

***Transportation and Environment:
Problems in Delhi and Beijing***

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September 28, 2000

- *Recently with the population growth and economic expansion, the number of vehicles has been increasing rapidly in China and India.*
- *Automobile emissions are the most rapidly growing source of urban air pollution in most developing cities.*
- *These emissions contribute to a disproportionate amount to human exposure. And also, the highest polluting vehicles provide an huge amount of these total emissions.*
- *Therefore, targeting vehicular pollution control is more cost effective than the industrial sector.*
- *The following slides include some international comparisons in transport system characteristics of different cities in the world, the description of Delhi's and Beijing's transportation sector and its effect on the environment.*

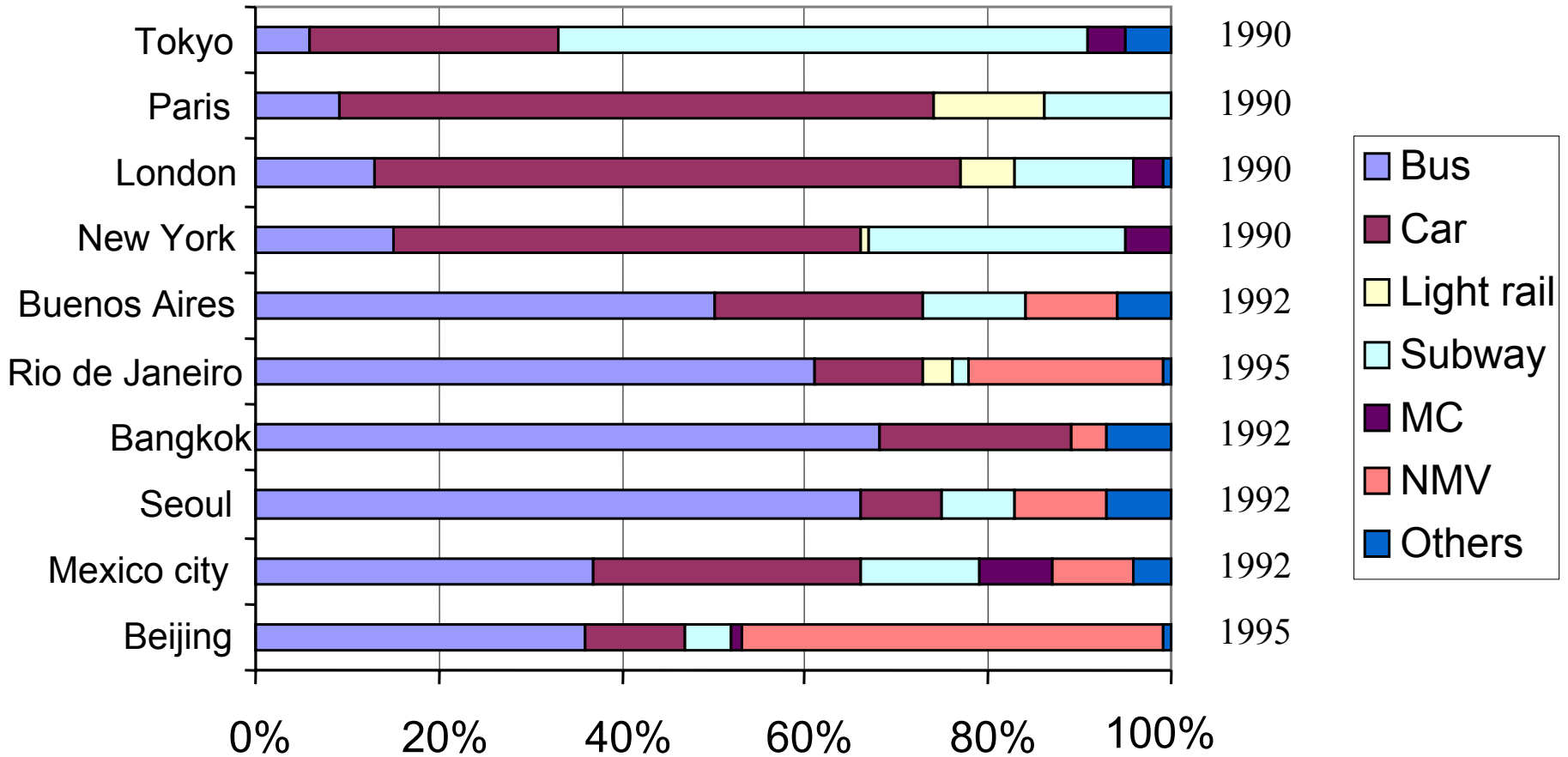
Share of Air Pollutant Emissions from the Mobile Sector

	CO	HC	NO _x	SO ₂	PM
Mexico, 1994	100%	53.3%	70%	26.5%	4.3%
Santiago, 1992	94.2%	82.7%	84.6%	24%	11.5%
São Paulo, 1995	96.4%	90.9%	97.3%	85.5%	42.7%
Rio de Janeiro, 1978	96.4%	73.2%	69.6%	9.5%	3.5%
Beijing, 1992	63.4%	73.5%	21.7%		
Beijing, 1995	86.2%		49.1%	10%	
Delhi, 1995	80.5%	95.2%	69.4%	4.6%	6.6%

As the polluting industries which are scattered all around the urban area in Delhi and Beijing move out to the suburban areas and the transportation sector continue to grow, the share of mobile sources emissions will keep on rising.

