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Original Research Paper

Development of Road Transport Fuel Consumption Model for Jaipur City - A Case Study

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Fuel consumption
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Traffic congestion Mixed traffic flow

ABSTRACT

The object of this study is to develop an empirical, mathematical energy consumption equation for the estimation of energy consumption at two highly busy commercial corridors of Jaipur city. This equation incorporates traffic volume, average traffic speed, passenger loading, length of roads and type of fuel used under heterogeneous traffic flow conditions. Monitoring and modelling were carried out at both of the selected locations. Further, a comparative study was also done by introducing a new theoretical concept of Bus Rapid Transit System (BRTS) in the study. It was found that 80-90% fuel consumption can be reduced, replacing personalized vehicles by BRTS.

INTRODUCTION

Transportation is the backbone of the economy of any country, and is indispensable for economic growth and development (Zachariadis 2001). The increase in urbanization and concentration of activities lead to higher demand in various sectors of which transport is an important one. Transport within and between urban settlements accounts for a major share of urban energy requirements (Sivacoumar 2000).

At present, transport sector accounts about half of the total consumption of petroleum products in India (Sharma 2005). The number of two wheelers, mainly driven by two stroke engines, accounts for 70% of the total vehicular population and 25% of the total energy of which 98% comes from oil accounts for energy consumption by the road sector in India (Bose 1996).

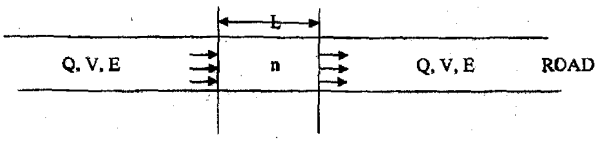
Jaipur, the capital of the State of Rajasthan, is a metropolitan city, which has annual growth rate of 5.6% for population and 12% for vehicles. The traffic flow condition is heterogeneous in nature, where slow vehicles outnumber other modes of transport (Srinivas 1996).

The present study is aimed to analyse the abnormal increase in energy consumption on urban road sector. In this study, two highly busy commercial corridors were selected for field studies. Using several road parameters and vehicular characteristics, an empirical equation was developed for calculation of energy consumption. Further, a comparative study was also carried out between energy consumption by heterogeneous traffic flow and BRTS for the similar identified intersections.

MATERIALS AND METHODS

Two highly busy commercial corridors, i.e., J.L.N. Marg and M.I. Road of Jaipur city were selected for the estimation of energy consumption values.

Model used (Khadiyali 1985, Alnaser 1995): For the energy estimation, a straight road section is considered, which is away from intersection as shown below.



Q = Traffic volume of vehicles (vehicles/min)
V = Average speed of the traffic stream (m/min)
E = Fuel consumption of vehicles (litres/min)
L = Length of road section (metre)
n = Number of vehicles present in the road space length 'L' meter

For estimation of energy consumption of particular category of vehicles, travelling at a particular speed, we have,

e_{v1} is the fuel consumption of a particular vehicle travelling at the speed of v_1, (litres/min).

q_1 is the traffic volume (vehicles/min) of a particular category of vehicles for a small duration of 't' minutes.

v_1 is the average speed of particular category of vehicles present in road space of length 'L' meter

n_1 is the number of vehicles of a particular category, occupying the length 'L' of road, travelling at speed of v_1.

$$n_1 = q_1 / v_1 \times L \quad ...(1)$$

t is the small time interval in which traffic parameters, q_1, v_1, n_1 are maintained.

