CHAPTER 2
REVIEW OF LITERATURE

2.1 Introduction

The existing studies on mitigating vehicular pollution can be broadly classified into i) command and control regulation, and ii) economic instruments, which are policies that create incentives or disincentives for the users whereby the behavior of the polluters can be altered. These can be further classified as direct and indirect instruments. The classification is shown in Table 2.1. In general, it is difficult to finely separate different types of instruments as very often one instrument is mixed with the other in order to have an effective solution. It is to be noted that the literature on this area in the Indian context is very scarce. Therefore, limited relevant literature is reviewed in this chapter.

Before launching into the survey of literature, at the outset, it is important to explain the theoretical underpinnings of the economic instruments. The economic principle of environmental policy is based on the principle of externality caused by market failure. Pigou pioneered this principle as early as 1928. In section 2.2, we give a brief introduction to the theories of environmental economics as propounded by experts. In section 2.3, we give the review of existing studies on vehicular pollution control. Section 2.4 concludes.

2.2 Theoretical Perspective

Environmental pollution problems typically arise when activities of one impose external costs on the other with no market for pricing. Eminent economists have suggested various corrective measures to deal with this problem. Noted works in this area are Pigou (1928), Coase (1960) and Baumol and Oates (1971).
a) Pigou's theory

In this section, we shall understand Pigou’s theory by applying it to transport based pollution. Air Pollution from transport is a typical case of negative externality. A vehicle can be seen as a production unit whose output are passenger kilometers and the by-product is emission of pollutants released in the atmosphere. To the vehicle owner, the marginal benefits of emitting pollutants into the atmosphere, a common property resource, outweigh the marginal costs that he has to bear because of air pollution (as negative costs of air pollution are distributed across all users of polluted air). This can be explained with the help of a standard externality diagram showing the divergence between private cost and social cost, the difference of which is called external cost.

FIGURE 2.1

PIGOVIAN SOLUTION
The potential users of transport will use transport services upto the point where the marginal benefits they derive, as represented by their demand schedule D, is equated with the marginal costs they have to incur, that is, to traffic volume \( Q_a \). What they do not take into account are the environmental costs that they impose on others. If they did so, their traffic volume would be \( Q_o \). In the absence of any intervention to correct the failure of the existing market system an equilibrium like \( Q_a \) would occur causing the society a welfare cost measured by the area abc. How do we correct this?

Pigou suggested a solution, which was considered to be a fundamental one for many following works in this area. He prescribed a tax, known as pigouvian tax, which is equal to the difference between private cost and social cost at the margin of socially optimal output. It is shown as ‘bd’ in the diagram. The polluter will have an incentive to consider this external cost in his decision making. It is a method of internalizing the external cost of any activity. This concept was later accepted as “polluter pays principle”.

b) Coase theory

Coase (1960) argued that voluntary negotiations between the polluters and those affected by pollution could provide for efficiency if property rights are properly defined, without any need for government intervention provided costless bargaining is possible between the polluter and the pollutee. However, the Coasian theory is justifiable only when there are a few parties involved.

c) Standards and charges

Baumol and Oates (1971) gave a second best solution because the Pigouvian first best solution requires full information on cost and damage. Difficulties in obtaining information on damage function were recognized. Baumol and Oates derived a ‘charge’ based on acceptable standards, which does not require information on the damage side.

Note: It is to be noted that the external cost varies with respect to the user and the location.
d) Classification of economic instruments

Following these notable works, various types of instruments were suggested in the literature with the core principle being the same. These are known as economic instruments. Those that are simply coercive type are called command and control. Table 2.1 gives the classification of the alternative measures.

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<th>TABLE 2.1: CLASSIFICATION OF INSTRUMENTS FOR VEHICULAR POLLUTION CONTROL</th>
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<td><strong>Type of Measure</strong></td>
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*Source: Cabajo (1991)*

2.3 Review of Existing Studies

In this section, we review the existing studies on the effectiveness of vehicular pollution control measures classified by the methodology viz. a) Simple statistical methods b) Econometric methods c) Modelling techniques.
a) Studies on vehicular pollution using simple statistical methods

In this section, we provide a review of studies of vehicular pollution control, which are based on simple statistical methods.

Repetto (1992) has discussed various economic instruments that could be used for controlling environmental pollution. The economic instruments that have been considered are vehicle emission charges; gasoline tax and deposit refund charges (on vehicles and tires). According to the study, vehicle emission charges can be levied based on the anticipated or expected emissions from the vehicle and the charge should be equal to the marginal value of damage. The study also concludes, that deposit refund charges could be an effective method in controlling pollution, apart from generating substantial revenues.

Krupnick (1992) reviews existing models of urban transport and evaluates their ability to simulate the effects of different policies on emissions and on other variables relevant to welfare. According to the study, little modeling work has been done on developing countries, but some stylized facts allows one to assess how well models from developed countries apply in developing countries.

Feitelson (1994) has assessed the potential of rail in reducing the pollutant emissions. According to the study, although rail development may reduce emissions by concentrating peak congestion spatially and temporally along some radial corridors, it is unlikely to reduce the total vehicle miles driven in most developed countries, at least in the short run. Therefore, the direct environmental benefits are likely to be limited in space and scope, and the direct environmental costs of rail may continue to hinder the opening of new rail services.

Opschoor (1994) has evaluated the effectiveness of the economic instruments- car sales tax, vehicle tax and gasoline tax (on leaded gasoline) in controlling the problem of

**Note:** It is a descriptive study.
pollution from transport in OECD countries. According to the study, there has been a steep increase in the share of unleaded gasoline in the gasoline in the OECD countries, however, it is not clear whether this has been due to the gasoline tax or due to pending regulations. The effect of car sales tax and annual vehicle tax was found to be indeterminate.

