To study the relationship between monthly per capita fuel consumption and factors such as number of vehicles, mileage, working adults etc.
  iv. To provide statistical evidence that can support local-level planning for fuel conservation and sustainable transport.

1.5 Hypotheses
  i. *Independent Samples t-Test*
  H_0: There is no significant difference in average monthly per capita vehicle fuel consumption between two groups.   Vs
  H_1: There is significant difference in average monthly per capita vehicle fuel consumption between two groups.

ii.   One-Way ANOVA / Welch ANOVA

H_0: The average monthly per capita vehicle fuel consumption are equal across two or more groups.

Vs

H_1: At least one group differs significantly in average monthly per capita vehicle fuel consumption.

iii.   Pearson Correlation

H_0: There is no significant linear relationship exists between monthly per capita vehicle fuel consumption and independent variable.   Vs

H_1: There is significant linear relationship exists between monthly per capita vehicle fuel consumption and independent variable.

iv.   Multiple Linear Regression

H_0: The independent variables do not significantly predict monthly per capita vehicle fuel consumption.   Vs

H_1: One or more independent variables significantly predict monthly per capita vehicle fuel consumption.

2. Research Methodology

2.1 Research Design

The present study adopts a descriptive and analytical research design to estimate monthly per capita vehicle fuel consumption and to examine the household-level factors influencing fuel use in Kavathe Mahankal Tahsil. A cross-sectional survey approach was employed, with data collected through personal interviews using a structured questionnaire. The study was conducted in Kavathe Mahankal Tahsil. The target population consists of all households in the study area that own at least one motorized vehicle.

2.2 Sample Size

The sample size was determined using standard sample size estimation methods appropriate for household surveys. For estimating a average monthly per capita fuel consumption the value of n_0 is:

$$n_0 = \frac{Z_{\alpha/2}^2 * S^2}{E^2} = \frac{(1.96)^2 * (10.6985)^2}{(1.08)^2} = 376.9731 \approx 377$$

Where $Z_{\alpha/2}$ =1.96 (at 5% level of significance), S= standard deviation of monthly per capita vehicle fuel consumption (from pilot study) = 10.6985 and E = margin of error = 1.08 (12% of average monthly per capita vehicle fuel consumption 9.012 L/person/month from pilot study).

Finite population correction is:

$$\mathbf{n} = \frac{n_0}{1 + \frac{n_0}{N}} = \frac{377}{1 + \frac{377}{32275}} = 372.6472 \approx \mathbf{373}$$

2.3 Sampling Technique

A stratified random sampling technique was adopted to ensure adequate representation of households. Households were stratified based on monthly household income. From each stratum, households were selected using simple random sampling. The *Neyman allocation method* was used to determine the sample size for each stratum in stratified random sampling. This method allocates the total sample size optimally by considering both the population size and the variability within each stratum. The sample size for the ith stratum is calculated using the following formula: $n_i = \boldsymbol{n} \times \frac{N_i * S_i}{\sum N_i * S_i}$

Stratum	Monthly Household Income (₹)	Households (N_i)	S_i	$N_i * S_i$	$\dfrac{N_i * S_i}{\sum N_i * S_i}$	n_i
Stratum 1	Less than 10,000	9,037	4.3551	39357.0033	0.1485	**55**
Stratum 2	10,000 – 25,000	10,974	5.4054	59319.0501	0.2238	**83**
Stratum 3	25,000 – 50,000	7,101	14.5830	103012.1020	0.3907	**146**
Stratum 4	50,000 – 1,00,000	3,550	13.1275	46602.7047	0.1758	**66**
Stratum 5	More than 1,00,000	1,613	10.0669	16237.8548	0.0613	**23**
Total		**N= 32,275**				**n=373**

The total Households (N) in locality is taken from https://www.pskavathemahankal.com/pgeGeneralInfo.aspx
The values of S_i are taken from pilot study.

2.4 Measurement of Key Variable: The key variable monthly Per-Capita Vehicle Fuel Consumption calculated as:

$$Monthly\ Per\text{-}Capita\ Vehicle\ Fuel\ Consumption\ (liters) = \frac{Total\ Monthly\ Household\ Fuel\ consumption\ (liters)}{Household\ size}$$

Where Total Monthly Household Fuel Consumption (liters) equals the sum of monthly petrol, diesel, and CNG/LPG (converted to liters) consumption

2.5 Analytical Tools and Statistical Techniques: The collected data were analyzed using MS-Excel and SPSS software**.** The statistical tools such as descriptive statistics**,** inferential statistics, correlation, and multiple linear regression were applied.