Therefore, energy consumed per min in length 'L' of road by n_1 vehicles

$$= n_1 \times e_{v1} \quad ...(2)$$

E_1 is total energy consumption in the road space length 'L' meter in small time interval of t minutes is given by

$$= n_1 \times e_{v1} \times t \qquad \text{where, } [n_1 = (q_1/v_1) \times L]$$

$$= q_1 \times e_{v1} \times L \times t/v_1 \quad ...(3)$$

Therefore, total energy consumption of all categories of vehicle present in mixed traffic condition, in t minutes is

$$E = \Sigma E_1 = t \times L \times (q_1 \times e_{v1}/v_1 + q_2 \times e_{v2}/v_2 + q_3 \times e_{v3}/v_3 + q_4 \times e_{v4}/v_4 + q_5 \times e_{v5}/v_5 ....) ...(4)$$

On the basis of fuel efficiency of engine, two wheelers were classified into two stroke and four stroke vehicles with observed field ratio of 9:1. Analysing the car/jeep category, on the basis of type of fuel used, it was observed that the ratio of petrol vehicles (car) to diesel vehicles (Tata Sumo, Jeep, etc.) was 10:1. Energy consumption of each class of vehicles (e_{v1}) with respect to speed, is shown in Fig. 1.

Field Studies: The various contemporary modes of vehicles were observed and classified under five categories are: 1. Cars/Jeep, 2. Two wheeler, 3. Three wheeler, 4. Mini bus, 5. Full size bus

All the five classes of the vehicles were counted manually in the evening peak hours (4:30 p.m.-6:20 p.m.) for both directions of the road section. Classified average speed data were recorded using Doppler radar speedometer. Energy consumption for each category of vehicle with speed was also noted by field observations.

Table 1: Total energy consumption of different categories of vehicles at JLN Marg and MI Road.

Time Interval	Two Wheelers		Car/Jeep		Mini Bus	3-Wheeler	Bus	Avg. speed (kmph)	Total energy consumption
	2-S	4-S	Petrol	Diesel					
Energy consumption of different categories of vehicles(L/10min/m) at JLN Marg									
4:30p.m.-4:40p.m.	87.5	5.737705	64.26885	7.180328	5.221311	8.5	4.557377	42	182.9656
4:40p.m.-4:50p.m.	97.6	7.272727	89.76	8.781818	7.445455	9.704545	2.563636	40	223.1282
4:50p.m.-5:00p.m.	117.73	8.6	88.04	9.66	5.7	11.59	4.23	37	245.55
5:00p.m.-5:10p.m.	133.2443	9.484536	107.2948	11.21649	8.814433	10.12784	6.061856	35	286.2443
5:10p.m.-5:20p.m.	171.6409	12.27273	122.1727	12.90909	10.79545	16.39659	9.034091	32	355.2216
5:20p.m.-5:30p.m.	139.8907	10.30928	75.05155	7.71134	9.793814	9.178351	9.092784	35	261.0278
5:30p.m.-5:40p.m.	170.7055	12.30769	105.033	11.20879	16.7033	15.85604	3.230769	33	335.0451
5:40p.m.-5:50p.m.	213.8534	15.45455	116.6591	12.36364	10.79545	14.65227	6.681818	32	390.4602
5:50p.m.-6:00p.m.	179.1396	12.96703	88.69451	9.714286	6.263736	9.446154	0	33	306.2253
6:00p.m.-6:10p.m.	123.12	9	72.42	7.59	9.1	7.6	1.41	36	230.24
6:10p.m.-6:20p.m.	122.208	8.8	70.29	7.59	6.37	8.208	5.64	37	229.106
Energy Consumption of Different Categories of Vehicles(L/10min/m)at MI Road									
4:30p.m.-4:40p.m.	373.7725	26.46	165.54	16.02	2.18875	27.75	5.9625	32	617.6938
4:40p.m.-4:50p.m.	323.5013	22.785	173.55	16.91	2.575	24	1.9875	30	565.3088
4:50p.m.-5:00p.m.	318.5125	22.54	167.32	16.02	2.575	24	3.975	30	554.9425
5:00p.m.-5.10p.m.	239.46	16.905	151.3	14.24	2.3175	25.5	0	29	449.7225
5:10p.m.-5:20p.m.	249.1086	17.64	196.3086	19.32571	2.354286	35.57143	2.271429	28	522.58
5:20p.m.-5:30p.m.	317.0871	22.4	198.3429	19.32571	2.648571	28.71429	2.271429	28	590.79
5:30p.m.-5:40p.m.	293.8429	20.72	174.9486	17.29143	3.09	25.71429	2.271429	28	537.8786
5:40p.m.-5:50p.m.	273.23	19.32	190.2057	18.30857	2.501429	24.42857	0	29	527.9943
5:50p.m.-6:00p.m.	220.6014	15.4	169.8629	16.27429	2.354286	24.42857	4.542857	30	453.4643
6:00p.m.-6:10p.m.	188.4213	13.23	149.52	14.24	2.18875	19.5	1.9875	30	389.0875
6:10p.m.-6:20p.m.	190.34	13.475	159.31	15.13	1.67375	19.5	3.975	30	403.4038

