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Interpreting & Modeling CO Concentration in Air with Traffic Density using Artificial Neural Network with Reference to Nagpur City

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Abstract—*Due to strict pollution control norms, % CO in exhaust of individual vehicles is decreased, however with the increase in number of vehicles, the total CO in ambient air is increasing. The present work has the main objective of interpreting and modelling the contribution of vehicular Carbon Monoxide emission in ambient air. ANN model is developed correlating the concentration of CO in air with the density of vehicles at five road intersections of Nagpur city. Based on the observations, result and discussion, it can be concluded that the present work has successfully addressed to the problem of estimation of CO concentration in air with vehicular density for a specific road intersection. The work is quite revealing and the situation is likely to be alarming in metro cities where traffic congestion is more.*
Keywords— ANN model, CO emission, Nagpur city, Road intersections, Time slots, Vehicular density.

I. INTRODUCTION:

1.1 OBJECTIVE:
The present work has the main objective of interpreting and modelling the contribution of vehicular Carbon Monoxide emission in ambient air. Efforts have been made to develop model correlating the concentration of CO in air with the density & frequency of passage of vehicles at particular road intersections of Nagpur city. The approximate concentration of CO in air could be predicted at a particular place at a given time slot when the number of vehicles passing through the intersection is known, using the model developed.

1.2 BACKGROUND:
Amongst the top six cities in terms of the number of registered motor vehicles, the highest Compound Annual Growth Rate 'CAGR' of 13.2 % was recorded by Pune during 2002-2012 followed by Chennai- 10.8, Hyderabad- 10.6, Bengaluru- 9.5, Delhi- 7.1 and Greater Mumbai- 6.6 respectively. Other million plus cities like Kochi, Coimbatore, Madurai, Kanpur, Jaipur & Nagpur recorded more than 10% CAGR during 2002-12. [1]
The present study is with reference to Nagpur city, so the detailed data for year 2015 has been collected from Regional Traffic Office, Nagpur. [2]

Sr. No.	Category	Name of RTO Office		
		Nagpur City	Nagpur East	Nagpur
1	2-Wheelers	1067160	115793	1182953
2	Motor Cars	108951	14329	123280
3	Jeeps	31449	4229	35678
4	Others	68015	16768	84783
	Total	1275575	151119	1426694

Table 1 shows the Motor vehicle population as on 31.03.2015 Of Nagpur, collected from the RTO office.

TABLE 1: Motor vehicle population in Nagpur as on 31.03.2015

The major part of total vehicular CO emission is by the petrol vehicles. It is estimated that CO fraction is is 1- 2% of exhaust emissions for petrol vehicles, whereas it is fraction of 0.5% for diesel driven vehicles. Similar comparison of petrol and diesel engine emissions has been given in some works. There are some estimates on CO emissions per km run for diesel and petrol driven vehicles reported in the literature. [3][4]

II. METHODOLOGY

The methodology adopted in the present work is depicted in the flowchart as shown in Fig. 1.
1. The present study is carried out at five specific road intersections of Nagpur city in the months of winter during January & February. [5]
2. These sites have 'display boards' mounted by local agency showing real Time, Temperature, % humidity and CO concentration in ppm.

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3. Five sites at different road intersections and five time slots of day were selected; the number of vehicles passing per minute was counted manually.