3. Statistical Analysis:
3.1 Descriptive statistics

The descriptive statistics of key variable presents in Table 3.1.1. Monthly per capita vehicle fuel consumption shows wide variability, with a mean of 10.1790 liters/person/month and a high standard deviation (13.8383), indicating substantial differences in fuel use across households. The average household size is 5.24 members, with households owning about two vehicles on average. Households make approximately 2.28 trips per day, while the mean fuel economy is 38.79 km per liter, reflecting mixed vehicle efficiency levels. The fuel consumption satisfaction score was calculated by summing respondents' ratings across the ten satisfaction items related to fuel availability, quality, price, service, accessibility, and related aspects. Higher total scores indicate a higher overall level of satisfaction with fuel consumption and fuel-related services, while lower scores reflect greater dissatisfaction. The average fuel consumption satisfaction score is moderately high (33.79), suggesting general satisfaction with fuel use. On average, households have about four adults and undertake approximately two long trips per month, highlighting moderate mobility needs within the locality.

Table 3.1.1: Descriptive Statistics

	Minimum	Maximum	Mean	Std. Deviation
Monthly Per Capita Vehicle Fuel Consumption	.60	116.67	10.1790	13.8383
Household size	1	24	5.24	2.180
Number of vehicles in family	1	7	1.86	1.041
Average number of household trips per day	.00	10.00	2.2788	1.4946
Average fuel economy (km/liter)	5.91	75.20	38.7929	14.8109
Fuel consumption satisfaction	18	48	33.79	6.332

| Number of adults (≥18 years) | 1 | 16 | 3.92 | 1.609 |
| Long trips (> 50 km) per month | .00 | 30.00 | 2.0402 | 2.7662 |

The Pie diagram 3.1.1 shows most households (65%) own only two-wheelers, making them the most common vehicle. About 13% have both two-wheelers and cars, 8% own two-wheelers with tractors, while other vehicle combinations are very minimal (1–3%)
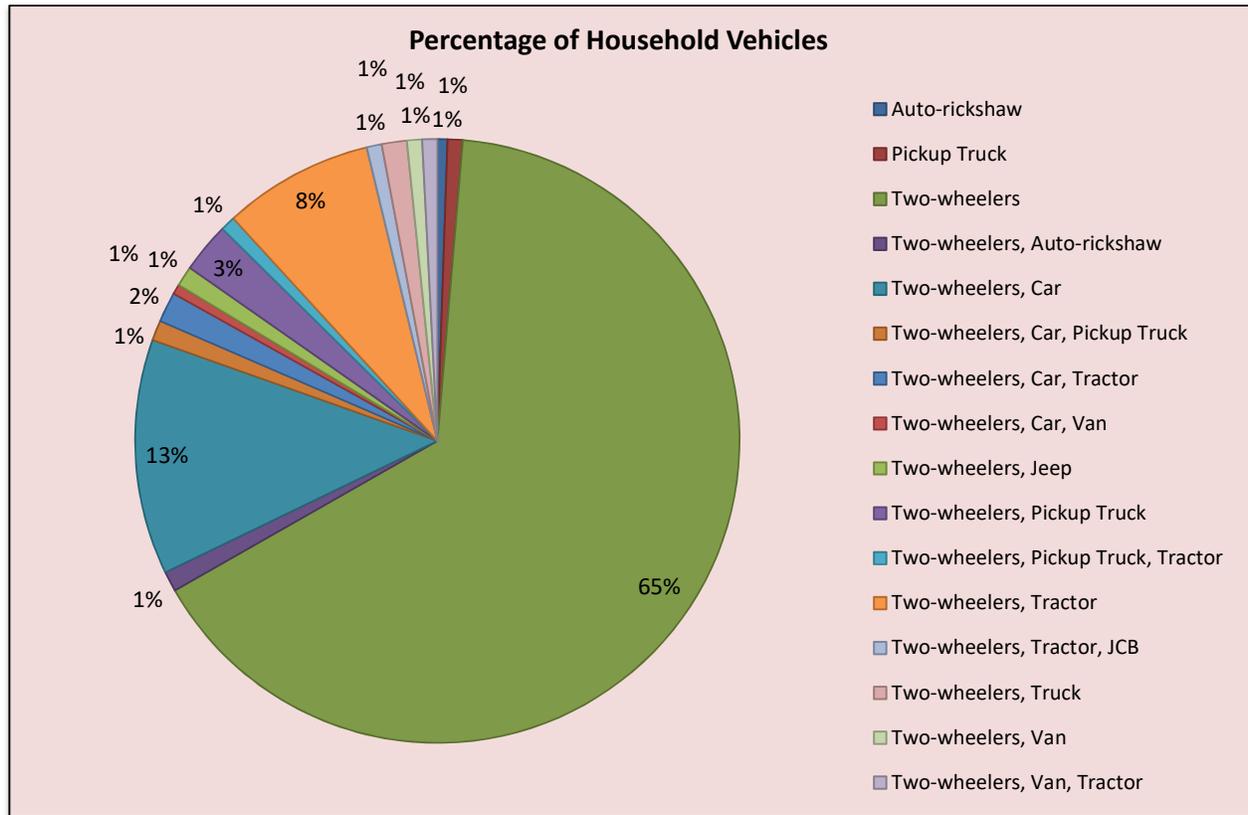

