CHAPTER 2

Vehicular pollution in Bangalore: an overview

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Abstract

Over the years, there has been a tremendous increase in road transportation and vehicular traffic due to an exponential growth in economic development and consumption habits throughout the world. The effect of vehicular pollutant emissions is significantly more pronounced in an urban scenario, as compared to regional or global scale. There is a general tendency of uncontrolled growth of both commercial and residential activities at traffic junctions giving rise to high human exposure to vehicular emissions. The problem is becoming more severe, day by day, due to the continuous increase of road traffic all over the world. Most of the metropolitan cities are facing serious air pollution problems due to concentration of motor vehicles and human population within the confined urban areas. Further, limited road space leads to road congestion and poor road surface conditions significantly add to pollution problems. The phenomenal growth in vehicular population is often identified with increasing urbanisation and this trend of urbanisation leads to higher vehicular density and results in air and noise pollution in an urban environment. Vehicles discharge emissions directly into the breathing zone; motor vehicles possess the greatest air pollution potential as compared to other sources. This is largely due to high numbers of vehicles in congested urban areas and the quantity of pollutants they emit, causing various adverse effects. It has been generally established in earlier studies that about 60% of the air pollution in cities is due to automobile exhaust emissions.

1 General history

Bangalore has a history of 457 years. The city is famous for old monuments and temples. Bangalore is situated in the South Eastern quadrant of the State of Karnataka at 12°58' North latitude and 77°35' East longitude at an altitude of 921m above Mean Sea Level (MSL). The city is situated about 450km from the

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Bay of Bengal and the Arabian Sea and about 700km from the Indian Ocean. It is obvious that various physical features such as its elevation, climate, beauty of its rolling countryside, its red earth and its granite hillocks and rock outcrops which contrast with the greenery of cultivated fields have all contributed to Bangalore city becoming a major city of modern India.

Bangalore seems to have been an inhabited area from the first century AD since Roman coins have been found in Yeshwanthpur and H.A.L. area. Bangalore was ruled by the Gangas for six centuries until the end of the tenth century AD. Then it was ruled by Cholas and Hoysalas. The Hoysala emperor Ballala II (12th century) named the village as ‘Benda Kalooru’. Then this was under the Vijayanagar kingdom ruled by Krishna Deva Raya. Magadi Kempegowda received ‘Benda Kalooru’ as jagir from Krishna Deva Raya and it was subsequently called ‘Bengaloour’ where a fort was constructed around the town in the year 1537. Inside the fort Kempegowda planned various extensions and named them as Chickpete, Dodpete, Balepete, Cottonpete and other commercial areas. These areas were earmarked for particular trades and artisans. They continue to be the city’s principal commercial centres even today. Kempegowda was a great builder of lakes and temples. He devoted a portion of the city’s revenue to build Gavi Gangadhareswara temple and the Bull (Basava) temple.

Kempegowda not only visualized a great future for this new town but also could foresee the probable growth of the city in different directions. Bearing this visualization in mind he built four watchtowers at elevated points around the town prophesying the extent to which the city would grow. At present the city has grown far beyond these limits. The four watchtowers constructed by him can be seen even today at: near Ulsoor tank (East); Bellary road near Sri Ramanashram (North); near Lalbagh (South); and near Gavi Gangadharaeswara temple, Gavipuram (West).

Around 1637 the Bijapur Sultans conquered Bangalore. After fifty years of Bijapur rule the Mughals, under the leadership of Mugal Subedar of Sira province, captured Bangalore. The Sira Subedar sold Bangalore to Chikkadeva Raja Wodeyar for three lakh pagodas (1673–1704). Since then Bangalore became a part of Mysore kingdom.