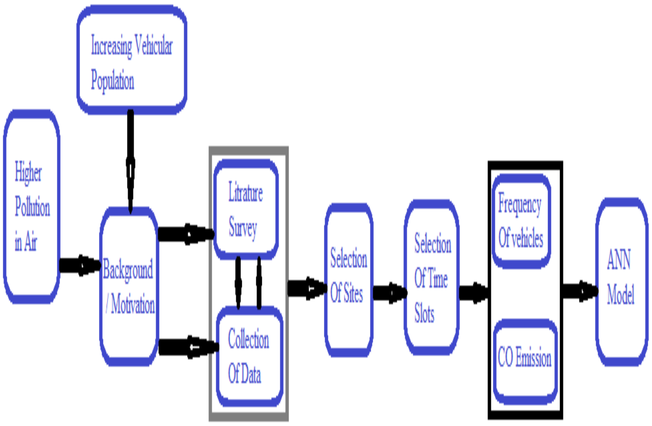

Fig. 1: Flow diagram of the steps followed in conducting the present work

4. The locations of the sites chosen are as follows,
Law College square (L)
Bhole Petrol Pump square (B)
Variety square (V)
Rahate square (R)
Chhatrapati square (Ch)
5. The time slots chosen were 7 am, 9 am, 1 pm, 4 pm, 6 pm, 8 pm and 11 pm.
6. The CO emissions displayed on the boards and number of vehicles was tabulated and correlated using Artificial Neural Network.
The vehicles were identified as 2-wheelers, 3-4 wheelers and Heavy vehicles.
The counting readings were taken two to three times for each square on different working days, and the average was worked out.

Fig. 2 is the photograph of the display board showing the CO concentration.

Fig. 2: Actual photograph of the display board at Rahate square

III. OBSERVATIONS:

Table 2 shows the details of vehicle density at different intersections.
Similarly Table 3 gives the details of CO readings, time slots and vehicle density.

TABLE 2: Vehicle density per minute at different intersections & time slots

Inter-setion	Categ-ory	time	7 am	9 am	1 pm	4 pm	6 pm	10 pm
Ch1	2 wheelers		25	44	45	42	61	35
	3-4 wheelers		9	19	22	25	32	17
	Heavy		2	9	14	8	9	4
Ch 2	2 wheelers		40	63	31	26	44	25
	3-4 wheelers		12	20	17	12	24	13
	Heavy		2	3	4	4	4	3
	Total		90	158	127	117	174	97
R	2 wheelers		35	85	60	51	70	47
	3-4 wheelers		18	33	30	27	40	20
	Heavy		4	10	14	9	9	6
	Total		57	128	104	87	119	73
V 1	2 wheelers		42	72	90	54	75	50
	3-4 wheelers		12	20	30	24	31	20
	Heavy		4	6	12	12	10	7
V 2	2 wheelers		28	63	45	36	45	18
	3-4 wheelers		9	21	15	15	21	13
	Heavy		3	8	2	8	6	2
	Total		98	190	194	149	188	110
B	2 wheelers		27	60	90	57	61	39
	3-4 wheelers		12	16	28	23	28	15
	Heavy		5	6	8	8	7	5
	Total		44	82	126	88	96	59
L	2 wheelers		22	53	57	40	39	32

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	3-4 wheelers	**12**	**8**	**31**	**28**	**8**	**16**
	Heavy	**4**	**5**	**6**	**6**	**7**	**4**
	Total	**38**	**76**	**94**	**74**	**74**	**52**

V 1: Variety Square, V 2: Variety Flyover;
Ch 1: Chhatrapati square, Ch 2: Chhatrapati Flyover

TABLE 3: CO readings and vehicle density at various intersections

Time	**Ch**		**R**	
	CO ppm	**Vehicle density**	**CO ppm**	**Vehicle density**
7 am	**0.8**	**90**	**0.8**	**57**
9 am	**2.1**	**158**	**2.2**	**128**
1 pm	**3.1**	**127**	**3.2**	**104**
4 pm	**3.1**	**117**	**3.1**	**87**
6 pm	**3.3**	**174**	**3.2**	**119**
10 pm	**1.8**	**97**	**1.6**	**73**

Time	**V**		**B**	
	CO ppm	**Vehicle density**	**CO ppm**	**Vehicle density**
7 am	**1.1**	**98**	**0.9**	**44**
9 am	**2.4**	**190**	**1.8**	**82**
1 pm	**3.8**	**194**	**3.4**	**126**
4 pm	**3.8**	**149**	**3.4**	**88**
6 pm	**4**	**188**	**3.4**	**96**
10 pm	**1.8**	**110**	**1.5**	**59**

Time	**L**	
	CO ppm	**Vehicle density**
7 am	**0.9**	**38**
9 am	**1.6**	**76**
1 pm	**3.2**	**94**
4 pm	**3.6**	**74**
6 pm	**3.6**	**74**
10 pm	**1.5**	**52**

