ABSTRACT

With rapid growth of urbanisation in the recent decades, there has been an increase in the personalised mode of travel in most cities, leading to the problem of congestion. This congestion problem had resulted in **longer travel time**, **reduced average speed** and **increased fuel consumption** and also **higher levels of pollution**.

This study develops a model and methodology to **estimate the congestion costs**, in order to levy an **optimal charge**. Three major congestion costs are analysed in this paper – **value of time cost**, **fuel cost** and **pollution cost**, all of which are responsible for cost. Using the estimated congestion cost, we plan to recommend the same to the transport department to help alleviate the congestion on the roads of the national capital. The same study can be further used to identify the cost for all the cities in the country and thus make India a less congested, and a more green nation.

Chapter 1

Introduction

Traffic congestion and associated problems have become a major worry for daily commuters. The conventional approach for dealing with traffic congestion was based on the supply - side measures. These policies were based on the criteria to ‘predict and provide’ i.e. by changing the supply to meet the demand which was done by building more roads and flyovers. But this approach is no longer feasible. The forecasts of vehicle usage were accommodated by building more roads, as it was widely accepted that unrestrained demand for travel by car cannot be sustained. Measures taken to address these problems have therefore shifted to ‘predict and manage’ or travel demand management measures (TDM). These measures focus on managing the demand rather than increasing supply i.e. decrease in the dependence of personal vehicles or shifting to the public transport.

In most of the cities around the world traffic congestion is serious and getting worse. In case of developing countries like India, there has been increase in the automobile dependence in the metropolitan cities of the country. In India between 1981 and 2013, the number of private 4-wheelers has increased by almost 22-fold. Indians bought 1.5 million cars in 2007, more than double that of 2003. The cumulative growth of the passenger vehicle segment during April 2007 – March 2008 was 12.17% in 2007-08 alone, 9.6 million motorised vehicles were sold in India. These figures from different studies show that there has been increase in automobile dependence especially rising share of personal-motorised vehicles.

In Delhi, the capital city, the demand for travel by motor vehicles has increased which is due to rising income and standard of living of the city. This growing car numbers had lead to problem of traffic congestion in the city. Due to congestion the speed level has decreased, also idling and frequently accelerating and decelerating of vehicles wastes a lot of fuel and also has led to higher pollution levels.

To match the increasing travel demand efforts had been taken up by government of the city. Supply - side measures like addition of more roads or widening of existing roads were added to provide additional capacity to deal with the growth of vehicles. Along with these measures, actions like introduction of CNG based public transport programs and restriction on the age of vehicles etc had been implemented over the years. But despite all these measures these problems have only increased, this is due to increase in the personal vehicles over the years. Also the ballooning number of vehicles has made it difficult to implement all schemes that have been proposed in the past.

Chapter 2

Literature Analysis

Congestion
Traffic congestion is defined as a condition of traffic delay (when the flow of traffic is slowed below reasonable speeds) because the number of vehicles trying to use the road exceeds the traffic network capacity to handle them. Traffic congestion is widely viewed as a problem in many urban areas because the overall volume of vehicular traffic in many areas continues to grow faster than the overall capacity of the transportation system.

Travel Demand Strategies(TDM)
TDM measures mainly focus on improving the automobile travel through widening roads so as to increase the traffic speeds of the motor vehicle and also increasing the amount of urban land which is used mainly for private - vehicle parking purposes. These measures are broadly classified as fiscal and non-fiscal measures. Public transport improvements, road space reductions, urban traffic management and control systems, traffic bans/restrictions and travel awareness campaigns are some of the non-fiscal measures which can be adopted by the policymakers & transport planners. Whereas fiscal measures include parking charges, workplace parking levies fuel taxes, vehicle excise duty, car ownership permits, public transport subsidies, priority measures for walking & cycling & road - user charging.