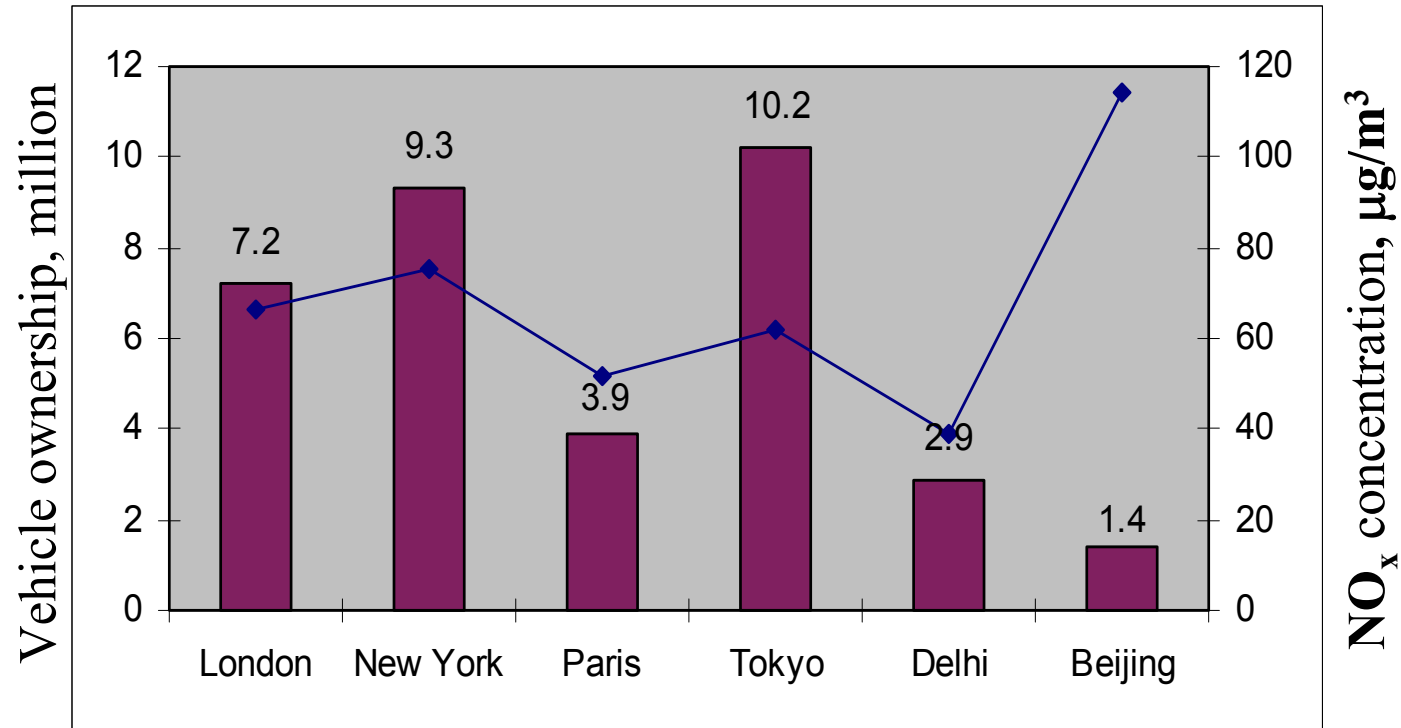
Source: World Bank Report. Vehicular Air Pollution: Experience from Seven Latin American Urban Cities, 1997. Data in Beijing comes from the report titled China's Strategies for Controlling Motor Vehicle Emissions, 1997.

Comparison of passenger trip mix among big cities in the world



Delhi, 1994		Buses	Cars	Light Rail/Subway	MC	NMV	Others
%		62.00%	6.94%	0.00%	17.59%	6.61%	6.86%
Others:	Autorickshaws	Taxis	Rail	Others			
%	2.80%	0.06%	0.38%	3.62%			

Comparison of Vehicle Ownership and Pollution in Big Cities in the World



Data for Delhi vehicle number is in 1997, NO_x pollution is monthly average in 1998. Data for Beijing is in 1998. Others are in 1990.

Comparison of Road Infrastructure & # of Vehicles in Big Cities in the World

	Road Supply (m/person)	Total Vehicles per km of Road
New York (1991)	4.70	99
Paris (1991)	0.90	410
London (1991)	1.90	186
Tokyo (1991)	1.90	140
Beijing (1995)	0.94	50
Delhi (1992)	2.17	90

Source: Newman and Kenworthy (1991). For Beijing; "China's Strategies for Controlling Motor Vehicle Emissions: Summary Report", China Environmental Technical Assistance Project: B-9-3, World Bank, May 1998.

Air Pollution in Different Cities in the World in 1995 ($\mu\text{g}/\text{m}^3$)

City	TSP	SO ₂	NO ₂
Beijing	377	90	122
Delhi	415	24	41
Tokyo	49	18	68
Mexico City	279	74	130
London		25	77
New York		26	79
Los Angeles		9	74

