

Air Quality Management in Delhi, India:

Then, Now, and Next

Dr. Sarath Guttikunda

May, 2009

Capital has more toxic particles in its
air than other major Indian metros

DELHI IS INDIA'S ASTHMA CAPITAL

DELHI has the highest levels of
Respirable Suspended Particulate
Matter (RSPM) among the
four metros, exposing its resi-
dents to a greater risk of
asthma than people elsewhere
in the country.

Acceptable levels of RSPM should not be
more than 50 microgram (mg) per cubic
meter (cu m) annually. In 2008, Delhi's

By Meenal Dubey in New Delhi

RSPM was recorded at a shocking 149
mg/cu m, according to a report published
by the Central Pollution Control Board
(CPCB) with the help of data collected
between January and August 2008.

This is well above Mumbai's RSPM mark of 118
mg/cu m, Kolkata's 104 mg/cu m and Chennai's
54 mg/cu m.

It is no secret that India's capital is highly
polluted.

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Mail Today, March 1st, 2009

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Air Quality Management in Delhi, India: Then, Now, & Next

Air Pollution in Delhi

In March, 2009, the central pollution control board (CPCB) declared that the city of Delhi was “India’s Asthma capital”¹. As a rapidly expanding city, transportation, energy generation, construction, domestic burning, and industrial activity are contributing to the increasing air pollution and its resulting health and respiratory impacts. **Figure 1** presents the summary of measured PM₁₀ and NO_x concentrations at the Siri Fort station in Delhi² and the data from four more stations is presented in **Annex 1**.

The National Capital Region (NCR) of Delhi has grown rapidly in the past two decades. It now covers an estimated area of 900 Sq. km that includes new townships and satellite centers such as Noida and Gurgaon (See the graphical representations in the Annex). In 2007, the population of NCR was estimated at 16 million. It is expected to reach 22.5 million in 2025³.

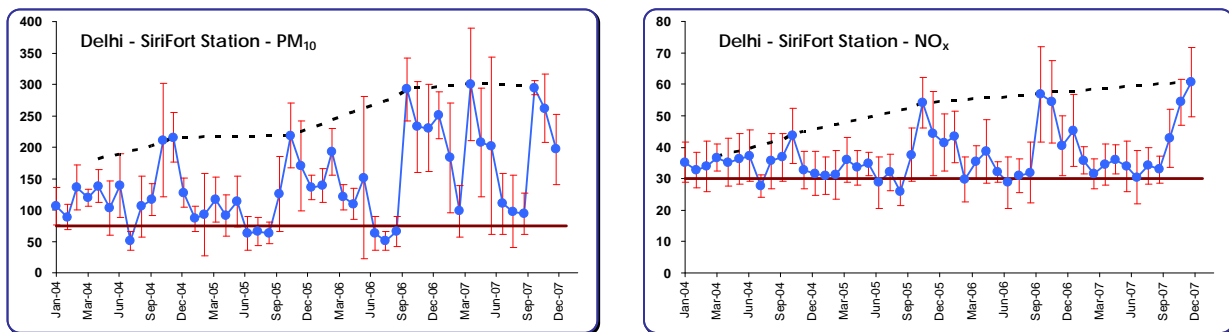


Figure 1: Air pollution in Delhi – 24hr monthly averages with variance over each month

Over the past decade, the government has introduced some green initiatives to address the air pollution problem in the city. Yet, there still remains a tremendous amount of potential to reduce the air pollution impacts as the demand rises for infrastructure and services.

¹ “Delhi is India’s Asthma capital”, March 1st, 2009, In Today News @ http://www.intoday.in/index.php?id=24240&option=com_content&task=view§ionid=5

“The pollution today In Black And Pink”, July 15th, 1999, Down to Earth @ http://www.downtoearth.org.in/full6.asp?foldername=19990715&filename=spr&sec_id=6&sid=4

² The measurement data of daily averages for the period of 2004-2007 are obtained from CPCB (Delhi, India). For the four year period, the collection efficiency at each of the stations is ~25 percent (~2-6 points per month) @ <http://cpcb.nic.in>

Real time monitoring data for Delhi @ <http://164.100.43.188/cpcbnew/movie.html>

³ UN HABITAT, 2008, “State of the World Cities” @ <http://www.unhabitat.org/content.asp?cid=5964&catid=7&typeid=46&subMenuId=0>

Pollution Sources & Seasonality

No single sector is responsible for Delhi's air pollution. Rather, it is a combination of factors including industries, power plants, domestic combustion of coal and biomass, and transport (direct vehicle exhaust and indirect road dust) that contribute to air pollution⁴. Seasonal changes in demand for fuel and natural pollution result in differing sources of air pollution in summer and winter. These need to be taken into account to maximize the effectiveness of anti-pollution initiatives. **Figure 2** presents the results of source apportionment of the urban air pollution in Delhi, conducted by the Georgia Tech University (USA) in 2005⁵.