Hahn (1995) has examined the impact of policies aimed at encouraging the retirement of older, high polluting vehicles for Los Angeles. The paper assesses the likely benefits and costs of vehicle scrappage programs. Then the interaction of a scrappage program with other policies such as improved inspection and maintenance programs is also addressed. The study has found that scrappage program results in emission reduction (for HC and NO$_x$) of less than 10%. According to the study, scrappage is likely to be most useful in highly polluted areas where there is a high fraction of older vehicles and the marginal benefits from reducing pollution are high. Secondly, inspection and maintenance programs can have a significant impact on the cost effectiveness of a scrappage program. That is, a more stringent inspection and maintenance program will increase total scrappage for a given bounty, but could worsen the cost effectiveness. According to this study, though scrappage is not the all-pervading solution, there is likely to be economic justification for its use in the United States and elsewhere.

Pierson and Vickerman (1995) in their study present a simple framework for analyzing the effects of imposing efficient pricing on both inter-urban passenger travel in the UK and passenger travel in London. The models developed in the study use estimates of the long-term marginal internal costs of the main nodes, to which have been added estimates of marginal external costs from various sources in order to obtain the true opportunity cost of using each mode. According to the study, the short term peak pricing has maximum effect on (air or rail) travel in London, with a drop of 12.8% due to a 1%
increase, while the long term pricing also has maximum effect on Rail Transport with the assumption of constant returns to scale. However, under increasing returns to scale, short term pricing affects the rail transport to the maximum extent, but long term pricing affects the bus transport (19.7%) the most. For inter-urban travel, short term for both peak and off-peak pricing under constant returns to scale affects the rail transport more than others; while, short term pricing under increasing returns to scale has the maximum effect on rail and the long term pricing also affects the rail travel. The main conclusion of this study is that efficient pricing and taxation of externalities are not sufficient to give substantial shifts to modes of transport with lower external costs.

Centre for Science and Environment (1996) has described the increasing problem of vehicular pollution in the major cities of India. The study traces the causes of the increase in the pollution due to the vehicles and also provides a critical analysis of the control measures taken by the Government of India.

World Bank (1997a&b) has developed action plans which would be an integral part of the air quality management system for the metropolitan regions viz. Jakarta and Bombay. The approach used in this study involves the assessment of air quality and environmental damage. The study first provides estimates of the population’s exposure to area air pollutants, and quantifies the contribution of different pollution sources to this exposure. Population exposure is estimated by describing existing air pollution concentration measurements and their variation in time and space, making an inventory of air pollution sources and their relative contributions; calculating their relative contributions; calculating the concentration distributions using dispersion modeling and calculating population exposure by combining spatial distributions of population and concentrations, and incorporating exposure on roads and in industrial areas. Then, the study estimates the health impact of (in terms of monetary damages) air pollution using
dose-response functions. Then, the study presents information about measures for reducing air pollution in the metropolitan region and for drafting an action plan that would translate these measures into practice. The proposed action plan is based on the cost-benefit analysis of various measures that reduce air pollution and resulting damages. These measures include measures for vehicular pollution control, industrial pollution control and from non-combustion sources.

Harrington et al. (1997) examined the results of a telephonic survey held during August and September 1996 on public support for pollution fees for motor vehicles. The pollution fee survey elicited support for a plan that levied a fee on vehicles in the region, depending on the vehicles emissions per mile and on the miles driven. The model was then split into two - with half the respondents being told that a portion of the revenues would be returned to the public in the form of reduction in motor vehicle fees and half were told that these returns would be made in the form of coupons. More than 50% of the respondents supported the first policy with rebates and support for the coupon policy was intermediate, attracting 42% of the sample. The paper concludes that the design features of the plans as well as the socio-demographic affect the levels of support and perceptual variables such as age, ethnicity etc.

Olszewski et al. (1997) have estimated the effects of the recent changes in the road pricing system of Singapore. The study has described the impact of area licensing scheme on usage of private vehicles for trips to restricted zone and has formulated an approach to travel choice modeling which is then used to estimate the impact of various possible future charging schemes. The study found that the changes in the road pricing system did affect the traffic pattern. For instance, the mid-day traffic flows had decreased and the morning peak traffic had become more distinct. Large increase in the inbound traffic volume, which occurred at 10:15 am, and the drop, which occurred at 4:30 p.m., are no longer present.

Note: * in Southern California
However, the study has found that there is still a surge of inbound traffic after the evening restricted period, which ends at 6:30 p.m. There were changes in travel behavior as well. The changes in time of travel due to the changes in the road pricing system were mostly for non-work related trips, which used to be scheduled during the free entry mid-day period. Finally, the choice of whether to buy a license and of what type seems to be the main decision which motorists face. This is because the license is valid for any number of trips and this to a large extent determines the subsequent trip pattern. However, the study concludes that this will change with the future electronic pricing system under which the charges will be on a per entry basis.

Heil and Pargal (1998) have provided a categorization of different pollutants and a general framework for evaluating alternative instruments in terms of ease of implementation. Faiz (1996) and Onursal and Gautam (1997) have given a technical background of different options of controlling pollution and the experiences of the Latin American countries in controlling vehicular pollution.

Hall (1998) examines whether vehicular emissions should be regulated at the central or at the local level. The study first provides a brief background on why vehicle-related regulation is necessary; the nature of relevant pollutants: the environmental objectives of regulations; and the role of transport emissions in air quality management. The study then describes the role of fuel composition in emissions reductions and contrasts the case of lead and hydrocarbon. Finally, the factors that determine whether local or central control is more appropriate are discussed and a framework is suggested to assist in making such determinations.

Harrington et al. (1998) have described the assignment of responsibilities for control of motor vehicle emission and ambient ozone policy among the state and the central

**Note:** It is a descriptive study.

© for USA
governments. The study presents arguments for and against centralized approach to air quality goals and advocates for more flexibility in the pollution control strategies.

Rietvald et al (1998) have estimated the optimal speed limits of passenger cars. This study focuses on two main aspects: the need to address the whole range of roads, the need to take into account behavioral changes as a result of changes in speed. The main conclusion of the paper is that changes in speeds have substantial effects on emissions, safety and welfare. The study shows that negative external effects of transport are relatively sensitive to changes in average speed. For example, the study found that a decrease of the average speed by 5% by strict obeyance leads to decrease in energy use by 6%, CO₂ by 6%, NOₓ by 10% and of traffic victims by 10-17%. The study found that, if one were to include the indirect effects (which is shift in the mode of transport, viz. from cars to public buses), then this leads to a 6% decrease in energy use, 11% reduction in CO₂ emissions and 21% fall in traffic victims. Therefore, the study indicates that the case for the imposition of lower limits from a cost-benefit perspective is the strongest for the roads with highest speeds.

