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Technical, Regulatory and Economic Measures to Abate Vehicular Emissions in Urban Areas in Indian Context

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A B S T R A C T

Human activities generate three sources of air pollution: stationary or point, mobile, and indoor. In developing countries especially in the rural area, indoor air pollution from using open fires for cooking and heating may be a serious problem. Industries, power plants etc. are the cause of stationary air pollution. But in urban areas – both developing and developed countries, it is predominantly mobile or vehicular pollution that contributes to overall air quality problem. Air quality crisis in cities is mainly due to vehicular emissions. Transportation systems are increasing everywhere and the improvements in technology are insufficient to counteract growth. Transport sectors contributes a major share to environmental pollution(around 70%).A among these pollutants CO is the major pollutant coming from the transport sector contributing 90% of total emission. Hydrocarbons are next to CO. It is indeed interesting to observe that the contribution of transport sector to the particulate pollution is as less as 3.5%,most of the SPM are generated due to re-suspension of dust out of which PM10 is the most prominent air pollutant. NOx is another important air quality indicator. All these situations indicate that air pollution becoming a major problem in Indian context and there is an essential need to built up healthy environment and increase level of research around the world. The present study is a review of an assessment model for emitted pollutants and effective strategies to reduce air pollution due to road transport.

Keywords: Air Pollution, Vehicular Emissions, Vehicular Pollution, Control Strategies

1. Introduction

Deteriorating air quality is a major environmental problem in many Indian cities. Air pollution levels in most of the Indian cities exceed the national and world health organization guidelines and threaten human health and quality of life. Although urban air quality in most of the industrial countries has been controlled to some extent during the past two decades in many cities it is worsening and becoming a major threat to the health and welfare of people and the environment. In most of the Indian cities the pollution loads are far above acceptable levels and Delhi has acquired the dubious distinction of being the second most polluted city in the world and pollution stress at other Metropolitan cities viz, Kolkatta, Mumbai and Chennai are on the increasing trends.

Air pollution has local, regional and global effects. At local level, some of the air pollutants (like particulates, hydrocarbons, Nitrogen oxides, carbon monoxide) affect human health. They are responsible for hundreds of thousands of deaths, respiratory, coronary and other diseases including cancer. At regional level, air pollutants like sulpher dioxide and oxides of nitrogen react with the moisture in the air to form sulphuric acid and nitric acid which are transported by winds (sometimes hundreds of Kilometers) before falling on earth by acid rain. Acid rain has environmental effects associated with damage to crops and acidification of soils and surface waters. Other environmental impacts include damage to buildings and structures, vegetation, forests, reduced visibility etc., The global warming pollutants (carbon-di oxide, methane, nitrogen oxide, etc) popularly known as green house gases

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results in climate change and global warming. Global warming affects human health, agriculture and rise in sea levels. The effects of climate change, heat waves, drought conditions etc, are already being felt in the recent years in the Indian sub continent.

Vehicles are responsible for fine particulates in the ambient air, Diesel vehicles and two stroke and three wheelers contribute to particulate emissions. While vehicles are responsible for about 20 % of the particulate emissions in the ambient air, they are responsible for about 60 to 70% of PM10(Respirable particulate matter) in the ambient air. One of the major reasons for higher RSPM levels in Delhi and other cities is due to higher number of two stroke two wheelers and diesel vehicles.

The worst thing about vehicular pollution is that it cannot be avoided as the emissions are emitted at the near-ground level where we breathe. Pollution from vehicles gets reflected in increased mortality and morbidity and is revealed through symptoms like cough, headache, nausea, irritation of eyes, various bronchial problems and visibility. The pollution from vehicles are due to discharges like CO, unburned HC, Pb compounds, NOx, soot suspended particulate matter (SPM) and aldehydes, among others, mainly from the tail pipes.

2. Vehicle Technology and Emissions

Vehicle technology improvements can dramatically reduce pollutant emissions and improve fuel efficiency. Changes in engine technology can achieve very large reductions in pollutant emissions. Such changes are most effective when incorporated in new vehicles. The most common approach to incorporating such changes has been through the establishment of vehicle emission standards. The establishment of emission standards has been a major impetus for research and development of engine designs and pollution control technologies. Major advances in this area have come from engine modifications, exhaust after treatment devices (catalytic converters and trap oxidizers), on-board canisters, on-board diagnostics etc., Major reduction in vehicle pollutant emissions are possible through changes in technology at relatively low cost, and, in many cases with a net savings in life cycle cost as a result of better fuel efficiency and reduced maintenance requirements.

Three waves of technology developments and innovations are sweeping through the automotive industry in the world. The first wave of innovation is aimed at increasing the energy efficiency of conventional engines. Better fuel efficiency not only saves fuel, it is also reduces emissions, especially CO2 emissions which cause green house effect. Improvements in the design of combustion chamber, ignition system, electronic fuel injection, increasing the number of valves per cylinder etc can substantially improve fuel economy and reduce pollutant emissions.