Diagram 3.1.1

The bar diagram 3.1.2 shows that average monthly per capita fuel consumption increases with the number and type of vehicles owned. Households owning multiple vehicles involving tractors and JCBs record the highest consumption as 72.50 liters/person/month, indicating heavy fuel use for agricultural or commercial activities. In contrast, households with only two-wheelers have the lowest consumption as 4.67 liters/person/month. Mixed ownership combinations such as two-wheelers with pickup trucks, cars, or tractors show moderate to high fuel consumption, reflecting higher mobility and utility demands. Overall, fuel consumption rises significantly with the inclusion of heavy or commercial vehicles.
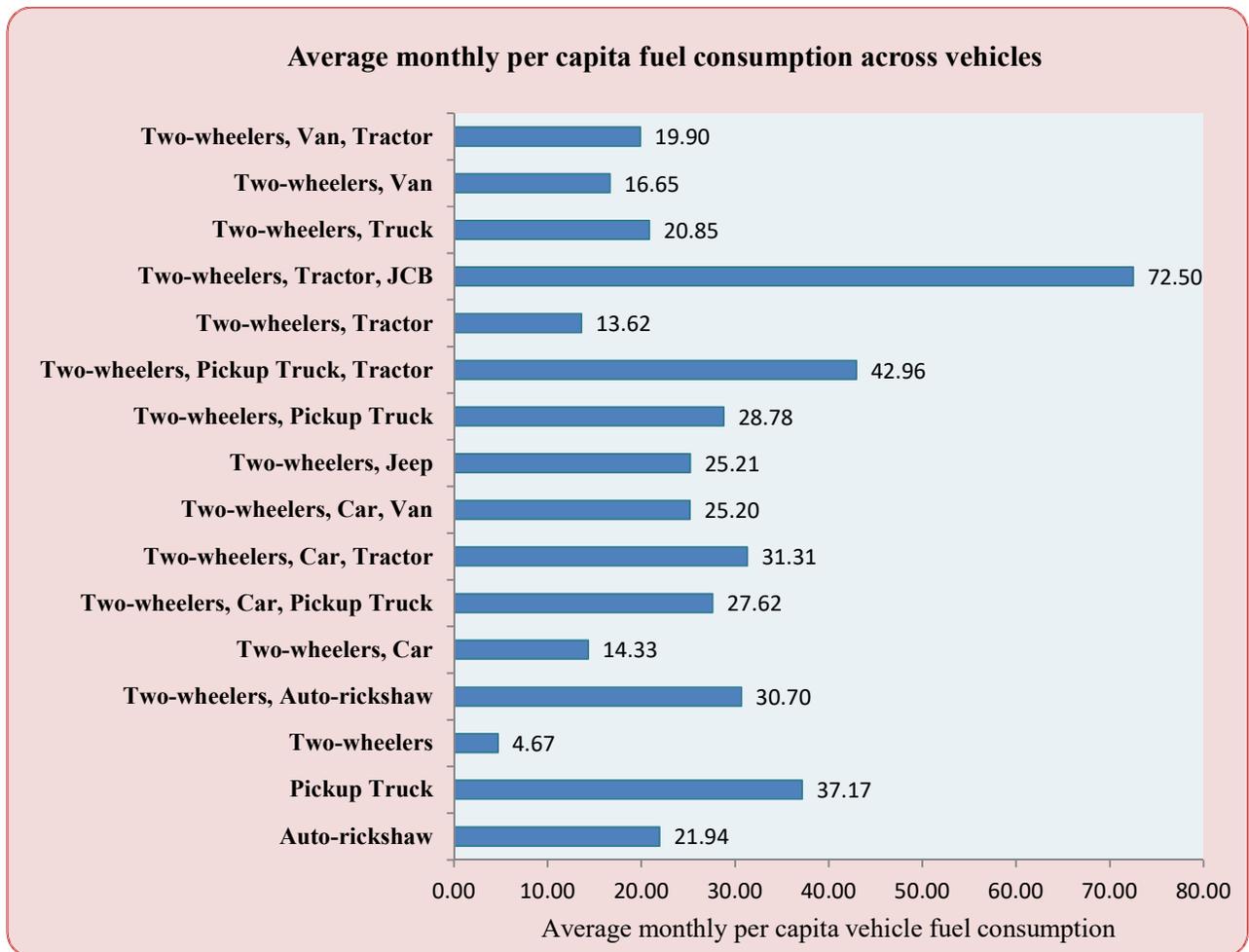
Average monthly per capita fuel consumption across vehicles

Vehicle	Value
Two-wheelers, Van, Tractor	19.90
Two-wheelers, Van	16.65
Two-wheelers, Truck	20.85
Two-wheelers, Tractor, JCB	72.50
Two-wheelers, Tractor	13.62
Two-wheelers, Pickup Truck, Tractor	42.96
Two-wheelers, Pickup Truck	28.78
Two-wheelers, Jeep	25.21
Two-wheelers, Car, Van	25.20
Two-wheelers, Car, Tractor	31.31
Two-wheelers, Car, Pickup Truck	27.62
Two-wheelers, Car	14.33
Two-wheelers, Auto-rickshaw	30.70
Two-wheelers	4.67
Pickup Truck	37.17
Auto-rickshaw	21.94

Average monthly per capita vehicle fuel consumption

Diagram 3.1.2

3.2 Estimation of monthly total fuel consumption by fuel type

The population-level estimates of monthly total fuel consumption by fuel type in Kavathe Mahankal Tahsil are presents in Table 3.2.1. The estimates are derived by scaling sample-based per capita fuel consumption to the population of households, taking into account the estimated proportion of households using each fuel type and the average household size.