Hyder Ali (1759) received Bangalore as jagir from Krishna Raja Wodeyar II. He made Bangalore an army town. It was Hyder Ali in 1760 who planned a new garden in Bangalore, that covered an area of forty acres and was named ‘Lalbagh’. Hyder Ali imported plants from Delhi and Lahore to Lalbah. Tippu Sultan (1782) expanded the garden and added exotic plants imported from Kabul, Persia, Turkey and Africa. After the death of Tippu Sultan in 1799, Bangalore was restored to the Mysore kingdom under the rule of Krishna Raja Wodeyar III. The British (1831) took over the administration of the Mysore kingdom by Krishna Raja Wodeyar III.

2 The British Cantonment

The British, because of the very good climate and elevation of Bangalore city, moved their troops from Srirangapatna, capital of Mysore, to Bangalore and established the civil and military station called ‘Contonment’ in 1809. The

British developed the city by introducing railways, posts and telegraphs. They also constructed new public offices, revenue and education departments in the year 1864. During the same regime, extensions such as Chamarajapet, Basavanagudi and Malleshwaram were formed for residential purposes. Krishna Raja Wodeyar IV (1910–1940), and his devan Sir Mirza Ismail took special interest in the development of Bangalore city as the 'garden city' and 'air-conditioned city'. In 1942 Bangalore citizens participated in the 'Quit India movement' organised by Mahatma Gandhi.

3 After India's independence

In the very beginning of the post-independence era Bangalore was selected as the capital of the Karnataka State. The Bangalore Municipal Corporation was formed (1949) by merging the city and the Contonment. Bangalore, a new capital city, was linked with the major cities of the country through roads and railways.

Another significant turn in the development of Bangalore city took place in the year 1950, when Sri Kengal Hanumanthaiah, the Chief Minister, decided to build Vidhana Soudha. The Vidhana Soudha was completed in 1955. Factors like the city's favorable climate, its Cosmopolitan and Western façade, its educational institutions, attracted many big hi-tech industries. This in turn led to the city's recent emergence as a global centre for software research. The population increased from 156,000 in 1881 to 778,977 in 1951. The state Government established a 'Technology Park' on 5000 acres at Whitefield. Bangalore city is also called 'Silicon Valley'. The government of India established many big industries such as aircraft, telephones, machine tools and electronics. The reorganisation of states in 1956 added further impetus to the rapid growth of the city. The inclusion of large chunks of area from a neighbouring state doubled the size of the Mysore state and consequently increased the importance of the city. In 1981, Hebbal, HMT watch factory layout, Kengari, Krishnarajapura, Lingarajapura, Baiyyappanahalli, Sarjapura were included in the Bangalore urban conglomeration. During 1980–1994 Bangalore became the centre for computer hardware and software companies.

4 Population

By 1971 the population of the city reached 16 lakhs and the city had grown to 60 square miles. Although the density had increased to 37 persons per acre, it was still very low by western standards. During 1971–1981 Bangalore grew by leaps and bounds. Population attained 29 lakhs thus recording the highest growth rate among the cities in India. As per 1991 census, the population was 45 lakhs and the city was ranked as the sixth largest city in India. Its area at present is 450km^2, including an extension spread out in different directions of the city (Bangalore Development Authority 1995). Though the area of this Metropolitan city is less than 0.5% of the state, it is astonishing to observe that it has nearly 10% of the total population of the state.

From the point of view of education Bangalore is said to be one of the largest educational centres of India. This is so because of the establishment of national institutions *e.g.* the Indian Institute of Science, Raman's Institute, Indian Institute of Management, All India Institute of Mental Health, University of Agricultural Science and University of Bangalore.

Many hospitals were opened in Bangalore during the British period. They include: Bowring Hospital; St. Martha's Hospital; St. Johan Medical Centre and Hospital; Victoria Hospital; Minto Ophthalmic Hospital and Leprosarium. At present, Bangalore has several hospitals: Sri Jayadeva Institute of Cardiology; Ramaiah Medical Institute; Kempe Gowda Institute Medical Science and Manipal Hospital.

The shopping areas like Balepete, Chikpete and Avenue road have now become the busiest and most crowded areas in the city. Other important shopping centres of the city are Gandhinagar, Kempegowda road, J.C. road, M.G. road, Residency road and St. Mark's road.

