Delhi's Transportation and Air Quality Future…

Current Policies

Simulation

Optimization

Current Policies: CNG for all buses Supreme Court regulation…

Annual Emissions Reductions from CNG Buses

tons/year	CO	NOx	SO2	HC	TSP	PM10	CO2
Case 1 minus Base Case	5,376	674	22	802	213	171	370,568
Case 2 minus Base Case	6,957	364	24	1,098	524	416	569,095

Base Case: Continuous technological advancement to meet fuel efficiency, emissions factors, and fuel quality improvements until 2020. Euro II standards in 2000, and Euro III, US Tier II, and Euro IV standards will be enforced for all new vehicles by 2005, 2010, and 2015 respectively. The corresponding fuel qualities for sulfur content of gasoline and diesel are also required to comply with the Euro norms accordingly. – spreadsheet simulation case

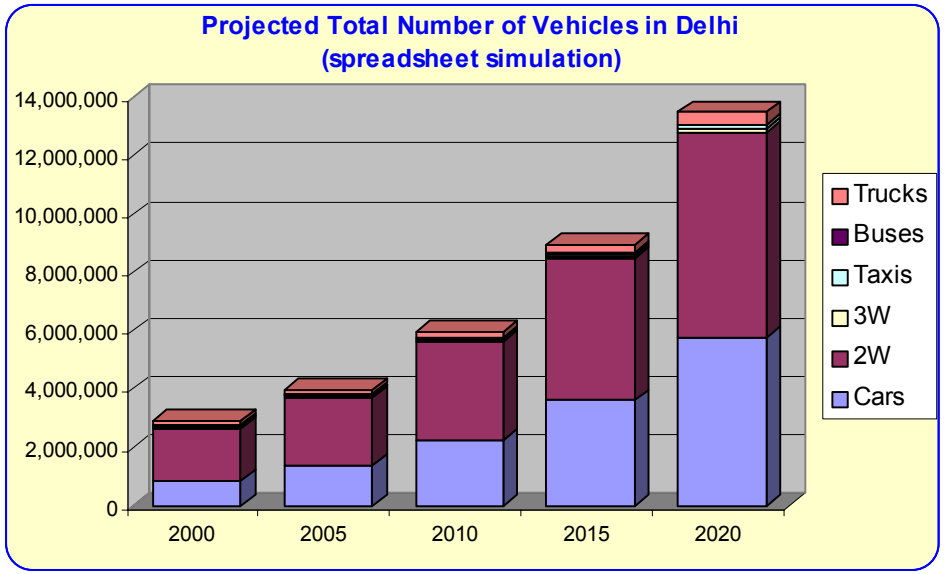
Case 1: Base case except starting 2001 all new buses coming in are CNG.

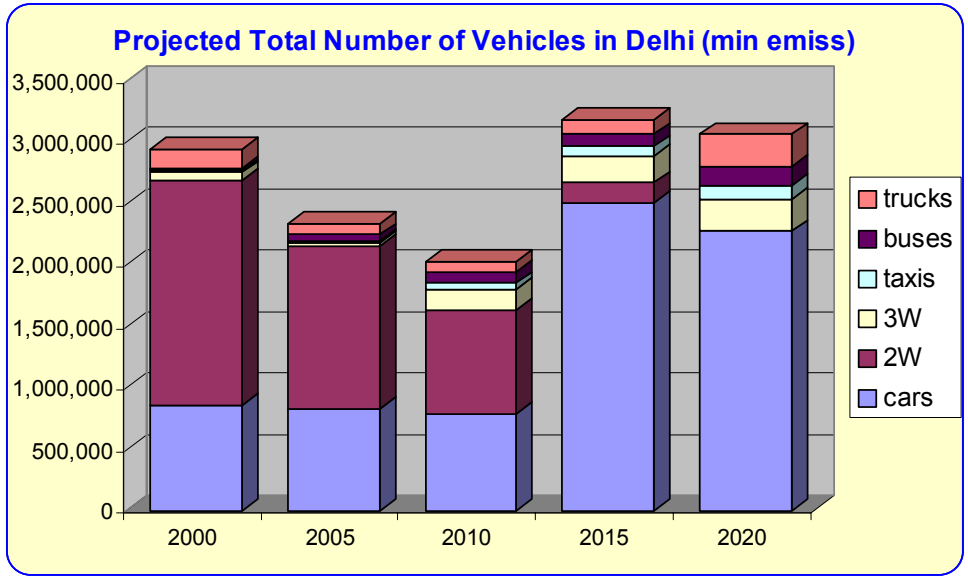
Case 2: Base case except all buses starting 2001 are CNG (new buses will be CNG buses and old buses will be retrofitted to CNG).