Fig. 3 shows the comparison of vehicle density for two, three, four wheelers amongst these intersections for a typical 9 am slot

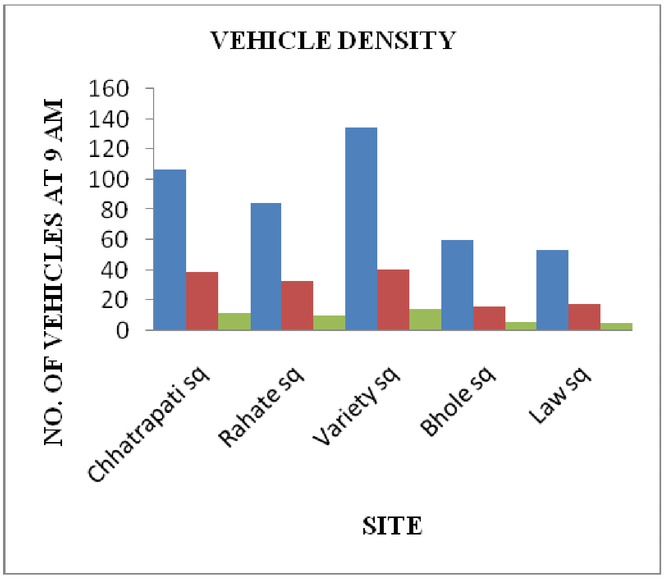

Fig. 3: Comparison of vehicle density at chosen sites at 9 am time slot

In Fig. 4, analysis of speed variation for a trip of 1.6 kms from Variety square to Rahate square is shown.
Three such trips were conducted at different time slots of a working day and the measured parameters are analysed to obtain the variation of speed with time and the graph is plotted as shown.

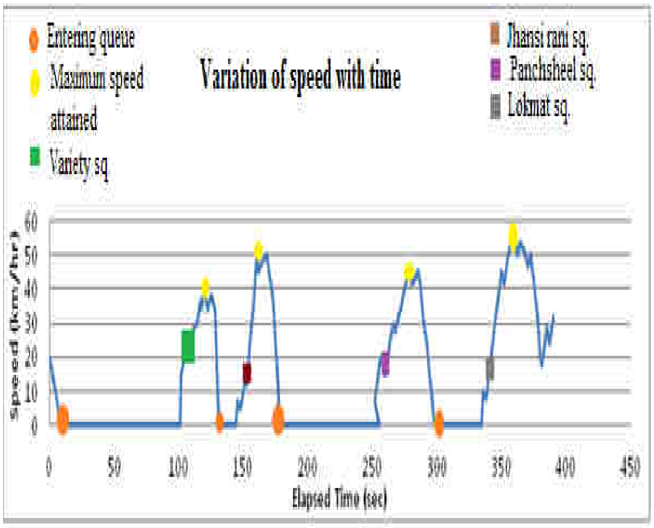

Fig 4: Variation in speed as a function of time for travel between two intersections V to R

3.1 Graphical Interpretations: The observations as given in Table 2 are graphically interpreted by plotting the vehicle density for various locations as shown in Fig. 5, 6, 7, 8 & 9.

