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OPTIMIZATIONS OF VEHICULAR EMISSIONS IN DELHI

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ABSTRACT

Delhi, the capital city of India, is very much plagued today by environmental degradation. Ever since its declaration as national Capital City in 1911, there has been a steady influx of people from every nook and corner of the country. Rise in population and growth in economic activities had led to increase in pollution in Delhi. For example, in 1971, there were only 0.2 million registered vehicles in this city, but their number has now crossed 4.6 million, which is more than the combined vehicular population of the other three metropolitan cities of India, viz. Mumbai, Chennai and Calcutta. In 1975, the vehicular population in Delhi and Mumbai were about the same; today Delhi has approximately three times more vehicles than Mumbai, the reason being that is the perhaps the only metropolitan city where the commuters are primarily dependent on a single mode of transport, i.e., the road. This paradigm has led to an enormous increase in the number of vehicles.^[2]

In the present study, we attempt to resolve the complexities of Delhi's transport sector, exploring what kind of a future is likely to be and how it may be altered to ensure minimum of environmental pollution. The instrument of Delphi research methodology was commissioned for the purpose. The authors studied the Indian transportation system and interviewed transportation experts, automobile manufacturers, engineering academicians and students the Indian automobile fuel processing units, and many other entities, for issues related to the transportation system of Delhi. The sectors studied included a wide spectrum of different modes of transportation, beginning with bicycles and cycle rickshaws, encompassing all the prevalent modes being used of automobiles, and extending up to fuel cells and solar powered vehicles, including advanced forms of fuel cells. Data gathered thus were analyzed, collated and compared with historical data, with a perspective to frame various policy options and strategies. In the first round of Delphi, about 300 experts were approached out of which 138 responded, spending on an average of 30 to 45 minutes of their rationed time. The responses of 38 respondents were found to be out of acceptable range, who were requested to participate in the second round, with a view to arrive at a consensus worthy of framing a feasible solution/policy framework.

In the ultimate analysis, we were able to come out with a conceptual strategy, which if implemented in its entire suggested framework, has the potential of bringing down the current environments pollution levels drastically and promises to be commercially viable too.

Introduction

Delhi is a rapidly expanding mega city. Population and vehicle use continue to expand, with vehicles being the principal source of severe air pollution. And yet, vehicle ownership is still

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fraction of that in industrialized countries. One study estimated that Delhi wastes \$300,000 in fuel daily through vehicles idling at traffic lights. Air pollution levels often exceeded several folds the ambient standards set by the Central Pollution Control Board, and are increasing. Local experts, planners, policy makers, and environmental advocates indicate that a large share of the problem with the transportation system in Delhi is that too many organizations are making disjointed decisions. While a draft bill has been proposed to enable the establishment of a unified metropolitan transport authority, there appears to be no serious effort to overcome this institutional handicap.

In recent years, a series of initiatives have been launched in Delhi to reduce vehicular emission like augment public transport; adhere to progressively strength standards for fuels and vehicles; scrap old buses, taxis and auto-rickshaws; establish inspection and maintenance of in-use vehicles; and promote use of clean alternative fuels. These initiatives have come not from the legislative or executive branches of government, but the Supreme Court. Under a constitutional provision that ensures a certain quality of life to residents of India, the Supreme Court heard several environmental lawsuits, a series of successful public interest litigation actions filed in 1996 and 1997.^[1,4] In response, the Indian Ministry of Environment and Forests created the Environment Pollution (Prevention and Control) Authority (EPCA) in January 1998. The EPCA's mission is to reduce pollution in the National Capital Region. It recommended the following strategies for immediately improving air quality.

1. Augment Public Transport
2. Reduce vehicle emissions by setting standards for fuels and auto emissions
3. Establish inspection and maintenance of in-use vehicles
4. Use clean alternative fuel
5. Improvement of road and flyover
6. Increase of sub site of public transport
7. Improvement of police transport
8. Use of high capacity buses
9. Accelerating the metro plan
10. Improve motor vehicle technologies.

The main aim of this research project is to control the growth of vehicles In this work we studied the Indian transportation system and interviewed transportation experts, automobile manufacturers, engineering academicians and students the Indian automobile fuel processing units, and many other entities, for issues related to the transportation system of Delhi.