Xie et al (1998) have used a cost-benefit analysis for various options for controlling the emissions of two stroke Engine three-wheelers. The study also discusses the potential effects of demand management via fuel tax and of traffic management on emission control. The study concludes that a number of win-win solutions are available for reducing the emissions from two-stroke engine three wheelers. The study also estimates the global benefits, apart from the local benefits. According to the study, CNG conversion is the most effective technical option, followed by modern carburetor system. Further, the global benefits are much smaller relative to local benefits. The study also suggests introducing fuel taxes, as a demand management measure to control fuel consumption which is also

Note: * in Netherlands.
@ in New Delhi.
critical for the city to solve its traffic congestion, and protect both local and global environment.

Dutta and Sengupta (1998) have considered direct regulation measures and their effect on pollution reduction. The measures considered in this study are: Implementation of emission norms and fuel quality specifications, implementation of Inspection and Maintenance programs, phasing out of old vehicles and a combination of these measures. According to the study, no single measure will be an effective solution to reduce the pollutant emissions to meet the target, but an integrated strategy is necessary (that is, a combination of different policy measures) and more appropriate to meet the target reduction. The study also uses a dispersion model to estimate the effect of these policy measures on the ambient air quality.

AIAM (1998a) have reexamined the various policy and technological options for reducing automotive pollution by 50% in Delhi by year 2005. The various policy and technological options considered are phasing out of old transport vehicles, engine rebuild options, retrofit options. According to the study, compliance to emission standards through technological upgradations results in avoiding 37 million tonnes of automotive pollution of CO and HC by year 2005. The phase out and Inspection and Maintenance programs are essential and adequate to meet the pollution reduction targets of CO and HC, but they are not adequate to reduce the NO\_x emission.

AIAM (1998b) have studied the effect of retrofitment of catalytic converter on in-use vehicles in Delhi, primarily the two and the three wheelers. According to the study, catalytic converter retrofitment without engine upgrade results in a reduction of CO and HC by 894 and 747 tonnes respectively by the year 2005. The cost impact to the user is Rs 0.45 per kilometer for two wheelers and Rs 0.10 per kilometer for three wheelers respectively.

\textbf{Note:} * for New Delhi.
AIAM (1998c) have discussed the drawbacks of the present vehicle fitness certification system in India and argued for the need of an alternative vehicle fitness certification system. Based on the existing system in other countries around the world, the study suggests a new model of vehicle fitness certification system in India.

Chandni (1998) has studied the recent measures taken by the Government of India to reduce the pollution from vehicles and their drawbacks. According to the study, the main drawback of the vehicular pollution control measures in India is the lack of the area-based strategy.

Pandey and Bharadwaj (1999) have examined the role of economic policy instruments in controlling the pollution from motor vehicles in Delhi. The study first considers the best mix of various technical options that control vehicular pollution. The study suggests the following technical options: catalytic retrofitment for 2-wheelers, and use of CNG for 3-wheelers, car, taxis and buses. According to the study, the recommended technical options would lead to a reduction of pollution by 41% with the catalytic converter retrofitment of 2-wheelers being responsible for 13% of the pollution reduction. Using the approach outlined by Gunnar, it considers an alternative fiscal instrument in the form of fuel tax. The optimal fuel tax rate in this study is equalized to the marginal cost of technological measures and the corresponding is calculated for each technical option. Apart from these, the study also looks at the direct control regulations, like emission tax for vehicles which do not comply with regulations, progressive surcharge on environmental tax for vehicles greater than 10 years old which can be imposed to control the problem of vehicular pollution. The study also recommends an increase of excise tax for diesel cars by 21% to prevent the growth of diesel cars.
Pickrell (1999) has examined the relationship between automobile pollution control measures and quality of air for U.S.A. According to this paper, the concentration of pollutants has declined dramatically and this has been primarily due to reduction in pollutant emissions by motor vehicles. However, according to the study, the on-road emissions are much more than the emission standards for new vehicles. This is due to various factors like deterioration of emission control systems in the cars as they age and malfunctioning of the emission control systems. The paper concludes that effort should be directed more towards bridging the gap between the on-road emissions and emissions under test conditions, rather than on new technologies to further reduce the pollutant emissions. According to the study, the adopted and current pending measures are expected to reduce nationwide on-road emissions of CO, VOCs and NO, from passenger vehicles by 7%, 35% and 25% from their 1995 levels when fully implemented. However, if additional measures like zero emission vehicles, enhanced inspection and maintenance programs as suggested by the study, were implemented, it would result in a further reduction from pre-controlled levels to the tune of 40-50% for CO, 75-80% for VOC and 40% for NO,.

Litman (1999a) in his study has provided an overall view of the available Transport Demand management options, which can be used to control the problem of vehicular pollution. These measures include measures, which are of direct regulation type, and also measures, which are incentive/disincentive based. The study considers the feasibility of such programs in terms of its cost effectiveness and also equity issue. Litman has estimated the optimal charging mechanism for the vehicles. According to the study, many costs of motor vehicle use are external, and a significant portion of the charges that

\[ \text{Note: } * \text{ for North America.} \]
vehicle users do pay is fixed, and therefore not marginal. This is economically inefficient and inequitable. Distance-based fees are the best way to charge for many costs imposed by vehicles, including road use, insurance, pollution emissions, and other environmental impacts. Distance-based charges are feasible and relatively inexpensive to implement with an "odometer audit," which means a verified recording of odometer data. According to the study, an average of 0.035$ of weight distance charge would result in a 7.6% reduction in travel, while a distance based charge of 0.06$ would lead to 12.6% reduction, while a distance based registration fees of 0.015$ would reduce travel by 3.3% while an emission fees of 0.03$ would reduce travel by 6.6%. Litman has also explored the role of distance based insurance fee as a transport demand management tool. The study indicates that distance-based insurance pricing is more actuarially accurate, and therefore more equitable and economically efficient than current pricing. Distance-based insurance provides specific benefits including reduced accidents, traffic congestion, and pollution, facility cost savings, insurance affordability, and increased consumer welfare. Vehicle travel foregone consists of low-value trips that consumers willingly give up in exchange for financial savings. This paper evaluates different distance-based insurance pricing options. Per-mile premiums are found to provide the greatest net benefits. It uses "odometer audits" to provide accurate mileage data, which is estimated to have minimal costs if performed in conjunction with scheduled vehicle maintenance. Total benefits are predicted to be many times greater than costs.

