Analytical Study of Air Quality Index of Vishrambag Chowk, Sangli, MS, India.

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Abstract:-

Per capita Increase in number of vehicles, shorter roads, reluctance in traffic management, cutting of trees and constructions had increased the value of Air Quality Index. The present study mainly focuses on estimation of frequency of vehicles, calculating the CO_2 emissions, mathematically estimating retention time period of CO_2 and impact of some factors such as wind speed, trees, grasslands etc. on accumulation of CO_2 in a study area. The estimated CO_2 was about 645.22 µg/m^3/year which was less than the standard value of 980 µg/m^3/year. Also suggestion for town planning has been proposed.

IndexTerms **-** Air quality Index (AQI), CO_2 emission, accumulation of CO_2, absorption of CO_2.

I. INTRODUCTION

The statistical report of CO_2 emission values of vehicles was made efficient while choosing vehicle travelling on the road. Sangli was the traffic prone city with minimum bridges, less awareness and unreliable traffic. Selection of one such site was preferred and then CO_2, AQI and other parameters were calculated. "Vishrambag Chowk", a junction road of 100ft road, Miraj-Sangli highway and Kupwad road has highly dense traffic area, where the number of vehicles would fleet now and then. It has some traffic signals and crew of policemen watching the safety of the people. This survey would bring a definite clear picture of polluted or non-polluted area. This would create awareness among people and would bring new found respect towards nature and better efficiency among traffic management. Air quality deteriorates due to vehicular pollution in the vicinity of Vishrambag. There is decrease in the maintenance of vehicles which causes increase in the emission levels, also increase in tree cutting has mad the intensity of CO_2 high. There is poor town planning in Vishrambag. We aim to calculate the CO_2 emission in µg/m^3 per vehicle, to calculate and compare the CO_2 emission of the hybrid vehicles, to calculate the number of trees in the premises, to estimate the retention period of the CO_2, to calculate the increased rate of vehicles, to suggest the control measure, to suggest town planning and design of silencers of vehicles.

II. Materials and methods

Fig.1

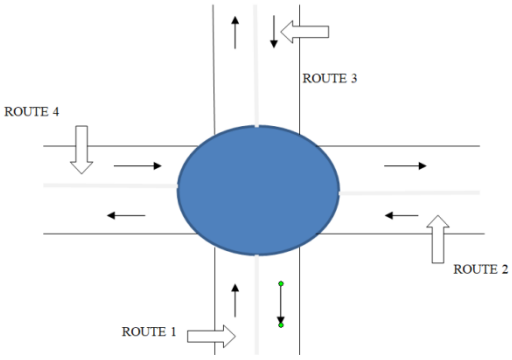


Fig.2

The site of the survey was selected as the junction of Sangli, Miraj and Kupwad, known as "VishrambagChowk". Also the area was the best surveillance site as the flow of vehicles through this area was huge. This area was preferred because the flow of air was free, without any obstruction. This helped in calculation of AQI much easier. In view of safety, this area held management in signals and a crew of traffic police.

The project was completed with the help of observation and survey method. Some of the standards were put forth initially. Then, a final plan was prepared, in accordance to which the project would be completed and CO_2 values of the vehicles were estimated for three consecutive days. With the help of certain observers on the site, frequency of the vehicles was estimated. Each day consisted of three phases and each phase was of 20minutes time duration. Total number of vehicles were calculated for a day and successively for a year. A formula was derived, to calculate the CO_2 emissions, which also consisted of other factors affecting like wind speed, trees, etc.

Total emission per day (in ug/m^3) is given by-

$$\text{T.E. per day} = \{[(8.427 \times a) + (5.477 \times b) + (10.299 \times c)] - [(59.650 \times d) + (0.921 \times e) + (0.5813 \times f)]\}$$

(*Refer results and discussion for derivation and meaning of above formula)

Now, the calculated value from the derived formula was compared with the standard value by following certain procedures. Then, the results of the survey were put forth. The project was concluded by giving some measures on the problem.

III. Results and Discussion

Derivation of the Mathematical Expression-

- STEP 1- Geometrical selection of survey site.