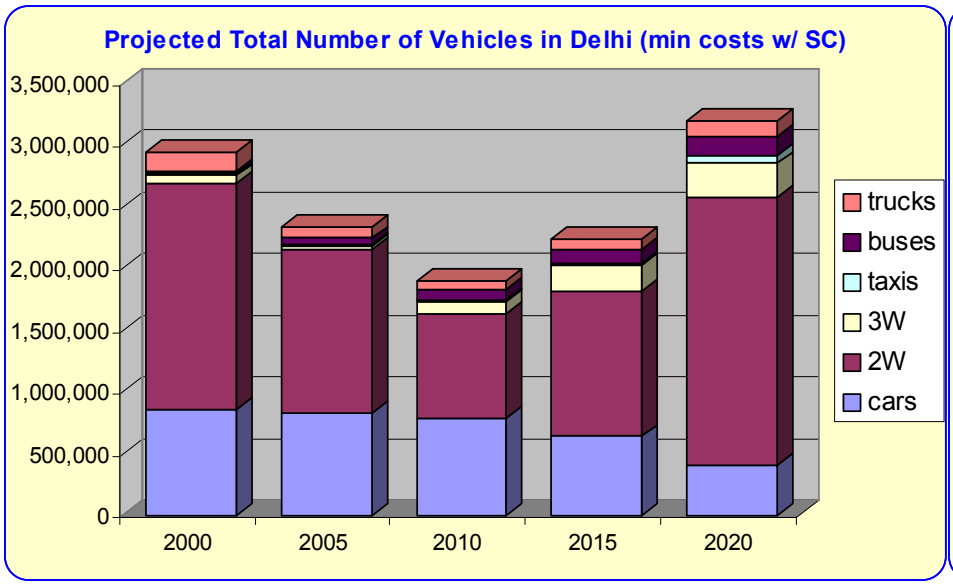
4 CASES – 3 Optimization Cases *and*

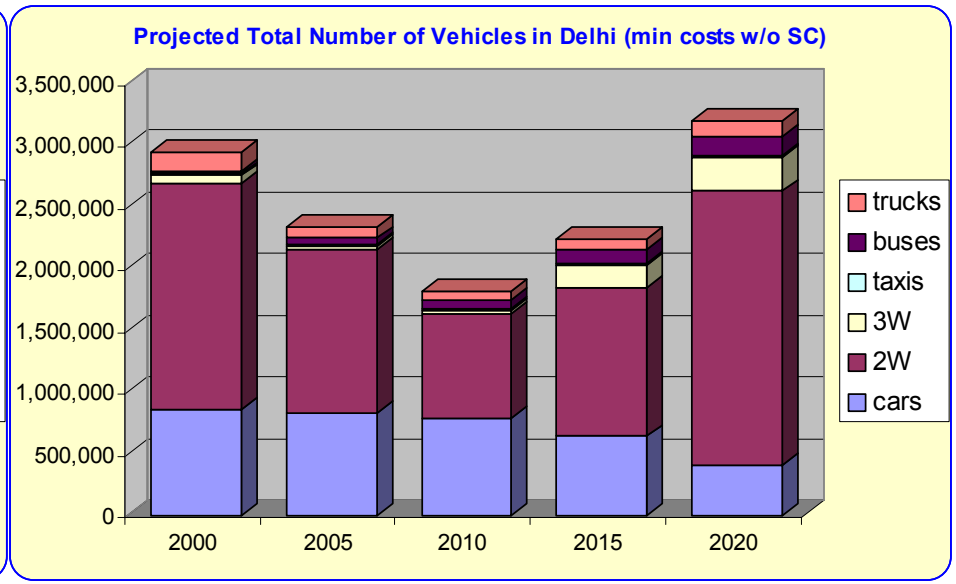
1 Spreadsheet Simulation Case

1. The spreadsheet simulation
2. Optimization with minimizing total costs (fuel costs, vehicle costs, O&M costs, infrastructure investments) including social costs (value of time and health costs)
3. Optimization with minimizing total costs without the social costs
4. Optimization with minimizing total emissions with only an accounting on total costs









Although total number of motor vehicles in the 3 optimization cases are similar, fuel types for each mode vary. Non-motorized vehicle numbers and rail use differ as well.

Total Fuel Consumption (f,t) – million liters/year

w/o SC	Gasoline	Diesel	Methanol	Ethanol	LPG	Electric	H2 Fuel Cell	CNG	Hybrid-Ga	Hybrid-Di
2000	879	915	0	0	0	3	0	21	0	0
2005	650	375	0	0	0	2	0	29	0	652
2010	491	61	0	0	0	56	0	43	0	1,135
2015	315	0	0	0	17	609	0	27	71	1,586
2020	176	0	0	0	128	884	0	18	143	2,153

