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EVALUATION OF VARIABILITY IN ON-ROAD VEHICLE FUEL CONSUMPTION UNDER CONTROLLED CONDITIONS

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ABSTRACT

The fuel consumption is an important component of the vehicle operating cost which is a significant component of the total transportation cost. Fuel consumption data are extensively used by transport planners, transport managers and other professional for various evaluation processes in overall gambit of sustainable transportation system. Accuracy of fuel consumption data is one of the key factors in deriving realistic vehicle operating cost component. Minimizing uncertainties in fuel consumption measurements enhance the quality of data. In an attempt to understand the variability in observed fuel consumption under controlled conditions, field studies were carried out using a petrol-driven control vehicle. The sophisticated on-line fuel flow meter and GPS were used to collect real time fuel consumption and distance data that was integrated through a data acquisition system. In the present study an attempt has been made to investigate the variability in fuel consumption under various steady speeds. For this various test runs were carried out. The results emphasize that the coefficient of variation in fuel consumption ranged from 2% to 8% and the corresponding optimum fuel consumption was observed at 40 km/hr , 50 km/hr and 60km/hr speed. Present study findings reveal that even under controlled conditions, variability in fuel consumption is inevitable.

Keywords: fuel consumption, variability, fuel flow, data acquisition system, steady speed

1. INTRODUCTION

Road transport is a vital sector in the economy of India. The road users often point out that bad condition of the road is leading to higher fuel consumption. Investment decisions are to be made with respect to road projects [1]. In order to facilitate in the decision making process there should be adequate data base pertaining to fuel consumption as these inputs will be of immense help in planning road improvement and working out strategies for efficient fuel management in the country [2]. Vehicle fuel consumption is a complex phenomena due to wide variety of factors such as traffic characteristics, driver characteristics, road surface characteristics etc. and hence a definite value of fuel consumption from a particular vehicle for a given speed is not expected [3]. But what is surprising to know is the high variability observed in fuel consumption under controlled conditions.

2. STUDY METHODOLOGY

Fuel consumption studies were carried out under controlled conditions for a Petrol vehicle fitted with fuel flow GPS based data acquisition system whereby the fuel flow data can be integrated with the distance data (Fig 1). The fuel flow detector fitted on the fuel line of the vehicle is a positive displacement type detector which has an accuracy of measurement of the order of 0.1 ml. To minimise the effect of vehicle, road and driving characteristics, the test was conducted under controlled conditions. The control condition means that the entire test runs at a particular test section, for a particular vehicle were conducted by availing the services of the same driver, to fill fuel from the same fuel filling station and with the predetermined gear position for each vehicle steady speed. The test was therefore called steady speed fuel consumption under controlled conditions. Steady speed fuel consumption test was carried out for speeds ranging from 20 km/hr to 70 km/hr with speed intervals of 10 km/hr. Ten runs for each speed were carried out on either side of carriage way in order to minimize the effect of wind for a predetermined distance of 1 km on a 6 lane divided carriageway access controlled Noida-Greater Expressway, which had least traffic conflict due to low volume of traffic and high speeds.

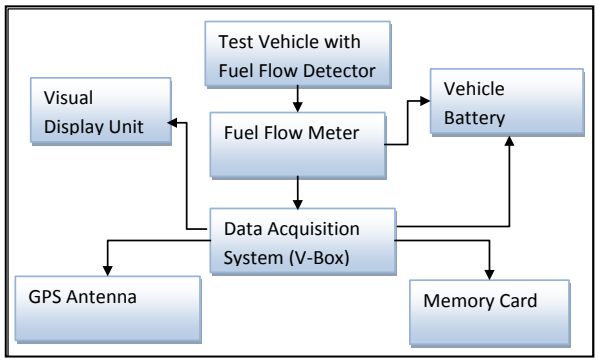

Fig.1. Fuel Flow Data Acquisition System

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The test section, as captured through the recorded test data and loaded on Google earth platform is shown in Fig 2. The test section is a plane terrain, bituminous surface and has a open background hence free from the interference of building, trees and underpass. This has facilitated to capture the GPS data without any loss of data due to discontinuity of the signal while the vehicle was in motion.