In summer, dust storms from the desert⁶, south-west of Delhi contribute to the increased fugitive dust in the city. This is exacerbated by the low moisture content in the air, which causes a higher resuspension of road dust (40 percent of particulate pollution in summer, compared to 4 percent in winter). In the winter months, the mix of pollution sources changes dramatically. The use of biomass, primarily for heating contributes to as much as 30 percent of particulate pollution in winter. Most of this burning takes place at night, when the “mixing layer height” is low due to inversion in the winter months. In summer, biomass accounts for only 9 percent of particulate pollution.

Another external factor is pollution due to agricultural clearing⁷. After the harvest of crops, clearing agricultural land is a common practice in surrounding (largely agricultural) states. The smoke reaches Delhi and contributes to the smog levels in the city⁸.

Apart from biomass burning and ambient dust, transportation and industries are major contributors to air pollution in Delhi. With a growing city, the corresponding transportation needs are fueling a rise in private vehicles (2 and 4 wheelers) and taxis and autorickshaws⁹.

⁴ Garg et al., 2006, “The sectoral trends of multigas emissions inventory of India”, Atmospheric Environment @ <http://dx.doi.org/10.1016/j.atmosenv.2006.03.045>

Gurjar et al., 2004, “Emission estimates and trends (1990–2000) for megacity Delhi and implications”, Atmospheric Environment @ <http://dx.doi.org/10.1016/j.atmosenv.2004.05.057>

Reddy et al., 2002, “Inventory of aerosols and sulfur dioxide emissions in India, Atmospheric Environment @ [http://dx.doi.org/10.1016/S1352-2310\(01\)00463-0](http://dx.doi.org/10.1016/S1352-2310(01)00463-0)

Shah et al., 2000, “Integrated analysis of acid rain in Asia”, @ <http://arjournals.annualreviews.org/doi/abs/10.1146/annurev.energy.25.1.339>

⁵ The source apportionment study was conducted in four Indian cities, via hydrocarbon analysis of the measured PM_{2.5} samples, under the guidance of Dr. Ted Russell @ Georgia Tech University. Other cities include Chandigarh, Kolkata, and Mumbai. Please note that the source apportionment results are indicative of the possible shares of various sources in the measured sample and most often represent the surroundings of the monitoring site, instead of a directive measure for the whole city.

⁶ Satellite images of forest fires, dust storms, and haze over Asia are presented @ <http://urbanemissions.blogspot.com/2009/05/dust-storm-haze-pollution-in-asia.html>

⁷ Fires in the Northwest India, November 2008 @ <http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35765>

⁸ BBC, November, 2008, “Pollution Fears over Delhi Smog” @ http://news.bbc.co.uk/1/hi/world/south_asia/7727114.stm

⁹ Indian Express, June 17th, 2008, “Delhi Traffic at Saturation” @ <http://www.indianexpress.com/news/Delhi-traffic-at-saturation-level:-Report/323616/>

As a result, operating traffic speeds have reduced for all vehicles, thus increasing idling time and pollution¹⁰.