Mobility Management or Travel Demand Management Practices
There are various examples of mobility management practices that could be implemented. Since TDM measures consist of both fiscal as well as non-fiscal measures, therefore the following Non-Fiscal Measures could be implemented in making the transportation system more equitable and efficient:

- <u>Improvements in non-motorised transport</u> - This will result in shift from automobile to non - motorised transport (NMT). NMT (such as walking and cycling) provides many benefits which are inexpensive for users and reduce costs such as congestion, parking subsidies, and energy consumption and pollution emissions.
- <u>Transportation market & pricing reforms</u> - There are both direct as well indirect costs associated with these problems that are borne by the whole society. Many market reforms or strategies have been implemented that charge directly the cost imposed by an individual motorist. With this charge, the motorists will use vehicles more efficiently and this will in turn lead to a lot of savings in terms of fuel costs, parking costs etc.
- <u>Commuter financial incentives</u> - This strategy reward the employees with financial rewards for not using their private - vehicle and using alternative commute modes instead.

Fiscal Measures
These measures consist of price-based instruments. In case of fiscal instruments, the cost associated with correcting negative externalities in the transport sector are included in the price charged for different transport problems. These include congestion, toll tax, fuel tax (an excise tax on fuel or vehicle tax and subsidies (subsidies for clean fuel, public transportation)). This price charge then helps to reduce the travel demands by switching from private to public transport.

There are several components such as type of problem(congestion or air pollution), seriousness of the problem, flexibility to achieve these goals and cost of the policy instrument on which the choice of any fiscal instrument depends. In case of Congestion charges: it is a charge imposed on travellers at places where road system are very congested. The implementation of congestion charge results in control of the traffic. Since the travellers respond by shifting to other alternative routes, using other mode of transport & switching the departure time etc.

The congestion pricing can be classified as one of the five types listed below:

- **Route choice** - Alternative routes may be chosen by the people in order to avoid the toll charged on a particular road.
- **Departure time choice** - If the toll is variable throughout the day i.e. during peak period the charge is higher. Then to avoid the higher charge travellers may alter their departure time.
- **Cancelling trips** - In order to avoid the congestion toll, travellers may decide to cancel the trips, if it is not necessary.
- **Mode choice** - With congestion pricing, travellers may consider switching from private to public transportation.
- **Destination choice** - Some people may change their destinations to avoid the toll. This is generally for travellers who have many alternate destinations & can choose one of them e.g. shopping.

However, the availability of alternate means of transport and difference in income levels make a difference in willingness to pay for the congestion charge. In many developed countries, some of these fiscal measures i.e. price - based instruments are used to encourage travellers to shift their behaviour, either by travelling in the off-peak period or by using alternate transportation modes. These instruments are discussed as follows :-

1. **Congestion Charge**
   It is a charge levied for use of road infrastructure. This fee varies depending on location, time or vehicle occupancy or offers a priced substitute to an existing congested road that facilitates the motorists to reduce the total travel time. The main objective of this fee is to reduce congestion by persuading people to change their travel patterns through shifting to public transport, or to travel during off-peak period.

2. **Road Pricing**

It is another pricing instrument to tackle the transport problems. Motorists are charged a fee for using their vehicles within specific areas or specific roads. The road - pricing is defined in two ways:

a) **Traffic engineers & transport planners** - A direct charge on road use, in order to manage the travel demand, to reduce traffic congestion & the environmental impacts from congestion for generating revenue to finance the transport services.
b) **Economists** - The price that includes the additional cost imposed by the travellers on the whole society by entering a congested road network.

3. **Fuel Tax**

Fuel tax is another pricing instrument used to correct the negative externalities such as air pollution and congestion. It is levied on the consumption of fuel in proportion to its pre - tax price. The immediate effect of the fuel tax is to increase the price of fuel which further reduces the usage of vehicles. But for long term it alters consumer purchasing behaviour, thereby causing a switch to more fuel - efficient methods. A fuel tax is mainly used by the government as an instrument to generate government revenues but it had significant impact towards the reduction of emissions and traffic congestion.