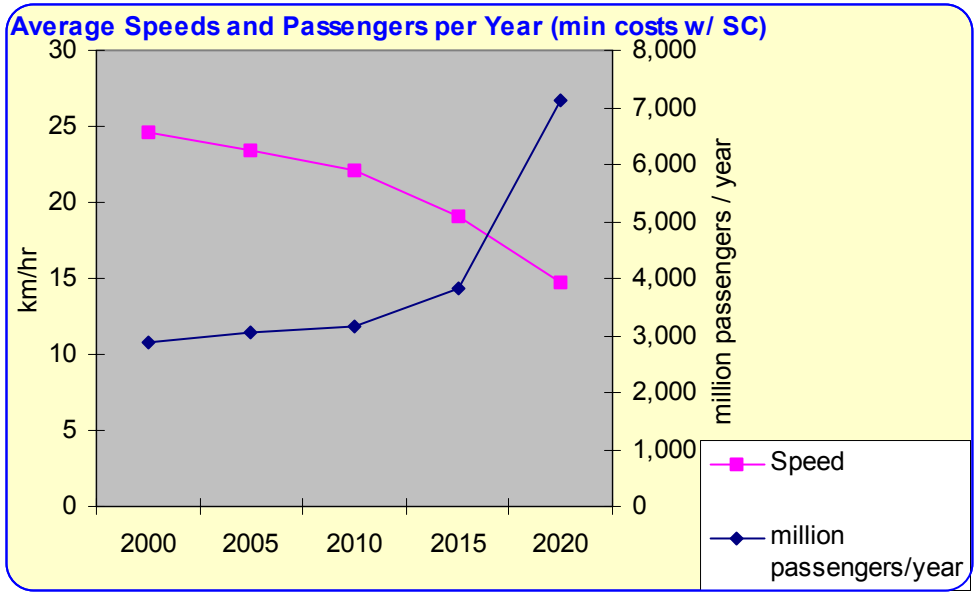
w/ SC	Gasoline	Diesel	Methanol	Ethanol	LPG	Electric	H2 Fuel Cell	CNG	Hybrid-Ga	Hybrid-Di
2000	879	915	0	0	0	3	0	21	0	0
2005	650	375	0	0	0	19	0	20	0	652
2010	491	61	0	0	0	232	50	19	0	1,148
2015	315	0	0	0	0	2,294	48	0	68	1,253
2020	176	0	0	0	100	2,389	45	0	139	1,836

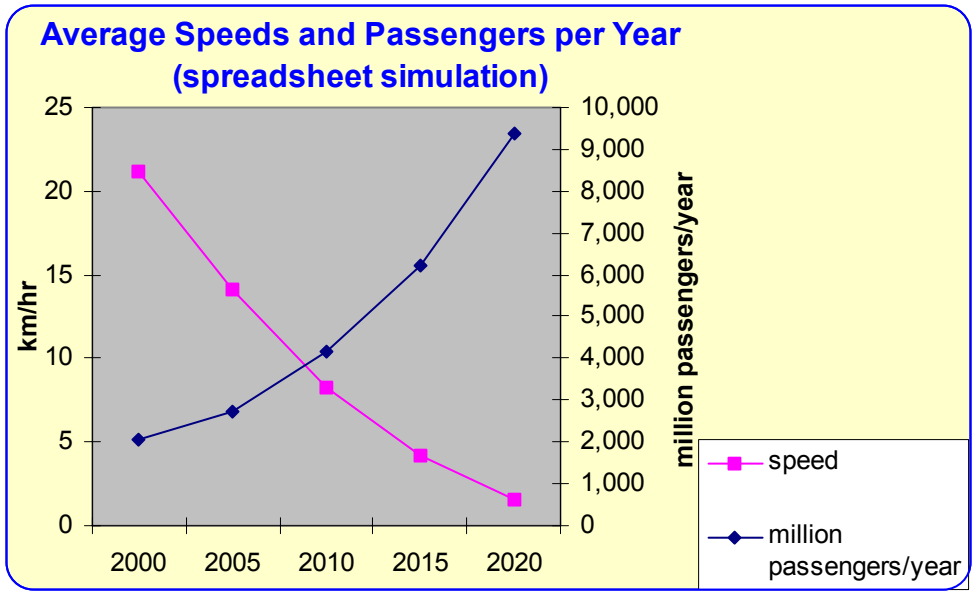
min emiss	Gasoline	Diesel	Methanol	Ethanol	LPG	Electric	H2 Fuel Cell	CNG	Hybrid-Ga	Hybrid-Di
2000	881	918	0	0	0	3	0	16	0	0
2005	653	378	0	0	0	327	516	15	0	0
2010	512	63	0	0	0	1,100	1,195	15	0	0
2015	334	0	0	0	0	4,936	1,271	0	0	0
2020	191	482	0	0	0	4,887	1,763	0	0	0