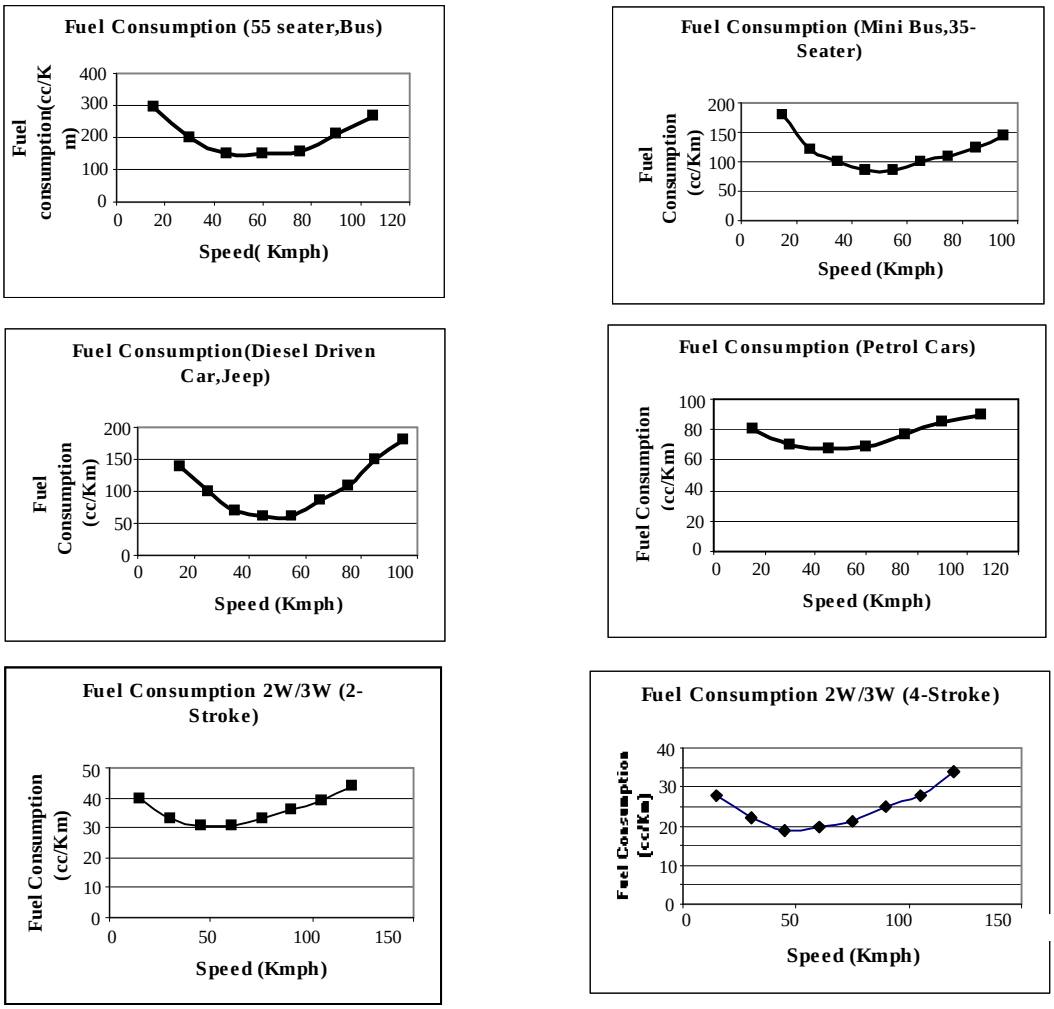


Fig. 1: Fuel consumption of different categories of vehicles with respect to speed.

RESULTS AND DISCUSSION

Table 1 show the total energy consumption for both the selected intersections of Jaipur city. The result of the study indicated that at JLN Marg, almost 72% of the vehicles observed consists of two wheelers followed by cars (21%), three wheelers (7%), while remaining 6% consisted of mini buses and full sized buses. At MI Road, 73% of the vehicles observed consist of two wheelers, followed by cars (20%), three wheelers (6%), while remaining 2% consisted mini buses and full sized buses. For this, it can be deduced that two wheelers are the major contributor to energy consumption.

Now, all categories of vehicles, i.e., two-wheelers (including 2-Stroke and 4-Stroke), three wheelers, cars/jeeps (driven by petrol and diesel) were theoretically replaced by BRTS (Bus Rapid Transit System). The additional buses (55 seater) were introduced for catering the passengers of two wheelers, three wheelers, cars and jeep. Traffic volume of mini buses and their passenger loading was

Table 2: Comparisons of energy consumption values under mixed traffic flow conditions and BRTS at JLN Marg and at MI Road.

Time	Mini bus	Energy) consumption (L/10min/m)	Bus	Energy consumption (L/10min/m)	Total passengers passed by different passenger modes	Total passengers passed by BRTS	Total E. consump. under mixed traffic flow condition (L/10min/m)	Total E. consump. with BRTS (L/10min/m)	E. saving (L/10min/m)	E. saving %
JLN Marg										
4:30p.m.-4:40p.m.	7	5.221311	17	19.36885	1205	1180	182.9656	24.59016	158.3754	86.56023
4:40p.m.-4:50p.m.	9	7.445455	16	20.50909	1206	1195	223.1282	27.95455	195.1737	87.47153