Consider a circle as shown in figure below which is in similar to survey site. Here the circle with dimensions joins four roads as mentioned earlier. For the sake of simplicity, let's consider 4 routes joining the circle as object to Vishrambag Chowk which are as follows:-

Route 1- 100 feet road. Route 2- Sangli-Miraj road. Route 3- Kupwad road. Route 4- Sangli-Miraj road.

STEP 2- Estimation of experimental area under the survey site.

Let's construct a geometrical standard circle of radius 5 cm with construction of four square blocks of square ABCD as in fig().

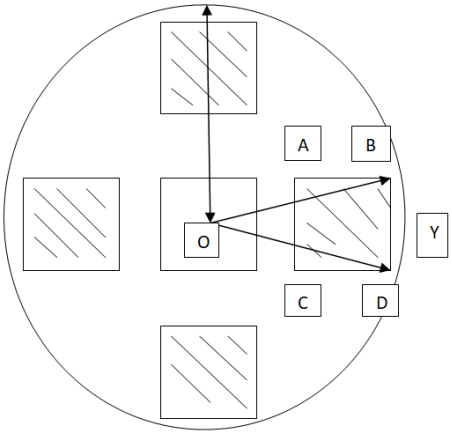


Fig.3

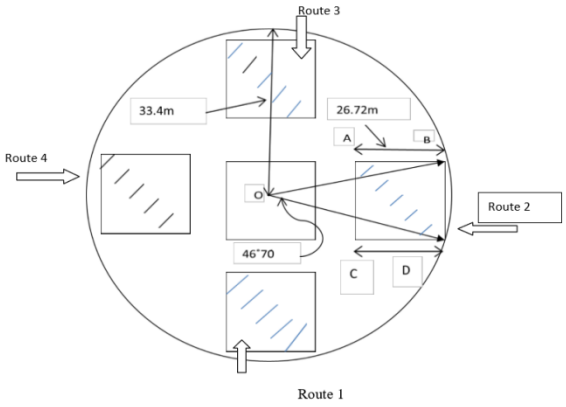


Fig.4

We have assumed,

Diameter 'D'=10cm=0.01m

Radius 'R'=5cm=0.05m

Consider, AB=4 cm=0.04m

In order to find the radius of the circle, a small experiment was conducted. A vehicle with speed(v) of 20 km/hr was made to travel constantly in time(t) 12second , 25 millisecond to reach one end to other.

So, v=20 km/hr =5.555m/s

t=12+0.025=12.025 second

∴ Distance= Speed×Time =5.55x12.025m

=66.80 m = 6680 cm= Diameter of experimental area

So, D=6680 cm

$R=\frac{D}{2}$ =3340cm

Now, Theoretical CD = $4.9 \times \frac{6680}{10}$ =3273.2 cm …..(by comparing with the assumed data)

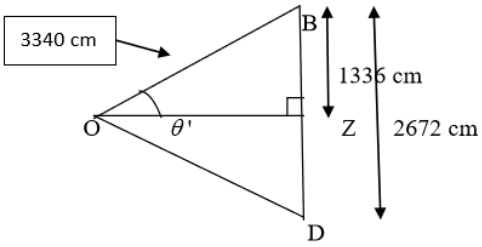


Fig.5

In order to find ∠ BOZ, consider ⌊ OBZ as in fig(5).

Let ∠ BOZ= θ'

$$\therefore \sin\theta' = \frac{BZ}{OB} = 0.4$$

θ' i.e. $\angle BOZ$ = 23°35'

So, $\angle BOD$ =2×23°35' ≅ 47°

Now, in order to find shaded region BDY,

A(BDY)=A(sector BOD) - A(⌊ BOD) = $\frac{1}{2}$ ×R²× θ - $\frac{1}{2}$ ×BD×OZ=203093.91 cm²

$\therefore A(ACDYB) = A(ABCD) + A(BDY)$ =734.267 m² …… (Refer fig.3)

∴ Total area under study = 4×734.267=2937.07m²

STEP 3 -Analytical formulation for CO_2 emission for two, four and heavy load vehicles.