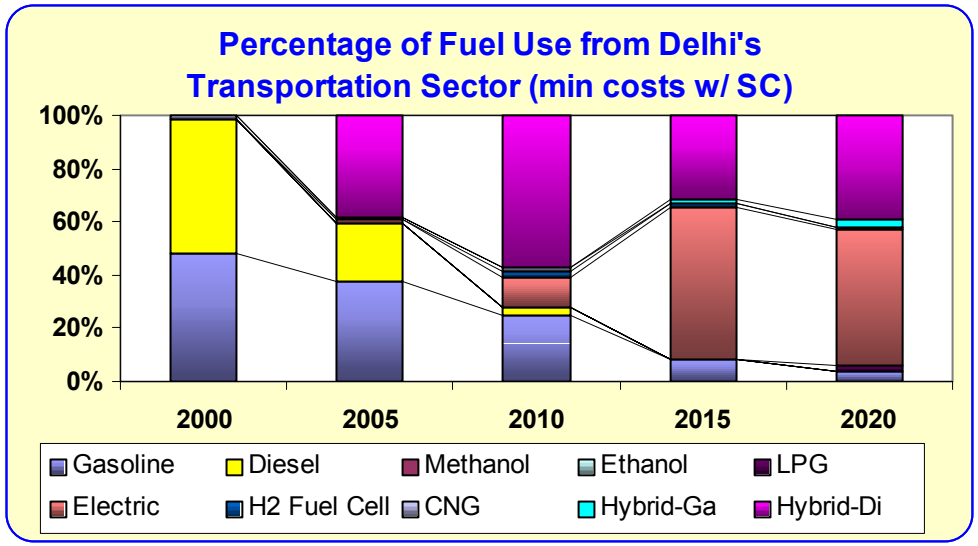
- more electric and hybrid vehicles in minimizing costs w/ SC case compared to w/o SC case

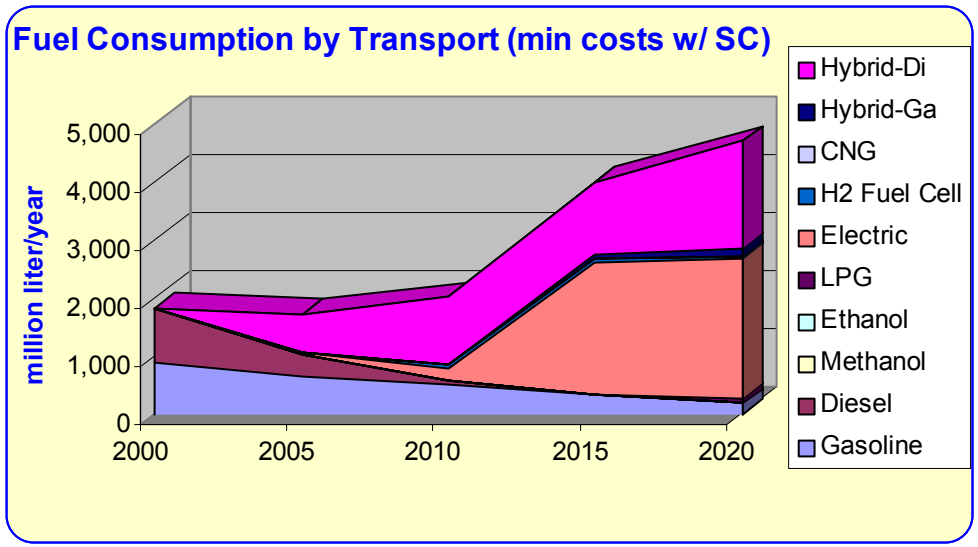
- some CNG and LPG use in minimizing costs w/o SC case

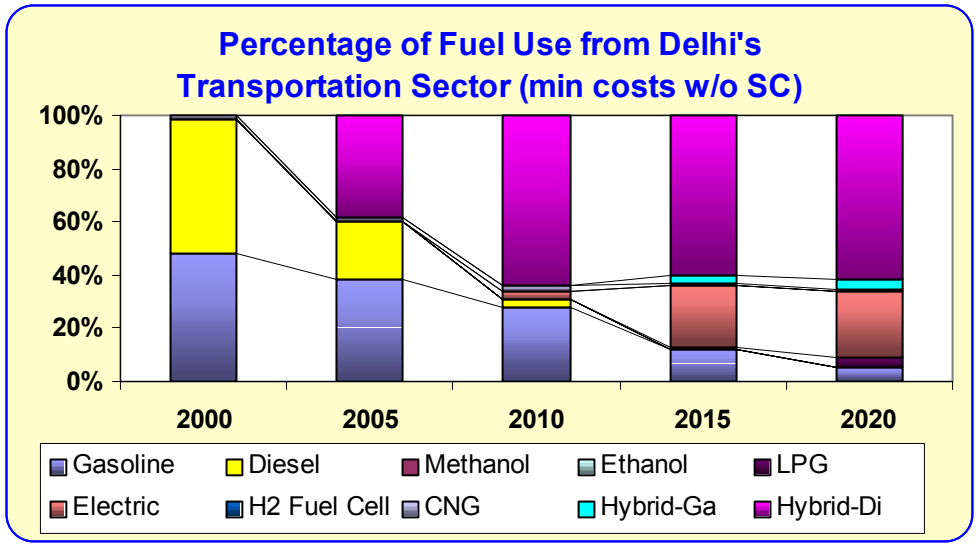
- electric and hydrogen fuel cell vehicles used in minimizing emissions case to achieve lowest possible emissions