5 Parks and gardens

Bangalore is famous for its flowering trees, broad avenues and narrow lanes, splashing the ground with their multihued blossoms and filling the air with their fragrance. Bangalore, with its salubrious climate and fertile soil, which favour the growth of flowers and trees, has earned itself the name 'Garden City'. It has two well-known parks, Lalbagh and Cubban and several smaller parks, and innumerable individual gardens. Sri Richard Sanky planned Cubban Park in 1864. Lalbagh has lived up to its reputation of being one of the foremost botanical gardens in south and southeast Asia.

6 Meteorological conditions

Bangalore is called an air-conditioned city, which enjoys a very salabrees climate, free from any extremes. The daytime temperature varies from a maximum of 37°C in March–May (warmer months) to a minimum of 16°C in December–January (cooler months). The mean monthly relative humidity is lowest in the month of March (44%) and highest during the period June–October (80–85%) [1].

The daytime temperature varied from a maximum of 34.7°C in the month of April 2002 to a minimum of 16.1°C in the month of September 2002. The mean monthly wind speed varied from a maximum of 48kmph in the month of August 2002 to a minimum of 24kmph in the months of August and September 2002 and the daytime mean monthly relative humidity varied from a maximum of 96% in the month of May 2002 to a minimum of 18% in the month of April 2002. The daytime mean monthly values of temperature, wind speed and relative humidity are presented in table 1.

7 Growth of motor vehicles in Bangalore

The personalised motor vehicles have been growing at 6–15% per annum in different cities. In most of the cities, scooters and motor cycles comprise more

Table 1: Mean monthly values of meteorological parameters.

Months	Temperature (°C)		Wind Speed (kmph)		Relative Humidity (%)	
	Min	Max	Min	Max	Min	Max
April 2002	22.3	34.70	25	37	18	83
May 2002	20.60	33.50	27	40	35	96
August 2002	19.80	31.50	24	48	36	94
September 2002	15.10	30.80	24	30	20	92

than 70% of total motor vehicles. Use of these modes is also high in these cities due to inadequacy of mass transportation services. The scooter and motor cycle ownership rate in metropolitan cities is expected to increase from 102 per 1000 population at present to 393 by 2021 and for cars from 14 to 48% per 1000 population by the same year. Considering this, the number of two-wheelers is expected to be 130 million in 2021 from a level in 1994 of 16 million, *i.e.* 8 times [2].

8 Status of air pollution in Bangalore

Under National Ambient Air Quality Monitoring (NAAQM) programme, Karnataka State Pollution Control Board (KSPCB) in 1989 has established High Volume Air Samplers in three stations namely: (i) Anand Rao Circle; (ii) AMCO Batteries; Mysore road; and (iii) Graphite India (White field road). At these stations concentrations of NO_x, SO_2, and SPM are being monitored daily at 8-h intervals. The data are entered in the logbook of the board and are used to determine the level of pollutants in Bangalore city's atmosphere. Under NAAQM programme during the year 1999–2000, 1240 ambient air samples were collected at Anand Rao Circle, AMCO and Graphite India at a frequency of twice a week for 24h (between 6 am and 6 am). The annual arithmetic mean values of the concentration of the pollutants at the three stations are presented in table 2. The annual arithmetic mean values of NO_x, SO_2, and SPM concentrations

Table 2: Annual arithmetic mean values of air pollutants in Bangalore city.

STATION	NO_x µg/m^3	SO_2 µg/m^3	SPM µg/m^3
Anand Rao Circle	45.96	36.92	181.40
Amco Batteries	30.76	31.75	160.12
India Graphite	25.64	27.63	113.70

Source: Annual report by KSPCB

were highest at 45.96, 36.92, and 181.40µg/m^3 at Anand Rao Circle, respectively. The annual arithmetic mean values of NO_x, SO_2, and SPM concentrations were lowest at 25.64, 27.63, and 113.70µg/m^3 at Graphite India, respectively [3].