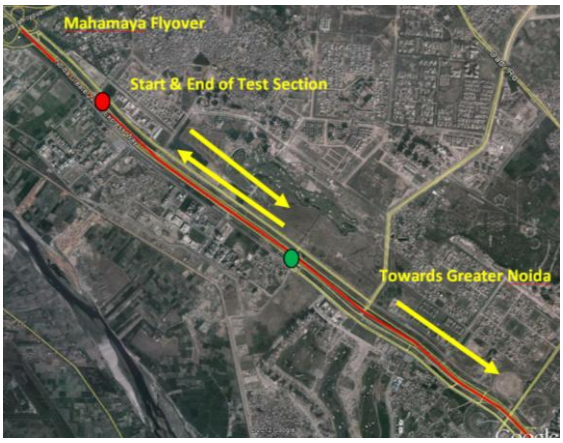

Fig.2. Test Section on Noida- Greater Noida Expressway

The driver was instructed to drive at predetermined gear position for a given steady speed based on field trials and as per manufacturer's recommendation (as indicated in the vehicle owner's manual). It was ensured that no repair, adjustments were carried out on the vehicle during the entire duration of the test and only necessary routine checks were carried out for trouble free running of the vehicle. Petrol for the vehicle was filled from the same fuel filling station so as to avoid any variation in fuel consumption due to changes in fuel quality if any. The vehicle was tested in fully warmed up condition (hot stabilized mode). The fuel consumption was recorded with the provision for marking the event to indicate the start and end of the test section with the help of data acquisition system.

The steady speed test was conducted by approaching and leaving the test section at the predetermined steady speed. The test vehicle is provided with on screen display to facilitate driver to maintain the steady speed with the co passenger instructing the driver to raise or lower speed so as to facilitate in maintaining the steady speed. A typical graph of the data of fuel consumption captured through V-Box is shown in Fig 3. The data was processed through the post processing V-Box software that convert the graph data into the desirable format of fuel consumption in to Excel spread sheet format. Event trigger facilitates to record the position of the test section on the graph and it further initialises the fuel flow data thereby enabling to easily capture the cumulative value of fuel consumption for the test section.

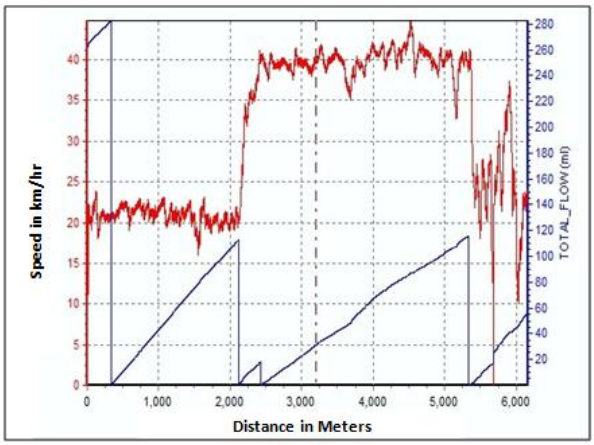

Fig.3. Captured Fuel Consumption and Distance Data

3. OBSERVATION

The observed value of fuel consumption for all the ten runs for both direction for different steady speed is given in Table 1 and Table 2. It was observed that optimum fuel consumption for all the runs was at 40 km//hr, 50 km/hr and 60 km/hr speed.

The mean value of fuel consumption for both the directions for each of the steady speed is shown in Table 3 and Table 4. From the mean and the standard deviation values of the respective sets of data for each of the steady speed, the coefficient of variation (Cv) is calculated. Coefficient of variation up to 6.6% was observed on one direction of the carriage way. Whereas, Cv value of 8.2% was observed for the other direction of the carriageway. There seems to be no definitive trend of the relationship between vehicle speed and variability.

Table 1: Fuel Consumption (ml/km) under Different Runs (Direction: Noida to Greater Noida)

	Steady speed in km/hr					
Run	**20**	**30**	**40**	**50**	**60**	**70**
1	64.9	40.1	38.4	39.8	43.8	51.7
2	60.1	44.1	36.8	35.8	44.0	46.9
3	62.3	45.2	37.9	36.3	45.3	45.0
4	63.3	46.3	57.9	35.0	41.3	47.1
5	63.8	41.4	36.4	36.5	47.6	45.1
6	58.5	40.3	37.0	37.6	50.9	48.1
7	60.9	43.2	38.4	40.1	41.0	48.0
8	62.6	45.5	36.6	40.0	42.3	51.1
9	61.9	46.2	36.6	40.2	44.8	47.1
10	62.6	47.1	37.2	40.4	41.8	47.8

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Table 2: Fuel Consumption (ml/km) under Different Runs (Direction: Greater Noida to Noida)