Now, according to the data sheet, the reading is in ton CO_2 per year. So it is necessary to convert in gram, per day and distance is to be standardized in meters. But, the reading mentioned are for 365 days counted for 20,000km.

So, the unknown distance= $\frac{2\times10^7}{365} m$ =54794.5m

Formulation of CO_2 emission for 2 wheelers:

So, from the CO_2 emission values in fig(14), standard consolidated average for 2 wheeler are 3.939 tons i.e. 3939 kg.

∴ the unknown emission= $\frac{3939}{365} = 10.7917\times10^{-3}$ g

So, the unknown emission in g/m is = $\frac{66.8\times10.7917}{54794.5}$ =13.15617g/m.

∴ 1 vehicle (2-wheleer) emits 13.15617 g/m CO_2 emission.

∴ CO_2 emission value for 2 wheeler in g/m³=0.5568×13.15617 g/m³

∴ CO_2 emission value for 'n' 2 wheelers=n×7.325 g/m³.

Formulation for CO_2 emission for 4 wheeler:

So, from the CO_2 emission values in fig(13), standard consolidated average for 4 wheeler are 4.531375gm i.e. 4531.375 kg

$\therefore$ unknown emission= $\frac{4531.375}{365} = 12.41\times10^{-3}$ g

So, unknown emission in g/m $= \frac{66.8\times12.41}{54794.5} = 15.1348$g/m.

$\therefore$ 1 vehicle (4-wheleer) emits 15.1348g/m CO_2 emission.

$\therefore$ CO_2 emission value for 1 wheeler in g/m^3 =0.5568×15.134g/m^3=8.42705g/m^3.

$\therefore$ CO_2 emission value for 'n' 4 wheelers=n×8.42705g/m^3.

Formulation for CO_2 emission for heavy load vehicles:

So, from the CO_2 emission values, standard consolidated average for 4 wheeler are 5.533 tons i.e. 5533.14 kg.

$\therefore$ unknown emission= $\frac{5533.14}{365} = 15.1592\times10^{-3}$ g.

$\therefore$ unknown emission in g/m is = $\frac{66.8\times15.1592}{54794.5} = 18.480$g/m

$\therefore$ CO_2 emission value for 1 wheeler in g/m^3 =0.5568×18.480g/m^3=10.29g/m^3.

$\therefore$ CO_2 emission value for 'n' heavy load wheelers= n×10.29g /m^3.

STEP 4- Analytical formulation for CO_2 absorbtion by trees and grassland.

Analytical for CO_2 absorbtion by trees:

Trees absorb 21772.41 gm of CO_2/year i.e. 59.6504 g/m^3 /day for 1 tree.

$\therefore$ CO_2 absorbtion by n trees =n×59.6504 g/m^3/day.

Analytical for CO_2 absorbtion by grassland:

1 acre grass land absorb 1360776gm CO_2/year i.e. 3728.15342 gm/day for 1 tree.

$\therefore$ CO_2 absorbtion by Nm^2 area of grasslands =n×0.921246gm^{-3}.

STEP 5- Analytical formulation of effect of wind.