Table 1: Growth of motor Vehicles in Delhi (Base year 1971)

Year	Population (Million)	No of vehicles (Millions)	Road length (Km)	Density (Vet/Km)	Density (Veh/1000 person)
1971	4.07	0.18	8380	21.48	44.27
1981	6.22	0.52	14316	36.39	83.76
1991	9.42	1.81	21564	84.08	192.44
2001	13.78	3.46	28508	121.26	250.82
Growth	3.39	19.21	3.40	5.65	5.67

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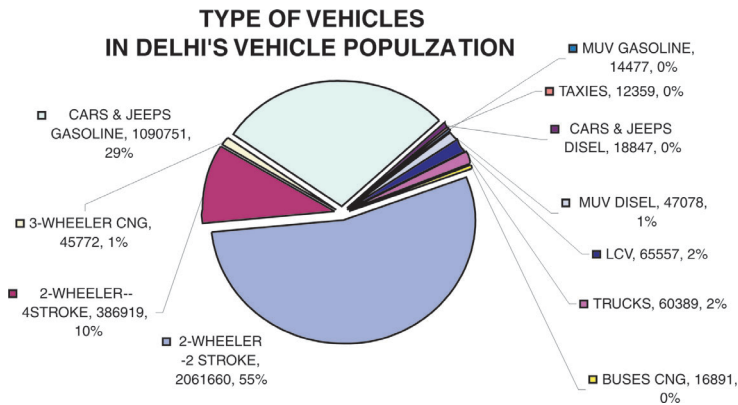


Figure 1: Composition of Delhi's Vehicle Population

Survey Work and Results

The sectors studied included a wide spectrum of different modes of transportation, beginning with bicycles and cycle rickshaws, encompassing all the prevalent modes being used of automobiles, and extending up to fuel cells and solar powered vehicles, including advanced forms of fuel cells. In the first round of Delphi, about 300 experts were approached out of which 138 responded, spending on an average of 30 to 45 minutes of their rationed time. The responses of 38 respondents were found to be out of acceptable range, which were requested to participate in the second round, with a view to arrive at a consensus worthy of framing a feasible solution/policy framework. Following survey form were used to gather the information from experts.^[5,6]

Survey form-Section A

Sr.No	Please indicate the level of your agreement with the following
	Question Level of agreement
1	Present Public Transportation System (PTS) of Delhi is very poorly organized.
2	There has been considerable improvement in the PTS after the introduction of Delhi Metro.
3	Govt. should take immediate steps to control the growth of private motor vehicles in Delhi.
*4.a	Cycle rickshaws are a source of nuisance and should be totally banned or
4.b	Cycle rickshaws should be operated on internal routes only and should be reorganized
**5.a	Entire PTS of Delhi should be operated by a single agency like DTC or
5.b	Entire PTS of Delhi should be operated by 5 to 10 competitors or
5.c	Entire PTS of Delhi should be operated by thousands of contractors as presently
6	Geographical Positioning System (GPS) enabled High Capacity Buses should be introduced with a marginal higher fare.
*7.a	Present vehicle Pollution Under Control (PUC) certification system is effective in controlling the vehicle emissions. Or
7.b	PUC system should be replaced with necessary Bi-annual inspection/maintenance system by manufacturer / authorized service providers.
8	All new Govt. Offices, Extensions etc. in Delhi should be preferably located outside Delhi
9	Frequency of present Metro trains should be increased during peak hours
10	Metro system should be further discounted for students/ salaried class and BPL card holders. (In addition to present 10% for smart card holders)

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	If you agree with the above please, indicate what should be revised % of discount
11	Public should be made aware of the Present Ring Rail System and its connectivity should be improved.
12	Public should be made aware of the Present Ring Rail System and its connectivity should be improved.