Table 3.2.1: Population estimates of monthly total fuel consumption by Fuel Type

Fuel Type	n_j	$\overline{y}_j$	SD	$\widehat{p}_j=\frac{n_j}{n}$	$\widehat{N}_j=N*\widehat{p}_j$	$\widehat{Y}_j=\widehat{N}_j*M*\overline{y}_j$
Petrol	368	5.0018	4.82996	0.9866	31842.3592	833917.1461
Diesel	106	15.5024	18.56923	0.2842	9171.9839	744480.9106
CNG/LPG	19	16.4652	5.80931	0.0509	1644.0349	141732.4759

Where $\overline{y}_j$ denotes average per capita fuel consumption, $\widehat{p}_j$ denotes the estimated proportion of households using fuel type, $\widehat{N}_j$ denotes the population estimate of number of households using fuel type, $\widehat{Y}_j$ denotes estimate of monthly total of fuel consumption (j= 1, 2, 3) for petrol, diesel, or CNG/LPG respectively, M denotes average household size (5.2359), N=32275, and n=373.

Petrol emerges as the dominant fuel in terms of total monthly consumption, with an estimated requirement of approximately *833917 liters per month*, reflecting its near-universal adoption among households in the locality. Diesel accounts for a substantial monthly consumption of about *744481 liters*, despite being used by a smaller

proportion of households, due to its relatively higher per capita consumption. CNG/LPG contributes a comparatively smaller share, with an estimated *141732 liters per month,* primarily because of its limited household penetration, even though its average per capita consumption is similar to diesel.

3.3 Perception Analysis of determinants of Vehicle Fuel Consumption

Table 3.3.1 presents respondents' opinions on various factors influencing fuel consumption. The condition of roads emerged as the most influential factor, with the highest mean score (3.47), indicating that poor or varying road conditions substantially increase fuel usage. This was followed by vehicle age (mean = 3.34) and driving behavior (mean = 3.32), suggesting that older vehicles and inefficient driving practices significantly contribute to higher fuel consumption. Vehicle condition (mean = 3.24) and travel distance (mean = 3.23) showed a moderate to high influence, reflecting the role of maintenance status and trip length in determining fuel use. In contrast, traffic conditions (mean = 3.08) and load/passengers (mean = 3.05) were ranked lower, although a considerable proportion of respondents still perceived them as having a moderate to high impact on fuel consumption.

Table 3.3.1: Opinion about factor that affects your fuel consumption

	Not influence		Low influence		Moderate influence		High influence		Very high influence		Mean Score	Rank
	n	%	n	%	n	%	n	%	n	%		
Vehicle condition	17	4.6	52	13.9	159	42.6	114	30.6	31	8.3	3.24	4
Driving behavior	27	7.2	42	11.3	118	31.6	157	42.1	29	7.8	3.32	3
Traffic	50	13.4	91	24.4	76	20.4	91	24.4	65	17.4	3.08	6
Condition of roads	26	7.0	51	13.7	88	23.6	139	37.3	69	18.5	3.47	1
Travel distance	24	6.4	60	16.1	132	35.4	120	32.2	37	9.9	3.23	5
Load / passengers	52	13.9	59	15.8	114	30.6	116	31.4	32	8.6	3.05	7
Vehicle age	26	7.0	48	12.9	125	33.5	120	32.2	54	14.5	3.34	2

3.4 Independent samples t-test

The independent samples **t**-test is a parametric statistical technique used to determine whether there is a statistically significant difference between the means of two independent groups on a continuous dependent variable.

Table 3.4.1: Independent samples t-test

Independent Variable (IV)	Category (IV)	n	Mean	Std. Deviation	Levene's Test for Equality of Variances		t-test for Equality of Means		
					F	Sig.	t	df	Sig.
Gender	Male	344	10.5998	14.30899	11.196	0.001	5.791	200.758	0.000
	Female	29	5.1874	2.84165					
Residential type	Rural	328	9.9060	14.27487	0.005	0.943	-1.029	371	0.304
	Urban	45	12.1687	10.00210					

Dependent Variable (DV): Monthly per Capita Vehicle Fuel Consumption

An independent samples t-test in Table 3.4.1 was carried out to examine whether monthly per capita vehicle fuel consumption differs with respect to the gender of the respondent and residential type.