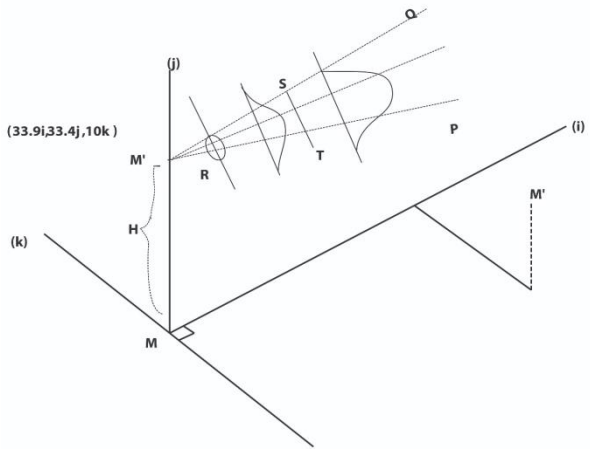


Fig.6

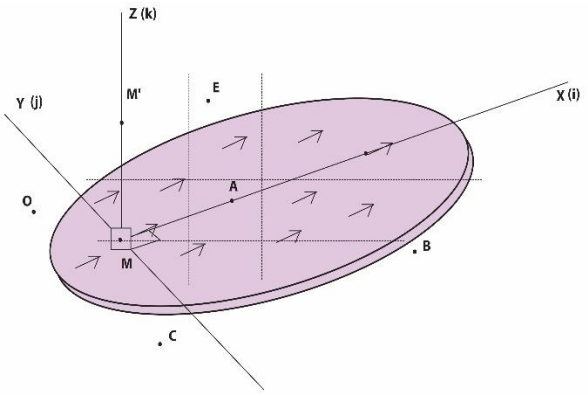


Fig.7

So consider, AM=33.9m on X-Y plane, where y-coordinate is 33.4.

The point M(33.9,33.4) in vector form is (33.9i,33.4j) for X-Y plane.

Let M be the major representative vehicle on the 3-D plane(fig.7) located at (33.9i, 33.4j, 0k).

Here block denotes the single vehicle. Suppose 'M' is located at (33.9i,33.4j,0k).

Now, we take imaginary point M' above M at distance (say) 10 m.

So, M' is located at (33.9i,33.4j,10k)

Now, consider the expression of Gifford's law -

$$C(x,y,z)=\left|\frac{Q}{2\pi u\partial y\partial z}\right|e^{\left|\left[\frac{-1}{2}\right]\left[\frac{y^2}{\partial y^2}+\frac{(Z-H)^2}{\partial z^2}\right]\right|}$$

Here, Q= concentration of emitted gas (g/sec),U=wind speed(m/sec), ∂ y=(j)distance from M', ∂ z=(k)distance from M'

Z= the fluctuation of wind distance up or below (m),Y= the fluctuation of wind distance up or below (m),Y=ST(in this case).

H=Height at M'. (MM')

Now, in our case

Q= 30.924gm/sec for 2 wheeler, 47.5794 gm/sec for 4 wheeler, 58.0979 gm/sec for heavy load. U=3.611(m/sec)

∂ y=33.4m ∂ z=10m Z= 0(Here we consider M' to be stationary) Y= 26.72 m as plotted in fig(9) H=10m

$$C(33.9i,33.4j,10k)=\left|\frac{Q}{2\pi u\partial y\partial z}\right|e^{\left|\left[\frac{-1}{2}\right]\left[\frac{y^2}{\partial y^2}+\frac{(Z-H)^2}{\partial z^2}\right]\right|}$$

$\therefore$ Wind effect on concentration =0.581358×Q µg/m^3.

Thus all factors affecting CO_2 emission and the sources are analytically formulated by the expression derived until now

STEP 6- Expression of formulae with its details

Thus, from step 1 to 6 we can conclude a final expression for total CO_2 emission or concentration present in the experimental area i.e the survey site.

Total concentration of CO_2 gas=concentration of CO_2 emitted by sources-concentration of CO_2 absorbed by natural sources.

$\therefore C_{Transmitted}=C_{Emitted}-C_{Absorbed}$

$\therefore C_T=(C_{two\text{-}wheelers}+C_{four\text{-}wheelers}+C_{heavy\text{-}loads})-(C_{grasslands}+C_{trees}+C_{wind})$

$C_T=(C_t\ g/m^3+C_f\ g/m^3+C_h\ g/m^3)-(C_g\ g/m^3+C_{ts}\ g/m^3+C_w\ \mu g/m^3)$

C_T is expressed in terms of µg/m^3.

Now, substituting the sub-expression in the above equation from STEPS 1-6:-

$$C_T=\left[\frac{a\times 7.325gm}{m^3}+\frac{b\times 8.4270gm}{m^3}+\frac{c\times 10.2990gm}{m^3}\right]-\left[\frac{d\times 0.9212gm}{m^3}+\frac{e\times 59.65gm}{m^3}+\frac{f\times 0.5813\mu gm}{m^3}\right]$$

where,

a = No. of 2 wheelers

b =No. of 4 wheelers

c =No. of heavy loads

d = Amount of grassland in m

e =No. of trees

f =Amount of wind factor in gm.sec

This is the final formula.