9 Pollution due to automobiles in Bangalore city

Bangalore has been experiencing, in the last few years, a vast increase in the number of personalised transport – basically the two-wheelers. This is attributable to increasing household income, which has brought large numbers of people within the threshold limits of buying two-wheelers and cars. The middle-class people are prominent in the city and most of them have two-wheelers.

The number of all types of vehicles in Bangalore has increased from 20,000 in 1960 to 750,000 in 1994. The total number of registered vehicles in the city during 1976–77 was 108,437 and in the year 1992–93 the numbers were 706,382 with an annual increase of 13%. A report from the Regional Transport Office, Bangalore showed that in November 1997, 109,5797 vehicles were registered in the city. In the city, between 1960 and 1997, there was an increase of 895,797 vehicles. Bangalore is reputed to have the largest number of two-wheelers in the country. The enormous increase in vehicular population and the inadequate road system have precipitated the problem of traffic thrombosis in the city. Inadequate bus services have also led to the proliferation of auto-rickshaws in the city, which are multiplying at an alarming rate, causing traffic congestion, road safety problems, noise, and air pollution. The vehicular pollution study by CPCB, Bangalore during the year 1996–97 estimated that 1145 tonnes of pollutant per day were released into the city atmosphere by vehicles. Out of this the petrol vehicles contribute 85.60% of total emission load of 979.54 tonnes per day and diesel driven vehicles contribute 14.4% of total pollution load which comes to 165.45 tonnes per day [1].

10 Air pollutant concentration at selected junctions

10.1 Vehicular flow

The data of classified traffic flow selected from 12 major study junctions are presented in table 3. After analysing the traffic data, it was clear that twowheeler vehicles were predominant at all the study junctions varying from 50 to 56% of the total traffic flow. The contribution of auto-rickshaws and cars/jeeps/vans varied from 19 to 41% and 7 to 24% of total traffic flows, respectively. In contrast, the percentage share of buses in the total traffic stream was only in the range of 3.0–15% at the study junctions. The contribution of trucks varied from 0.20 to 3% of total traffic flows.

(1) Jayanagara Bus Stand (2) South End Circle (3) National College Circle (4) Prof. Shivashankara Circle (5) K.R. Market (6) Town Hall (7) Hudson Circle (8) Cauvery Bhavan (9) K.R. Circle (10) Balekundri Circle (11) Shivajinagara Bus Stand (12) Anand Rao Circle

Figure 1: Map of Bangalore.

Table 3: Percentage share of each vehicular group at study junctions.

Jn. No.	Name of Junction	TW	Auto	C/J/V	Bus	Truck
J-1	Jayanagara Bus Stand	52.89	20.64	22.39	3.71	0.36
J-2	South End Circle	53.62	21.20	20.98	3.00	1.21
J-3	National College Circle	55.55	20.63	18.74	3.50	1.58
J-4	Prof. Shivashankara Circle	48.65	23.58	14.83	10.26	2.68
J-5	K.R. Market	46.89	36.33	9.34	6.63	0.82
J-6	Town Hall	54.32	19.35	17.91	7.38	1.04
J-7	Hudson Circle	48.55	25.24	18.83	6.97	0.14
J-8	Cauvery Bhavan	42.26	26.43	15.24	15.45	0.62
J-9	K.R. Circle	50.72	20.79	24.25	3.82	0.42
J-10	Balekundri Circle	48.43	24.45	20.29	6.25	0.59
J-11	Shivajinagara Bus Stand	37.59	40.58	6.60	15.03	0.20
J-12	Anand Rao Circle	53.14	25.45	16.00	4.90	0.51

11 Ambient air quality

11.1 Carbon monoxide (CO)

From the analysis of the concentrations of CO recorded at the study junctions, it was observed that, daytime 8-h average CO concentration levels exceeded the standard permissible limit of 2.0 mg/m^3 prescribed by Central Pollution Control Board (CPCB) at all the selected study junctions except at J-2 (0.82mg/m^3) and J-11 (1.33 mg/m^3). High CO concentrations of 8.97, 6.19, 5.20, and 4.04mg/m^3 were observed at J-5, J-12, J-9 and J-6, respectively. The values varied between a maximum of 8.97 and a minimum of 0.82mg/m^3 at J-5 and J-2, respectively. The variation of traffic flow and CO concentrations with respect to time at Anand Rao circle are shown in fig. 3. The high CO concentrations measured at the junctions may be attributed to the deceleration, idling, and acceleration caused by the interruptions to traffic flows and reduced dispersion due to the lack of traffic-generated turbulence. This may be attributed to the interrupted flow of traffic near the junctions [4].