Survey form Section-B

	Please give your rating on a 10 points scale (0 to 10), More than one options may be given same rating. (0 = Absolute minimum/nil; 10= Absolute maximum/full) to the following:-
Sr.No.	Which of the following step you think is best to control the vehicle emissions
B 1	i Phasing out of old Vehicles ii Improving the PTS iii Augmenting the Delhi Metro iv Constructing more Roads/ Elevated corridors and Flyovers v Using advanced Engine technologies like CRDI, TDSI etc vi Development of Bicycle Tracks vii Removing encroachments from the roads viii Improving parking facilities ix More subways or foot over bridges (conventional) More subways or foot over bridges (with escalators) x Creating awareness for efficient and safe driving xi Controlling adulteration of the fuel and improving fuel quality
B 2	Please indicate your level of awareness about the following i Fuel Cells ii Mono Rail System iii Ring Rail System iv GPS v Hybrid vehicles vi Electric vehicles vii Euro Norms viii CRDI ix MPFI x Elevated corridor
B 3	Please give your rating to the following steps to control the growth of private vehicles i High taxation on vehicles ii Subsidized fares for PTS iii User friendly routes of PTS iv Enhancing punctuality of PTS services v Creating Networked System for hiring conveyances (taxi) vi Creating Networked System for hiring conveyances (auto rickshaw) vii Reorganization Ring Rail System viii Creating and strengthening of Mono Rail System ix GPS enabled High Capacity Buses
B 4	If you agree that increase / decrease in the road tax is one of the tools to control the growth of Private Vehicles, then please give your rating to the following :- i Increase the tax in proportion to the size of the Vehicle ii Increase the tax in proportion to the cost of the Vehicle iii Increase the tax in proportion to the age of the Vehicle iv Increase the tax, if the vehicle uses diesel as a fuel (using petrol as a reference) v Decrease the tax, if the vehicle uses CNG/LPG/Hydrogen as a fuel vi Decrease the tax, if the vehicle is operated on battery vii Increase/Decrease the tax in proportion to the fraction of Emissions per passenger viii Decrease the tax, if old vehicle are fitted with Catalytic converter/oxidation catalyst
B 5	Please give your rating to the following as a tool to control the vehicle emissions Your Rating i Using Bio-Diesel ii Using Ethanol/Methanol vi Using CNG/LPG as Dual-Fuel v Using Hybrid Vehicles

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iii	Using Hydrogen	viii	Using Electric Vehicles
iv	Using CNG	ix	Using Fuel Cells
v	Using LPG	x	Using Solar Vehicle