4:50p.m.-5:00p.m.	6	5.7	18	25.38	1201	1200	245.55	31.08	214.47	87.3427
5:00p.m.-5:10p.m.	9	8.814433	21	31.82474	1471	1470	286.2443	40.63918	245.6051	85.80262
5:10p.m.-5:20p.m.	10	10.79545	24	43.36364	1661	1670	355.2216	54.15909	301.0625	84.75344
5:20p.m.-5:30p.m.	10	9.793814	23	34.85567	1610	1685	261.0278	44.64948	216.3775	82.89469
5:30p.m.-5:40p.m.	16	16.7033	21	33.92308	1693	1715	335.0451	50.62637	284.4186	84.88968
5:40p.m.-5:50p.m.	10	10.79545	24	40.09091	1633	1670	390.4602	50.88636	339.5738	86.96759
5:50p.m.-6:00p.m.	6	6.263736	18	29.07692	1199	1200	306.2253	35.34066	270.8846	88.45926
6:00p.m.-6:10p.m.	10	9.1	16	22.56	1197	1230	230.24	31.66	198.58	86.24913
6:10p.m.-6:20p.m.	7	6.37	18	25.38	1249	1235	229.106	31.75	197.356	86.14179
MI Road										
4:30p.m.-4:40p.m.	17	2.18875	33	65.5875	2242	2410	617.6938	67.77625	549.9176	89.02753
4:40p.m.-4:50p.m.	20	2.575	28	55.65	2317	2240	565.3088	58.225	507.0838	89.70032
4:50p.m.-5:00p.m.	20	2.575	29	57.6375	2269	2295	554.9425	60.2125	494.73	89.14978
5:00p.m.-5:10p.m.	18	2.3175	21	41.7375	1778	1785	449.7225	44.055	405.6675	90.20396
5:10p.m.-5:20p.m.	16	2.354286	22	49.97143	1783	1770	522.58	52.32571	470.2543	89.98704
5:20p.m.-5:30p.m.	18	2.648571	23	52.24286	1898	1895	590.79	54.89143	535.8986	90.70881
5:30p.m.-5:40p.m.	21	3.09	23	52.24286	1983	2000	537.8786	55.33286	482.5457	89.71276
5:40p.m.-5:50p.m.	17	2.501429	19	43.15714	1620	1640	527.9943	45.65857	482.3357	91.35245
5:50p.m.-6:00p.m.	16	2.354286	19	43.15714	1633	1605	453.4643	45.51143	407.9529	89.96361
6:00p.m.-6:10p.m.	17	2.18875	18	35.775	1581	1585	389.0875	37.96375	351.1238	90.24288
6:10p.m.-6:20p.m.	13	1.67375	19	37.7625	1581	1500	403.4038	39.43625	363.9676	90.22413