4. **Vehicle Ownership taxes**

It is another policy instrument for reducing congestion and level of emissions. It is one of the policies that acts as a direct substitute of private vehicles with public transport. During 1990 - 2002, this tax has succeeded in bringing down the annual motor - vehicle population growth rate to 2.8% from 4.2% in Singapore.

5. **Parking Management Strategies**

By managing parking resources efficiently most of the negative externalities related to transport can be corrected. It is important for the developing cities to manage parking as parking space is limited. Some of the parking management strategies are:

a) Parking Plan - Focus on where parking facilities should be provided, its management and regulation, parking rate and parking regulations to be enforced.
b) Limit on parking supply - Minimising the public space devoted to parking.
c) Limit on-street parking duration (maximum amount of time that a vehicle could be in one place) - To discourage people from bringing cars to the workplaces and discourage use of street parking for a long - time. A penalty should be there if the time exceeds the maximum amount a vehicle could be in a place.

Chapter 3

Data and Methodology

1. **Data**
   In this study, secondary data is used from various reports.

a) Traffic Characteristics of the New Delhi
The data was collected from the Government of Delhi, Transport Department Annual report in 2014

Year	Number of cars registered
1996-97	705923
1997-98	765470
1998-99	818962
1999-00	869820
2000-01	957925
2001-02	1047048
2002-03	1139753
2003-04	1243759
2004-05	1359273
2005-06	1471858
Total	**10379791**

Table 1

b) Speed Flow Data
The average journey speed on major corridors during peak hour (KMPH) was taken from the MOUD Report: ‘Study on Traffic and Transportation Policies and Strategies in Urban Areas in India’.

Category of the cities	Average journey speed on major corridors during peak hour
Category - 1a (< 5 lakhs with plain terrain)	28
Category - 1b (< 5 lakhs with hilly terrain)	25
Category - 2 (5-10 lakhs)	24
Category - 3 (10-20 lakhs)	24
Category - 4 (20-40 lakhs)	22
Category - 5 (40-80 lakhs) 21	21
Category - 6 > 80 lakhs	17

Table 2 - Average Peak hour journey Speed of the cities in India

The above table shows the journey speed of the major cities of India. The cities here are categorised according to their population. Delhi lies in the Category-6 with a population of 2.5 crore (Census Of India, 2014).

c) Fuel consumption rate
For calculating the fuel consumption of cars, the following algorithm was used which was taken from the MOUD Report: ‘Study on Traffic and Transportation Policies and Strategies in Urban Areas in India’.

$$\mathbf{FCR=1.031+167.522/v+0.00133v^2+0.00006RG+0.13879RF}$$

where
FC= Fuel consumption rate in Litres/100km
V =speed of the vehicle in km/hr = 17km/hr (for Delhi)
RF = Rise and fall in M/KM = 0 (for Delhi)
RG = Roughness inMM/Km = 4000 MM/km (for Delhi)

d) Emission Factors of the pollutants
For calculating the pollution cost, emissions factors were applied the Emission Factors were taken from the draft report on – “Emission factor development for Indian vehicles” as part of Ambient Air Quality Monitoring and Emission Source Apportionment Studies, CPCB/MOEF.

Type	Year	CO	HC	NOx	PM
PCG	1996-2000	3.9	0.8	1.1	0.05
	2001-2005	1.98	0.25	0.2	0.03
PCD	1996-2000	1.2	0.37	0.69	0.42
	2001-2005	0.9	0.13	0.5	0.07

Table 3 Emission Factors of the pollutants

2. Methodology for the Data Analysis

The analysis involved a series of systematic steps. The first step involved the identification of the parameters considered for the calculation of the external costs or the congestion costs. The parameters considered were value of time, fuel consumption of the different cars (petrol or diesel) and pollution generated by the volume of the cars.