Litman (1999b) has evaluated the benefits of car sharing. According to the study, the benefits due to car sharing are Increased mobility, economic development benefits, and increased equity. More importantly, car sharing typically reduces average vehicle use by 40-60% among drivers, thus making it an important and an effective transportation demand management strategy.

Note:

\[ i.e., \text{prices more accurately reflect the insurance costs of each vehicle} \]
Meyer (1999) has described the characteristics of transportation demand management. The paper then examines the effectiveness of transportation demand options and concludes that those actions which are most likely to increase the "price" of travel for single occupant vehicle use will be most effective. The paper then identifies several strategies for improving the effectiveness of transportation demand options in the context of regional transportation planning, thereby making the costs of travel more apparent to the user, and making transportation demand options more palatable to the general public.

Litman (2000) has discussed the potential win-win solution that solves the problems associated with transportation, which includes pollution, safety, congestion etc. The study defines win-win strategies as those, which has positive economic, environmental and equity impacts. Some of the win-win strategies are removal of subsidies to oil production, least-cost transportation planning and funding, revenue-neutral tax shifting, and Parking "Cash Out". According to the study, win-win strategies help solve transportation problems by removing barriers and market distortions that reduce consumer choice and thereby encouraging inefficient travel behavior. Win-Win strategies are cost effective, technically feasible reforms based on market principles. Win-Win strategies can help address a variety of problems including traffic congestion, road and parking facility costs, road safety, economic development, consumer costs, environmental quality, community livability, and equity. These multiple benefits create opportunities for cooperation and coordination between interest groups and organizations. If fully implemented, win-win strategies could reduce motor vehicle travel by 15-30%, or even more if implemented with other transportation management strategies. They are "no regrets" measures that are justified regardless of uncertainties about global warming or other environmental and social impacts. They are essential for sustainable transportation. This paper discusses the win-win concept and describes more than a dozen win-win strategies.

**Note:** *\* for North America.
IGIDR (2000) have advocated an integrated air quality management strategy consisting of economic incentives, technological interventions, institutional mechanism, people's participation and law enforcement for effective control of air pollution, primarily pollution due to vehicles.

b) Studies on vehicular pollution using econometric methods

In this section, we provide a review of studies of vehicular pollution control, which are based on econometric methods.

Sterner et al (1992) have estimated the impact of a uniform gasoline tax for OECD countries. The paper first describes the various models for estimating the gasoline elasticity. The study then, uses the lagged endogenous variable method to estimate the gasoline elasticities for the OECD countries individually. Then, based on the mean price elasticity, the study estimates the impact of gasoline tax on carbon emissions. The study found out that, in no gasoline tax scenario, carbon emissions from OECD countries rose by 47% in year 2000 as compared to 1987. If all countries raised their tax level to the maximum, then the emissions declined by 32%, on the other hand, if the tax level was set at a minimum, then the emissions actually doubled over the 1987 value.

Kim and Hanley (1996) have assessed the impact of the transportation measures, particularly pricing strategies, on the reduction of mobile source emission and vehicle miles traveled. The study primarily considers parking fees and gasoline tax. The study uses multinomial logit model to determine the changes in mode choice given the set of trips based on changes in cost of the trips. The study uses pivot-point model for estimating the impact of travel conservation management measure on mode choice and is modeled as:

$$\Delta p^s(A) = -\beta [1-p^s(A)]p^s(A)[\Delta c^s]$$

Where,

*Note:* for India

* for California
p^s_k(A): denotes the changes in probability of choosing automobile for the trip purpose k under scenario s.

k: denotes trip purpose

s: denotes different scenarios of the travel conservation measures.

\( \beta \): denotes mode choice coefficient, which is 0.0072 for work related trip and for non-CBD destination, 0.0085 for work related trips and for CBD destination and 0.0329 for Non work related trips.

\( \Delta c^{SA} \): denotes changes in costs for driving an automobile under scenarios.

The study then estimates the new probability of choosing an automobile due to cost increases using the multinomial logit model. These are then multiplied by the corresponding trip tables, in order to calculate the new total person trips by purpose. That is,

\[ [\Delta p]^s_k \times [P]^k = [PT]^k \]

The new person trip tables for each scenario are converted to automobile trip tables. The resulting value for each zone in the automobile trips are multiplied by the corresponding distance between zones to obtain new VMT tables as shown:

\[ \{[PT(i,j)]^s_k \times [VOR(i,j)]^k \} \times [D(i,j)] = [VMT]^s_k \]

where,

\( [PT(i,j)]^s_k \): person trip tables by scenario s and trip purpose k.

\( [VOR(i,j)]^k \): denotes vehicle occupancy rate tables by trip purpose k.

\( [D(i,j)] \): denotes the distance table between zones

\( [VMT]^s_k \): denotes matrices for the vehicle miles travelled by scenario s and trip purpose k.

The trip models produced by the model show the shift of person trips from automobile to transit induced by increase in driving costs imposed by each scenario. This study considers
different mixes of the two policy instrument and concludes that the most effective travel conservation measure for reducing vehicle miles traveled is either 3$ additional parking fee + 0.50$/gallon gasoline tax or the 1$ gasoline tax increase.

Gunnar and Feyzigolu (1997) have estimated the welfare costs and the benefits of such a policy in Mexico City. The study first shows how the results of rationing can be compared with those that would be obtained using market based instruments. Then, the study presents an empirical framework for estimating the emission reduction due to the regulation. A model of gasoline demand is estimated using aggregate time-series data. This model is used to simulate a counterfactual scenario for demand in subsequent periods as if the regulation had not been imposed. Then, the study presents a model of car ownership based on household survey data. The regulation is modeled as a reduction in the service flow from each car. Finally, the study considers additional information indicating changes in the market for used cars. The study concluded that the total car use in Mexico City has increased after the regulation. This has been attributed to the additional car purchases. The study also concluded that the ban imposed high compliance costs for households, much more than those of alternative market based policies.