The second wave is aimed at reducing pollutant emissions from conventional gasoline and diesel vehicles. They include improvements in combustion process, in addition to exhaust gas after treatment (viz catalytic converters, particulate traps etc) and use of cleaner burning fuels. These changes are coming in the vehicles manufactured in India in response to the country's adoption of stringent emission standards.

A third wave of innovations is more radical. It involves the transition away from internal combustion engines to zero-pollution and ultra-low pollution vehicles viz electric propulsion vehicles and electric hybrid vehicles. These innovations have the potential for the greatest reduction in pollutant emissions and green house gases. The use of electric propulsion systems-using batteries, fuel cells and electric hybrid vehicles-would improve energy efficiencies by 50 percent or more with much less pollution. These technologies are under commercial trials in many countries including India and their costs are dropping quickly and could become cost-competitive with conventional in a short period. Compressed Natural Gas (CNG) buses are under commercial operation in Delhi and Mumbai. Battery operated electric vehicles made in India are gradually penetrating into the market. Electric hybrid buses are likely to come on Indian roads shortly. But pricing is central to both, developing and deploying technology. The Government can held and encourage innovation in vehicle technology through subsidies and reforming taxation at Central and State levels.

In Indian cities, two wheelers are responsible for about 75% three wheelers for about 5%, cars for about 10% and buses and trucks for about 10% of the total pollution loads (1). Health effects-wise, fine particulates are the most serious and studies indicate that two and three wheelers and diesel commercial vehicles in India contribute to more than 70% of the ambient fine particulates. While two and three wheelers and commercial vehicles are responsible for bulk of the pollutant emissions, their technology in India for reducing emissions needs to be improved. Most of the car manufacturers in India have foreign collaborations for new technologies. This is however not true for heavy commercial vehicles and two and three wheelers. In contrast to passenger cars, the technology developments for two and three wheelers have to be done with indigenous efforts since ready made technologies for these vehicles are not available from abroad. Two and three wheelers are the mode of transport for majority of the population in India in contrast to the Western countries where two wheelers are the mode of entertainment. Hence technology development for these vehicles are of little interest to the western world. The sheer large numbers of two wheelers in India demands that the technology be up graded to reduce the air pollution in India cities. Technology wise, the commercial vehicle segment in India significant lags behind U.S, Europe and Japan. Electronic control is absent and the very concept of pollution control devices (catalytic converters, particulate traps, de-nox catalysts etc.,) has not yet entered the Indian market. The buses and trucks currently used in India have several disadvantages. They are not fuel efficient and confirm to only Euro-1 norms and are not passenger and driver friendly.

Status of vehicle technology in India

In the last two decades, the face of automobile industry in Indian has changed significantly. From being a protected and relatively small market, it has become a major international market with almost all the international giants opening production facilities in the country. The Indian automobile sector is dominated by two and three wheelers, followed by passenger cars and the commercial vehicles.

Design and technology improvements in diesel engines for controlling emissions

The diesel engines have an excellent reputation for fuel efficiency, reliability and durability. The diesel engines having very high thermal efficiencies produce lower CO and HC emissions compared to gasoline engines. However diesel engines produce higher PM and Nox emissions. Diesel emissions in the form of black smoke is a public nuisance apart from it's health impacts.

These are two types of diesel engines: indirect and direct injection. In an indirect injection (IDI) diesel engine, the fuel is injected into a pre-chamber (generally located in the cylinder head) where ignition occurs and the combustion then spreads to the main combustion chamber in the cylinder. Indirect

diesel technology is mainly used for small size, high speed application such as passenger cars and multi utility vehicles, where low noise and high performance are important.

In a direct injection (DI) engine, the diesel fuel is sprayed directly into and ignited in the combustion chamber of the engine. These engines are used in light and heavy commercial vehicles and some multi utility vehicles and give higher power output and better fuel economy, but they are considerably noisier. Developments in reducing noise and improving performance have led to the use of direct injection engines in some of the cars in the recent years. Common Rail Direct Injection (CRDI) cars have become popular even in the high end market in India.

3. Control Strategies to Abate Vehicular Emissions

Rapid urbanization and growth of motor vehicles impose a serious effect on human life and its environment in recent years. Most of the cities of India are being suffered by extremely high level of urban air pollution particularly in the form of CO,SO2,NO2,PM and RSPM. Transport sectors contributes a major share to environmental pollution(around 70%).A among these pollutants CO is the major pollutant coming from the transport sector contributing 90% of total emission. Hydrocarbons are next to CO. It is indeed interesting to observe that the contribution of transport sector to the particulate pollution is as less as 3.5%,most of the SPM are generated due to re-suspension of dust out of which PM10 is the most prominent air pollutant. NOx is another important air quality indicator.