11.2 Oxides of nitrogen (NO_x)

The daytime 8-h average concentration of oxides of nitrogen at J-7 and J-12 were 145.12 and 161.01μg/m^3, respectively. These values were significantly higher than the maximum 8-h average of 80μg/m^3 prescribed by the CPCB. The concentrations at all the other study junctions were under the permissible limits. The oxides of nitrogen concentrations during the study period were quite significant and could be attributed mainly to the significant vehicle flows at these junctions [5]. The daytime 8-h average oxides of nitrogen concentration variations at the study junctions are shown in fig. 2. Typical variations of traffic flow and oxides of nitrogen concentration with respect to time at Anand Rao circle (J-12) are presented in fig. 4.

11.3 Sulphur dioxide (SO_2)

The concentrations of sulphur dioxide observed at all the junctions were significantly lower than the concentrations of other primary pollutants. The daytime 8-h average sulphur dioxide concentration values were well within the relevant ambient air quality standards of 80µg/m^3 at all the study junctions. Sulphur dioxide concentration depends on the sulphur content of the fuel used. Moreover, the growing consciousness and availability of low-sulphur fuels have further reduced the concentrations of sulphur dioxide in the ambient air [6]. The daytime variations of the 8-h average sulphur dioxide concentrations at the study junctions are shown in fig. 2. Typical variations of traffic flow and sulphur dioxide concentrations with respect to time at Anand Rao circle are presented in fig. 4.

11.4 Suspended particulate matter (SPM)

The 8-h average suspended particulate matter concentration showed high values of 402.38, 250.58, 199.15 and 198.21µg/m^3 at J-5, J-3, J-12 and J-4, respectively. The minimum value of 42.32µg/m^3 was recorded at J-2. The values at J-5 and J-3 were higher than the 8-h permissible standards of 200µg/m^3 prescribed by the CPCB. The daytime variations of 8-h average suspended particulate matter concentrations at the study junctions are shown in fig. 2. Typical variations of traffic flow and suspended particulate matter concentrations with respect to time at Anand Rao circle are presented in fig. 4. Re-suspension could be the main cause attributed to these high values of SPM observed. The passage of vehicles along a road may cause surface material to be re-suspended either by the shearing stress of the tyres or by induced turbulence [7].

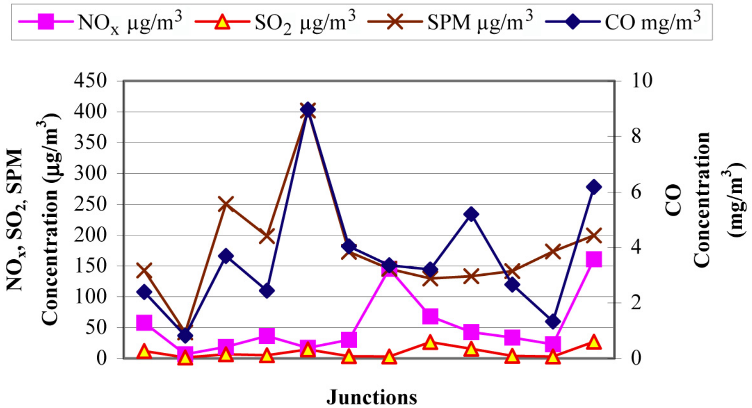

Figure 2: Variation of air pollutant concentrations at study junctions.