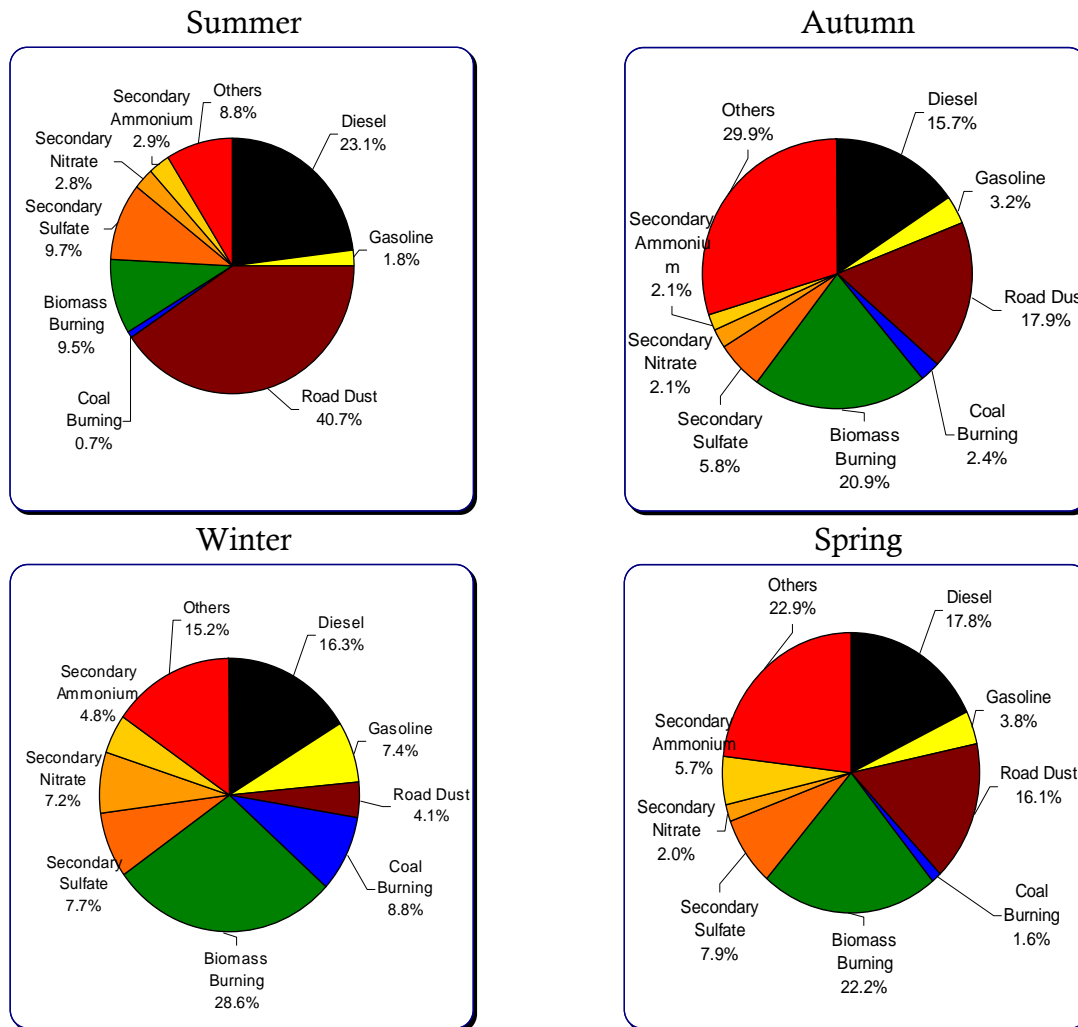


Figure 2: PM_{2.5} Source apportionment results for Delhi

The efforts to address this by building flyovers that connect and bypass major junctions in the city have not yielded results as expected. For one, this solution addresses only the supply side of the equation and does not influence demand management. In fact, as it becomes easier to take a private vehicle, the number of vehicles have increased (about 1000 new registrations per day in 2006¹¹) thus negating many of the planned improvements. In addition, the increase in the on-street parking and encroachments by hawkers has exacerbated the situation.

¹⁰ Down to Earth, May 31st, 2008, “Caravan to Disaster” @ http://www.downtoearth.org.in/full6.asp?foldername=20080531&filename=news&sec_id=9&sid=46

¹¹ Times of India, May 11th, 2009, “..~103,000 new passenger cars registered in India in April 2009” @ <http://timesofindia.indiatimes.com/Car-sales-up-420-bikes-jump-1211-in-April/articleshow/4508229.cms>

Industry, the other major source – accounts for about a fifth of air pollution and includes the three power plants, at Indraprastha, Badarpur and Rajghat and ~200 brick kilns that use coal and fuel oil¹².

Delhi Then - What Worked

In 1998, the Supreme Court ruled that the city of Delhi should take concrete steps to address air pollution in the transport and industrial sectors¹³.

For the transport sector, this ruling led to the largest ever CNG switch in the world for public vehicles. More than 100,000 vehicles (including the three wheelers and taxis) were converted to CNG in Delhi over five years¹⁴. This resulted in a dramatic decrease in the reduction of the air pollution. The largest improvement came from the conversion of ~3,000 diesel buses to CNG¹⁵. Delhi has since 2000 also enforced Euro II emission standards, five years ahead of schedule, and Euro III in 2005 for all passenger vehicles.

Another significant fallout of the ruling was that in the industrial sector, approximately 500 heavy industries were shut down and relocated to areas outside the Delhi administrative boundaries. This not only led to a significant drop in air pollution, but also energy efficiency as several relocated industries took the opportunity of the relocation to upgrade their systems.

In 2003, the Indian Supreme Court issued another rule that 14 cities had to perform air pollution analysis and submit an air pollution control action plan covering all the major contributing sectors. Delhi was one of the 14 cities.

The pollution control board is in the process of conducting an air pollution analysis that will consolidate the top-down monitoring data and the bottom-up energy consumption and emissions analysis¹⁶. This was a requirement of the Supreme Court ruling and a part basis for allocation of funds from the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) for the cities¹⁷.