The worst thing about vehicular pollution is that it cannot be avoided as the emissions are emitted at the near-ground level where we breathe. Pollution from vehicles gets reflected in increased mortality and morbidity and is revealed through symptoms like cough, headache, nausea, irritation of eyes, various bronchial problems and visibility. The pollution from vehicles are due to discharges like CO, unburned HC, Pb compounds, NOx, soot suspended particulate matter (SPM) and aldehydes, among others, mainly from the tail pipes.

The different air pollutants due to vehicles can have effects at all the three levels – local (e.g., smoke affecting visibility, ambient air, noise etc.), regional (such as smog, acidification) and global (i.e., global warming). The vehicles besides being the prominent source of air pollutants also account for a number of external effects, such as congestion, noise, accidents, road wear and tear, and 'barrier effects' All these situations indicate that air pollution becoming a major problem in Indian context and there is an essential need to built up healthy environment and increase level of research around the world. The present study is a review of an assessment model for emitted pollutants and effective strategies to reduce air pollution due to road transport and investigates what the economics of vehicular pollution control and what policy instruments / initiatives can be employed to control the vehicular pollution.

Specific reasons for increasing vehicular pollution in Urban area

1.High vehicle density in urban cities.
2.Older vehicles predominant in vehicular vintage.
3.Predominance of private vehicles especially cars and two wheelers
4.Unsatisfactory public transport system causing higher idling emissions and traffic congestion
5.Absence of adequate land use planning in development urban and rural areas thereby causing more vehicle travel and fuel consumption
6.Improper traffic management system and road conditions.
7.Inadequate inspection and maintenance facilities
8.Increasing number of skyrocketing building in urban areas causes stagnation of the vehicular emission to the ground level and unable its proper dispersion.

Owing to their rapidly increasing number and very limited use of emission control technologies, motor vehicles are emerging as the largest source of urban air pollution in India. Other adverse impacts of motor vehicle use include accidents, noise, congestion, increased energy consumption and green house gas emissions. Stopping the growth in motor vehicle use is neither feasible nor desirable, given the economic and other benefits of increased mobility. The challenge, then, is to manage the growth of vehicles so as to maximize the benefits while minimizing its adverse impact on the environment and the society. **Such a management strategy will generally require**

(A) Technical measures,
(B) Regulatory measures and
(C) Economic measures.

(A)TECHNICAL MEASURES

Under this topic, the vehicular emissions can be controlled at three stages:

Stage 1 or pre-combustion stage where the quality of fuel can be upgraded;
Stage 2 or combustion stage where engine modifications are needed; and
Stage 3 or post-combustion stage where exhaust treatment devices like catalytic converters are required.

Further alternate propulsion systems such as Electric vehicles, Electric hybrid vehicles and fuel cell vehicles are also coming under this topic.

(i) Control of emissions at Pre-combustion stage

Control of emissions at Pre-combustion stage can be successfully achieved by change in fuel. Alternative fuels commonly considered for vehicular use are natural gas (in compressed or liquefied form), liquefied petroleum gas (LPG), methanol (made from natural gas, coal or bio mass), ethanol(made from molasses, sugar cane etc), vegetable oils, bio diesel, hydrogen and various blends such as gasohol(mixtures of gasoline and ethanol)

Natural gas(CNG) vehicles*:* In response to emerging epidemiological evidence of the toxicity of gasoline and diesel emissions there is growing interest in substituting conventional auto fuels with natural gas in cities where ambient air quality is considered unsatisfactory. Natural gas is a clean burning alternative fuel with a significant potential for reducing harmful emissions from vehicles. Over 1.5 million vehicles run on natural gas world wide. Argentina, Italy, Pakistan, Brazil, United States, Canada,NewZeland and Russia are some of the countries operating large number of natural gas vehicles.

CNG fueled buses have lower NOx,CO and PM emissions. Combustion of CNG does not emit Sox. Transit buses three wheeler autos and taxis are high usage vehicles in urban areas that operate in heavily congested city centres where air quality improvements are critical. As such they are good candidates for achieving emission reductions and substituting natural gas for conventional gasoline and diesel fuels is one way of reducing particles and air borne toxins dramatically.

There are two principle reasons for switching to natural gas. One is the significantly lowest exhaust emissions, especially particulate matter. The second reason is the diversification of energy resources. World wide, natural gas reserves are more abundant than oil reserves, giving greater potential to the use of natural gas.