❖ The analysis reveals that males (n = 344) report a higher mean fuel consumption (mean = 10.5998, SD = 14.30899) compared to females (n = 29; Mean = 5.1874, SD = 2.84165). Levene's test for equality of variances is significant (F = 11.196, p = 0.001), indicating violation of the homogeneity of variances assumption. Accordingly, the Welch t-test was considered. The p-value (0.000) of independent samples t-test is less than 0.05 (significance level). Hence reject the null hypothesis and conclude that households with male vehicle users consume significantly more vehicle fuel per capita than those female vehicle users.

❖ The rural residents (n = 328) had a mean consumption of 9.9060 (SD = 14.27487), while urban residents (n = 45) had a slightly higher mean of 12.1687 (SD = 10.00210). Levene's test was not significant (F = 0.005, p = 0.943), indicating that the assumption of equal variances was met. The independent samples t-test p-value (0.304) is greater that 0.05 (significance level) and conclude that there is no statistically significant difference in average monthly per capita vehicle fuel consumption between rural and urban respondents.

3.5 ANOVA / Welch ANOVA

3.5.1 Comparison of Monthly per Capita Vehicle Fuel Consumption by monthly Household Income

Average monthly per capita vehicle fuel consumption in table 3.5.1 shows a clear positive relationship with household income. Lower-income households (<Rs. 10,000) have the lowest and relatively uniform fuel use (Mean = 3.7266, SD = 2.9718), while households in the Rs. 10,000–25,000 range exhibit higher consumption (Mean = 7.5986) with greater variability (SD = 8.0139), reflecting differences in vehicle ownership and travel requirements.

As income rises further, households earning Rs. 25,000–50,000 and Rs. 50,000–100,000 report substantially higher fuel consumption (Means = 11.8962 and 13.7322) with large dispersion (SDs = 16.8267 and 15.6002), and the highest-income group (>Rs. 100,000) shows the highest mean fuel use (Mean = 13.8241, SD = 13.8319).

Table 3.5.1: Descriptives, Levene's test, Welch ANOVA, and post-hoc test

Monthly Household Income (Rs)	n	Mean	SD	Test of Homogeneity of Variances		Welch ANOVA				Post-hoc Group[†]
				Levene Statistic	Sig.	F	df_1	df_2	Sig.	
Less than 10000	55	3.7266	2.9718	8.190	0.000	17.841	4	107.16	0.000	a
10000–25000	83	7.5986	8.0139							b
25000 - 50000	146	11.8962	16.8267							bc
50000 - 100000	66	13.7322	15.6002							c
More than 100000	23	13.8241	13.8319							bc

Dependent Variable: Monthly per Capita Vehicle Fuel Consumption
Post-hoc Test: Games–Howell (α = 0.05). [†]Groups sharing the same letter are not significantly different.

The Levene's test indicated unequal variances across income groups (Levene statistic = 8.190, p < 0.001), justifying the use of Welch ANOVA. The Welch ANOVA results show a highly significant difference in mean fuel consumption among the five income groups (F(4, 107.16) = 17.841, p < 0.001), confirming the effect of income on per capita fuel use.

Post-hoc analysis using the Games–Howell test reveals that households earning less than Rs. 10,000 (Group a) consume significantly less fuel than all other groups. Households earnings Rs. 10,000–25,000, Rs. 25,000–50,000, and over Rs. 100,000 brackets (Group b) show no significant differences among themselves but consume more than Group a.

Group c, including households earning Rs. 25,000–50,000, Rs. 50,000–100,000, and over Rs. 100,000, also shows no significant differences, indicating comparable fuel consumption among middle- and high-income households.

3.5.2 Comparison of monthly per Capita Fuel Consumption by occupation of household head

The table 3.5.2 shows that the average monthly per capita fuel consumption is lowest among Labour/Daily Wage Workers (Mean = 3.6065) and highest among Business/Self-Employed households (Mean = 18.5988). The standard deviation is notably higher for Business/Self-Employed and Contractual Job groups, indicating substantial variability in fuel consumption, whereas lower SD values suggest more consistent fuel use among Labour and Housewife households.

Table 3.5.2: Descriptives, Levene's test, Welch ANOVA, and post-hoc test

Occupation of Household Head	n	Mean	SD	Test of Homogeneity of Variances		Welch ANOVA				Post-hoc Group†
				Levene Statistic	Sig.	F	df$_1$	df$_2$	Sig.	
Business/ Self Employed	74	18.5988	20.2963	11.828	0.000	11.183	7	55.063	0.000	c
Contractual Job	13	18.5295	29.8452							abc
Farmer	142	7.7254	9.7584							b
Government Job	46	9.9751	11.4520							bc
Housewife	6	4.4250	1.8867							ab
Labour/Daily Wage Worker	31	3.6065	2.1160							a
Private Job	49	7.6902	5.9247							b
Retired	12	9.0451	6.3657							ab

Dependent Variable: Monthly per Capita Vehicle Fuel Consumption
Post-hoc Test: Games–Howell (α = 0.05). †Groups sharing the same letter are not significantly different.

The Levene's test (Levene statistic = 11.828, $p < 0.001$),) confirms heterogeneity of variances, validating the use of Welch ANOVA. The Welch ANOVA results show a highly significant difference in mean fuel consumption among the eight categories of Occupation groups ($F(4, 107.16) = 17.841$, $p < 0.001$), confirming the effect of occupation of household head on per capita fuel use.