¹² White paper on pollution in Delhi, by Govt. of India @

<http://envfor.nic.in/divisions/cpoll/delpolln.html>

¹³ More on the Supreme Court ruling @

<http://www.cleanairnet.org/infopool/1411/propertyvalue-19513.html>

The timeline of implementation (in the transport and industrial sector) and the experience for instituting change which has become a model for other Indian cities, by Narain, et al., 2005, “Who Changed Delhi’s Air? The Roles of the Court and the Executive in Environmental Decisionmaking”, RFF @

<http://www.rff.org/Publications/Pages/PublicationDetails.aspx?PublicationID=17425>

¹⁴ More on Delhi Transport Corporation @

http://en.wikipedia.org/wiki/Delhi_Transport_Corporation

¹⁵ Down to Earth, March 2002, “The Supreme Court Not to Budge on CNG Issue” @

http://www.downtoearth.org.in/full6.asp?foldername=20020331&filename=News&sec_id=4&sid=6

¹⁶ Details on the air pollution analysis program under CPCB @

http://cpcb.nic.in/Source_Apportionment_Studies.php

¹⁷ Jawaharlal Nehru National Urban Renewal Mission (JNNURM) @ <http://jnnurm.nic.in/>

Delhi Now - Problems

The introduction of CNG was the highlight of the strategy to address air pollution in Delhi¹⁸. Early results of the switch were very good soon after the conversion and Delhites could perceive the improvement in air pollution. However, over the 10 years since the switch, pollution levels have inched back up and the measured annual respirable particulate matter (RSPM) averaged 150 µg/m³ in 2008 – a 40 percent increase over the last decade¹⁹.

The reasons for this are many. The sheer number of new vehicles on the road. In 2000-01, approximately 580 vehicles were registered every day, this has almost doubled in 5 years to approximately 1000 in 2005-06²⁰. The total number of vehicles increased from 3.6 million in 2001 to 4.8 million in 2006, resulting in longer congestion and idling times, more pollutant emissions (in spite of the introduction of stricter norms). A recent survey and analysis indicate ~7 percent of the vehicle exhaust emissions in Delhi are due to idling²¹. The growing traffic also increases the resuspension of the road dust and this has become a critical source.

Lack of proper care and maintenance of private and public vehicles is a major factor affecting air pollution. The public buses operated by Delhi Transport Corporation, were retrofitted from a diesel base in 2000-01. Over the past 8 years, maintenance has lagged and many of the buses are old and as a result pollution per kilometer from the fleet is greater than it was when CNG was first introduced in 2000²². The lack of maintenance is a problem even for three and two wheelers. They continue to spew white smoke as they use inferior oil to lubricate their pistons.

There is an urgent need to update the bus fleet with newer vehicles. However, the supply of new buses has been slow. Two bus manufacturers in India – Tata and Ashok Leyland – together produce nearly 90 percent of standard buses in the country. At their current rate of production they can deliver only about 100 buses a month unless they ramp up production²³. This rate of supply is inadequate to meet the demand for buses in Indian cities that are investing in public transport. To underscore this point, the demand for buses under the JNNURM funds alone is approximately 70,000 buses for public transport purposes²⁴.

¹⁸ Narain, et al., 2007, “The Impact of Delhi’s CNG Program on Air Quality”, RFF @ <http://www.rff.org/Publications/Pages/PublicationDetails.aspx?PublicationID=17476>

¹⁹ Green Car Congress, November, 2006, “Air Pollution in Delhi Increasing with Rapid Growth in Diesel Cars” @ http://www.greencarcongress.com/2006/11/air_pollution_i.html

²⁰ Presentation by Ms. Anumita Roychoudary, at the Integrated Environmental Strategies program, December, 2007 @ http://www.epa.gov/ies/india/apportionment_documents.htm

²¹ Guttikunda, 2009, “SIM 18-2009: Indicative Impacts of Vehicular Idling on Air Emissions” @ <http://urbanemissions.info/simair/simseries.html>

²² Down to Earth, October, 2008, “City bus: In demand, out of supply” @ http://www.downtoearth.org.in/cover.asp?foldername=20081031&filename=news&sid=45&page=1&sec_id=9&p=1

²³ Times of India, February 8th, 2009, “BRTS dreams may go bust” @ <http://timesofindia.indiatimes.com/articleshow/msid-4096144,prtpage-1.cms>

²⁴ Times of India, May 13th, 2009, “Low floor buses delayed in Delhi” @ <http://timesofindia.indiatimes.com/Delhi/Low-floor-buses-delayed-Bluelines-get-a-breather/articleshow/4521904.cms>
The Hindu, May 13th, 2009, “Delhi Govt. faces cancellation of bus funding under JNNURM” @ <http://www.hindu.com/thehindu/holnus/004200905131452.htm>

In addition to the bus fleet, smoke from badly maintained old trucks is a problem in the city. Adulteration of diesel is common and results in noxious fumes that add to the pollution in the city. As a green measure, the trucks are not allowed to enter the city limits during the day²⁵. This was introduced mainly to reduce the exposure levels to higher pollution due to diesel emissions. However, during the early morning hours, the lingering effects of night time truck emissions are perceptible by the reduced visibility due to smog.