SUMMARY OF TOTAL COUNT OF VEHICLES-

DAY 1 - morning			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	40	10	1
ROUTE 2	150	78	5
ROUTE 3	70	4	7
ROUTE 4	102	97	10
Subtotal:	362	189	23
DAY 1 - afternoon			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	90	23	1
ROUTE 2	229	152	11
ROUTE 3	93	9	5
ROUTE 4	154	124	18
Sub total:	566	308	35
DAY 1 - evening			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	110	37	2
ROUTE 2	240	168	19
ROUTE 3	100	12	7
ROUTE 4	160	130	19
Subtotal:	610	347	47

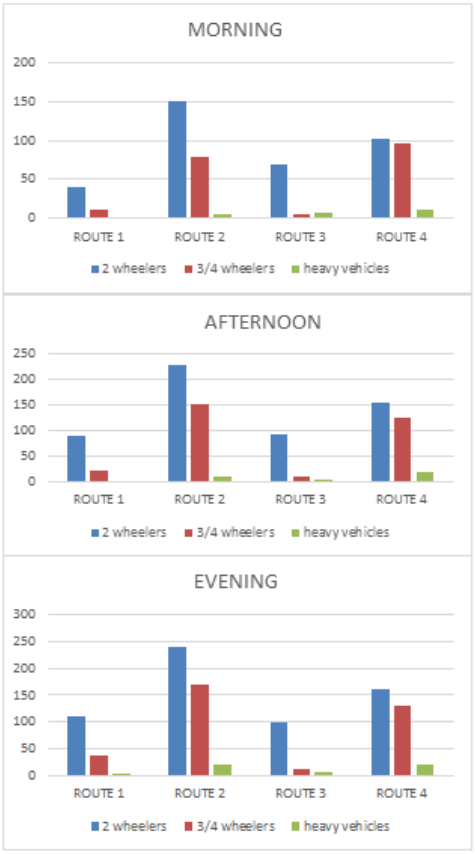


Fig.8

DAY 2 - morning			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	62	15	0
ROUTE 2	200	86	8
ROUTE 3	73	6	4
ROUTE 4	105	108	20
Subtotal:	440	215	32
DAY 2 - afternoon			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	89	28	1
ROUTE 2	270	126	15
ROUTE 3	80	8	3
ROUTE 4	177	119	8
Subtotal:	616	281	27
DAY 2 - evening			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	112	40	2
ROUTE 2	286	153	19
ROUTE 3	102	11	5
ROUTE 4	198	131	11
Subtotal:	698	335	37

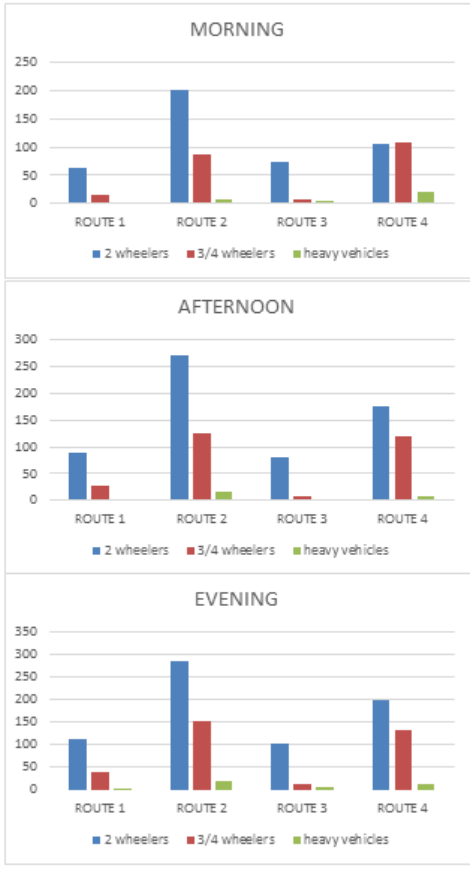


Fig.9

DAY 3 - morning			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	112	19	4
ROUTE 2	300	110	90
ROUTE 3	342	187	29
ROUTE 4	170	15	2
Sub total:	924	331	125
DAY 3 - afternoon			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	122	25	5
ROUTE 2	345	115	98
ROUTE 3	429	230	35
ROUTE 4	182	17	3
Sub total:	1078	387	141
DAY 3 - evening			
	2 wheelers	3/4 wheelers	heavy vehicles
ROUTE 1	150	27	10
ROUTE 2	360	112	101
ROUTE 3	433	263	83
ROUTE 4	192	18	5
Sub total:	1135	420	199