Games–Howell post-hoc results show that Labour/Daily Wage Workers have the lowest fuel consumption (Group a), while Business/Self-Employed households exhibit the highest consumption (Group c). Occupations such as Farmers, Private Job, and Government Job fall in intermediate groups, with no significant differences among them.

3.5.3 Comparison of Monthly per Capita Vehicle Fuel Consumption by Vehicle service interval

The average monthly per capita fuel consumption is highest for vehicles serviced *every 3 months* (Mean = 12.7936), indicating greater average fuel use, while it is lowest for vehicles *never serviced* (Mean = 4.3750) shown in table 3.5.3.

Table 3.5.3: Descriptives, Levene's test, Welch ANOVA and post-hoc test

Vehicle Service interval	n	Mean	SD	Test of Homogeneity of Variances	Welch ANOVA	

				Levene Statistic	Sig.	F	df$_1$	df$_2$	Sig.	Post-hoc Group[†]
Every 3 months	185	12.7936	17.1305							a
Every 6 months	128	7.7082	9.5238							b
Ones year	33	8.3177	9.1170	6.584	0.000	4.395	4	8.75	0.032	ab
Rarely	25	6.4026	4.4349							b
Never	2	4.3750	2.6516							ab

Dependent Variable: Monthly per Capita Vehicle Fuel Consumption
Post-hoc Test: Games–Howell (α = 0.05). [†]Groups sharing the same letter are not significantly different.

The Levene's test (Levene statistic = 6.584, p < 0.001),) confirms heterogeneity of variances, validating the use of Welch ANOVA. The Welch ANOVA revealed a statistically significant difference in monthly per capita vehicle fuel consumption across different vehicle service cycles (F = 4.395, p = 0.032).

Post-hoc results indicate that vehicles serviced every 3 months have significantly higher fuel consumption (Group a) compared to those serviced every 6 months and rarely (Group b). Vehicles serviced once a year and never fall into an intermediate category (ab), showing no significant difference from either group. Hence more frequent servicing is associated with higher fuel consumption.

3.5.4 Comparison of Monthly per Capita Vehicle Fuel Consumption by Frequent Extra load
The table 3.5.4 gives average monthly per capita fuel consumption is highest for vehicles that frequently carry extra load (Mean = 13.0466) and lowest for those that sometimes carry extra load (Mean = 6.2725)

Table 3.5.4: Descriptives, Levene's test, Welch ANOVA and post-hoc test

Frequent Extra load	n	Mean	SD	Test of Homogeneity of Variances		Welch ANOVA				Post-hoc Group[†]
				Levene Statistic	Sig.	F	df$_1$	df$_2$	Sig.	
Yes	143	13.0466	17.0884							a
No	169	9.1626	12.1314	10.250	0.000	8.570	2	217.93	0.000	ab
Sometimes	61	6.2725	6.7894							b

Dependent Variable: Monthly per Capita Vehicle Fuel Consumption
Post-hoc Test: Games–Howell (α = 0.05). [†]Groups sharing the same letter are not significantly different.

The Levene's test (Levene statistic = 10.250, p < 0.001),) confirms heterogeneity of variances, validating the use of Welch ANOVA. The Welch ANOVA shows a statistically significant difference in monthly per capita vehicle fuel consumption by extra load usage (F = 8.570, p < 0.001). Games–Howell post-hoc results indicate that vehicles frequently carrying extra load have significantly higher fuel consumption (Group a) compared to those that sometimes carry extra load (Group b). Vehicles that do not carry extra load fall into an intermediate group (ab) and do not differ significantly from either category.

3.5.5 Comparison of Monthly per Capita Vehicle Fuel Consumption by purpose of most trips
The average monthly per capita vehicle fuel consumption (shown in table 3.5.5) is highest for business trips (Mean = 17.0823), followed by work (Mean = 9.7744) and school trips (Mean = 9.5802). The lowest mean fuel consumption is observed for shopping trips (Mean = 4.1251), with leisure trips showing a moderate mean value (Mean = 6.5625).

Table 3.5.5: Descriptives, Levene's test, Welch ANOVA and post-hoc test

Purpose of most trips	n	Mean	SD	Test of Homogeneity of Variances		Welch ANOVA				Post-hoc Group[†]
				Levene Statistic	Sig.	F	df₁	df₂	Sig.	
Work	268	9.7744	13.9797	4.397	0.002	12.350	4	7.72	0.002	a
School	31	9.5802	8.9587							a
Shopping	28	4.1251	2.1357							b
Business	44	17.0823	17.5863							a
Leisure	2	6.5625	4.8614							ab

Dependent Variable: Monthly per Capita Vehicle Fuel Consumption
Post-hoc Test: Games–Howell (α = 0.05). †Groups sharing the same letter are not significantly different.