Delhi Next - New Ways

With the 2010 Commonwealth Games approaching, the Delhi Government is trying to put in place measures to improve air quality. All the measures involve improving public transportation and streamlining traffic flow.

Bus Rapid Transport

The push for an integrated urban transport management is strong and the Bus Rapid Transport (BRT) is being promoted as an improvement to the public transport system.

The results have been mixed. After two years of planning and construction, only a section of a 5 km road is being piloted and has immediately been dubbed as the “corridor of chaos”. This is unfair, as to actually avail of the benefits of BRT, it needs to be implemented on a certain scale. A pilot of ~5 kilometers is inadequate to bring about significant change in public bus usage²⁶.

Despite the small scale pilot and the teething problems in the initial two months, negative press releases primarily focusing on the operational and design issues, the BRT system received good approval rating from the commuters in the past few months, primarily due to the improvement in bus fleet and the bus information systems installed in bus-stops²⁷.

The Delhi Government should continue with its measures to improve buses and should enforce and monitor the use of the BRT lanes. Without proper monitoring, the BRT will not meet its original objectives. For example, special lanes were provided for pedestrians and other non-motorized transport in the Delhi BRT plan. However, at one junction in



²⁵ Financial Times, September 2002, “Truckers Seek A Way Out Of Transit Problem In Delhi” @ <http://www.financialexpress.com/news/truckers-seek-a-way-out-of-transit-problem-in-delhi/37127/>

²⁶ ITDP, June, 2008, “Delhi BRT trial stirs public furor” @ http://www.itdp.org/index.php/projects/update/delhi_high_capacity_bus_trial_stirs_public_furor/

IDTP, May, 2008, “Delhi BRT, as good as scrapped” @ http://www.itdp.org/index.php/news_events/news_detail/brt_as_good_as_scrapped/

²⁷ Assessment of the BRT System by EMBARQ for CSE, February, 2009 @ http://www.cseindia.org/AboutUs/press_releases/press-20090207.htm
http://www.cseindia.org/pdf/evaluation_bus.pdf

Delhi, "Chirag Delhi", the lane originally dedicated for cycling and walking, is now converted to a left only lane for cars²⁸. For the rest of the cycle lanes on the BRT project, motor cycles are dominating the space originally intended for non-motorized transport (NMT). In which case, the BRT concept will become an excuse for road widening instead of promoting public transport.

Metro Rail

In 2002, a much awaited 65 km metro rail system was introduced in Delhi. Work to expand the metro system is underway for the next phase of 128 km and will cover a large portion of Delhi. The Metro has proved itself to be a popular and efficient public transport system and has already contributed towards changing peoples mode of transport from private to public – especially among those who live close to a metro stop. For the first phase itself, ridership is approximately 650,000 passengers a day.

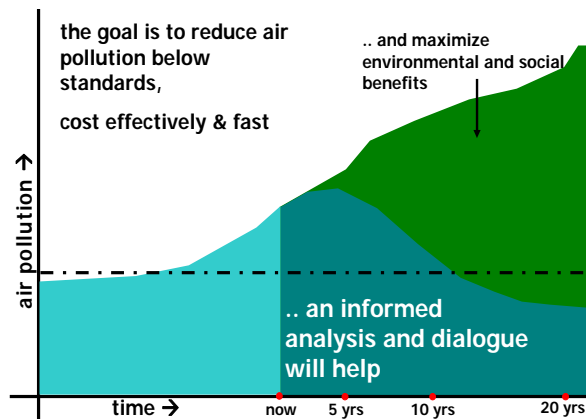
As the metro expands, with the expected growth in ridership, estimates suggest an immediate reduction of at least 10 percent in the criteria pollutants like RSPM and NO_x in 2010²⁹.

While the BRT and Metro Rail is effective in improving the traffic conditions and creating opportunities to shift people from personal to public transport, an equal emphasis should be given to promote walking and cycling – both to build a sense of community and a vibrant urban space as well as to promote movement of people that results in “zero emissions”³⁰.

In conclusion

Policymakers increasingly recognize that addressing air quality as an urgent priority, primarily from the public health perspective.

Studies and dialogues should include properly identifying the sources to formulate rational and effective policies and make informed investment decisions. Besides the capacity to make the investment decisions, it is important that the decisions are better communicated to the public for maximizing the possible benefits.