In the second step two scenarios were considered to see the changes in congestion costs - the first scenario was the Business - as - Usual (BAU) case and the second scenario was the Congestion Pricing Policy (CPP) case.

In the BAU Case, the traffic volume increased as it is the case when no congestion pricing policy is levied. This was according to the data collected. One assumption to calculate the congestion cost was that the speed levels of the cars decrease with the increase in volume of the cars (as the number of cars increase which develops congestion and decrease in speed levels) which also lead to a relationship between traffic volume and the speed levels.
In the Congestion Pricing Policy (CPP) Case, the assumption was the level of traffic is decreasing if a congestion price is levied, which will lead to optimal volume of cars and price. Once the congestion pricing policy proposed is applied, the volume of the cars is believed to decrease which leads to less congested area and thereby improves the speed levels.

In the third step the external costs/congestion costs or the welfare losses and gains were calculated for both the cases with increase or decrease in traffic. This also leads to determination of a relationship of external costs.

In the last step, the effect of pricing on traffic was determined through the relationship between traffic, external costs and pricing.

Two basic types of total cost and welfare loss deriving from congestion were identified – direct and indirect. The method proposed here provides the indicators for measuring these costs and welfare losses and then a procedure for converting them into financial terms. This will then provide the total external costs due to congestion.

1. **Direct Costs**
   The direct costs associated with congestion were identified as follows –
   - The value of time lost as a result of congestion (vehicle delay)
   - Additional costs due to additional fuel consumption.

1.1 Time Cost

Value of time lost caused by the congestion. The effects of congestion are estimated in terms of the value of time lost, calculated as the difference between the travel speed considered normal (free-flow speeds, according to the MOUD study) on a road with the relevant category (expected speed) and the average peak hour journey speed of the city (actual speed). Here the average peak hour speed is considered because during peak hour the volume of the traffic is high which leads to a situation of congestion.

On the basis of this we first calculate the time taken when travelling at the actual speed level (the peak hour journey speed which is 17 KMPH for Delhi) and then the time taken travelling at the free flow speed (i.e. 40 KMPH). The difference between these two equations will give the time lost due to congestion. We then convert this time into monetary units by using the value of time as Rs 105 KM/HR (Rites report). The equations used to calculate the value of time loss are as follows :-

Value of Time Loss - The variables are the total traffic volume of the cars in the New Delhi Area and the average peak hour journey speed in the city.

$$A/ S_p = T_p$$

Where A is the area of the case study area or the distance travelled by the cars when crossing it.
S_p = is the average peak hour journey speed of the Delhi city
T_p = is the time taken per car when travelling at the peak hour speed.

$$A/S_i = T_i$$

Where A is the area of the case study area or the distance travelled by the cars when crossing it.
S_i = is the ideal speed assumed for a particular.
T_i = is the time taken per car when travelling at the ideal speed.

$$V*T_p = T_{vp} \;\&\; V*T_i = T_{vi}$$

Where V is the traffic volume i.e. number of cars entering the area during 12 hours
T_p = is the time taken per car when travelling at the peak hour journey speed.
T_i = is the time taken per when travelling at the free- flow or ideal speed
T_{vp} = is the total time taken by the cars entering the area (at the peak hour journey speed).
T_{vi} = is the total time taken by the cars entering the area (at the ideal speed).

Now ,

$$T_{vp} - T_{vi} = L_h$$

The above equation gives us the number of hours lost during the 12 hours when travelling through the New Delhi area. The time lost are then converted into monetary terms by using the Value of time Rs 93/hr. The time cost is then calculated using the above VOT value

$$L_h * VOT = \text{Time Cost.}$$

1.2 Fuel Cost

Valuation of additional fuel consumption due to congestion. This is another financial cost which results due to congestion. To estimate the additional fuel consumed a fuel consumption rate is considered which is a function of the parameters like speed levels, roughness of the roads and the rise and fall of the Delhi roads.

$$V * FCR = FC\ pc$$

Where V is the traffic volume for 12 hours and FCR is the per car fuel consumption in litres/100km of a journey speed and FC pc is the per car fuel consumption during the 12 hours at a particular speed level for 1km.

$$P\ p * FC\ pc = CF\ t$$

Where P p is the price of the petrol and FC pc is the fuel consumption of the petrol cars and CF t is the cost of fuel of the petrol cars.

$$P\ d * FC\ dc = CF\ t$$

Where P d is the price of the diesel and FC dc is the fuel consumption of the diesel cars and CF t is the cost of fuel of the diesel cars.