Emission benefits of CNG buses compared to conventional Diesel buses is shown in Table (1)

Table 1 Emission Benefits of Replacing Conventional Diesel with CNG in Buses

Fuel	Pollution Parameter		
	CO	NOx	PM
Diesel	2.4 g/km	21 g/km	0.38 g/km
CNG	0.4 g/km	8.9 g/km	0.012 g/km
% Reduction	84	58	97

Source : *Frailey et al. (2000) as referred in World Bank (2001b: 2).*

Liquefied Petroleum Gas (LPG): LPG is very popular in Asian countries, including Japan, Thailand and Republic of Korea. Most of the LPG fueled 2 and 3 wheelers and cars in India are gasoline fueled vehicles retrofitted with LPG kits, although there are few LPG fueled original vehicles. Maruthi has been producing LPG fueled vans and cars in India.

LPG is typically a mixture of several gases in varying proportions. Major constituent gases are propane (C3H8) and Butane (C4H10), with minor quantities of Propane (C3H6) and Butane (C4H8), iso-butane and small amounts of ethane(C2H6).The composition of commercial LPG is quite variable. Since propane has superior knock resistance (with an octane number of 112), it is preferred over butane for use as transportation fuel .

On energy basis, LPG has a lower carbon content than gasoline or diesel fuel. Hence LPG fueled vehicles have lower CO, CO2 and PM emissions than gasoline fueled vehicles. CO emissions are 25 to 80 percent lower. NOx emissions are slightly higher than gasoline fueled vehicles due to higher flame temperatures, but significantly less than diesel vehicles.LPG do not emit SO2.

Bio diesel: It is produced by reacting vegetable oils with methanol or ethanol to produce a lower viscosity fuel that is similar in characteristics to diesel and can be used neat or blended with petroleum diesel. Bio-diesel, apart from being produced from renewable sources has high cetane number, low viscosity and very low sulphur content. Bio diesel is being produced in 21 countries and mainly used extensively in European countries, USA, Brazil, Argentina, Malaysia, Germany, France, Italy, Sweden, Australia Czech republic and many other countries of the above 21 countries Brazil and Argentina are the major users of bio diesel in urban areas. In most of the countries including Malaysia, bio-diesel is produced from edible oils, palm oils, rape seed oil, corn, sunflower, pea nut etc. A programme to convert palm oil into bio diesel for use in taxis has been successful in Malaysia.

Important characteristics of Bio Diesel: The major characteristics of bio diesel can be compared with those of petroleum diesel fuel. The following are some of the characteristics of bio diesel

i)Cetane number of bio diesel is similar or higher than petroleum diesel.

ii)Bio diesel is an oxygenated fuel with oxygen content of about 10 percent and therefore gives better emission characteristics in terms of CO, HC and PM.

iii)Bio-degradable, non toxic and free of sulphur and aromatic compounds therefore free of Sox and toxic emissions.

iv)As the flash point of bio diesel is higher, handling in service stations is safer.

v))Low volatility and poor cold flow properties could constrain the use of bio diesel in colder climates.

vi)Bio diesel has lower energy content(due to its higher oxygen content) which reduces engine output.

vii)It has stronger affinity for water. Being hydrophilic, bio diesel requires special care in storage.

viii)Viscosity of bio diesel(made from different vegetable oils) is almost the same as of petroleum diesel

xi)Bio diesel is a good solvent and hence attacks sealing compounds, hoses, paints and coating of the engine.

x) Coconut oil, Corn oil, Cottonseed oil, Olive oil, Palm oil, Peanut oil, Rapeseed/canola oil and Safflower oil are some of the edible oils from which bio diesel can be produced

xi) Engines running on bio diesel or blended with petroleum diesel tends to have lower Sox, black smoke, polycyclic aromatic hydro carbons and CO but higher cetane number of bio diesel which causes shorter ignition delay and higher cylinder pressures and temperatures.

The comparison between emission results of Gasoline, CNG and LPG vehicles with three way Catalyst is shown in Table (2)

Table 2 : Emission results of Gasoline, CNG and LPG vehicles

Emission, g/km	Pollution Parameter		
	Petrol	LPG	CNG
CO	1.12	0.91	0.45
HC	0.15	0.12	0.36
NOx	0.15	0.21	0.13
SPM	0.015	0.005	0.025

Other alternate Fuels: Ethanol, Methanol, Di-Methyl Ether and Hydrogen are also considered to be promising alternate fuel

Ethanol is being considered a feasible replacement for gasoline in cars, bio-diesel in diesel cars and heavy duty vehicles. Ethanol or ethyl alcohol is a chemical that can be produced through the process of fermentation and distillation of molasses a by product of sugar industry. Other possible raw materials are beet root, corn, cassava, rice straw and potato. In Brazil, the ethanol industry is based almost entirely on sugarcane whereas more than 80 percent of the US ethanol production is based on corn as the raw material. Ethanol can also be produced from other sources like damaged food grains and bio mass.

Methanol is an oxygenated fuel. With an octane number 112 and excellent combustion properties, methanol is a good alternative fuel in gasoline engines. Methanol is a liquid boiling at 148 degree F. Hence it has all the advantages of conventional fuels(gasoline and diesel) in storage, transportation and refining and at the same time, it produces significantly low pollutants, being an oxygenate. Methonal is dispensed from fuel pumps in a similar to gasoline.