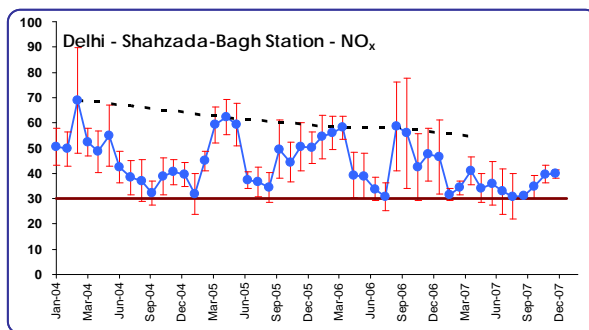
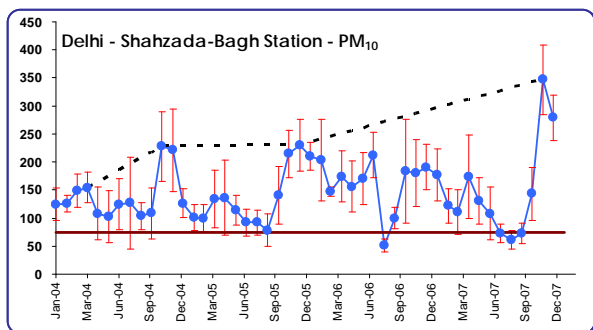
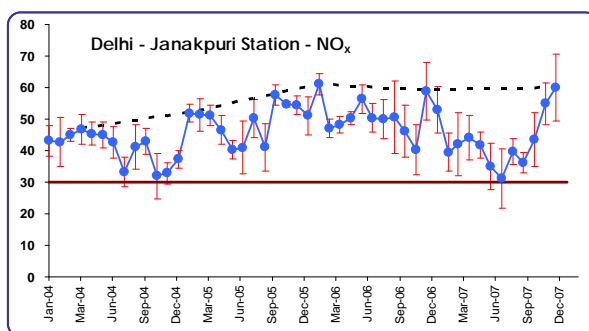
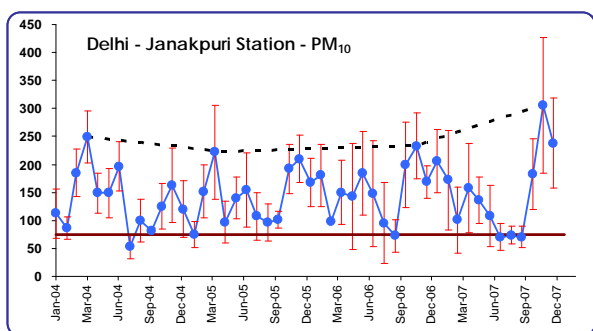
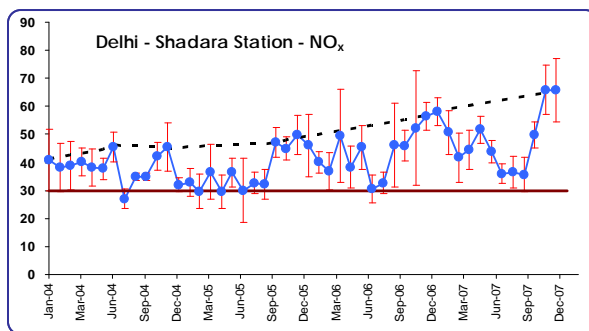
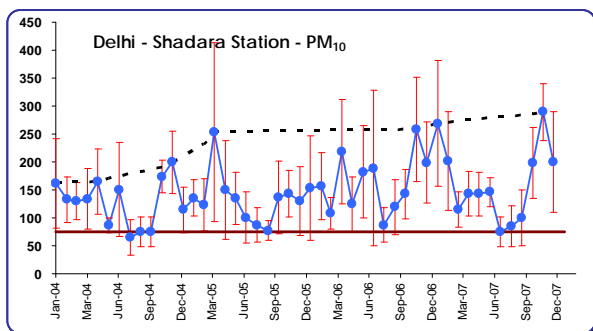
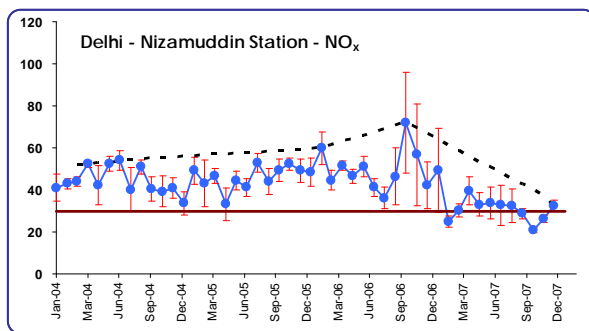
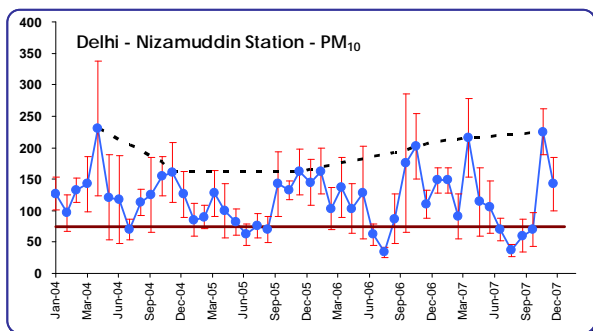
While the Delhi government has taken considerable interest in improving the public transport system, they should also address the other sources such as industry and biomass burning to gain cost effective reductions.