Harrington (1997) has tested the hypothesis using a simple statistical model that there is no relationship between fuel economy and vehicle emissions. According to the study, better fuel economy is associated with lower emissions primarily for CO and HC and the effects get stronger as the vehicles age.

IPEA (1998) in their study “Air Pollution control in Brazil” have analyzed the compliance trend of the Brazilian fleet with environmental standards between 1992 and 1997. According to the study, larger automobiles have the fastest compliance schedule while popular models adjust slowly. The study also analyzes the relationship between pollutant emission and car characteristics. The study has found that, on average, single-
point fuel injection cars emit 73% more CO than multi point fuel injection cars and 58% more NO\textsubscript{x}, after controlling for rpm, horsepower and fuel type. There is not much difference between the two types of injection system as far as HC is concerned. The study has also found that, after controlling for rpm and horsepower, ethanol vehicles emit, on average, 36% more HC than gasoline fueled vehicles with multi point fuel injection. Therefore, multifuel point injection could be an important technology in controlling emissions from automobiles.

Sevigny (1998) has examined the role of an automobile emission tax in reducing emissions in the United States. The study, after a theoretical description of the first best tax, develops a second best tax on passenger vehicles. The study mainly deals with: the design of a tax, the behavioral response that leads to an emission reduction; the effect of tax on reduction of emissions; the effect of tax on households in different income quantiles; the emission reduction potential of a gasoline tax to an emission tax. The study uses a simulation model to analyze the sensitivity of travel demand and the resulting emissions reductions to different tax rates and demand elasticities. According to the study, an emission tax by itself would reduce HC by 76%, CO by 71% and NO\textsubscript{x} by 62%. In comparison, a reduction in gasoline tax of 15 cents per gallon would result in increase of HC by 10%, CO by 10.6% and NO\textsubscript{x} by 10.6%, while a combination of emission tax and reduced gasoline tax would reduce HC by 70.2%, CO by 65.3% and NO\textsubscript{x} by 54.5%. This study concludes that an emission tax has the potential to reduce emissions from household vehicles significantly even when travel demand is price inelastic.

Sarah and Fullerton (2000) has evaluated the effectiveness of different combination of economic instruments\textsuperscript{*}. The study considers gasoline tax, tax on vehicle size and subsidy to the "newness" of the vehicle and the different policy combinations of the economic instruments. According to the study, a three-part instrument comprising of

\textbf{Note:} \textsuperscript{*} for California

30
gasoline tax, size tax and subsidy to the "newness" of the vehicle attains 71% of the gain achieved by the Pigouvian tax, while a two-part tax comprising of gasoline tax and tax on vehicle size achieves the same gain. A two-part instrument comprising gasoline tax and subsidy achieves a 62% gain, which is also achieved by a 29cent gasoline tax. The study concludes that gasoline tax is the most effective instrument to achieve a reduction in vehicle miles driven and hence emissions.

c) Studies on vehicular pollution using modelling techniques

Harrington etal (1993) have developed a model of remote sensing to identify the important policy and technological parameters of a remote-sensing program. According to the study, remote sensing is more cost effective than universal inspection and maintenance program for most test regimes, even under different assumptions. Further, if inspection and maintenance programs are already in place, remote sensing provides additional emission reduction at low cost.

Gunnar (1994) has developed a theoretical model for the optimal tax on gasoline. The study employs a model with separability along two lines in the direct utility function and a representative consumer model. The study first considers the maximization problem of the consumer, which is characterized by the equation given below:

\[ U^i = u^i(y^i, x^i, \sum_{i=1}^n e^i(x^i), a') \]

Where individual j's emissions \( e^j \) of pollutants depends on her consumption of the polluting good, \( x^j \), and the abatement the person applies, \( a' \) and her utility \( u^j \) depends on quantities consumed, \( y^j, x^j \) of non-polluting and polluting goods respectively, as well as the total amount of emissions from all \( n \) individuals. This could also be extended by assuming a non-linear abatement cost function \( a^j \).

According to the study, individual optimization is characterized by:

\[ \text{NOTE: } \text{not for USA.} \]
\begin{align*}
\frac{u_x}{u_y} &= p_x + t_x \quad \text{and} \\
\alpha' &= \bar{\alpha}',
\end{align*}

where $p_x$ is the producer price and $t_x$ is the price on the polluting good. The $\alpha' = \bar{\alpha}'$, denotes that the consumer will adjust the level of abatement to the lowest possible level.

The study then considers the optimization problem of the planner, which is characterized by:

$$
\text{Max } w_{k,1} = u(y(a,t_x), x(a,t_x), n\cdot e(x(a,t_x), a))
$$

The difference between the individual's objective function, and the planner's is that the individual does not take into account his effect on emissions, since only a negligible amount affects the person, while the planner has to take into account the effect of emissions on all individuals.

According to the study, optimal allocation is characterized by:

\begin{align*}
(u_x/u_y) + n\nu_e x/y &= p_x \\
(n\nu_e/u_y) &= p_x/e_a
\end{align*}

Assuming that the marginal rates of substitution in consumption will equal consumer prices and eliminating $n\nu_e$, we arrive at:

$$
t_x/e_x = -p_x/e_a
$$

That is, the optimal tax rate on the polluting good should be equal to the direct marginal cost of abatement per unit of achieved emission reductions. The study then uses comparative statics to characterize a cost-effective program and concludes that for a program to be cost effective, the above equality must hold. The study then uses the model described above to the air pollution control program in Mexico and concludes that gasoline tax if combined with technical options can lead to a saving of 24 cents per tonne of pollution reduced as compared to the option of achieving the target pollution reduction entirely by technical modifications.
Johnstone (1995) has described a model of passenger demand, energy consumption and pollution emissions in the transport sector. The model described in his study is designed to serve as a sub-model to the Cambridge Multisectoral Dynamic Model of the United Kingdom. It combines the strengths of economic modeling with the strengths of engineering model, which determine the fuel efficiency and the pollution emission rates. The study models the effects of vehicle substitution, fuel switching and changes in mode splits and is sufficiently flexible to analyze the effects of a broad range of policies in the sector. The study estimates the passenger travel demand over the historical and forecast period on the basis of economic functions. Passenger kilometers are then converted into vehicle kilometers, which become the basis for the estimation of energy consumption and pollutant emission. The other major set is related to ‘network’ types. Four primary road types are distinguished, with pavements and cycle paths included for completeness. On the energy environment side, three other sets are included. These are, the pollutants, the fuel types and the age of the vehicle.