Di-Methyl Ether(DME) DME is similar to LPG. It is stored as a liquid under low pressure. It has very high cetane number and hence more suited for use in diesel engines. The main advantage of DME compared to diesel is the reduction of particulate emissions, visible smoke, HC and CO emissions to extremely low levels.

DME is an optimum substitute for diesel fuel.DME which is manufactured by oxidation of natural gas is a solution for better utilization of natural gas in vehicles especially diesel vehicles.DME is an excellent alternative to conventional diesel because it has optimum combustion related properties and economical to produce and distribute. The main advantage over diesel is the reduction of particulate matter to extremely low levels. No vehicle smoke is observed. HC and CO emissions are reduced to ultra low values since there is no sulphur in DME. It is produced from natural gas , crude oil, heavy residue, coal and bio mass. Since it is a liquid at low pressures, handling of DME is similar to natural gas as it is transported as luquid.DME is widely used in USA

Hydrogen is being considered a very promising alternate fuel for the future because it can be obtained from water using non conventional energy sources and thus has tremendous potential to become cleanest source of energy. Hydrogen powered vehicles can be driven by an internal combustion engine or fuel cell powered electric motor.

Advantages of Hydrogen: Hydrogen contains no hydro carbons and hence has the potential to be the cleanest burning vehicle fuel. With the virtual elimination of CO,HC and PM exhaust emissions, only nitreogen oxide emissions are present in the vehicle exhaust. NOx emissions from hydrogen vehicles are similar to those from gasoline vehicles. They can be further lowered by reducing the combustion chamber temperature or by reducing combustion time at high temperatures. These steps are generally accomplished by exhaust gas recirculation, water injection into cylinder, retarding spark timing or by using an exhaust catalyst. Hydrogen filling stations to fuel buses and cars have been set up at Hamburg and Munich in Germany

(ii) Control of emissions at combustion stage:

This is one of the method to control emissions at combustion stage where engine modifications are needed i.e by making improvements in the present vehicle technology.

Vehicle technology improvements can dramatically reduce pollutant emissions and improve fuel efficiency. Changes in engine technology can achieve very large reductions in pollutant emissions. Such changes are most effective when incorporated in new vehicles. The most common approach to incorporating such changes has been through the establishment of vehicle emission standards. The establishment of emission standards has been a major impetus for research and development of engine designs and pollution control technologies. Major advances in this area have come from engine modifications, exhaust after treatment devices (catalytic converters and trap oxidizers), on-board canisters, on-board diagnostics etc., Major reduction in vehicle pollutant emissions are possible through changes in technology at relatively low cost, and, in many cases with a net savings in life cycle cost as a result of better fuel efficiency and reduced maintenance requirements.

While two and three wheelers and commercial vehicles are responsible for bulk of the pollutant emissions, their technology in India for reducing emissions needs to be improved.

Manufacture of two stroke engine vehicles have been completely abandoned and BSIV technology have come into force w.e.f 01.04.2018.Most of the car manufacturers in India have foreign collaborations for new technologies. But this is however not true for heavy commercial vehicles for which, the technology developments for four wheelers have to be done with indigenous efforts.

Design and technology improvements in diesel engines for controlling emissions

The diesel engines have an excellent reputation for fuel efficiency, reliability and durability. The diesel engines having very high thermal efficiencies produce lower CO and HC emissions compared to gasoline engines. However diesel engines produce higher PM and Nox emissions. Diesel emissions in the form of black smoke is a public nuisance apart from it's health impacts.

These are two types of diesel engines: indirect and direct injection. In an indirect injection (IDI) diesel engine, the fuel is injected into a pre-chamber (generally located in the cylinder head) where ignition occurs and the combustion then spreads to the main combustion chamber in the cylinder. Indirect

diesel technology is mainly used for small size, high speed application such as passenger cars and multi utility vehicles, where low noise and high performance are important.

In a direct injection (DI) engine, the diesel fuel is sprayed directly into and ignited in the combustion chamber of the engine. These engines are used in light and heavy commercial vehicles and some multi utility vehicles and give higher power output and better fuel economy, but they are considerably noisier. Developments in reducing noise and improving performance have led to the use of direct injection engines in some of the cars in the recent years. Common Rail Direct Injection (CRDI) cars have become popular even in the high end market in India.

Diesel engines meeting current U.S and Euro norms are smokeless, have better fuel efficiency, less noisy and emir significantly less pollutants than equivalent diesel engines manufactured in India. Engine variables with the greatest effect on diesel emission rates are the combustion process, air-fuel ratio, rate of air-fuel mixing, compression ratio, the temperature and composition of the charge in the cylinder, fuel injection pressure and timing and combustion chamber design.