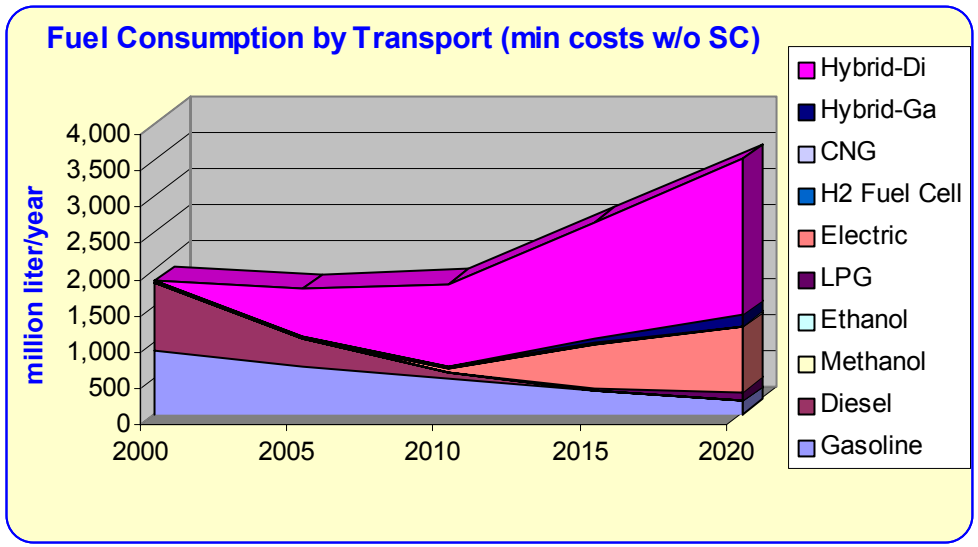

Average Speeds and Passengers per Year (min costs w/ SC)
km/hr
million passengers / year
30
25
20
15
10
5
0
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2000
2005
2010
2015
2020
Speed
million passengers/year

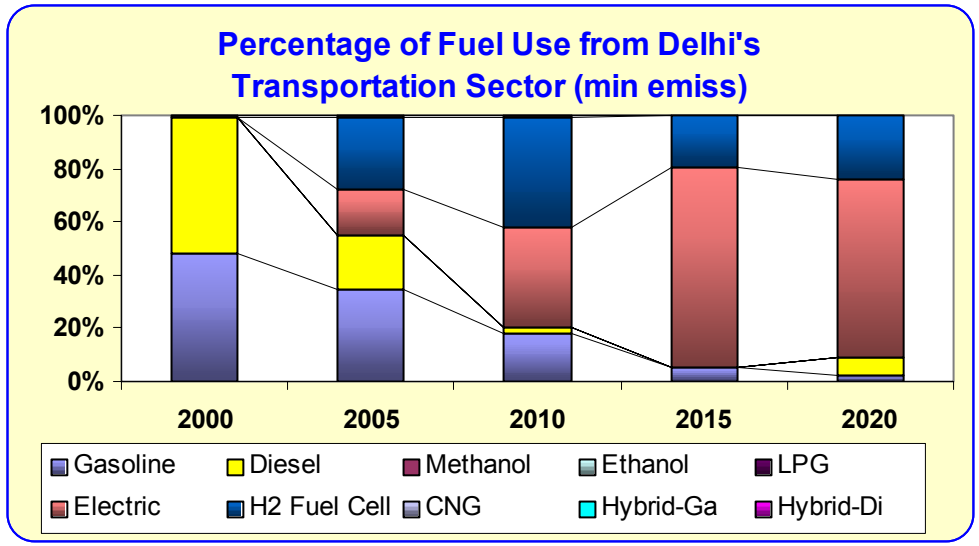

Average Speeds and Passengers per Year (spreadsheet simulation)
km/hr
million passengers/year
25
20
15
10
5
0
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2000
2005
2010
2015
2020
speed
million passengers/year