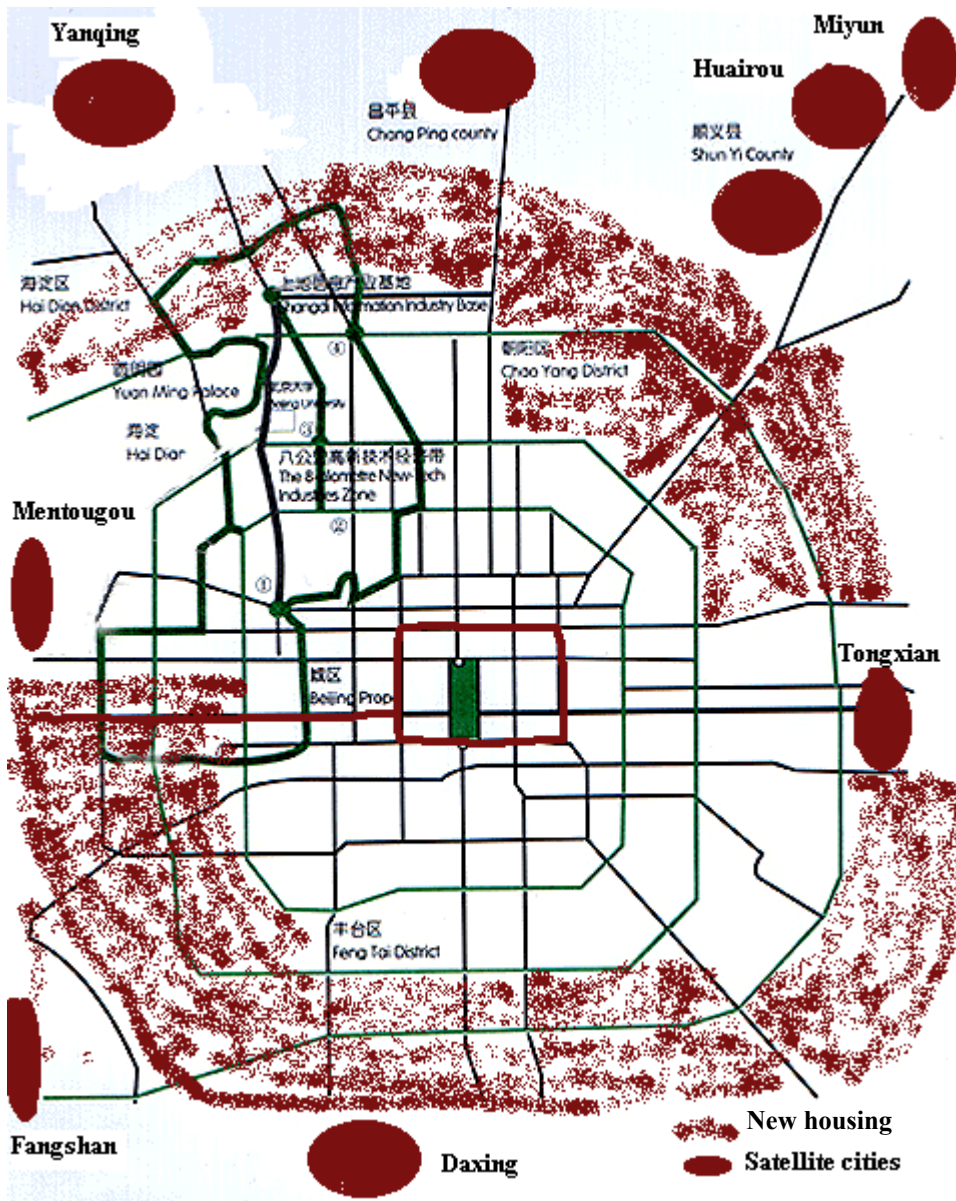
WHO Standards and Standards in Beijing

WHO / Beijing	Time-Weighted Average			Other
	1 hour	24 hours	1 year	Averaging Times
NO _x (µg/m ³)	/ 150	/ 100	30 / 50	95 (4 hours)
Ozone (µg/m ³)	150-200 / 160			100-120 (8 hours)
SO ₂ (µg/m ³)	350 / 500	125 / 150	40-60 / 60	500 (10 min)
TSP (µg/m ³)		120 / 300	60-90 / 200	
PM-10 (µg/m ³)		70 / 150	50 / 100	
CO (mg/m ³)	30 / 10	/ 4		60 (30min) 100 (15 min)

Annual Ambient Air Quality Standards in Delhi

Pollutant (µg/m ³)	Concentration in Ambient Air			WHO
	Industrial	Residential	Sensitive	(µg/m ³)
SO ₂	80	60	15	40-60
NO _x	80	60	15	
SPM	360	140	70	60-90
PM10	120	60	50	50
CO (mg/m ³)	5	2	1	

Beijing

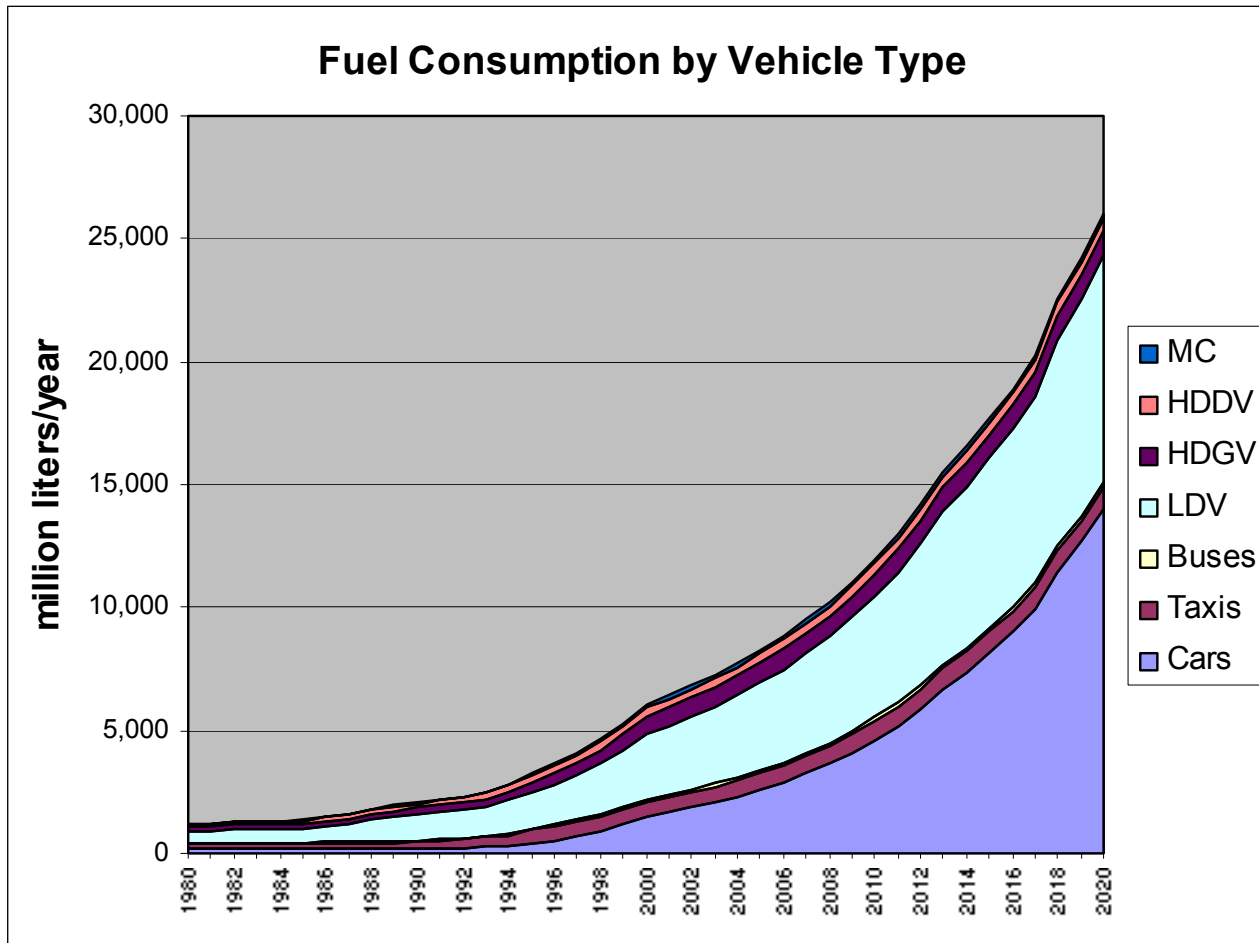


- 5 ring roads
- new housing under construction around the 5th ring road area
- 14 satellite cities being built in the suburban and rural areas
- This suburbanization and decentralization plan of Beijing will increase future pass-km demand and put more strain on the transportation system.
- Car ownership (1995): 9 vehicles/1000 people



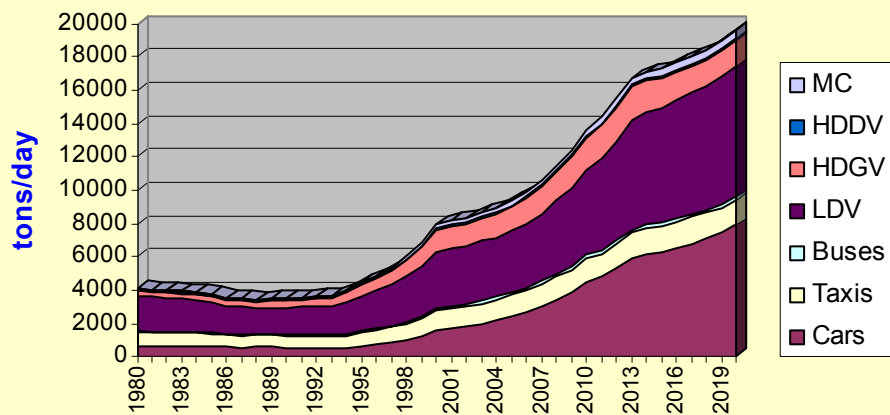
Beijing, China

- 1 meter resolution black-and-white image of the Forbidden City, Beijing.
- IKONOS satellite collected the image on October 20, 1999.