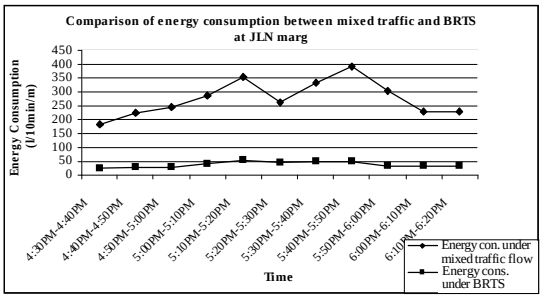


Fig. 2: Comparison of energy consumption under mixed traffic and BRTS traffic flow at JLN Marg.

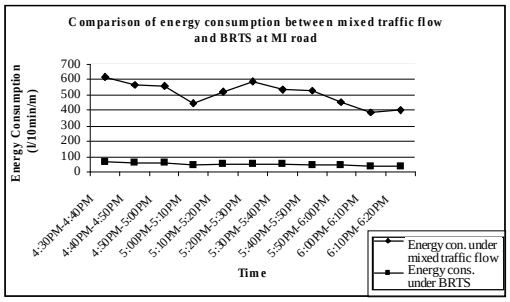


Fig.3: Comparison of energy consumption under mixed traffic and BRTS traffic flow at MI Road.

maintained as per existing mixed traffic conditions. The estimation of energy consumption of newly introduced buses, average speed of buses was taken as 50 kmph.

Figs. 2-3 show the comparison for energy consumption in existing mixed traffic condition and BRTS for both the selected locations. Table 2 shows comparison of energy consumption under mixed traffic flow conditions and BRTS at JLN Marg and MI Road respectively. It was found that the maximum energy consumption under mixed traffic flow conditions was 390.46 litres/10min/m and 617.69 litres/10min/m at JLN Marg and MI Road respectively. While maximum energy consumption with BRTS conditions was 54.15 litres/10min/m and 67.77 litres/10min/m at JLN Marg and MI Road respectively.

CONCLUSION

Transportation sector is the major contributor of fuel consumption because about 75% vehicles consist of two wheelers only. It directly influences the quality of ambient environment. In the present study, fuel consumption values (under mixed traffic flow conditions) were calculated by a newly developed equation, which relates the vehicular fuel consumption to various traffic parameters and road geometry. Further, a detailed study was done by comparing these values with values calculated by BRTS. Hence, the BRTS can not only minimize the fuel consumption levels but can also reduce traffic congestion problem and environmental pollution levels at all other commercial corridors having similar traffic conditions as that of Jaipur city.

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