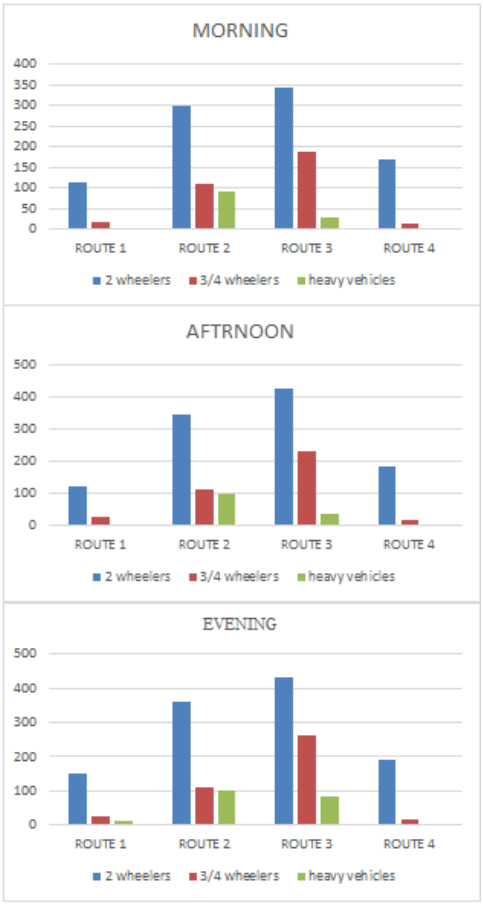
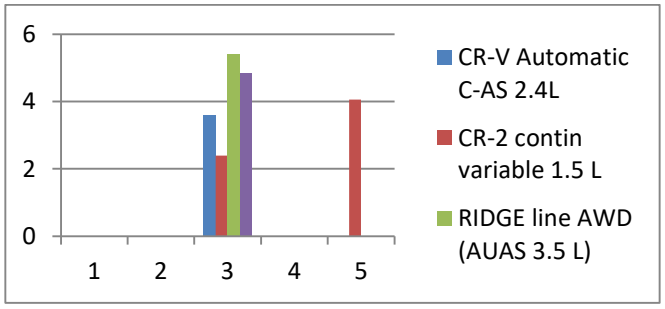


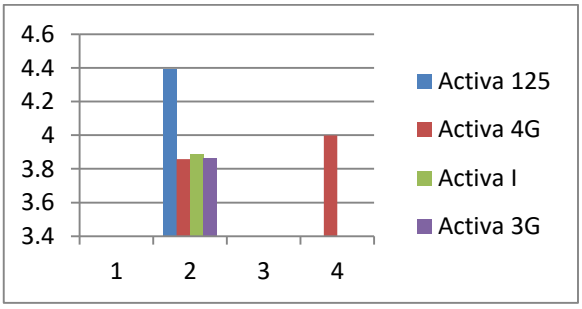
Fig.10

CO2 emission values of 4 wheelers (with their brands)(fig.11)