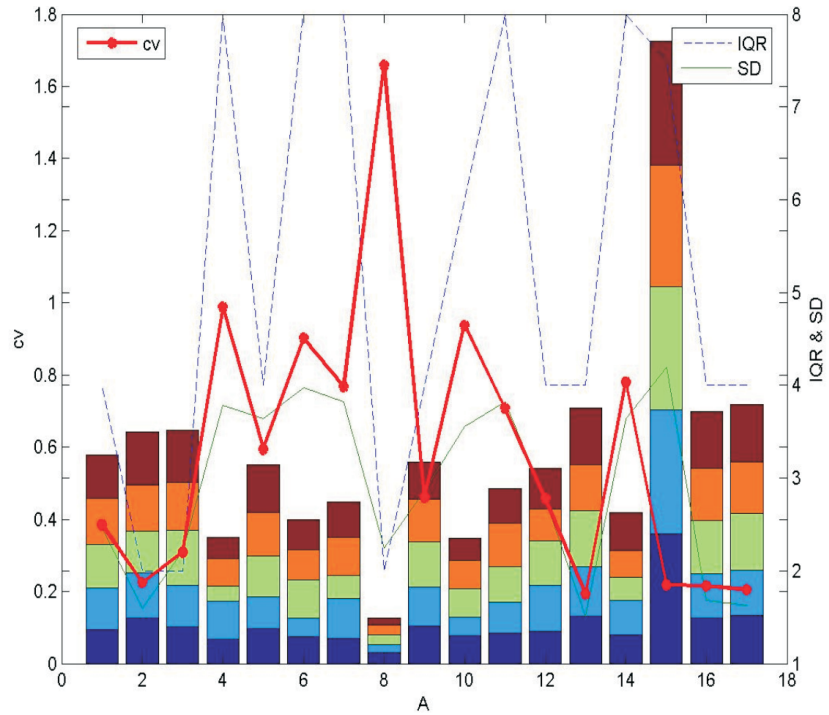


Figure 2: Results for the Survey section A

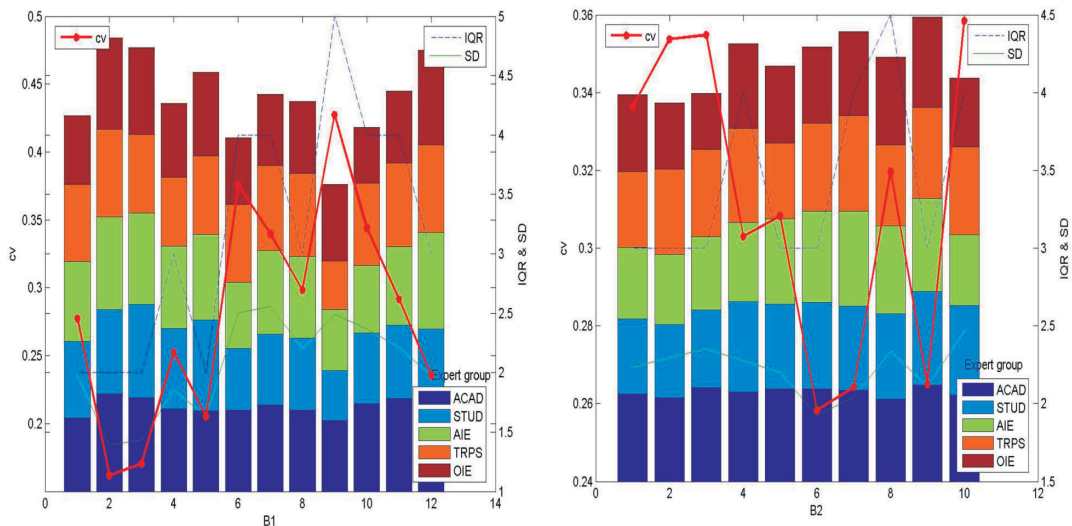


Figure 3: Results for the Survey section B1 and B2

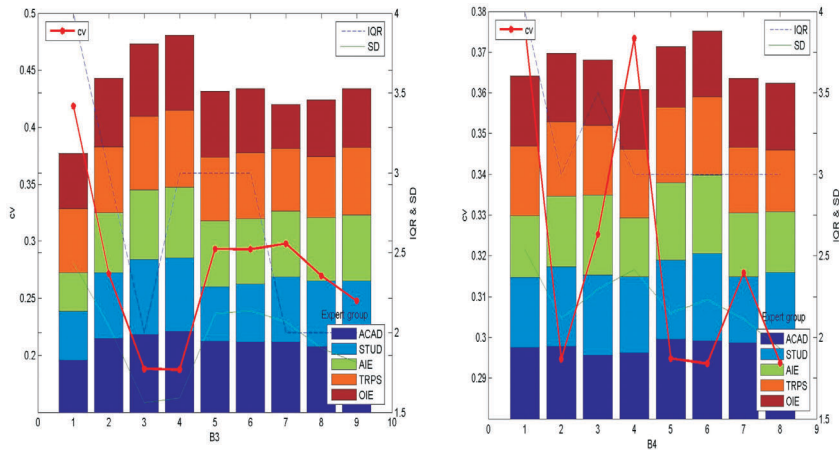


Figure 4: Results for the Survey section B3 and B4

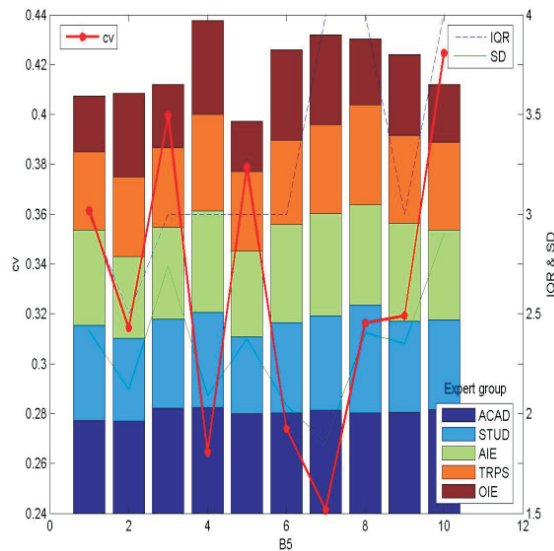


Figure 5: Results for the Survey section B5

The responses of above questionnaire were analyzed using Delphi methodology with Mat lab software. Statistically Acceptable RANGE followed for Delphi second round were

RANGE (H/L) = AVERAGE \pm 1.5 STDV, IF STDV \leq 2.0 , (H/L) = AVERAGE \pm 1.5 STDV , IF STDV $>$ 2.0

The results of the survey analysis are presented here (Figure A and B1 to B5) in graphical format using Mat lab for the data processing. These graphs are pictorial representations of various statistical parameters like Standard Deviation, Coefficient of Variance, Inter quartile range and averages for various expert groups surveyed.

In the ultimate analysis, we were able to come out with a conceptual strategy, which if implemented in its entire suggested framework, has the potential of bringing down the current environments pollution levels drastically and promises to be commercially viable too. Following are the appropriate actions needed for optimization of vehicle emissions in Delhi.