²⁸ Photo by Mr. Joshua Apte, April, 2009

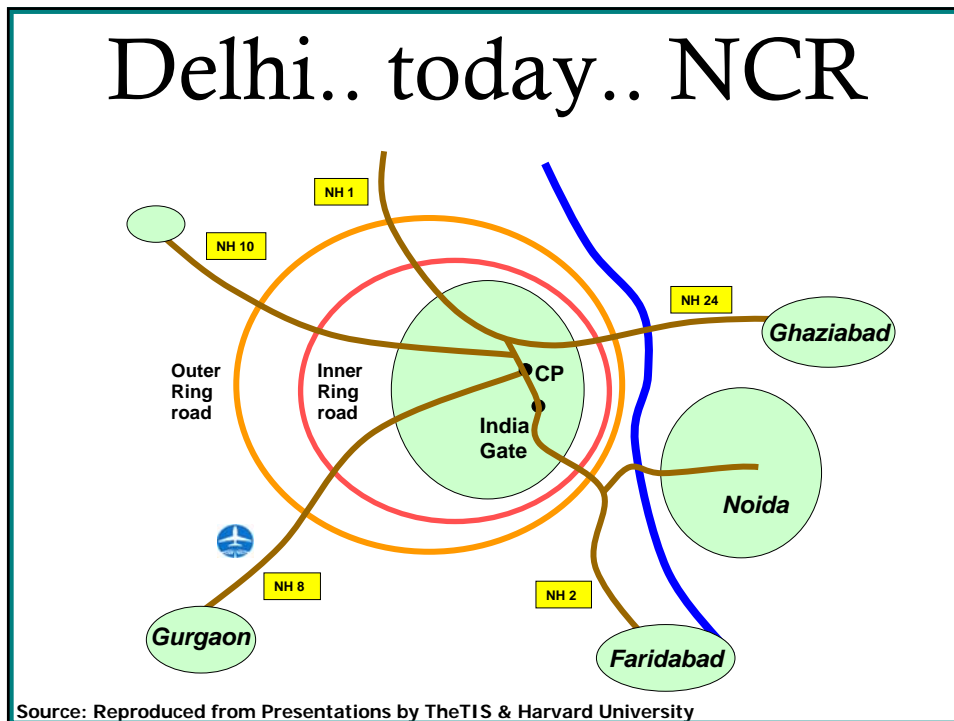
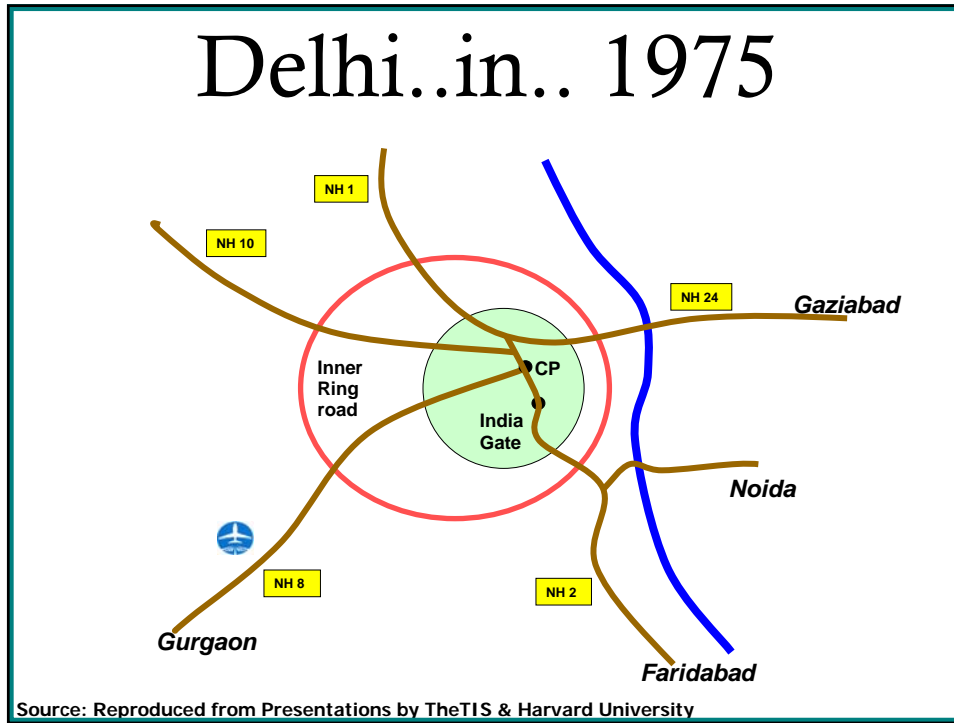
²⁹ Guttikunda, 2009, “Impact of Metro Rail System on Air Emissions” @ <http://urbanemissions.info/Applications.html>