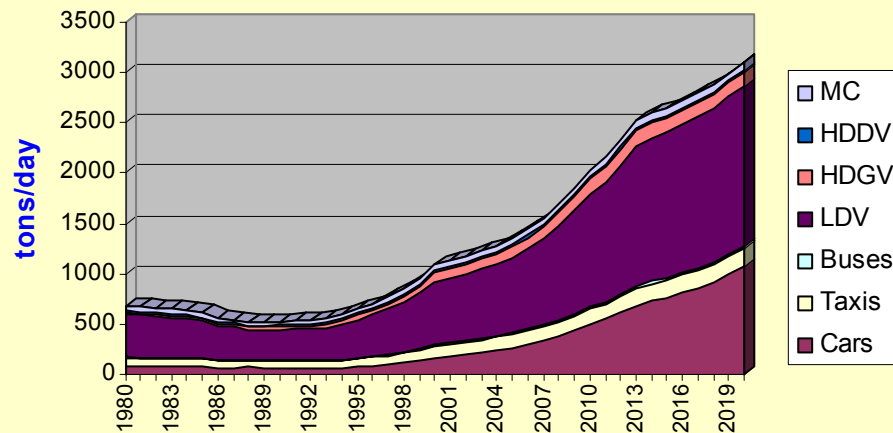


- Fuel consumption increases by 8 times from 1995 to 2020
- This will result in a need for increased imports in the future.