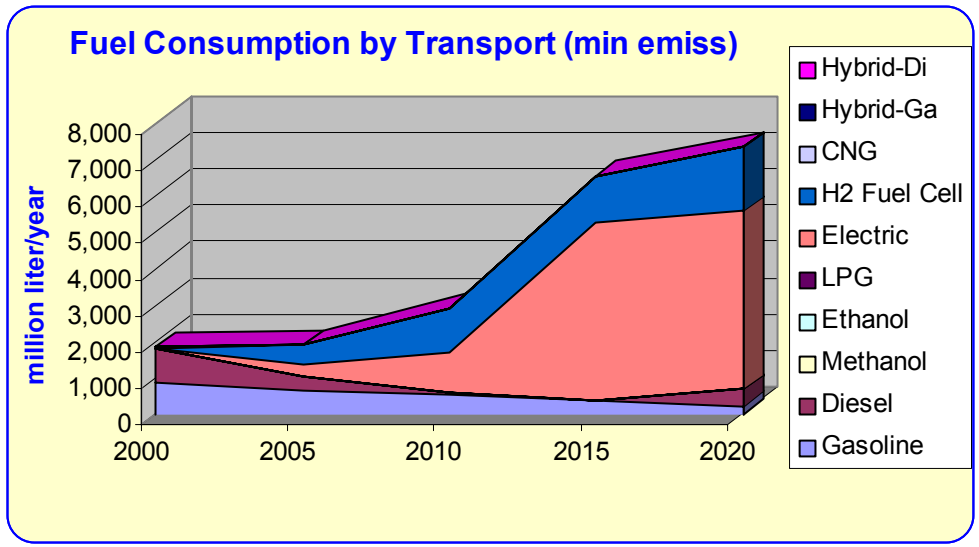

Percentage of Fuel Use from Delhi's Transportation Sector (min costs w/ SC)
100%
80%
60%
40%
20%
0%
2000
2005
2010
2015
2020
Gasoline
Diesel
Methanol
Ethanol
LPG
Electric
H2 Fuel Cell
CNG
Hybrid-Ga
Hybrid-Di


Fuel Consumption by Transport (min costs w/ SC)
million liter/year
5,000
4,000
3,000
2,000
1,000
0
2000
2005
2010
2015
2020
Hybrid-Di
Hybrid-Ga
CNG
H2 Fuel Cell
Electric
LPG
Ethanol
Methanol
Diesel
Gasoline

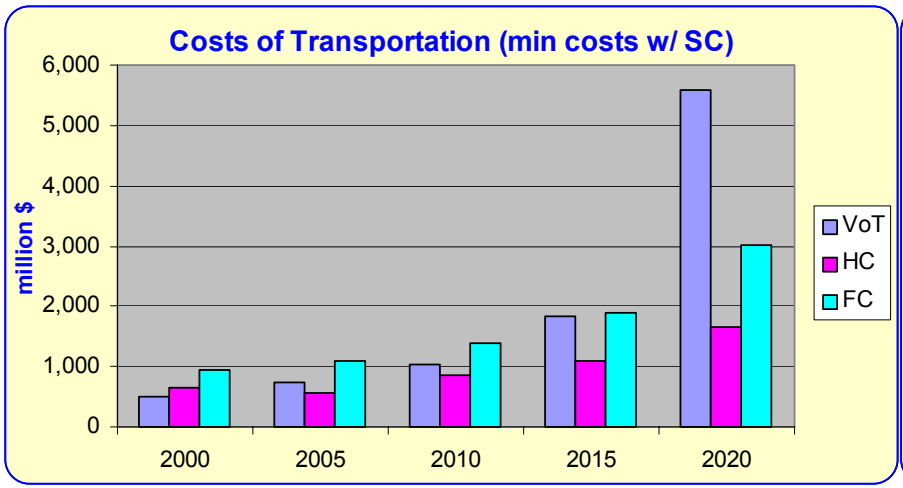

Percentage of Fuel Use from Delhi's Transportation Sector (min costs w/o SC)
100%
80%
60%
40%
20%
0%
2000
2005
2010
2015
2020
Gasoline
Diesel
Methanol
Ethanol
LPG
Electric
H2 Fuel Cell
CNG
Hybrid-Ga
Hybrid-Di

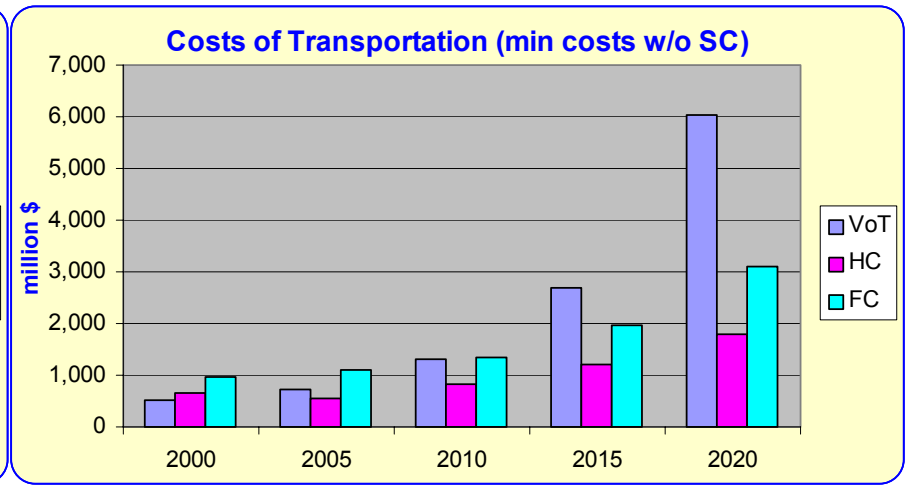

Fuel Consumption by Transport (min costs w/o SC)
million liter/year
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2000
2005
2010
2015
2020
Hybrid-Di
Hybrid-Ga
CNG
H2 Fuel Cell
Electric
LPG
Ethanol
Methanol
Diesel
Gasoline