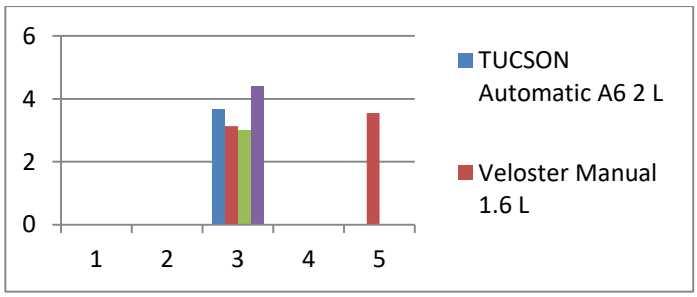


Brand-Honda

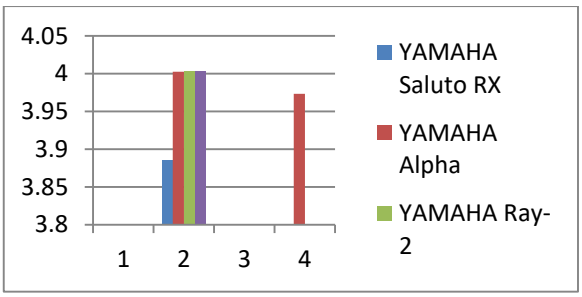
CO2 emission values of 2 wheelers(with their brands (fig.12)



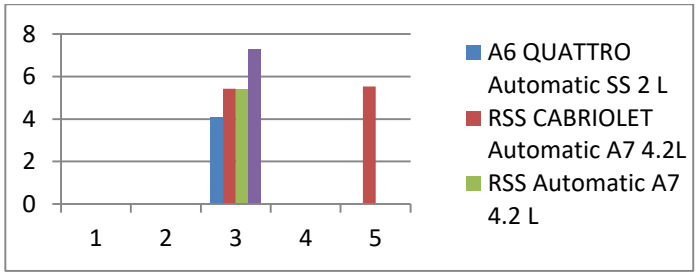
Brand-Honda (Activa)