(iii) Control of emissions at post combustion stage

As the emission legislations are becoming more and more stringent, these internal changes in the engine are not adequate in controlling emissions from vehicles.

A useful alternative to control emissions further within the engine is to reduce them instead with subsequent treatment of the exhaust gas, This allows the combustion process within the cylinder to be optimised for best power and fuel economy rather than for lowest emissions. The concept governing after treatment devices is simple and straight forward. The effluent stream from the engine is brought into contact with a catalytic surface, where the pollutant emissions and the oxygen remaining in the exhaust gases come into contact resulting in the conversion of health affecting pollutants into harmless pollutants. To date, the vehicle exhaust after treatment devices are by far, the most effective and cost effective method of reducing critical pollutants to the levels required by stringent emissions standards.

To meet the stringent emission norms, almost all vehicles need some or other types of pollution control equipment and out of all the pollution control devices, catalytic converter is the most important and effective emission control device available. Catalytic converters are used in gasoline vehicles(both four stroke and two stroke engines) and diesel vehicles. The importance of catalytic converter can be assessed from the fact that in gasoline vehicles, the difference in the emissions between an uncontrolled vehicle and a vehicle fitted with a three way catalytic converter is more than 90 percent. In diesel vehicles, in addition to catalytic converters, particulate traps and NOx catalysts are used for reducing PM and NOx emissions.

The exhaust gas composition of various combustion processes such as two stroke two and three wheelers, four stroke gasoline cars and diesel fuelled buses and trucks are different. This results in wide variations in the pollutant emissions from different types of vehicles. Two stroke engines for instance produce higher amounts of HC and PM in their exhaust than a four stroke engine. Similarly a diesel bus or a truck produces more PM and NOx than a gasoline vehicles. Therefore requirements of catalyst technologies are different for different types of vehicles and depend on the combustion process.

Catalytic converters are used for oxidizing HC and CO in two stroke two wheelers, gasoline cars and diesel vehicles. For reduction of NOx into nitrogen and oxygen, while three way converters are used in gasoline vehicles, De Nox catalysts are used in diesel vehicles.

Catalytic converter

There are basically two types of catalytic converters-oxidation catalyst or two way catalytic converters and three way catalytic converters,Two way catalytic converter controls only carbon monoxide (CO) and hydrocarbon (HC) emissions. It is also known as oxidation catalyst because the transformation of harmful pollutants into harmless gases is accomplished by oxidation. The substrate surfaces inside the converter are coated with a thin layer of platinum and palladium. The carbon monoxide, hydro carbon and oxygen molecules are adsorbed within the catalytic layer and react to form carbon dioxide and water vapour.

Three way catalytic converter can simultaneously remove all the three major pollutants oxides of nitrogen as well as carbon monoxide and oxygen while oxidizing CO and HC to carbon dioxide and water vapour. The three way catalyst uses a combination of platinum, palladium and rhodium.

Diesel oxidation catalyst looks very similar to the three way catalyst used on gasoline vehicles. The oxidation catalyst in diesel vehicles can be from 50 percent to 90 percent effective in converting HC. An oxidation catalyst apart from reducing HCS can reduce total PM emissions by roughly 15- 30 percent. The main difficulty with using an oxidation catalyst on heavy duty buses and trucks is that they can cause the formation of sulphuric acid and sulphates from sulphur dioxide in the exhaust. Diesel fuel with less than 0.05% sulphur by weight is required for diesel oxidation catalyst to perform well.

(B) REGULATARY MEASURES

Technical measures alone are insufficient to ensure the desired reduction of air pollution. They are necessary competent on any effective strategy for limiting vehicular emission. Employed as part of an integrated transport and environmental program, these measures can buy the time necessary to bring about the needed behavioral changes in transport demand and the development of environmentally substantial transport system. The following are some of regulatory measures being followed.

(i)Emission standards and regulations

Stopping the growth in motor vehicle use is neither feasible nor desirable, given the economic and other benefits of mobility. Strategy to abate vehicular pollution in an urban area requires policy measures which can be broadly classified as command and control measures for curtailing vehicular pollution mainly rely on regulatory options -emission standards for new vehicles, fuel quality standards or specification, testing and certification rules for new vehicles, inspection requirements for in use vehicles.etc.,

Changes in engine technology can achieve very large reductions in pollutant emissions often at modest cost. The most common approach in incorporating such changes has been through the establishment of emission standards. Emission standards are established to limit discharge of air pollutants from new vehicles. Emission standards set a legal ceiling on the quantity or concentration of pollutants discharged from new vehicles. The establishment of emission standards for new vehicles has been a major impetus for research and development of engine design and pollution control technologies

Vehicle emission standards can be classified as either "technology-forcing" or "technology- following " emission standards. Technology – forcing standards are at a level that though technically feasible, have not yet been demonstrated in practice. Manufacturers must research, develop and commercialize new technologies to meet these standards. Technology-following standards involve emission levels that can be met with demonstrated technology