Levene's test indicates a violation of the homogeneity of variances assumption ($p = 0.002$); therefore, Welch ANOVA was appropriately used. The Welch ANOVA results show a statistically significant difference in monthly per capita vehicle fuel consumption across different purposes of most trips ($F(4, 7.72) = 12.350$, $p = 0.002$). The Games–Howell post-hoc test reveals that respondents whose primary travel purpose is shopping (Group b) have significantly lower mean fuel consumption compared to those traveling mainly for work, school, and business purposes, which all fall into Group a. The leisure group belongs to Group ab, indicating that its mean fuel consumption does not differ significantly from either Group a or Group b.

3.5.6 *Comparison of Monthly per Capita Vehicle Fuel Consumption by traffic congestion in locality*

The average monthly per capita vehicle fuel consumption increases with the level of traffic congestion in the locality. The table 3.5.6 shows, respondents from low traffic congestion areas reported the lowest mean fuel consumption (Mean = 8.3812), followed by those from moderate congestion areas (Mean = 10.5907). Higher mean values are observed in high congestion (Mean = 13.4603) and very high congestion localities (Mean = 14.1527), indicating greater fuel usage under heavier traffic conditions. This indicates that the mean fuel consumption shows an upward trend as traffic congestion intensifies.

Table 3.5.6: Descriptives, Levene's test, ANOVA and post-hoc test

Traffic congestion in locality	n	Mean	SD	Test of Homogeneity of Variances		ANOVA				Post-hoc Group[†]
				Levene Statistic	Sig.	F	df₁	df₂	Sig.	
Low	185	8.3812	14.0529	2.248	0.082	2.812	3	369	0.039	a
Moderate	101	10.5907	11.5560							ab
High	79	13.4603	15.4669							b
Very High	8	14.1527	13.6016							ab

Dependent Variable: Monthly per Capita Vehicle Fuel Consumption
Post-hoc Test: Tukey HSD (α = 0.05). †Groups sharing the same letter are not significantly different.

Levene's test indicates that the assumption of homogeneity of variances is satisfied ($p = 0.082$), justifying the use of one-way ANOVA. The ANOVA results show a statistically significant difference in monthly per capita vehicle fuel consumption across levels of traffic congestion ($F(3, 369) = 2.812$, $p = 0.039$).

Tukey HSD post-hoc comparisons reveal that low traffic congestion areas (Group a) have significantly lower fuel consumption compared to high traffic congestion areas (Group b). The moderate and very high congestion groups (ab) do not differ significantly from either the low or high congestion groups, indicating

intermediate fuel consumption levels. Overall, fuel consumption tends to increase with traffic congestion, but statistically significant differences are observed only between low and high congestion levels.

3.6 Karl Pearson Correlation

The Pearson Correlation is a statistical technique used to measure the strength and direction of the relationship between two variables. Table 3.6.1 presents results of the Pearson correlation analysis between monthly per capita vehicle fuel consumption and household- and travel-related variables.

Table 3.6.1: Correlation

		Number of adults	Distance from main workplace / market(km)	Number of vehicles in your family	Average number of household trips per day	Long trips (> 50 km) per month	Average fuel economy (km/liter)	Satisfaction level about fuel consumption
Monthly Per Capita Vehicle Fuel Consumption	Pearson Correlation	-0.076	0.145**	0.376**	0.170**	0.236**	-0.501**	0.292**
	Sig. (2-tailed)	0.143	0.005	0.000	0.001	0.000	0.000	0.000
	N	373	373	373	373	373	373	373

**. Correlation is significant at the 0.01 level (2-tailed).   *. Correlation is significant at the 0.05 level (2-tailed).

The monthly per capita fuel consumption shows a moderate and statistically significant positive correlation with the number of vehicles in the family (r = 0.376, p < 0.01), indicating that households owning more vehicles tend to have higher per capita fuel consumption. Similarly, distance from the main workplace/market (r = 0.145, p < 0.01), average number of household trips per day (r = 0.170, p < 0.01), and number of long trips (> 50 km) per month (r = 0.236, p < 0.01) are positively and significantly associated with fuel consumption, suggesting that greater travel intensity and longer travel distances increase fuel use.

A strong and significant negative correlation is observed between average fuel economy (km/liter) and per capita fuel consumption (r = −0.501, p < 0.01), implying that households with more fuel-efficient vehicles consume less fuel on a per capita basis. Satisfaction level regarding fuel consumption is also positively and significantly correlated with per capita fuel consumption (r = 0.292, p < 0.01), indicating that higher fuel use may be associated with greater perceived adequacy or acceptance of fuel consumption levels. In contrast, the number of working adults shows a weak and statistically insignificant correlation (r = −0.076, p > 0.05), suggesting that it does not have a direct linear relationship with monthly per capita fuel consumption in the study area. Hence the findings indicate that vehicle ownership, travel distance and frequency, and fuel efficiency are key correlates of monthly per capita vehicle fuel consumption, while household labor composition appears to play a limited role.