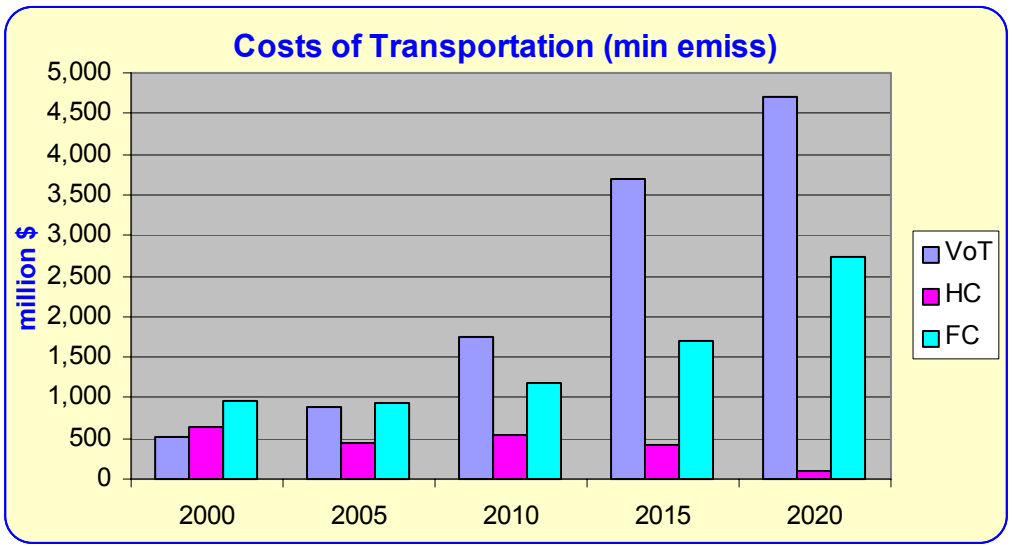

Percentage of Fuel Use from Delhi's Transportation Sector (min emiss)
100%
80%
60%
40%
20%
0%
2000
2005
2010
2015
2020
Gasoline
Diesel
Methanol
Ethanol
LPG
Electric
H2 Fuel Cell
CNG
Hybrid-Ga
Hybrid-Di


Fuel Consumption by Transport (min emiss)
million liter/year
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2000
2005
2010
2015
2020
Hybrid-Di
Hybrid-Ga
CNG
H2 Fuel Cell
Electric
LPG
Ethanol
Methanol
Diesel
Gasoline