FCR = 1.031+167.522/v+0.00133v^2+0.00006RG+0.13879RF

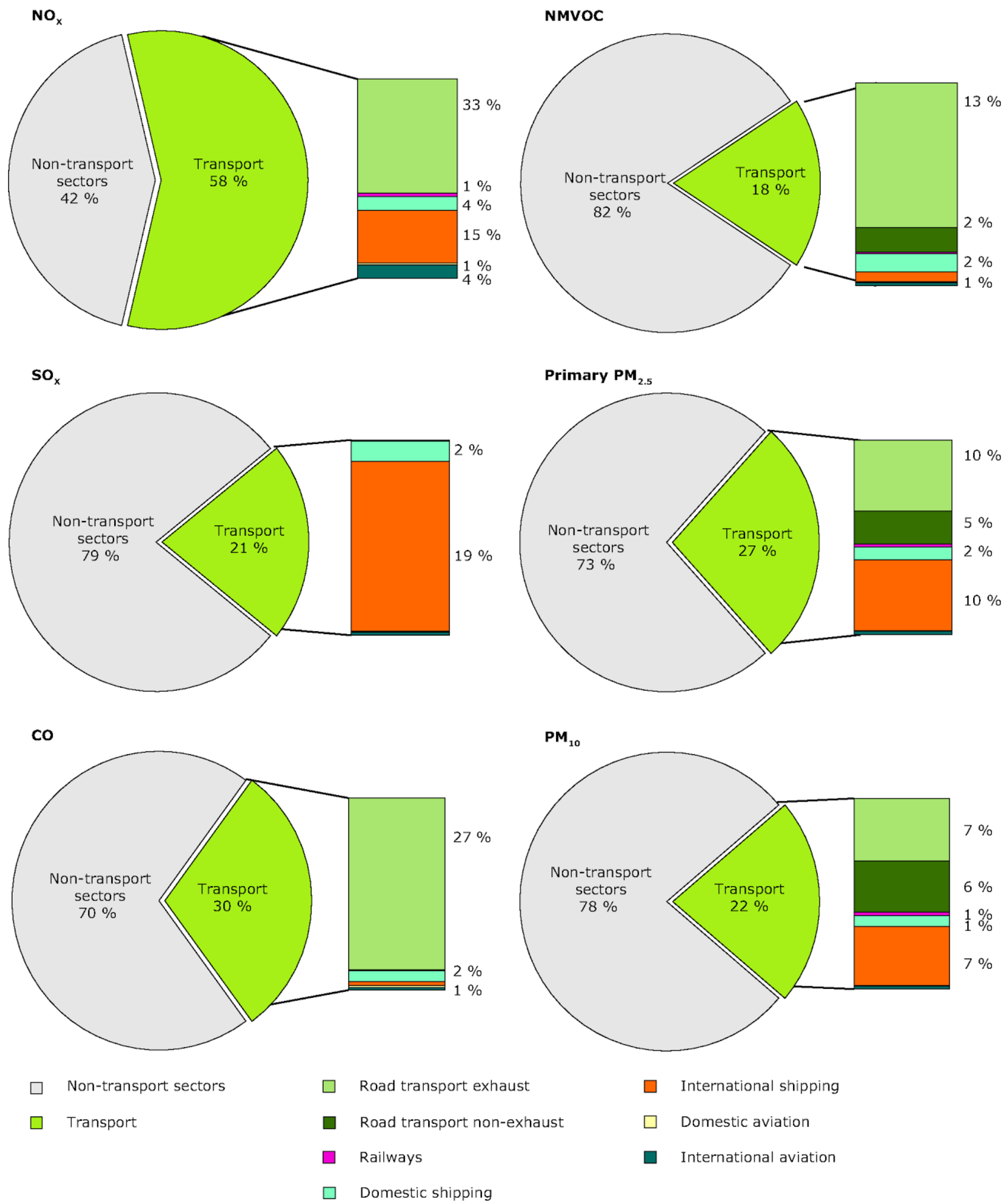
Where
FC= Fuel consumption rate in Litres/100km
V =speed of the vehicle in km/hr
RF = Rise and fall in M/KM
RG = Roughness inMM/Km
For Delhi
RF =0
RG= 4000MM/km