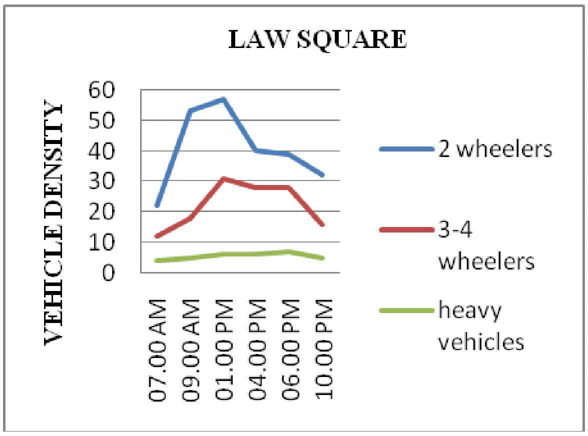

Fig. 5: vehicle density as a function of time, Law square

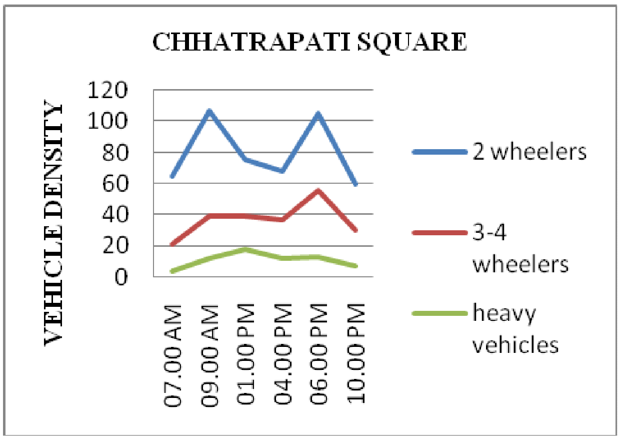

Fig. 8: vehicle density as a function of time, Chhatrapati square

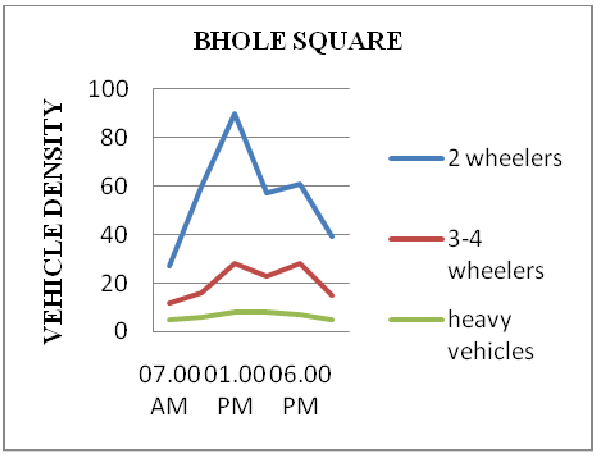

Fig. 6: vehicle density as a function of time, Bhole petrol pump square

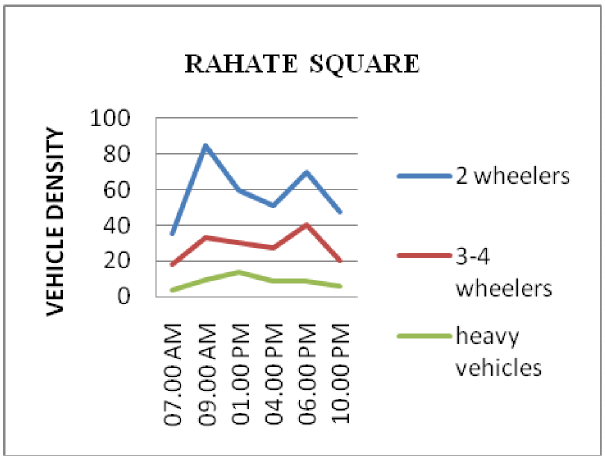

Fig. 9: vehicle density as a function of time, Rahate square

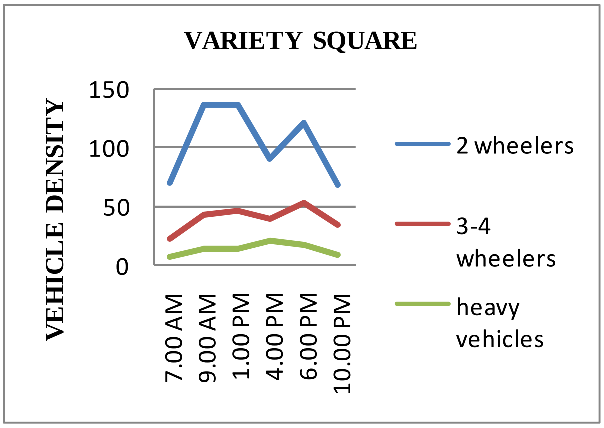

Fig. 7: vehicle density as a function of time, Variety square

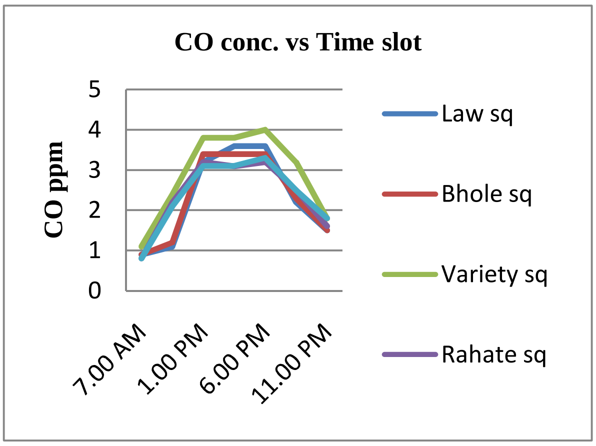

Fig. 10: CO concentration in ppm as a function of time at chosen sites

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Fig. 10 shows the comparison in CO concentration as a function of time slots for various intersections.

It can be said that, at all the intersections, CO concentration is lowest in the early hours, increases linearly from 9 am to 1 pm, remains almost constant during 1 pm to 6 pm, reaches its maximum value at 6 pm and then decreases in the late evening.

The CO concentration is lower in the early morning than late evening and night hours.

IV. ANN MODEL DEVELOPMENT

Artificial Neural Network Modelling of the data of CO concentration and vehicle density has been done using elite-ANN© [6]. The input parameters considered are; coded numbers for road intersections, CO concentration in ppm