The past, present and future Euro standards for heavy duty diesel vehicles recommended for implementation by Mashelkar committee are detailed in Table (3)

Type of Emission	Standards (g.km)					
	1992	1996	2000 Euro1	Euro 2	Euro 3	Euro 4
CO	14	11.2	4.5	4.0	2.10	1.5
HC	3.5	2.4	1.1	1.1	0.66	0.46
NOx	18	14.4	8.0	7.0	5.00	3.5
SPM			0.36	0.15	0.10	0.02

(ii)Controlling emissions from in-use vehicles-inspection and maintenance programmes

To mitigate the adverse effects of emissions from vehicles, stringent emission norms are being proposed for all new vehicles. However, they will only help to control emissions from new vehicles and have no effect on the emissions of large number of "in-use vehicles. Large number of "in-use" vehicles. Effective I & M programme is therefore of primary importance to bring down the emission standards and also the procedures for I & M in India. Following Two types of organizations exist for inspection and maintenance programmes viz. centralized and decentralized

(a)Centralized inspection and certification

In centralized inspection and certification programme, vehicles are inspected at one of the few high volume inspection facilities. These facilities are regulated by the government and run either by the government or independent contractors

(b)Decentralized inspection and certification

In a decentralized programme, vehicles are inspected at large number of private service stations and garages which also carry out repairs on vehicles that fail the emissions test. They are generally not operated by the Government. This results in malpractices, both in passing vehicles that should have failed in return for a bribe and failing vehicles that should have passed in order to repair them and collecting repair charges without adequate attention and issuing the certificate. A large surveillance team is needed for the regulatory agency to supervise the inspection programme and ensure their proper working.

(C)ECONOMIC MEASURES

Owing to their rapidly increasing number and very limited use of emission control technologies, motor vehicles are emerging as the largest source of urban air pollution in India. Other adverse impacts of motor vehicle use include accidents, noise, congestion, increased energy consumption and green house gas emissions. Stopping the growth in motor vehicle use is neither feasible nor desirable, given the economic and other benefits of increased mobility. The challenge, then, is to manage the growth of vehicles so as to maximize the benefits while minimizing its adverse impact on the environment.

Technical measures involving vehicles and fuels can dramatically reduce air pollution and other adverse environmental impacts of road transport . However technical measures by themselves are not sufficient to guarantee environmentally acceptable outcomes over the long run. They need to be encouraged and supplemented by regulatory and economic incentives/discentives.

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Economic measures such as emission taxes, fuel taxes, congestion pricing, environmental excise duty, differential taxation etc afford large scope for encouraging non polluting behavior. For example, emission taxes are expected to result in vehicle owners buying lower polluting vehicles, maintaining their vehicles better and change their travel to reduce vehicle usage etc. Economic measures encourage vehicle manufacturers to invest in Research and Development (R &D) for developing better vehicles with lower emissions. Similarly effective congestion pricing is capable of directing traffic flows toward socially optimum levels and educe vehicular emissions significantly.

(i)**Congestion pricing to reduce vehicular emissions**

The slow movement of motor vehicles on congested roads results in higher fuel consumption and increased rates of pollutant emissions. Vehicles under stop and start conditions use about three times more fuel and cause about three times more pollutant emissions than those in free flowing traffic.

Charging for the use of roads to control congestion is not a new idea. Many cities around the world have implemented the concept either manually or electronically (eg.Singapore, Hongkong, London, Cambridge, Paris, Los Angeles, etc,) Many more cities have initiated detailed studies and are in the process of doing so. The area Licensing scheme of Singapore area wide congestion scheme of London, toll rings to reduce congestion in city centres introduced in Los Angles and France have been effective in reducing congestion. Some of these schemes with necessary modifications can be implemented effectively in India to reduce congestion and ambient air pollution.

(ii)Traffic Management Measures to control Vehicular Emissions

The slow movement of motor vehicles on the congested Indian city roads results in higher fuel consumption and increased rates of pollutant emissions. Vehicles under start-stop conditions use about three times more fuel and cause about three times more pollutant emissions than those in free flowing traffic. Effective traffic management can improve the flow of traffic on the roads, reducing emissions and enhancing mobility.

The objective of traffic management is to improve the quality of traffic flow as a results of which the number of stops, uneven speeds of operation, sudden braking, idling of vehicles etc are minimized, thereby reducing vehicular pollution. Traffic management measures are intended to establish a smooth

traffic flow and increase road safety by minimizing conflicting movements between vehicles and between vehicles and pedestrians In many urban areas in India and other developing countries, road capacities are reduced mostly by on street parking and stopping of vehicles to load and unload passengers and goods. Especially during peak hours, these movements slow down the traffic flow and raise pollutant emissions from motor vehicles, Traffic flows can be improved in congested streets by imposing on street parking restrictions which can be implemented either during peak hours or through out the day.