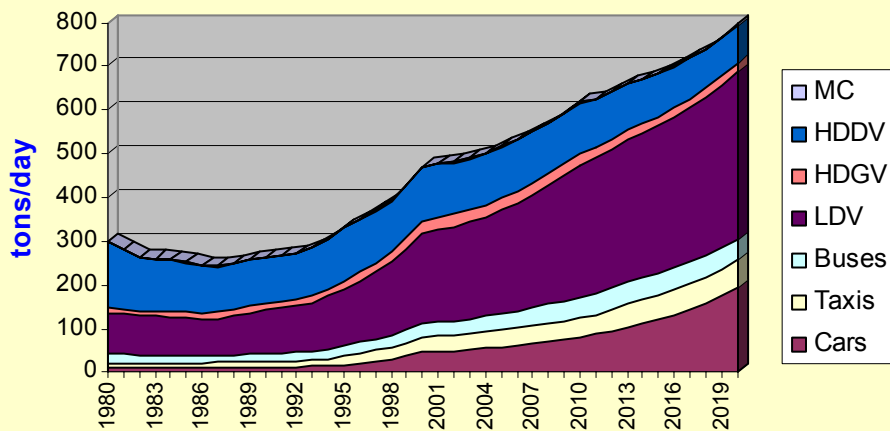
CO Emissions from Vehicles in Beijing



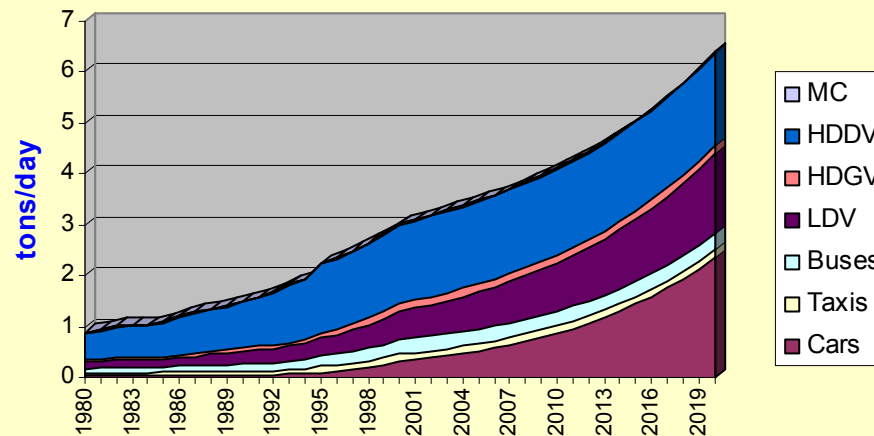
HC Emissions from Vehicles in Beijing



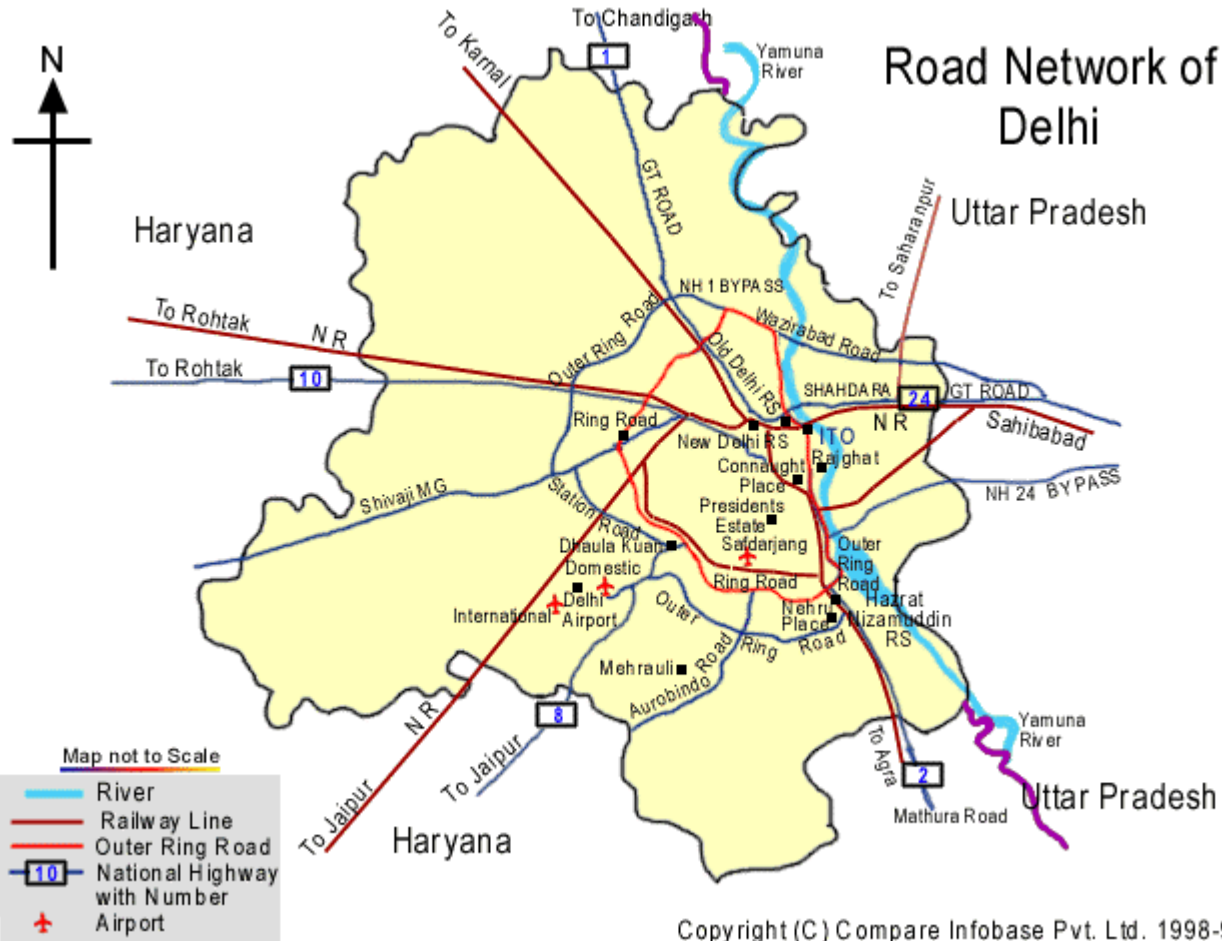
NOx Emissions from Vehicles in Beijing



TSP Emissions from Vehicles in Beijing



Delhi



New Delhi, India

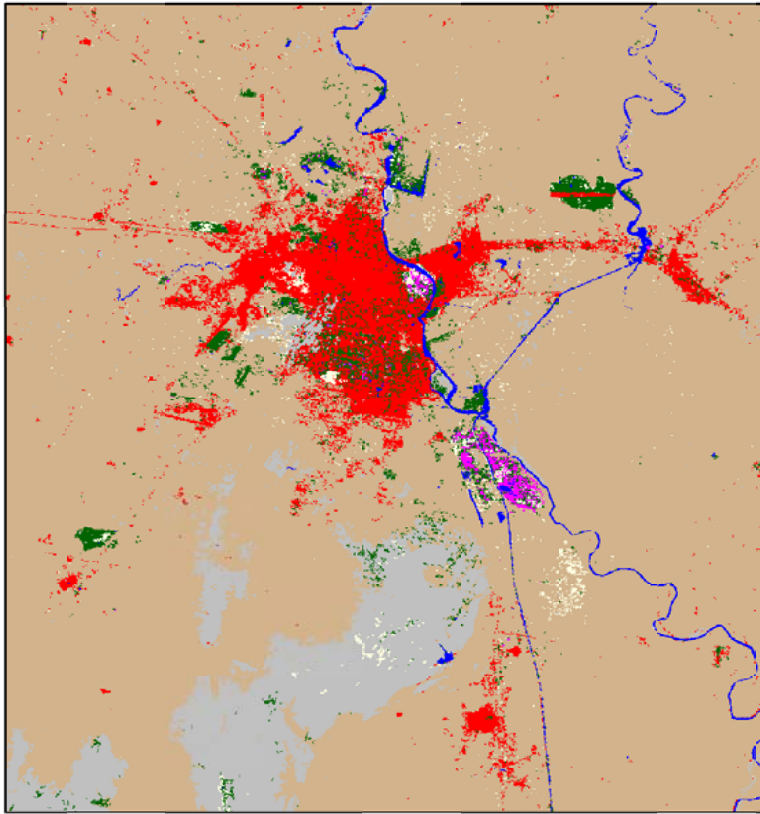


- 1 meter resolution black-and-white image of the Government District, New Delhi.
- IKONOS satellite collected the image on October 10, 1999.

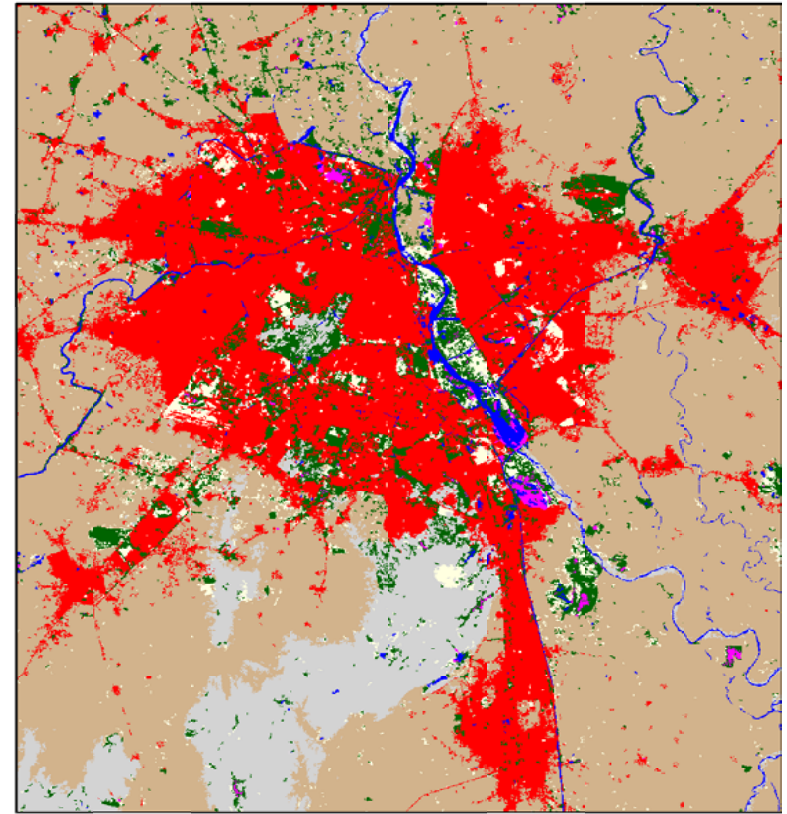
Land Use Change: Delhi 1974 - 1999 (25yrs.)