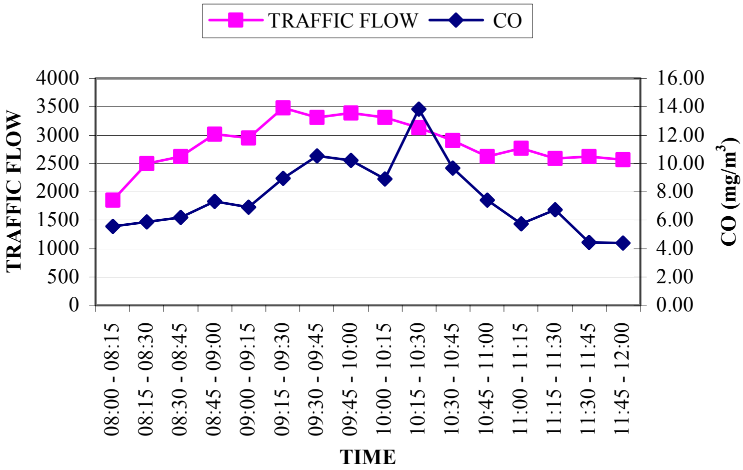

Figure 3: Variation of traffic flow and CO concentration with respect to time at Anand Rao circle.

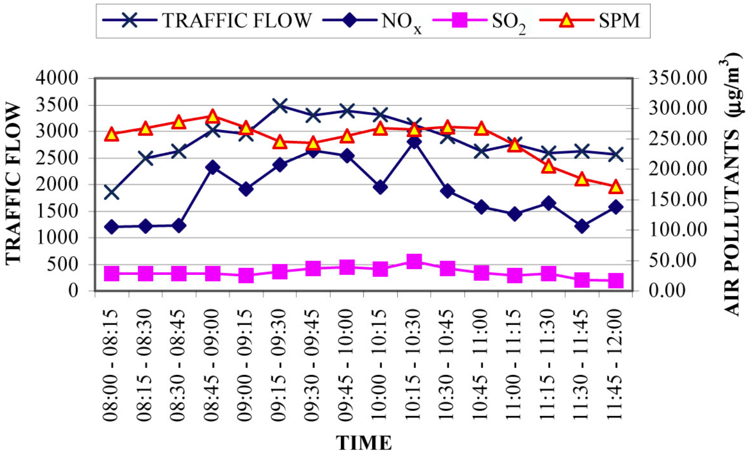

Figure 4: Variation of traffic flow and concentrations of NO_x, SO_2 and SPM with respect to time at Anand Rao Circle.

12 Some efforts taken by the authority to reduce vehicular pollution levels:

1. The mobile laboratory of the Karnataka State Pollution Board (KSPCB) which has been measuring the ambient air quality in Bangalore, has

found that the readings of pollution levels are higher than those recorded earlier. An official attached to the mobile lab said errors used to creep into conventional methods of sampling air and analysing it in a laboratory. But the mobile lab fitted with sophisticated equipment does not leave any room for inaccuracies. The mobile lab, costing Rs 1.38 crore, is the first of its kind in the county. It was launched on World Environment Day on June 8th 2001. It is meant to move around the city and collect samples of ambient air.

2. The transport department will not permit any new auto rickshaws for Bangalore. At present there are over 68,000 auto rickshaws plying on the city roads. Government had approved the registration of 2,000 autos, which have run on bi-fuel (LPG and Petrol) from November 1, 2002. The department has launched a massive drive against vehicle pollution in the city. Cases have been taken against 2,000 vehicles in the last few days.
3. A special drive against polluting vehicles has been initiated in the city each day to check 3,046 vehicles for emission. Of these, 542 vehicles were booked and temporarily detained under the Air Act, 1981. A total fine of Rs 4,700 has been collected.
4. In an effort to reduce the air pollution level in Bangalore city, the transport department is making it mandatory for auto rickshaws, which renew registration from November 1, 2002 to use LPG fuel.
5. Bangalore, chocking with traffic, can breathe easy. At last, authorities have woken up to its traffic problems. To decongest traffic, a one-way rule was implemented on the arterial roads in phases effected from July, 2001.