3.7 Multiple linear regression

A multiple linear regression model was employed to examine the combined effect of selected household, travel, and vehicle-related variables on monthly per capita vehicle fuel consumption and to identify the significant determinants of fuel use. The multiple linear regression analysis was conducted using SPSS with the *stepwise method*. The model summary table 3.7.1 indicates a progressive improvement in model fit as additional predictors are included, with R increasing from 0.501 to 0.649 and R² rising from 0.251 to 0.421. The final model (model - 10) explains about 42.1% of the variation in monthly per capita vehicle fuel consumption, while the decreasing standard error of estimate suggests improved prediction accuracy.

Table 3.7.1: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.501	0.251	0.249	11.99433
2	0.536	0.288	0.284	11.71042
3	0.557	0.311	0.305	11.53616
4	0.573	0.329	0.321	11.39885
5	0.593	0.351	0.342	11.22169
6	0.608	0.369	0.359	11.07919
7	0.621	0.386	0.374	10.94858
8	0.634	0.402	0.389	10.81804
9	0.641	0.411	0.397	10.74714
10	0.649	0.421	0.405	10.67587

The ANOVA table 3.7.2 results indicate that p-value less than 0.05 (significance level). Hence reject null hypothesis and conclude that final regression model is statistically significant, demonstrating that the set of independent variables jointly explains a significant proportion of the variation in monthly per capita vehicle fuel consumption.

Table 3.7.2: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	29979.209	10	2997.921	26.303	0.000
10	Residual	41258.678	362	113.974		
	Total	71237.887	372			

The coefficients table 3.7.3, model -10 indicates that monthly per capita vehicle fuel consumption is significantly influenced by several household- and vehicle-related factors. Variables such as number of vehicles, long trips (> 50 km) per month, traffic congestion, fuel consumption satisfaction, and type of vehicle owned are positively associated with per capita fuel consumption, whereas average fuel economy, occupation of household head, number of working adults, frequent extra load, and vehicle service interval are negatively associated. All reported coefficients are statistically significant (p < 0.05), highlighting their meaningful contribution to variations in per capita fuel use.

Table 3.7.3: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	12.785	5.689		2.247	0.025
	Average fuel economy (km/liter) (x_1)	-0.185	0.058	-0.198	-3.211	0.001
	Long trips (> 50 km) per month (x_2)	0.632	0.212	0.126	2.989	0.003
10	Occupation of Household head (x_3)	-0.827	0.283	-0.123	-2.919	0.004
	Number of adults (≥18 years) (x_4)	-2.149	0.394	-0.250	-5.456	0.000
	Number of vehicles in family (x_5)	2.893	0.757	0.218	3.819	0.000
	Traffic congestion in locality (x_6)	1.997	0.686	0.124	2.912	0.004

Fuel consumption satisfaction (x_7)	0.306	0.096	0.140	3.192	0.002
Frequent Extra load (x_8)	-2.476	0.815	-0.127	-3.037	0.003
Vehicle service interval (x_9)	-1.629	0.629	-0.108	-2.591	0.010
Type of vehicle own (x_{10})	0.571	0.236	0.139	2.421	0.016
a. Dependent Variable: Monthly Per Capita Vehicle Fuel Consumption					

The multiple linear regression model is:

$$\hat{y} = 12.785 - 0.185x_1 + 0.632x_2 - 0.827x_3 - 2.149x_4 + 2.893x_5 + 1.997\,x_6 + 0.306\,x_7 - 2.476x_8$$
$$- 1.629\,x_9 + 0.571x_{10}$$

4. Conclusions

- Average monthly per capita vehicle fuel consumption is approximately 10.18 liters /person / month.
- Petrol dominates monthly fuel demand in Kavathe Mahankal Tahsil (8.34 lakh L), followed by diesel (7.44 lakh L), while CNG/LPG accounts for much smaller share (1.42 lakh L).
- Fuel consumption increases significantly with income at lower income levels, while middle- and high-income groups show similar consumption patterns.
- Business and self-employed households record the highest fuel usage.
- Factors such as number of vehicles, type of vehicle, long-distance travel, traffic congestion, Fuel consumption satisfaction and extra load significantly increase fuel consumption.
- Higher fuel economy significantly reduces per capita fuel consumption.
- Fuel consumption is most affected by road condition, followed by vehicle age and driving behavior.
- The findings are useful for fuel providers in planning fuel distribution and inventory at the local level.

5. Recommendations

- Government should improve road infrastructure and traffic management to reduce consumption.
- Incentives and awareness should promote fuel-efficient, well-maintained & alternative-fuel vehicles.
- Awareness on efficient driving and avoiding extra load and unnecessary travel can reduce fuel use.
- Policymakers should use local fuel data for effective transport planning and fuel distribution.

6. Limitations of the Study

- The study uses cross-sectional, self-reported data, which may involve recall or reporting bias.
- Seasonal variations in fuel use were not considered, limiting the applicability of findings over time.

7. Future scope of the study

- The study can be extended to other regions (Tahsil /districts) for comparison.
- Future research can track fuel consumption trends over time.
- The environmental impact of household fuel use can be assessed.
- The role of electric vehicles and public transport can be explored.

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