Main Strategic Options

Improvement of Public Transport

This premised on strong local leadership that restrains vehicle use and creates a transportation system that is economically, environmentally, and socially sustainable for the long term. This is possible if ambitious initiatives are mounted in the near future to reduce vehicle and energy use. The low emission entails a shift away from current trends. It requires aggressive leadership and strong support from a frustrated populace. In this the motivation for change comes from worsening air quality and a realization that Delhi is too poor to divert a large share of its resources to a transportation system that does not serve the needs of a large share of the population. Local leaders and institutions embrace a series of reforms aimed at enhancing transit services, managing land use growth, restraining car and energy use, and accelerating the use of leapfrog technologies and concepts. It is a future of creativity, urban organization, efficient growth, and improved quality of life. Steps are taken to improve mass transit, in part to restrain the purchase of personal vehicles. The Planned bus ways and rail transit lines are completed on time in 2020-2021. Importantly, local governments work together to link bus service to the new rail lines and bus ways. They also direct dense commercial and residential activities to areas immediately adjacent to rail stations. Private charter bus services are strengthened and expanded. Incentives are provided to private companies to offer these services, and to travelers to use them. Traffic managers provide special dedicated lanes for private and public buses to increase their speed relative to personal vehicles. Rider ship on high quality charter bus services increases from 12 percent of total bus rider ship in 2000 to 18 percent in 2020, and continues to increase thereafter. Use of non-motorized vehicles is encouraged as well, mostly to serve the very poor who cannot afford even low-cost mass transit. Subsidies for bicycle use also slow the purchase and use of motorized vehicles by the more affluent. A network of protected lanes for bicycle use is provided, often separated from motorized vehicle roadways, to reduce congestion and increase the safety of bicycle riders. Innovative transport services are created to provide personalized transport services at less cost and greater system efficiency than cars. Ideally, they are linked to conventional transit services.

One important component is car sharing, practiced to some extent now in Europe. In its most simple form, a group of neighbors join together to form a “club” in which they each have rights to use a pool of vehicles located at one or more sites in their neighborhood. In more elaborate versions that are assumed to proliferate through Delhi (in this low scenario), thousands of vehicles are scattered in clusters throughout the city, at apartment buildings, shopping and employment centers, and rail stations. Users pay a monthly fee plus a usage fee whenever they drive these vehicles. Since these are largely short term “rentals,” the vehicles tend to be used for several trips by several people each day. Initially, transactions are reutilized through sign-up sheets and telephone reservations, but electronic reservations and billing systems are eventually instituted. Car sharing services respond to the desire for personal transport in a manner that is attractive from a societal perspective. Travelers gain access to vehicles when they want them for special errands (e.g., to deliver furniture), and social, business, and work trips without having to purchase one. The immediate benefit of car sharing is access to personal transport at reduced costs. Importantly, participants do not become wedded to the use of a personal vehicle. It is widely observed around the world that once a person buys a personal vehicle, his or her use of mass transit falls significantly. Many car owners no longer consider alternatives to their vehicle, even when mass transit is easily accessible and convenient. Thus, car sharing slows the transition to larger, less efficient vehicles. It also reduces demand for parking since the vehicles do not stay in one location very long. Car sharing may be the first step in creating other no conventional personalized transport services. Incentives and

disincentives are provided to restrain the purchase and use of personal vehicles. An effort is made to assure that vehicle owners pay their fair share of building and maintaining roads. These measures include an annual registration fee tied to the size of the vehicle and variable vehicle purchase taxes, also based on vehicle size and engine efficiency.

CNG Conversion

The use of cleaner burning natural gas fuels by light duty vehicles is accelerated. All taxis and one-third of all personal cars are powered by CNG by 2005. By 2020, two-thirds of all cars run on CNG. All scooters switch from two-stroke to efficient four-stroke engines, and three-wheelers gradually shift to propane use. The net effect of these initiatives is greater access to higher quality mass transit for most people at reduced cost to individuals and society, and with less environmental impact. Rider ship for buses and rail increases from 49 percent of all passenger travel (measured as passenger-kilometers) in 2000 to 53 percent in 2020, and would continue increasing thereafter. Meanwhile, car travel drops from 30 percent of all motorized travel to 24 percent (of which 5 percent are more efficient mini cars) in 2020. Total motorized travel increases from 94 to 400 billion kilometers, 20 percent less than the business-as-usual scenario. Non-motorized travel increases from 9 to 40 billion passenger-kilometers, more than 50 percent higher than the Business as usual scenario.^[3]