(iii)Public transport polices affecting vehicular emissions

In India buses are the major public transport providers. In metropolitan cities and the other agglomerations in India, the public transportation system has not been able to cater fully to the rapidly increasing demand for the various reasons. As a result there has been a phenomenal increase in smaller vehicles such as two wheelers, three wheelers, cars, tempos, etc. As more and more urban commuters switch over to the smaller vehicles, they consume greater quantities of petroleum fuels impose an increasing burden on the already heavy congestion that has become a serious hazard in cities. In the long run, therefore, for the balanced growth of the urban transportation system, it is imperative that the public transport that depends on the larger vehicles are strengthened in such a manner that the shift in favour of the smaller vehicles is contained and more and more commuters are attracted towards public transport. Hence the national urban transport policy must include measures to give priority to buses and Metro Rail System.

Mixing the public transport buses with other vehicle categories (two wheelers, cars, three wheelers, etc) reduces the speed of both. Cars and two wheelers are impeded by buses. Similarly buses are impeded by two wheelers and cars, typically moving at less than two thirds of the speed of cars and two wheelers because of delays in stopping and re-entering the traffic flow. This is the main reason for shift to small vehicles from buses. But the net result of such shift is that total traffic volumes, congestion, and average travel times are all increased.

Bus priorities i.e. dedicated bus lanes or totally segregated bus ways will counter act this effect. The simplest measures are priority lanes, which exists for buses in several Asian cities such as Manila, Kaula Lumper and Bangkok.

Since buses consume less energy, causes less pollution and occupies less road space than personal vehicles for the same travel demand, they should be encouraged. The national urban transport policy should encourage public transport in general and bus transport in particular in all the cities. Bus transport in India is currently provided by public transport under takings. Their internal efficiency should be improved. The long term solution is to create effective competition and regulation in public transport in urban areas.

4. Conclusion

The present study is a review of an assessment model for emitted pollutants and effective strategies to reduce air pollution due to road transport and investigates what the economics of vehicular pollution control and what policy instruments / initiatives can be employed to control the vehicular pollution. Such a management strategy for a long term measure will generally require

i) Technical measures,
ii) Regulatory measures and
iii) Economic measures.

Under the topic **Technical measures**, the vehicular emissions can be controlled at three stages:

Stage 1 or pre-combustion stage where the quality of fuel can be upgraded;
Stage 2 or combustion stage where engine modifications are needed; and
Stage 3 or post-combustion stage where exhaust treatment devices like catalytic converters are required.

Under the topic **Regulatory measures**, the vehicular emissions can be controlled as below.

(i)Strict implementation on Emission standards and regulations
(ii)Controlling emissions from in-use vehicles by carrying out effective inspection and maintenance programmes

Economic measures :Stopping the growth in motor vehicle use is neither feasible nor desirable, given the economic and other benefits of increased mobility. The challenge, then, is to manage the growth of vehicles so as to maximize the benefits while minimizing its adverse impact on the environment. Technical measures involving vehicles and fuels can dramatically reduce air pollution and other adverse environmental impacts of road transport . However technical measures by themselves are not sufficient to guarantee environmentally acceptable outcomes over the long run. They need to be encouraged and supplemented by regulatory and economic incentives. Following are some of the economic measures to be implemented .

(i)Congestion pricing to reduce vehicular emissions
(ii)Traffic Management Measures to control Vehicular Emissions
(iii)Public transport polices affecting vehicular emissions

Summing up, the inhibition of vehicular pollution requires an integrated approach, with following components; (i) improvement of public transport system such as buses and MRTS; (ii) optimisation of traffic and improvements in traffic management (e.g., area traffic control system, timers at intersection, no-traffic zone, green corridors, removal of encroachment on road, regulation of digging of roads); (iii) comprehensive inspection and certification system for on-road vehicles; (iv) phasing out of grossly polluting units; (v) fuel quality improvement (e.g., benzene and aromatics in petrol, reduction of sulphur in diesel); (vi) tightening of emission norms (e.g., EURO-IV); (vii) improvement in vehicle technology (e.g., restriction on manufacturing of 2-stroke engines, emission warranty, on-board diagnostic system); (viii) checking fuel adulteration; and (ix) checking evaporative emissions from storage tanks and fuel distribution system.

Whether, it is pollution from Industry or local body or transport activity, it is the basic knowledge of the stake holders in the field of the latest legislations, technology, standards and all connected issues which will help for effective implementation of the Environment protection programmes. Many issues of environmental concern can be solved by making all stake holders to understand the problems in greater depth, so that it is possible to find appropriate

solutions. Industries, NGO's and all other stake holders must contribute their might to solve Environmental problems in addition to Government and regulatory Authorities.

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