Passenger demand for road travel is estimated on the basis of the vehicle transport. This level of desegregations is required since it is felt that transport demand is partly a function of the vehicle used and partly a function of the location of travel. Depending on the vehicle and the network, the demand is estimated using different explanatory variables. In case of motor vehicles and car passenger kilometers, the following explanatory variables are employed: weighted vehicle running costs, an activity variable (employment or GDP), vehicle ownership and network capacity. Vehicle ownership is estimated in a separate function using real disposable income and a price index for vehicles as the explanatory variables.

The study then estimates, the energy consumption. The estimation of energy consumption by mode and by vehicle is determined on the basis of interdependent

\[ \text{Note: } * \text{ for United Kingdom} \]
economic and technological relationships. The estimation of energy consumption in road transport consists of the following steps.

The study first derives the survival rate and the estimates of vehicle purchases, in order to estimate the fuel efficiency characteristics of the entire vehicle stock.

The function for the survival rate is of the following form:

\[ TVSR_{i,m} = 1 - \beta_i m^2 \]

where, \( TVSR_{i,m} \) = Proportion of Vehicle I of age m which have survived.

Vehicle purchases are estimated on the basis of consumer's expenditures on vehicles. Proportion between classes of vehicle is assumed constant for all classes of road vehicle, except the following splits: petrol/diesel vehicles. The diesel shares are estimated on the basis of logarithmic functions and petrol is taken as residual.

\[ \ln \left( \frac{1-TVKP}{\lambda + TVKP} \right) = \beta_{0,i} + \beta_{1,i} \times \text{DATE} \]

Where,
- \( TVKP \) = Proportion of Petrol consumed by vehicle i.
- \( \text{DATE} \) = Vintage of the vehicle
- \( \lambda \) = Assumed maximum penetration of diesel for vehicle i.

The study then estimates the fuel efficiency of the vehicle stock by running a regression with the price of fuel and fuel efficiency of the vehicle stock (lagged) as the dependent variable.

The estimated stock fuel efficiency is then adjusted by the type of roadway to capture the effect of different driving conditions, with urban conditions being the numeraire. Finally, the effect of changing driving conditions on fuel efficiency within classes of vehicles is captured by attempting to account for the effect of changes in traffic
congestion on vehicle speed and on fuel efficiency. The study uses “floating car” methods to determine the effect of flow on congestion, and thus speed over the entire network. Finally, The change in the vehicle speed is then used to adjust fuel efficiency using quadratic functions. The study then estimates the pollutant emission from the road transport, by regressing the emission parameter of the fuel for each pollutant on the emission intensity of the vehicle and the vehicle speed.

Morisugi and Ohno (1996) have studied the effects of the policy to reduce nitrogen oxides from diesel automobiles and its influence on price changes. This paper presents a cohort type of simulation model both, to predict the number of diesel automobiles and the NOx volume, and to analyze the impact of the policy to reduce diesel automobiles. This model is estimated by using the time series data from 1974 to 1991 and the estimated model explains:

i) Without any policy in 1992, the NOx volume will increase, where the diesel automobiles share in the sedan (a type of automobile) market will change from 4% in 1991 to 20% in 2005, and the share in the small truck will also increase from 50% to 75%.

ii) The policy to stop producing the diesel automobiles reduces its share and consequently, the NOx volume will decrease drastically; however it is difficult to have consensus because it results in producer loss and user inconvenience.

iii) The light oil price tax increase might be the most appropriate policy because it has an efficient effect on reduction of the NOx volume and might obtain the consensus if it does not result in a big commodity increase.

iv) The policy to set the upper limit of age on the diesel automobile is not so efficient and may induce an increase in commodity prices.

*Note: * for Japan.
A certain combination of policies can achieve enough results even if each policy is not adequate.

Harrington et al (1996) has compared a traditional regulatory program for reducing the vehicle emissions, with various fee emission policies. The study found that both command and control measures and emission fees reduce emissions by 5-10 tones (15-35%) as compared with a pre-repair emission level of 30.6 weighted tones per year. This paper has found that fees have higher net benefits than command and control policy in all cases. However, it was found that the extent of uncertainty in measuring and repairing vehicle emissions could have important impact on the evaluation of policy instruments. With uncertainty, both command and control and emission fee policies have much lower potential to reduce emissions and have lower net benefits. The command and control policy is particularly affected by the uncertainty and there is a limit to the amount of possible emission reductions. The study also considers the various other policies like expenditure caps that are used as part of the Inspection/Maintenance program and that can be used with fees and baseline fees. According to the study, caps also reduce the efficiency of emission fees to reduce emissions and tends to set a limit on the total amount of emission reduction that can be achieved under any policy, and baseline fees fares worse as compared to a pure fee under uncertainty.

Bose (1998) has developed a policy framework for emission reduction and for determining the cost effectiveness of alternative measures. It estimates the pollution loads for future years under Business as Usual scenario using LEAP simulation package for the year 2010/11. The study then estimates the effect on emission reduction of introduction of clean technology, increase in the number of buses and the mix of the two polices for the year 2010/11. According to the study, increasing the number of buses leads to a net energy savings of 16% and 8% reduction in weighted toxicity of emissions. The option of clean

Note: *of California
**for New Delhi. 36
technology would lead to a net energy saving of 8% and 25% reduction in weighted toxicity of emissions. An integrated strategy (combining both the policy measures) is much more cost-effective as it leads to a net energy savings of 22% and 29% reduction in weighted toxicity of emissions.