Assumption - As the prices of the fuel differ with the fuel type (petrol/diesel), a ratio was assumed between petrol and diesel cars on the Delhi roads which were taken as 55:45 i.e. 55% of the cars were petrol cars and 45% were the diesel cars. This ratio was based on the growth rate of the petrol and diesel cars over the years. The price of the petrol and diesel for the year 2014 is Rs 64.24 (petrol) and Rs 53.35 (diesel).

2. Indirect Costs

2.1 Pollution Cost (Health Damage Cost)

This is another major cost that arises from congestion; this cost includes the additional emissions of fumes and particles into the atmosphere and their effect on the health of the residents. In order to calculate the pollution load the major pollutants which were considered are - CO (carbon monoxide), NOx (oxides of nitrogen), PM (particulate matter) and HC (hydrocarbons). These were included because in general automotive vehicles emit several pollutants depending upon the type of quality of fuel consumed by them. The major pollutants released are carbon monoxide, hydrocarbons, nitrogen oxides, air toxic namely benzene, lead and particulate matter. Various studies have been carried out in the past in order to estimate the contribution of the various sources towards ambient air quality for Delhi. The following infograph then shows the contribution of the various sources of pollutants by the transport sector in case of Delhi.



NO_x
Non-transport sectors 42 %
Transport 58 %
33 %
1 %
4 %
15 %
1 %
4 %
NMVOC
Non-transport sectors 82 %
Transport 18 %
13 %
2 %
2 %
1 %
SO_x
Non-transport sectors 79 %
Transport 21 %
2 %
19 %
Primary $PM_{2.5}$
Non-transport sectors 73 %
Transport 27 %
10 %
5 %
2 %
10 %
CO
Non-transport sectors 70 %
Transport 30 %
27 %
2 %
1 %
PM_{10}
Non-transport sectors 78 %
Transport 22 %
7 %
6 %
1 %
1 %
7 %
Non-transport sectors
Transport
Road transport exhaust
Road transport non-exhaust
Railways
Domestic shipping
International shipping
Domestic aviation
International aviation

Pollutant	Effect on Human Health
CO	Affects the cardio - vascular system and the nervous system which reduce productivity and increase personal discomfort
NOx	Increase Susceptibility to infections, pulmonary diseases, impairment of lung function and eye, nose throat irritations.
PM	Affects the respiratory and immune system.

Table 4: Effect Of Pollutants on Human Health

The major variables used for calculating the pollution cost were - volume of the cars, emission norms of the pollutants and associated health damage cost of these pollutants (based on US estimates). The equations used for calculating the pollution cost are as follows :-

RC y / TC s = S yc

Assumption has been taken that the share of petrol - diesel is 55:45%, so as to calculate the share of petrol and diesel cars. Emission norms of the pollutants (separate for the petrol and diesel cars) like - CO, HC, NOx and PM are used to calculate pollution load.

$$PCG \rightarrow EN_p * S_{pc} = PL_{pyg}$$
$$PCD \rightarrow EN_p * S_{dc} = PL_{pyd}$$