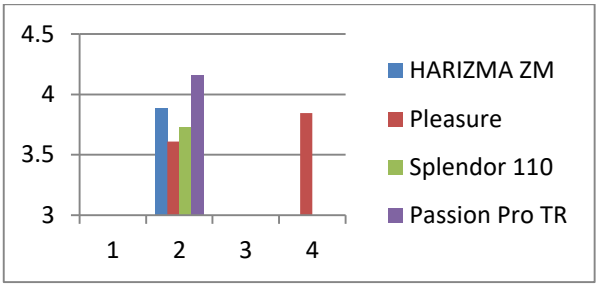
Brand-Hyundai



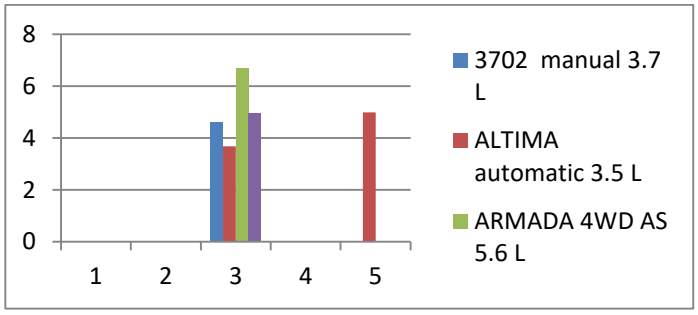
Brand-Yamaha



Brand-Audi



Brand- Hero



Brand-Nissan

One of the main solutions of this problem is-

- ❖ Town planning

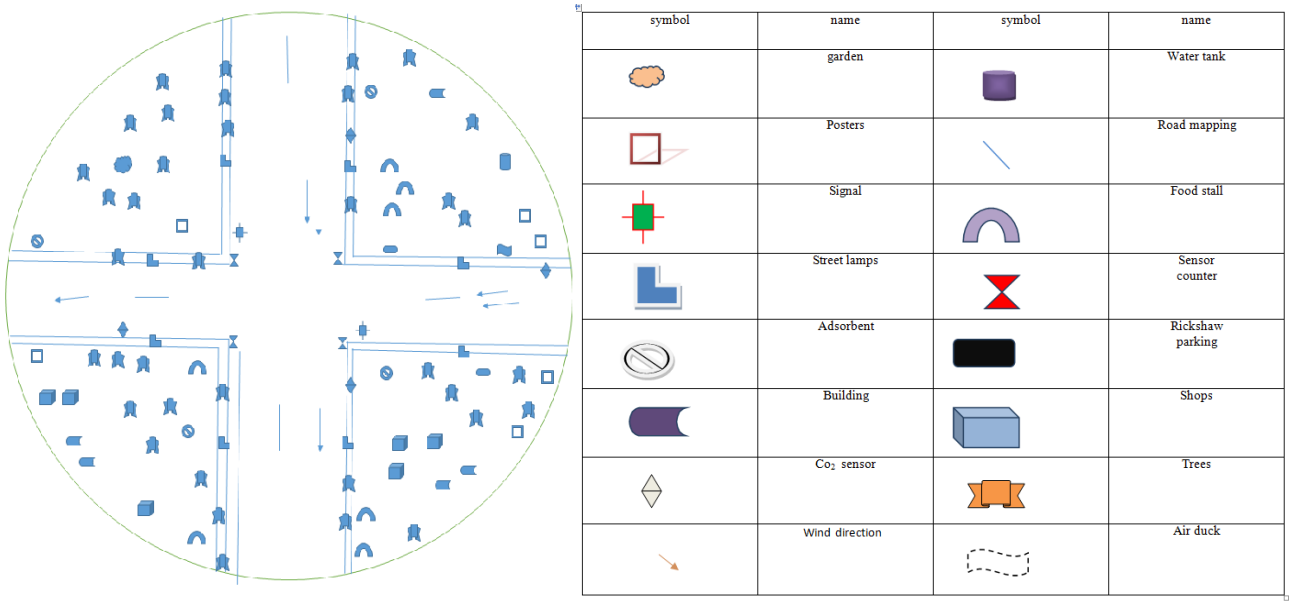


Fig.13-Suggested area for town planning with index

Usage of factors that will lead a town to a considerable development are-

- Adsorbent Paints
- Trees and plants
- Hi tech sensors
- Instruments used to detect wind direction
- Adsorbents
- Traffic management

This town planning will help the citizens to live there with sufficient oxygen and less concentration of carbondioxide, so that the areas neighbouring to it will implement the same techniques everywhere, making the state with the less CO_2 concentration. This town planning would be much faithfully helpful due to its developed and modified contents.

This project was basically chosen so as to put forth air quality index of VishrambagChowk and make aware the inhabitants that it was a big issue. The project aimed to calculate the present CO_2 emission value in the study area and give the conclusions regarding the air quality. Thus, the project was not just about the awareness among people but a step towards the progress.

CONCLUSION

Considering all the above factors discussed, total emission per day in $\mu g / m^3$ is given by-

$$T.E. = \left[\frac{a \times 7.325 gm}{m^3} + \frac{b \times 8.4270 gm}{m^3} + \frac{c \times 10.2990 gm}{m^3} \right] - \left[\frac{d \times 0.9212 gm}{m^3} + \frac{e \times 59.65 gm}{m^3} + \frac{f \times 0.5813 \mu gm}{m^3} \right]$$

Where,

a = No. of 2 wheelers

b =No. of 4 wheelers

c =No. of heavy loads

d = Amount of grassland in m

e =No. of trees

f =Amount of wind factor in gm. sec

OBSERVATION TABLE

Sr.no.	Date of survey	Day of survey	CO_2 emission rating(in ug/m^3)	Status
1	18/06/2017	Sunday	1.171	Good
2	19/06/2017	Monday	1.438	Better
3	21/06/2017	Wednesday	2.694	Poor

The standard CO_2 emission rate put forth for Sangli district was 2.684ug/m^3.

The average calculated final CO_2 emission=1.767 ug/m^3 per day.

Thus, the status of AQI is satisfactory.

RECOMMENDATIONS

- Battery operated vehicles and Hybrid vehicles should be used. Battery operated electric vehicle is a type that uses chemical energy stored in a rechargeable battery packs. Hybrid vehicles use internal combustion engines as well as batteries relying on both. These vehicles result in a small engine size more for average usage.
- Silencers of two, four and heavy load vehicles can be modified. The emitted CO_2 or partial CO gas from silencer of the vehicle can be diluted.
- New plan for a particular part of the town is suggested so as to improve the carbon emission rate.

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