Increase in population of 4.2 million; 60,000 hectares of agricultural land lost

Delhi 1974 Land cover derived from Landsat MSS
acquired May 8, 1974



Delhi 1999 Land cover derived from Landsat TM
acquired April 21, 1999



Delhi's Vehicle Fleet

	1970-1971	1980-1981	1990-1991	1995
population (millions)	3.65	6.22	9.42	
# of vehicles	204,078	557,000	1,813,000	2,432,320

year	1996	1997	1998	1999	2001	2006	2011
# of vehicles	2,734,400	2,904,359	3,033,000	3,210,000	3,924,000		6,000,000
population (million)				13.42	14.37	17.16	19.51

- Delhi has 1% of all the country's population but 10% of the total vehicles registered in India (largest vehicle population in the country).
- Population more than doubled while number of vehicles changed by 9 times from 1970 to 1990.
- Vehicle numbers include two wheelers.

Delhi's Vehicle Fleet

- Average ownership of private vehicles: 178 vehicles/1000 people in 1995-1996. Total # of motor vehicles per 1000 people was 205 in 1993 (and 238 in 1998).
- Delhi has the highest road length in India: 1284km/100km² area (26,379km of total length in 1998/99)
- Car ownership (1995): 52 vehicles/1000 people

- Delhi has one of the highest per capita road lengths and lowest number of vehicles per unit road length when compared with large cities around the world.
- Delhi's roads, if good traffic management is applied, can accommodate 2-3 times the existing number of vehicles.
- Source: Indian Institute of Technology, May 1997

Congestion & Traffic Accidents in Delhi

Delhi	1972	1981	1991	1997	1999	2001	2011
road length (km)	8,380	14,320	21,670	25,949	26,379		
# of vehicles (millions)	0.214			2.848	3.21	3.924	6
Speeds (km/hr)	23	19	18	15		10	5

- Road length increased by 3 times from 1972 to 1997 in Delhi while # of vehicles increased by 13 times!
- TERI 1996: Delhi is the most congested city in India.
- Average speeds during peak hour range from 10 to 15 km/hr in central areas and from 25-40 km/hr in arterial streets. Delhi's traffic fatalities in 1993 were more than double those of all other major Indian cities combined.
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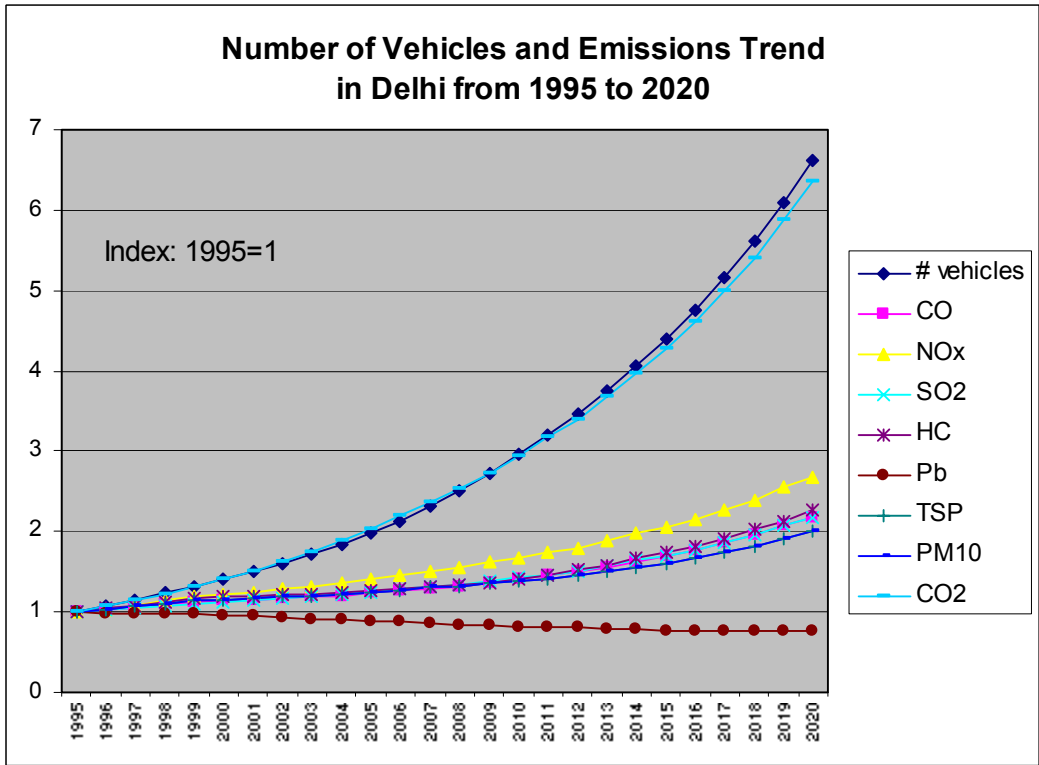
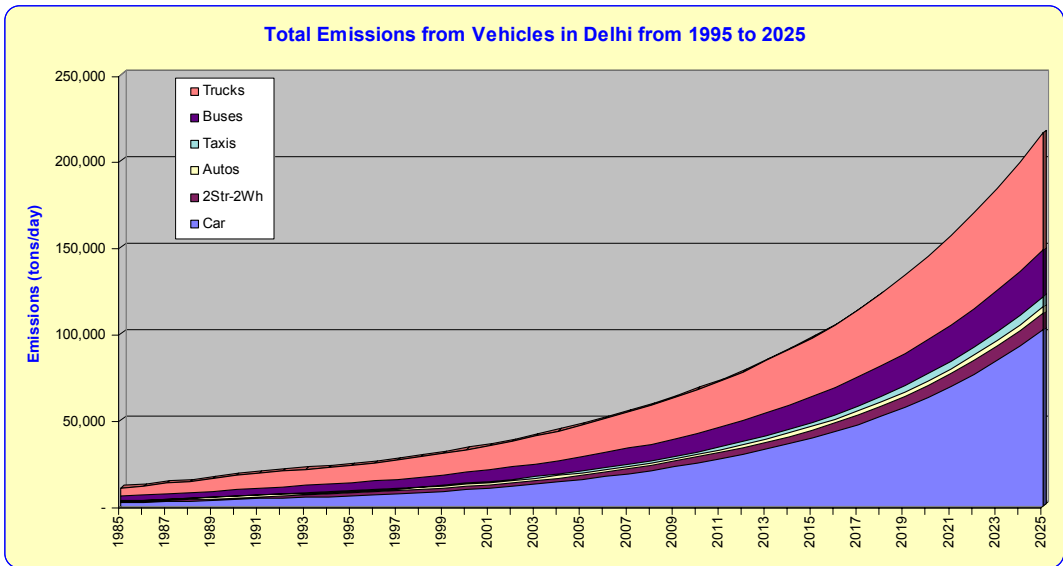
Current Road Accidents in Delhi:

Average No. of Persons Killed / Day - 5

Average No. of persons injured - 13

Buses contribute to the majority of the accidents

Source: <http://www.delhimetrorail.com>



Air pollution kills in Delhi!