13 Measures for reducing vehicular pollutants

The following are some of the measures suggested for reducing vehicular pollutants:

1. It has been observed that the main sources of carbon monoxide emissions are petrol-driven vehicles, more specifically, two-wheelers and cars. With personalised vehicles constituting around 90% of the total vehicle fleet, steps must be taken to strengthen the public transportation system and to discourage the use of personalised modes.
2. Expansion or promotion of the use of mass transportation facilities through measures such as increases in the frequency, convenience, and passenger-carrying capacity of mass transportation systems or providing for special bus lanes on major streets. Also, various traffic management measures must be enforced to reduce the number of personalised vehicles on the roads.
3. As the central core area facilitates air quality stress through greater congestion, better urban planning could influence air pollution through planning for reduced traffic events. The immediate response would be to suggest that a city should reduce congestion through having more

land use, like the suburbs with less junctions, the potential for lower traffic events and consequently more free flowing traffic. This would imply suburban centres and more central city freeways and a bypass. Thus, vehicles should have less congested conditions and correspondingly lower emissions [8].

4. From an air pollution control viewpoint, bypassing through traffic would shift vehicle-miles of travel away from already congested central city streets and smoothen traffic flows by a separation of through and local traffic in the areas affected. Both results would reduce emissions in high pollution areas of the central city, the first by redistributing emissions elsewhere, and the second by bringing higher average vehicle speeds, fewer stops and starts, less idling, and reduced emissions associated with those improvements [9].
5. Modification in the design of engines and carburettors especially in respect of two-wheelers in order to switch over from two stroke engines to four stroke engines. This will significantly reduce carbon monoxide and hydrocarbon emissions from the two-wheelers [10].
6. A program of conversion to gaseous fuels would take advantage of the fact that such fuels produce fewer heavy hydrocarbons that contribute to the formation of photochemical smog than gasoline because they have lower molecular weight and carbon content, they ignite more rapidly, and the combustion process proceeds more close to completion and leaves less unburned fuel in the exhaust system. Studies conducted have established that the use of CNG as a fuel reduces the emissions of carbon monoxide and hydrocarbons significantly. Therefore efforts should be made to achieve complete phasing out of diesel-driven vehicles as well as to increase the availability of CNG [11].
7. Periodic inspections and testing of motor vehicle emission control systems, at such time as the administrator determines that such programs are feasible and practicable. Mandatory inspection and maintenance of in-use motor vehicles for air pollution control can make a significant contribution to maintaining air quality by ensuring that emission control devices are actually achieving substantial reductions in vehicle emissions.
8. If the relations between transportation and air pollution control are to be dealt with effectively, a substantial improvement in coordination and communication among state, local, and regional planning, transportation, and air pollution control agencies and the general public will be absolutely essential.
9. Pollutants are produced at a high rate while vehicle engines are idling. One strategy is to ensure that engines stop during traffic delays and goods delivery.
10. Air quality standards must be realistic and supported with factual information showing the dangers to public health that would result from pollution levels in excess of the standards. Costs and benefits of the strategies should be identified, and the public should understand who

pays what amount and who benefits to what degree in both social and economic terms.

11. Although the Supreme Court of India has ordered that all the diesel vehicles plying in Delhi should be converted to CNG, our country depends on imports for CNG.
12. Alternatively, Gasohol which is an admixture of 76% petrol and 24% alcohol, can be an efficient and environment friendly fuel for automobiles without any modification to the carburettor or engine. Also, admixtures of 5–10% ethanol with petrol and 15% ethanol with diesel will bring down the pollution under permissible limits. Such an alternative proposition remains to be understood and adopted.
13. Natural gas is a very promising fuel for lower vehicular pollution. Advantages of natural gas engines are given below:

No measurable smoke
No sulphur dioxide emissions
No lead emissions
Very low particulate emissions
Very low tendency to smog formation
Relatively low greenhouse effect
Excellent anti-knock characteristics
Low HC, CO and NO_x emissions possible with catalysts

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