Saleh et al (1997) have explored alternative transport policy scenarios in the context of air emissions looking at two independent case studies in the city of Newcastle upon Tyne; first, the effects of improvements in fuel emissions in the city of Newcastle. The study considers seven different scenarios ranging from base case to various combination of change in vehicle kilometer traveled and penetration of clean technology for low and high traffic growth scenarios for various reference years. For low traffic growth scenario, in terms of total emissions from 1990 to 1995, an increase in about 18% in sulphur dioxide, an increase of 21% of nitrogen oxides and an increase of 6.1% of particulate matter is found. The effect of improvement in emissions due to penetration of clean technology to the year 2000 leads to an estimated reduction of 8.5% locally and 6.5% globally in SO$_2$; a reduction of 8.5% locally and 1% globally in NO$_x$; a reduction of about 7% locally and 9% globally in CO$_2$ and a reduction of about 33% locally and 1% global reduction in particulate matter is found. Second, the effects of different access management strategies for the proposed Inner Distributor Road for different scenarios were studied, viz. 'do nothing', maximum forecast growth in traffic in 2011 with access management, increase in the supply of public parking with access management in place, and no increase in public parking with no access management strategies in place. According to the study, there is a reduction of more than 50% as a result of applying access management strategies, and there is a reduction in energy usage of 6.6% from holding the private non-residential parking places at 1990 levels, while allowing the supply of public parking to accommodate forecast traffic growth and applying access management strategies. A reduction of 26% of energy usage results from sustaining both public parking and private non-residential
parking places to 1990 levels, with access management scenarios in place. A reduction of 50% locally in NO$_x$, SO$_2$ and particulate matter result from applying access management strategies. The effect of sustaining private non-residential parking and public parking places at 1990 levels while applying access management measures would result in a reduction in local emissions in average of about 30% in SO$_2$, NO$_x$ and particulates. A reduction of 50% (locally and globally) in CO$_2$, CO and CH$_4$ occurs from applying access management measures only, while allowing for maximum growth in public parking and private non-residential parking places. The effects of sustaining private non-residential and public parking spaces to 1990 levels would result in a reduction of about 26% in greenhouse gases. Therefore, the study shows that other policies such as traffic restraint measures should be actively promoted, particularly in combination with other policies.

Dagraeve, Koofman, and Denis (1998) have developed a methodological model, which enables one to select a least-cost mix of transport and other policy measures to meet the air quality standards for the European Union, and the target year is 2010. The paper considers the transport-related measures such as: a) technical measures b) mandatory fuel standards c) non-technical measures and d) inspection-maintenance programs. The study uses a non-linear integer programming technique and uses a special decomposition technique, which will allow one to build a customary solution algorithm. The analysis presented in this study suggests that a rebalancing of the air quality policy mix could result in substantial cost savings. For example, the study found that the objective of urban NO$_x$ reduction by 51% could not be met by BAT (Best available technology alone), and this necessitates changes in transport patterns to meet the desired reduction.

Proost and Lendr (1998) have examined the merits of a switch from ownership type of taxes to motor fuel taxes. The study first examines the potential effects of a budget neutral shift between two types of taxes. The empirical evidence seems to demonstrate that

\textbf{Note:} * for EU countries.
the net effect on the volume of the car use could be negative but small. The paper then examines the welfare effects of a substitution of ownership taxes by motor fuel taxes. The results obtained show that the welfare effects are likely to be negative. The volume of car use will not change by much. The major welfare cost will be the inefficiency of car manufacturers and consumers to improve the fuel efficiency of cars. There is welfare loss because resources are used to save mainly fuel taxes, as these constitute already 75% of pump price in most European Union countries. The study also compares the relative efficiency of various pricing instruments in an urban and a non-urban atmosphere. According to the study, in an urban city like Brussels, (for the reference year 2005), perfect pricing results in a welfare efficiency of 100%. Compared to perfect pricing, environmental standard for cars results in a welfare efficiency of 11%, while public transport results in a relative welfare efficiency of 12%, motor fuel tax results in a welfare efficiency of 30%, kilometer tax results in a welfare efficiency of 43%, while cordon pricing results in a welfare efficiency of 48%. However, for a non-urban city like Belgium, the policy which would result in the highest welfare efficiency (after perfect pricing) is motor fuel taxes, followed by environmental standard for cars (2%), public transport pricing (1%).

Borger and Swysen (1998) have studied optimal pricing and regulatory policies in the transport sector within the framework of a welfare maximization problem. This paper first develops a simple theoretical model. The paper then constructs a simulation model consistent with the theoretical framework to study a variety of policies using data on Belgian inter-regional transport. The model used in this study allows for a large number of transports through the use of nested CES utility and cost functions, and it captures the most important external effects associated with transport services. The model was used to determine optimal tax and public transport prices, optimal choice of technologies and combination of two policies. According to the study, optimal pricing would have a non-
negligible impact on traffic flows. Peak car transport would decline by some 11%, while off-peak traffic would increase by 7%. Moreover, public transport use, and especially peak truck traffic, would both go down. However, the optimal pricing in the absence of a toll reduces the welfare gain dramatically from 0.87 to 0.20 million ECU per day. However, the introduction of new technology (like the introduction of subsidized catalytic converters) would reduce the pollution substantially, but would lead to a welfare gain of only 0.11 million ECUs per day, which amounts to 13% of the welfare gain at the full pricing optimum. According to the study, using only public transport prices is not an efficient solution as it attains only 13% of the welfare gain that is attainable in the full pricing optimum.

Plautt (1998) in his study reviews the range of policy alternatives used for controlling vehicle emissions. A formal methodology for assessing the relative efficiency of alternative policies is proposed with formal measures that lend themselves to relatively easy quantification for empirical application. It is shown that the most important components of these efficiency components are the elasticity of emissions with respect to ‘travel activity’ taxed or subsidized by an abatement policy, the impact of the policy upon travel consumer surplus, and the ‘noisiness’ or the stochastic uncertainty of the relationship between the emissions level and the ‘activity’ being taxed or subsidized. This last factor makes the abatement policy ‘noisier’ and less efficient. According to the study, pricing instruments are more preferred forms of pollution control than direct command and control instruments.