Increase of Subsidies on Public Transport

There are many ways to restrain the rapid growth in vehicle use in Delhi. Experience worldwide has shown that an approach aimed at both demand and supply is most effective. The demand approach discourages the use of personal vehicles and encourages the use of alternative modes. This can be accomplished by increasing the cost of driving to reflect the large infrastructure costs of accommodating vehicles and the costs they impose on the environment. Increased parking fees, fuel taxes, and registration fees and greater incentives for carpooling are options. The supply approach is to enhance the supply and quality of infrastructure for non-car modes. This includes building and maintaining sidewalks, bicycle lanes, and rail and bus infrastructure. Traffic management techniques such as downtown pedestrian zones, dedicated bus lanes, and traffic signals that favor buses could also be successful. Because earlier attempts at making downtown areas more pedestrian friendly have failed, future attempts would likely require education programs such as outreach to downtown shop owners. Creativity is needed in fashioning effective initiatives. One suggestion for mitigating opposition to new taxes and fees is a polluter-pays system that rewards environmentally friendly technologies and fuels while imposing charges on more polluting vehicles. Mass transit is often considered one of the best low-polluting alternatives to cars and motorcycles, and Delhi's investment in the multi-modal transit system of rail and bus ways enjoys strong support from policymakers.

Use of High Capacity Buses

Traffic management techniques such as downtown pedestrian zones, dedicated bus lanes, and traffic signals that favor buses could also be successful. Because earlier attempts at making downtown areas more pedestrian friendly have failed, future attempts would likely require education programs such as outreach to downtown shop owners

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Court-approved directives based on those strategies are now driving the planning and management of Delhi's surface transport system. One outcome has been the adoption of increasingly stringent emission standards for new vehicles. The new Indian standards will require use of international state-of-the-practice emissions control technology. Enforcement has been weak, but the ready availability of this technology on the world market and the relative ease of regulating a limited number of vehicle suppliers suggest that compliance is likely to improve and alternative fuel use in Delhi that will affect air pollution, energy use, and GHG emissions. Only one is meeting the deadline, but considerable progress is being made. Compliance with these directives can be expensive. On the one hand, compressed natural gas (CNG) and liquefied petroleum gases (LPG) are less expensive than gasoline. If vehicles are used intensively, the full lifecycle cost of owning and operating CNG and LPG vehicles will be less than for a comparable gasoline vehicle. However, the initial cost of a vehicle outfitted for these fuels, is somewhat greater due to the cost of the high-pressure tank needed to store the fuels. Each CNG bus, for example, currently costs about 60 percent more than a diesel bus (about \$12,000 extra). In many cases, the initial cost is so high that it outweighs by a large margin the long-term economic benefits. As the technology matures, this cost differential is expected to diminish, but not disappear, primarily because of the cost of high-pressure fuel storage tanks. So far, debate over the higher cost of alternative fuel vehicles has been muted.

Improvement of Roads and Flyovers

In this sequel to last year's technical evaluation of the CNG bus technology we attempt another assessment. This study once again confirms that maintaining the quality of Delhi's CNG program is an even greater challenge than introducing CNG technology in the city. The process is still riddled with problems. The reason is that the government had delayed the firming up of rules and regulations for implementing the CNG program as mandated by the Supreme Court. Inert official response to meet the challenges of introducing a new technology could destroy this crucial strategy to control particulate emissions in Delhi.

References

1. Urvashi Narayan and Alan Krupnick (2007), The Impact of Delhi's CNG Program on Air Quality, RFF DP 07-06, February
2. Towards Cleaner Air: A Case Study of Delhi by Department of Environment, Government of NCT of Delhi and Delhi Pollution Control Committee
3. M N Karimi and B K Nath, (2004), Implementation of Compressed Natural Gas Technology in Delhi Transport System, *Proceedings of GLOGIFT*, March 13-15,
4. Sandhya Wakdikar, (2002) Compressed Natural Gas: A Problem or a Solution?, *Current Science*, 82(1), 10 January
5. Om Prakash Sharma, (2000), Management of Flexible Manufacturing Technology : A Study in Indian Context, Ph.D. Thesis, , University of Delhi
6. Dr. Hansraj Pal ,Educational Research,2004 ,Madhya Pradesh Hindi Granth Academy