	Steady speed in km/hr					
Run	**20**	**30**	**40**	**50**	**60**	**70**
1	61.3	45.3	41.4	41.4	40.3	48.1
2	63.4	48.3	40.9	42.7	39.1	47.5
3	64.5	47.7	41.1	44.5	39.3	49.7
4	64.0	45.1	41.9	43.2	38.7	50.9
5	65.3	44.8	40.9	36.3	39.0	51.1
6	62.3	45.3	39.5	35.7	42.3	48.5
7	63.0	47.3	42.1	36.8	43.1	49.4
8	63.4	48.5	40.7	36.6	42.1	46.6
9	63.7	49.2	41.4	37.1	43.0	50.4
10	64.4	49.1	41.3	37.4	44.5	50.8

Table 3: Fuel Consumption (mean value) at Steady Speed (Direction: Noida to Greater Noida)

Speed km/hr	**Fuel consumption ml/km**	**Co efficient of Variation %**
20	62.1	2.8
30	43.9	5.5
40	37.1	2.2
50	38.2	5.3
60	44.3	6.6
70	47.8	4.3

Table 4: Fuel Consumption (mean value) at Steady Speed (Direction: Greater Noida to Noida)

Speed km/hr	**Fuel consumption ml/km**	**Co efficient of Variation %**
20	63.5	1.7
30	47.1	3.5
40	41.1	1.7
50	39.2	8.2
60	41.1	4.9
70	49.3	3.0

The pattern of fuel consumption observed from the graph of steady speed and mean value of fuel consumption is of typical parabolic nature as is usually observed and reported for steady speed fuel consumption studies (Fig 4 and Fig 5).

From the data observed for Noida to Greater Noida direction, the steady speed can be related to the fuel consumption. The equation for fuel consumption (1) considering the mean value of fuel consumption, FC (ml/km) can be related in terms of steady speed (km/hr)

$$FC = 2.86\,V^2 - 21.98\,V + 79.2, \quad R^2 = 0.92 \qquad (1)$$

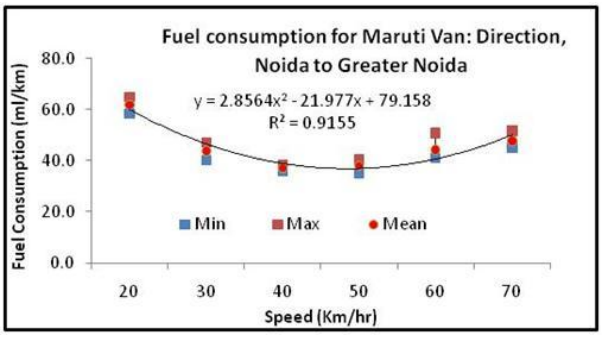

Fig.4. Fuel Consumption of Maruti Van: (Direction: Noida to Greater Noida)

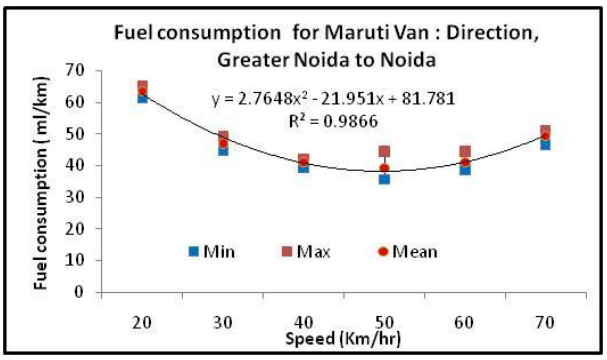

Fig.5. Fuel Consumption of Maruti Van: (Direction: Greater Noida to Noida)

Similarly, the data observed for Greater Noida to Noida direction, The equation for fuel consumption ((mean value of fuel consumption in ml/km) can be related in terms of steady speed (km/hr) as given below.

$$FC = 2.76\,V^2 - 21.95\,V + 81.8 \quad R^2 = 0.99 \qquad (2)$$

From the Equations (1) and (2) it was observed that insignificant difference in the model coefficients for the relation between the FC and speed exists. This is probably due to the difference in road surface characteristics on both sides of the carriageway. To identify the statistical trend of the fuel consumption data both the directions were combined and fitted a distribution with the help of Statistical tool box [4]. The most widely used probability distribution, such as normal distribution, was considered and corresponding probability as well as cumulative normal distribution curves was fitted against the observed data (Fig.6 and Fig.7). It was observed from these figures that the fitted distribution curves follow the observed distribution closely for each of the steady speeds as is observed in any naturally occurring process. For statistical validity chi-square goodness of fit test was considered and it

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was observed in all the cases that the chi-square critical value obtained from the standard statistical table [5] is 30.14 at 5% level of significance is greater than the chi-square estimated value of each case. This emphasizes that insignificant variation exists between observed and fitted distribution for different steady speeds (Table 5).