Bates (1998) has estimated the effect of road pricing in London. The study uses APRIL which is an incremental equilibrium model, which predicts changes in travel resulting from, a wide range of policies associated with congestion pricing. The study takes as given a base description of travel movements, considered to be in equilibrium and

Note: It is a theoretical study.
predicts changes relative to the base, given a change in generalized costs. According to the study, at the highest charge tested, car trips to Central London from Inner London during the peak fall by over 60%, from outer London by almost 50% and from outside London by over 30%. Car traffic in Central London all day falls by over 40% and all traffic by almost 25%. However, around two-thirds of these effects are achieved by a charge of only 4 pounds, suggesting diminishing returns from higher charges. The reduction in traffic in Central London leads to increased speeds, which rise, on average over the day, by almost 35%. The traffic reductions also lead to improvements in the environment and safety. With a 10 pound charge London wide CO emissions fall by over 5% and fuel consumption, CO$_2$ and accidents by 3%. In Central and Inner London, the reductions are 13% and 6% respectively. According to the study, the greater reduction in Inner London traffic does not substantially improve London speeds, which are only 7% faster at the highest charge level. The environmental and safety effects are, however, almost double those obtained from Central London charging, because the area affected is much wider. The highest charge reduces London-wide CO emissions by 9% and fuel consumption by 11%. In Central and Inner London the reductions are 20% and 11% respectively.

Harrington et al (1998a) have examined the factors affecting owner’s valuations of the old vehicles using a longitudinal data set for the year 1995. The estimated model of vehicle value is used as an input into a simulation model of a 1,000-car fleet of California’s fleet. The simulation model is used to examine the role of scrap policies, regulatory inspection program, emission fees with exemption emission and emission fees with no emission exemption. The model incorporates both technical and behavioral relationships and assumes that of all possible options, the owner chooses the one with the least cost. It was found that stand-alone scrap programs are relatively low cost but provide relatively few emissions. The regulatory inspection and maintenance program attains a much higher level of emissions (20 to 35 tones) at a much higher cost (both without and with scrap page
program). Of the two emission fee programs, the one with exempt emissions has emissions reduction potential comparable to that of regulatory inspection and maintenance program (21 to 32 tones), but is less costly (without and with scrap programs). The greatest emission reduction potential comes from the fee program with emissions exemption, which can eliminate up to 39 tonnes of pollutants, however, it is more costly than emission fee with emission exemption, but better than regulatory inspection and maintenance program. However, a stand-alone scrap program is unlikely to provide very much in the way of emission reductions.

Romilly (1999) has estimated the economic and other costs of exhaust emission due to substitution of bus for car travel in urban Britain. This study provides a synthesis of monetary estimates of these exhausts emission and other costs. The other costs considered are traffic congestion, fuel consumption, noise pollution, road accidents and road damage. The exhaust emission monetary cost estimates, mainly from the United States and the United Kingdom, are discussed within the context of a sensitivity analysis, which allows for changes in parameters such as load factors, emission factors and the individual exhaust emission cost estimates. The simulation results show that the substitution of bus for car travel generally yields significant monetary gains when a number of costs are considered. The most important gain is the reduction in congestion costs, although fuel savings also become substantial at higher load factors. The study has found that for load factors in the range of 35 to 55%, the monetary cost reduction varies from 63,950 pounds per annum to 123,410 pounds per annum for every 100 cars ceasing to travel. Within these costs, emission and road damage costs increase. The increase in exhaust emission costs occurs because buses have relatively high emission factors for that emission, which have the highest health costs, mainly PM$_{10}$. According to the study, in order to reduce exhaust emission costs from car to bus transfer at given load factors, the most effective policy option according to the study, is to encourage the reduction of particulate emissions from bus engines. In terms of
the overall costs, increasing busload factors by relatively modest amounts can lead to substantial reduction in these overall costs.

Johannson (1999) has discussed the various road transport externalities and the policy instruments that would deal with those externalities. According to the study, for local and regional air pollution, a successful strategy is to combine standards with economic policy instruments such as fuel taxes.

2.4 Conclusion

Review of past studies clearly indicated that there is a dearth of quantitative studies, which explore appropriate economic instruments to control vehicular pollution in the Indian context. Difficulties in gathering information may be the main reason as the departments and officials do not maintain proper time series data set to suit these kind of analysis because environmental concern due to vehicular pollution started recently. This thesis attempts to provide a quantitative approach in this area with the available information.

Note: * for Sweden.
<table>
<thead>
<tr>
<th>Author</th>
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<th>Methodology</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterner, T</td>
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<td>Elasticity approach</td>
<td>The tax, if set at the maximum value reduces emissions by 32%, while if set at minimum value, doubled the emissions over the 1987 level.</td>
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<td>Rietvald, P</td>
<td>Speed Limits</td>
<td>Cost benefit analysis</td>
<td>A decrease of the average speed by 5% leads to decrease in energy use by 6%, CO₂ by 6%, NOₓ by 10% and of traffic victims by 10-17%</td>
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<td>Tata Energy Research Institute</td>
<td>Clean Technology and Public Transport</td>
<td>Simulation analysis using LEAP model</td>
<td>An integrated strategy consisting of clean technology and increase in the number of buses is the most effective way as it leads to a reduction of 29 % in weighted emissions.</td>
</tr>
<tr>
<td>Sarah, W and Fullerton, D</td>
<td>Gasoline Tax and Vehicle Tax (on size and by vintage)</td>
<td>Regression technique</td>
<td>Gasoline tax is the most effective way of reducing vehicle mileage and hence emissions.</td>
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</table>
TABLE 2.2 a: SUMMARY OF IMPORTANT EMPIRICAL STUDIES ON VEHICULAR POLLUTION

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<td>Proost and Lendr</td>
<td>Fuel Tax and other instruments</td>
<td>Partial Equilibrium</td>
<td>Motor fuel tax results in 30% welfare efficiency. Perfect Pricing results in a welfare efficiency of 100%. Compared to perfect pricing, environmental standards for cars result in a welfare efficiency of 11% and public transport results in a relative welfare efficiency of 12%.</td>
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<td>Multivariate Regression</td>
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