³⁰ Down to Earth, April, 2009, “Never Too Many Pedals” @ http://www.downtoearth.org.in/full6.asp?foldername=20090430&filename=croc&sec_id=10&sid=2

Annex 1: Air Pollution Monitoring in Delhi



Annex 2: Supporting pictures and maps of Delhi, India



Smoke Alarm in Delhi

November, 2008



Mail India
March 1st, 2009

Smoke alarm in Delhi



See what you breathe

A LOOK AT THE AMOUNT OF POLLUTANTS IN THE CAPITAL'S AIR

Respirable Suspended Particulate Matter

City	2006	2007	2008
Delhi	100	100	100
Mumbai	100	100	100
Chennai	100	100	100
Bombay	100	100	100
Hyderabad	100	100	100
Coimbatore	100	100	100
Chennai	100	100	100
Bombay	100	100	100
Hyderabad	100	100	100
Coimbatore	100	100	100

MAIN CULPRITS

100,000 vehicles

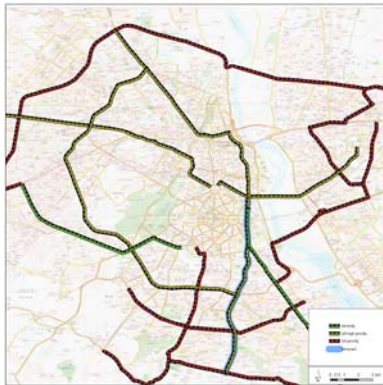
10,000 trucks

Children suffer

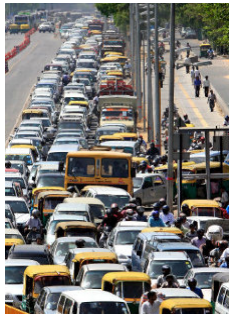
Govt says things will improve in 3 years

<http://urbanemissions.blogspot.com/2009/05/dust-storm-haze-pollution-in-asia.html>
http://news.bbc.co.uk/1/hi/world/south_asia/7727114.stm

BRT: Teething Problems



Planned for
80 km

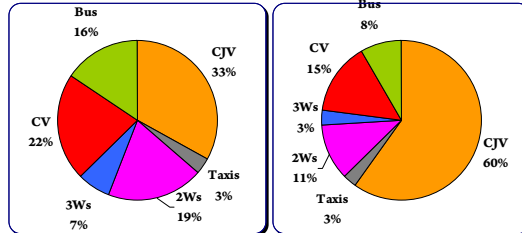


Metro: The New Face

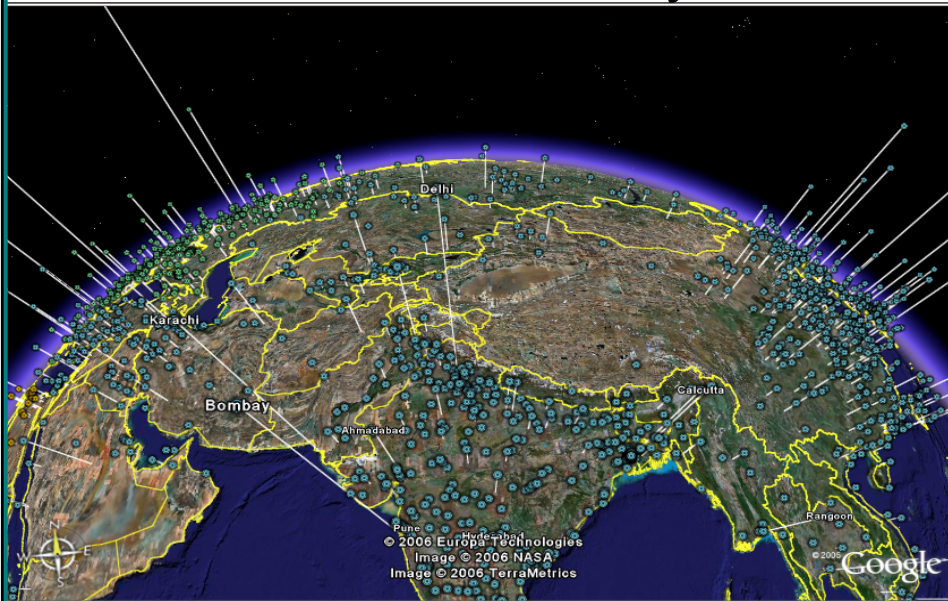


Planned for
65 + 125 km

10% drop in 2010 PM₁₀ Emissions
2002 2010



.. hundreds of secondary Cities



Source: Google Earth & www.demographia.org