Table 5: Chi-Squre of Observed and Critical Values (Sample Size: 20 and Degree Freedom is 19)

Steady Speed km/hr	Chi Square Value	
	Estimated	Critical
20	1.74	30.14
30	2.53	30.14
40	1.35	30.14
50	1.66	30.14
60	1.95	30.14
70	1.12	30.14

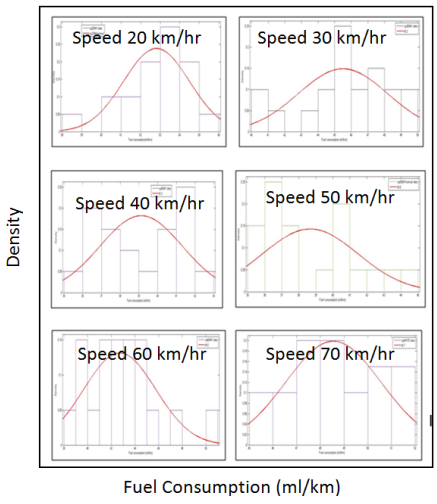

Fig.6. Probability Distribution of Fuel Consumption for different Steady Speeds of Maruti Van

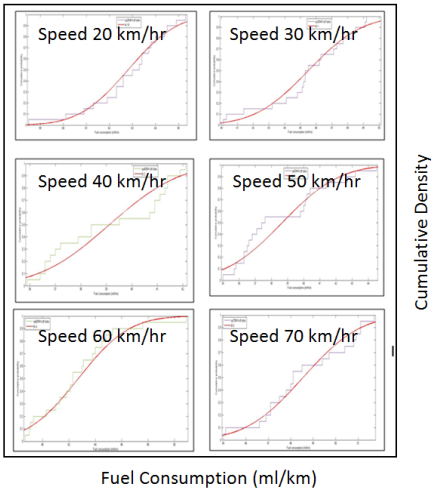

Fig.7. Cumulative Distribution of Fuel Consumption for different Steady Speeds of Maruti Van

4. CAUSES FOR VARIABITY

The possible causes for the observed variability in fuel consumption may be due to varying riding quality of the road surface as driver will not be able to follow the same wheel path. The driver, in order to maintain the steady speed, will be manipulating the accelerator pedal which will cause variability in fuel consumption. Further, the effect of wind speed and humidity factor could contribute to the variability. Cyclic variability is an inherent feature of any internal combustion engine due to variation in residual gas fraction as well as mixture preparation, which all will contribute to variability in fuel consumption [6].

5. CONCLUSION

The average fuel consumption was observed to vary from 38 ml/km to 64 ml/km at steady speeds of 20 km/hr to 70 km/hr. However, the optimum fuel consumption was observed at 40 km/hr, 50 km/hr and at 60 km/hr speeds over ten runs for each steady speed. The possible reasons for this variation could be due to variation in road surface roughness, inherent engine variability, maintaining the designated steady speed and influence of metrological factors (such as wind speed, ambient temperature and related humidity).

The study results revealed that despite these controlled conditions and use of sophisticated equipment there is an observed variability of up to 8% and hence it is desired that any quantification of data regarding fuel consumption estimates should take this aspect into consideration to minimize uncertainty in fuel consumption estimate during various fuel flow data management scenarios.

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NOMENCLATURE

Symbol

FC	Fuel consumption	(ml/km)
V	Speed	(km/hr)
R^2	Coefficient of Determination	
Cv	Coefficient of variation	(%)

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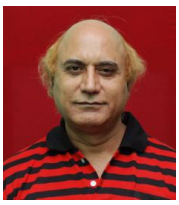

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Dr. Ch. Ravi Sekhar is a Senior Scientist in Transportation Planning Division at CSIR-Central Road Research Institute, New Delhi. He has 11 years of Reseach experience. He has research interst in Transportation Netwok Analysis, Travel Time Reliability analysis etc. He has several publications in various journals.