for previous time slot for respective intersection and vehicle density per minute, whereas CO concentration for the current time slot is the output parameter. The training data set is shown in Table 4 used in developing ANN model.

TABLE 4: Training data set for ANN model

Coding of the road intersection	CO concentration in ppm (previous time slot)	Vehicle Density per minute	CO concentration in ppm (current time slot)
11	0.8	90	0.8
11	0.8	158	2.1
11	2.1	127	3.1
11	3.1	117	3.1
11	3.1	174	3.3
11	3.3	97	1.8
22	0.8	57	0.8
22	0.8	128	2.2
22	2.2	104	3.2
22	3.2	87	3.1
22	3.1	119	3.2
22	3.2	73	1.6
33	1.1	98	1.1
33	1.1	190	2.4
33	2.4	194	3.8
33	3.8	149	3.8
33	3.8	188	4
33	4	110	1.8
44	0.9	44	0.9
44	0.9	82	1.8
44	1.8	126	3.4
44	3.4	88	3.4
44	3.4	96	3.4
44	3.4	59	1.5
55	0.9	38	0.9
55	0.9	76	1.6
55	1.6	94	3.2
55	3.2	74	3.6
55	3.6	74	3.6
55	3.6	52	1.5
Coded numbers for road intersections: 11- Ch, 22-R, 33-V, 44-B, 55-L			

The details of the topology of ANN model developed is shown in Table 5.

TABLE 5: Topology of ANN model developed

Number of neurons					**TDSP**	**I**	**RMSE**
IP	**O P**	**1st HL**	**2nd HL**	**3rd HL**			
03	**01**	**0**	**5**	**5**	**30**	**10,000**	**0.0166**
IP- Input Parameters, OP- Output Parameters, HL- Hidden Layer, TDSP- Training Data Set Points, I- Iterations, RMSE- Root Mean Square Error							

The snapshot of elite-ANN© in run-mode is shown in Fig. 11.