Value of Time, Health Costs and Fuel Costs in 3 Optimization Cases

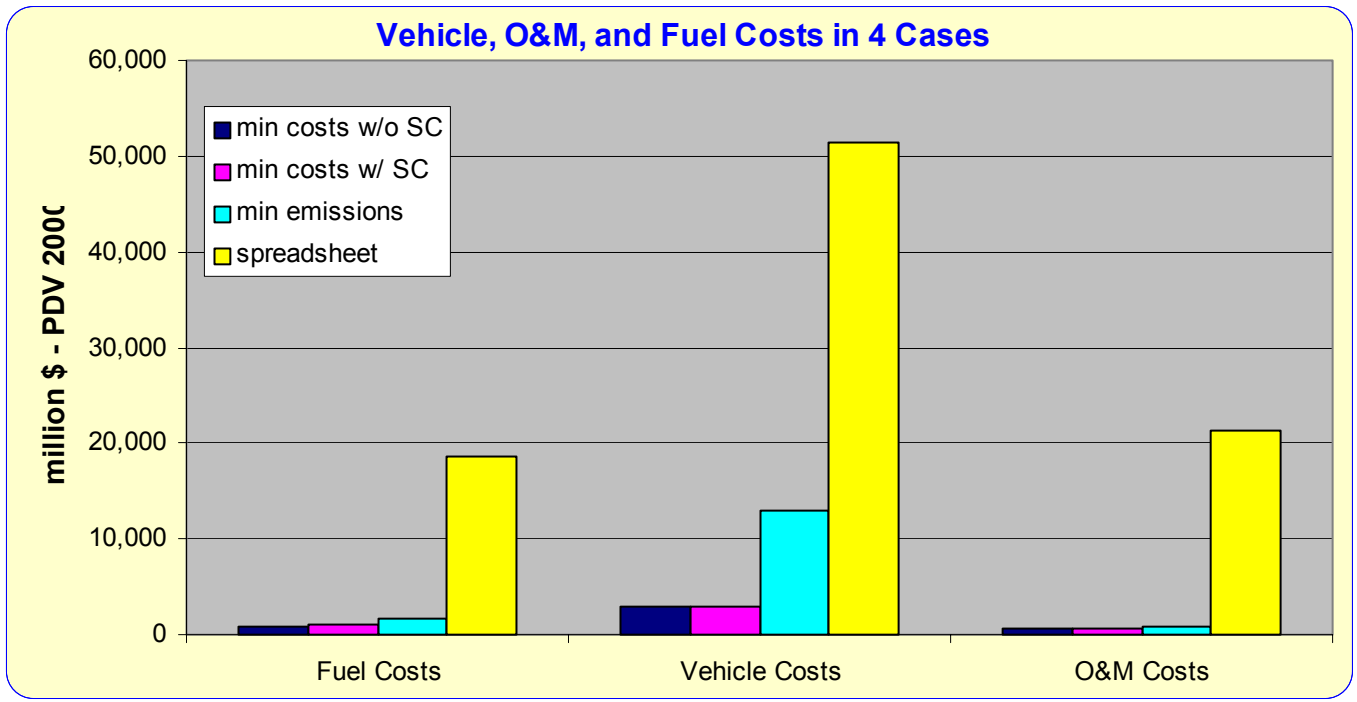






Present discounted value of the future 20 years of vehicle, O&M, and fuel costs for 3 optimization cases and the simulation case…

	min costs w/o SC	min costs w/ SC	min emissions	spreadsheet
Fuel Costs	880	962	1,642	18,698
Vehicle Costs	2,832	2,944	13,004	51,400
O&M Costs	708	716	900	21,265



		min costs w/o SC	min costs w/ SC	min emissions	spreadsheet
PDV of Total Future Costs (no SC)	*million $*	4,483	4,757	15,703	91,363
PDV of Future Fuel Costs	*million $*	880	962	1,642	18,698
PDV of Future Vehicle Costs	*million $*	2,832	2,944	13,004	51,400
PDV of Future OM Costs	*million $*	708	716	900	21,265
PDV of Future Rail Infrastructure Costs	*million $*	63	136	157	
PDV of Future Value of Time Costs	*million $*	2,203	1,867	2,497	
PDV of Future Health Costs	*million $*	1,093	1,056	552	
Health Costs in 2020	*million $*	1,778.85	1,657.87	95.24	2,210.97
VoT in 2020	*million $*	6,048.68	5,600.49	4,700.25	13,939.38
Fuel Costs in 2020	*million $*	3,116.03	3,002.69	2,736.52	8,134.81
# of motor vehicles in 2020		3,190,769	3,190,769	3,057,265	13,556,004
# of buses in 2020		159,538	159,538	152,789	53,569
# of subway / light rail in 2020		0 / 167	0 / 167	44 / 167	
# of bicycles in 2020		9,607,174	8,000,000	4,000,000	
# of tricycles in 2020		210,000	210,000	115,000	
Passengers in 2020	*millions*	7,686	7,116	6,134	9,378
Speed in 2020	*km/hr*	14.74	14.74	15.14	1.61 (5-6)
PM10 conc in 2020	*micrograms/m3*	18.86	17.49	0.99	23.59
SO2 conc in 2020	*micrograms/m3*	0.37	0.33	0.17	0.18
MTC in 2020	*million tons/year*	2.23	2.34	0.47	8.88
PMD in 2020		4,056	3,759	222	5,003
LYL in 2020		150,077	139,074	8,202	185,122
DALYs in 2020		410,087	380,066	21,758	507,035
PKM travelled in 2020	*bpkm*	500	500	514	354

Comparison of optimization with minimizing total costs and limiting bus numbers…

		min costs w/ SC	min costs w/ SC w/ 83,000 bus limit
PDV of Total Future Costs (no SC)	*million $*	4,757	28,513
PDV of Future Fuel Costs	*million $*	962	2,235
PDV of Future Vehicle Costs	*million $*	2,944	24,467
PDV of Future OM Costs	*million $*	716	1,581
PDV of Future Rail Infrastructure Costs	*million $*	136	229
PDV of Future Value of Time Costs	*million $*	1,867	32,230
PDV of Future Health Costs	*million $*	1,056	895
Health Costs in 2020	*million $*	1,657.87	974.01
VoT in 2020	*million $*	5,600.49	35,946.40
Fuel Costs in 2020	*million $*	3,002.69	7,967.15
# of motor vehicles in 2020		3,190,769	17,669,381
# of buses in 2020		159,538	83,000
# of subway / light rail in 2020		0 / 167	44 / 167
# of bicycles in 2020		8,000,000	13,000,000
# of tricycles in 2020		210,000	210,000
Passengers in 2020	*millions*	7,116	17,039
Speed in 2020	*km/hr*	14.74	0.81 (5-6)
PM10 conc in 2020	*micrograms/m3*	17.49	10.27
SO2 conc in 2020	*micrograms/m3*	0.33	0.19
MTC in 2020	*million tons/year*	2.34	2.92
PMD in 2020		3,759	2,208
LYL in 2020		139,074	81,707
DALYs in 2020		380,066	223,293
PKM travelled in 2020	*bpkm*	500	554