Main sources of pollution are:

vehicular emissions
untreated industrial smoke
untreated water effluence



Air Pollutant Emissions (1990s):

Domestic - 8%

Industrial - 12%

Power Plants - 16%

Motor Vehicles - 64% (67% in 1997)

Percentage Share of Air Pollution by Various Sources in Delhi

(%)	1970-1971	1980-1981	1990-1991	2000-2001
Industrial	56	40	29	20
Vehicular	23	42	63	72
Domestic	21	18	8	8

- With the Supreme Court directive of relocating polluting industries outside Delhi, share of vehicular pollution will go up significantly.
- Vehicle emissions account for 65% of the air pollution in Delhi and cause a similar proportion of the 9,900 deaths due to air pollution each year.

WHO announces Delhi to be one of the top ten most polluted cities in the world!

- Particle levels in Delhi consistently remain 3 to 5 times the national standards and maximum levels have even reached 8 times the standards during the winter of 1998.
- Particulate pollution kills 1 person per hour in Delhi
- WHO: Delhi is the 4th most polluted city in the world in terms of SPM.
- One out of two policemen suffers from respiratory diseases and one in every four have been diagnosed positive for initial symptoms of tuberculosis (Times of India, October 1998).
- If air pollution is reduced to WHO annual average standards then 7500 premature deaths, 4 millions hospital admissions and sickness requiring medical treatment, and 242 millions of incidence of minor sicknesses (including RADs and RSDs) could be avoided in Delhi. (Source: Jian Xie, Jitendra J. Shah, Carter J. Brandon, "Fighting Urban Transport Air Pollution for Local and Global Good: The case of two-stroke engine three-wheelers in Delhi", 1998.)

Transport Sector and Emissions in Beijing & Delhi

- Delhi has 2 to 3 times more vehicles than Beijing.
- Delhi vehicles have 2 to 3 times higher fuel efficiencies.
- Higher VKT/day for Beijing drivers.
- Higher total emission from transport in Beijing for all pollutants except TSP (about 20 times higher in Delhi).
- Cleaner vehicles in Delhi (emission factors for all vehicles lower than Beijing ones except for TSP which is about 20 times higher).
- Beijing air pollution: higher SO₂ and NO_x concentration but lower TSP concentration compared to Delhi.
- Much more transport infrastructure in Delhi (high road area - 23% - and extensive length of roads).
- Higher speeds on Delhi roads.

Emission Factors in 1996 in Beijing and Delhi (g/km)

Delhi	CO	NO _x	SO ₂	HC	TSP	CO ₂
cras/jeeps/s.wagons	12.20	1.90	0.053	3.60	0.19	399
2wheelers	8.30	0.10	0.023	4.87	0.14	68
autorickshaws	11.75	0.26	0.03	6.97	0.27	298
taxis	20.48	1.95	0.053	4.17	0.19	399
buses	12.51	20.71	1.45	2.05	2.93	1233
trucks	8.50	14.07	0.98	1.39	1.99	838
Beijing						
Cars	64.57	1.79	0.187	6.64	0.011	399
LDV	75.68	4.71	0.217	13.92	0.013	466
HDGV	169.49	4.60	0.407	12.00	0.024	342.31
HDDV	23.07	45.40	2.644	7.58	0.529	1249
Buses	100.72	24.71	1.215	10.19	0.215	795.6
taxis	72.27	2.00	0.180	7.24	0.011	410
MC	17.13	0.09	0.050	5.91	0.003	186

- Emission factors of vehicles in Beijing are higher for all pollutants except for TSP which is about 20 times higher in Delhi.

Emission Factors in 2020 in Beijing and Delhi (g/km)

Delhi	CO	NOx	SO2	HC	TSP	CO2
cras/jeeps/s.wagons	4.61	0.68	0.05	0.82	0.04	399
2wheelers	2.83	0.1	0.02	2.63	0.08	68
autorickshaws	6.06	0.26	0.03	3.3	0.05	116
taxis	4.38	0.66	0.05	0.79	0.04	399
buses	6.68	11.46	0.56	0.91	1.31	1233
trucks	4.44	7.63	0.36	0.6	0.86	838
Beijing						
Cars	23.98	0.59	0.17	3.25	0.01	254
LDV	49.61	2.42	0.23	10.09	0.01	422
HDGV	187.04	2.54	0.50	17.16	0.03	215
HDDV	33.82	23.47	3.48	6.41	0.70	991
Buses	111.13	29.94	1.56	13.72	0.28	603
taxis	75.74	3.13	0.17	8.77	0.01	300
MC	39.62	0.09	0.05	5.74	0.00	160

- Beijing's emission factors in the future includes the detrimental effect of speed while Delhi's emission factors have no speed effect in their projections.

Total Emissions from Transport in Beijing and Delhi (tons/year)

1995	CO	NOx	SO2	HC	TSP	CO2
Beijing	1627111	120846	5759	235024	818	9922926
Delhi	252154	100489	6849	80393	15486	8135730
2000						
Beijing	2892822	171906	11793	397028	1216	17523711
Delhi	403094	171495	10771	134064	25012	15983254
2020						
Beijing	7149756	290540	41992	1132125	3278	60153968
Delhi	826388	404906	22422	272274	46397	77589630

- Higher total emissions from motor vehicles of all pollutants in Beijing except TSP which is much higher (about 20 times) in Delhi.

Beijing		Avg. VKT/day	Fuel Efficiency
Vehicle Type		km/day	km/lt 1995
Cars		81	7.69
LDV		75	6.67
HDGV		63	3.57
HDDV		48	3.33
Buses		148	4
taxis		212	8
MC		27	28.57

Delhi		Avg. VKT/day	Fuel Efficiency
Vehicle Type		km/day	km/lt 1995
cras/jeeps/s.wagons		27	14.18
2wheelers		13.5	44.44
autorickshaws		120	20.41
taxis		85	9.43
buses		186	3.7
trucks		100	8

- Delhi vehicles has 2 to 3 times higher fuel efficiencies.
- Beijing vehicle owners drive more on average than Delhi drivers.