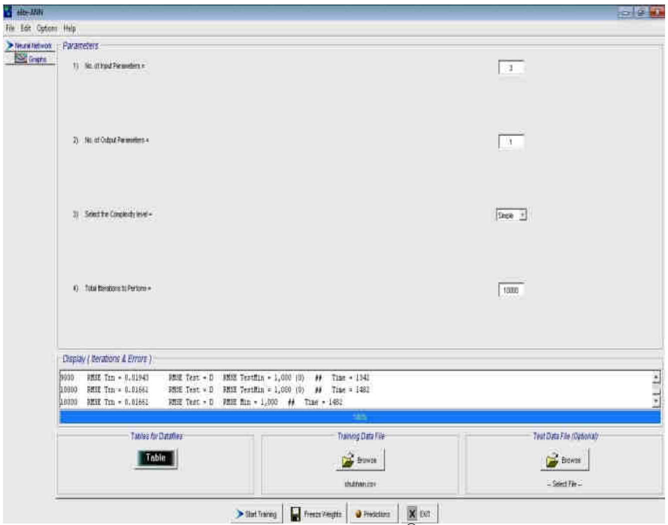

Fig. 11: Snapshot of elite-ANN© in run-mode

The comparison of the predicted CO concentration and actual concentration for training data set is carried out using developed ANN model.

Fig. 12 shows the bar graphics for the comparison.

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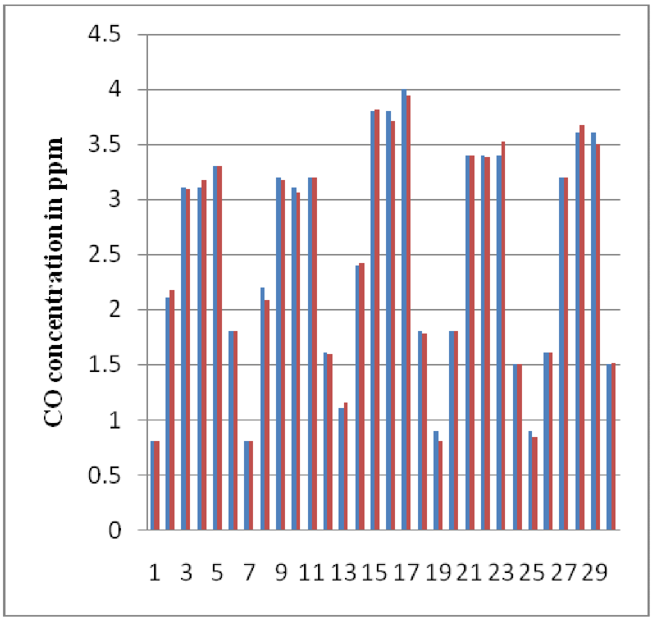

Fig. 12 : Comparison between actual and predicted values for CO concentration in ambient air

V. RESULT DISCUSSION

- The number of vehicles at Variety square is maximum, and it is the busiest of the chosen sites.
- The maximum CO concentration of 4 ppm is recorded at the Variety square during 6 pm slot of working day. On an average basis also, Variety square tops the CO concentration followed by Law college square, Bhole petrol pump square, Chhatrapati square and Rahate square. This is supportive of the claim that CO concentration is linked with the emissions of number of petrol driven vehicles.
- The actual concentrations of CO at different locations and corresponding predicted values obtained using the ANN model developed are very close to each other.
- This is indicative of the success of ANN model developed in correlating CO concentration with vehicular density.
- The model can be further improved with observations at more time slots, more input parameters like temperature, wind velocity, humidity, rate of dispersion etc.

VI. CONCLUSION

Due to stringent pollution control norms, the actual CO emission per vehicle is decreased. However, due to urbanization, the number of vehicles in metro cities is increasing 10 to 15% per year, which is contributing to the increase in CO emissions in ambient air.

The present work is related to study and the interpretation of CO concentration in ambient air with vehicular density by selecting five road intersections in Nagpur city. It is further extended in development of Artificial Neural Network model to correlate the CO emissions at these road intersections with vehicle density.

It is observed that, the CO emissions in the ambient air is the function of the number of vehicles plying. The CO emission in the atmosphere is the function of number of vehicles plying, and varies from intersection to intersection and time slot to time slot.

Based on the observations, result and discussion, it can be concluded that the present work has successfully addressed to the problem of estimation of CO concentration in air with vehicular density for a specific road intersection.

The work is quite revealing, and there is a need to readdress the policies regarding the number of vehicles plying on any road at any particular time slot. The situation is likely to be alarming in metro cities where traffic congestion is more.

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