Fuel Consumption for Transport in Beijing & Delhi (million lt/yr)

	1995		2000		2020	
	<i>gasoline</i>	<i>diesel</i>	<i>gasoline</i>	<i>diesel</i>	<i>gasoline</i>	<i>diesel</i>
Beijing	2929	325	5660	423	25390	630
Delhi	670	897	984	1171	4018	3102

- More diesel use (about 3 times in 1995 and 2000 and almost 5 times in 2020) and less gasoline use (around 1/5th) in Delhi.
- Although the percentage of diesel vehicles is similar in 1995 (6.5-7%), vehicle km traveled is very different in the two cities (19% in Beijing to 54% in Delhi). As a result, percentage of diesel fuel used for transport is 10% in Beijing while it is 57% in Delhi.
- Amount of diesel vehicles and diesel fuel use decreases by a lot in Beijing but much less in Delhi (2020: 1% of vehicles use diesel fuel in Beijing while 5% in Delhi and 2.4% of fuel use is diesel in Beijing while the same figure for Delhi is 44%).

Fuel Prices		1995	2000
Delhi	gasoline	0.58	0.55
\$/lt	diesel	0.29	0.26
Beijing	gasoline	0.25	0.31
\$/lt	diesel	0.23	0.29

- Diesel slightly less expensive (subsidized) and gasoline about 2 times more expensive in Delhi.

Incomes (average hourly wage):			
\$/hr	1995	2000	2020
Beijing	0.49	0.62	1.65
Delhi	0.37	0.47	1.25

- Averages wages about 32% higher in Beijing. GDP/capita of China is higher (more than 2 times) than India.

Beijing's and Delhi's Population, Vehicle Fleet, and Their Projections for 2020

Delhi, June 1997	# of Vehicles	% Modal Share	Beijing, 1997	# of Vehicles	% Modal Share
Cars/Jeeps/Station Wagons	720,921	25%	Cars	178,566	16%
MC/SC/MPD	1,906,232	66%	MC	289,231	26%
Taxis	15,362	1%	Taxis	58,976	5%
Autorickshaws	80,210	3%	LDV	438,157	40%
Trucks	142,290	5%	HDTV	77,053	7%
Buses	39,344	1%	HDDV	57,088	5%
			Buses	7,269	1%

		1995	2000	2020
Beijing	<i># of vehicles</i>	858,482	1,669,447	6,951,405
	<i>population</i>	11,705,000	12,511,209	13,860,955
Delhi	<i># of vehicles</i>	2,432,320	3,597,021	17,755,356
	<i>population</i>	11,232,000	13,964,000	21,937,000

- 2 to 3 times more # of vehicles in Delhi.
- Similar population in 1995 and 2000 in Delhi and Beijing but higher growth for Delhi resulting in a much larger population in 2020 in Delhi (due to controlled population growth in Beijing).

Value of Time, Fuel Costs, & Health Costs from Passenger Transport in Delhi

million \$	1995	2000	2020
Value of Time	67.97	192.7	9878.72
Fuel Costs	650.07	866.29	10783.42
Health Costs	472.72	1270.48	9664.11

million tons of	1995	2000	2020
carbon per year	2.33	4.53	21.51

Value of Time, Fuel Costs, & Health Costs from Passenger Transport in 2020 Under Different Scenarios for Delhi

million \$	2020	2020 with 2000's speed	Difference
Value of Time	9878.72	5174.57	4704.15
Fuel Costs	10783.42	8094.67	2688.75
Health Costs	9664.11	6175.15	3488.96
Total	30326.25	19444.39	10881.86

Value of Time, Fuel Costs, & Health Costs from Passenger Transport in Beijing

million \$	1995	2000	2020
Value of Time	182.33	743.63	19,514.94
Fuel Costs	641.00	1,569.22	19,509.85
Health Costs	975.18	1,898.65	15,117.62

million tons of	1995	2000	2020
carbon per year	3.40	6.02	19.47

Value of Time, Fuel Costs, & Health Costs from Passenger Transport in 2020 Under Different Scenarios for Beijing

	At 6 km/hr	At 16km/hr	With Tokyo's pass-trip mix
million \$	2020	2020	2020
Value of Time	19,514.94	9,348.51	8,631.77
Fuel Cost	19,509.85	15,281.42	17,879.25
Health Costs	15,117.62	11,794.00	8,635.45
Total	54,142.41	36,423.93	35,146.47

- On average a car in India weighs 800kg!
- On average cars in Delhi emit the following amounts of gases in 1 year:

1999	CO	NOx	SO2	HC
kg/car/year	160.2	16.26	0.4928	28.88
% gas weight of car weight	20.03%	2.03%	0.06%	3.61%
1999	Pb	TSP	PM10	CO2
kg/car/year	0.1971	1.577	1.281	3932
% gas weight of car weight	0.02%	0.20%	0.16%	491.52%

STRATEGY:

Move people not vehicles!

For a more efficient transportation system:

- * use low *energy use per passenger-km* modes
- * use low *emissions per passenger-km* modes
- * use modes with low *road space consumption per passenger*

Public transportation (buses, subway, light rail) achieves best values of above parameters. Therefore, their development is essential for attaining a sustainable transportation system in the future.

1. Clean fuels, clean vehicle technologies (electronic fuel injection, catalytic converters), new vehicle emission standards

2. Infrastructure investments
- build new roads to add more capacity

3. Traffic and demand management (manage existing street space to maximize available capacity and implement vehicle use controls)

4. I/M programs

5. Improve public transit

6. Land-use planning

Effect on:

- speeds
- emission factors
- fuel efficiencies
- traffic flow
- driver behavior

1. Reduction of emissions per vehicle kilometers traveled

2. Reduction of the total number of vehicle kilometers traveled

• New capacity attracts new demand and so traffic congestion will continue as long as incomes, population, and vehicle ownership continue to grow.

• So while managing road space, also implement vehicle use controls (rather than vehicle ownership controls) and develop public transit!

Pollution Control Options for The Transportation Sector

- Technology options (such as new vehicle emission standards, fuel reformulation, alternative fuels) alone are not enough - standards will still be exceeded
- Infrastructure investments (build roads and develop infrastructure to sustain the growth in transportation) - road area in Beijing is 6.1% and in Delhi is 23%, whereas in other developed cities goes up to 30%
- Traffic management options to reduce congestion and increase speeds (a set of transportation system improvements such as arranging the traffic flow direction, and installation and better coordination of traffic signals)
- Employer based controls such as giving transit passes, arranging telecommuting programs, providing ride-matching information and services, and modified work schedules
- Enhanced I/M and accelerated vehicle retirement programs
- Improve public transit as a good alternative for the commuters and also by options such as parking management and road fees discourage extensive use of cars
- Environmental education and awareness programs
- Land use management