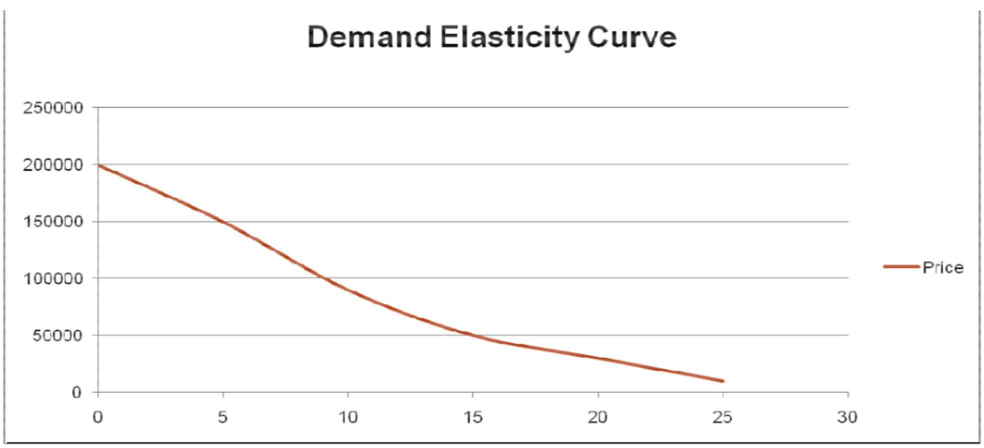
Where PCG is the passenger car (gasoline)
PCD is the passenger car (diesel)
EN_p is the emission norms of the pollutants taken – CO, NOx, HC & PM
S_{pc} is the share of petrol cars
S_{dc} is the share of the diesel cars
PL_{py} is the pollution load of the pollutant by the cars (petrol and diesel) for a given period i.e. (1996 - 2010)

To calculate the pollution cost the pollution load was then multiplied by the health damage cost for Delhi (which was based on the health damage costs of the US).

$$\mathbf{PL_{pyg} + PL_{pyd} = PL_t}$$
$$\mathbf{PL_t * HDC_d = PC_t}$$

Where PL_{pyg} is the pollution load by petrol cars of a pollutant for a given period.
PL_{pyd} is the pollution load by diesel cars of a pollutant for a given period.
PL_t = is the total pollution load by cars
HDC_d = is the health damage cost in Delhi
PC_t = is the total pollution cost.

The above mentioned methodology was adopted to calculate the external costs associated with the congestion, which involved the calculation of the major cost parameters considered - the value of time cost, fuel cost and the pollution cost. To arrive at the optimum prices with the calculation of external costs, a price curve is also needed to set the optimum charge and volume.
To obtain the price curve, a demand elasticity curve based on the willingness to pay survey was taken from the Study on Determination of Congestion Costs in Central Business District of New Delhi - School of Planning and Architecture



This above curve is the demand elasticity curve for cars. This curve shows the percentage reduction in volume with change in price. It shows that the slope of the curve is same as price increases from 5 to 10. But as the price changes from 10 to 15 the percentage reduction in volume is more.

Chapter 4

Result Analysis and Application

The following table shows the change in volume with change in price :-

Volume	Price
199731	0
149798.3	5
89878.95	10
49932.75	15
29959.65	20
9986.55	25

Table 5: Effect of price change on traffic Volume of Cars

Two Scenarios were taken to estimate the external costs from congestion - BAU and CPP cases. The results are shown simultaneously so as to compare the two scenarios - with the congestion pricing policy and without the pricing policy (BAU case). The 2005 data on the traffic volume was taken as the base year data. It was assumed that in BAU scenario the traffic volume will increase at a fixed rate, in CPP scenario the traffic volume will decrease at a fixed rate. The relationship between the traffic flow and the speed levels were obtained for both the cases which are as follows:

BAU Scenario Y = 48.1227 - .000091X

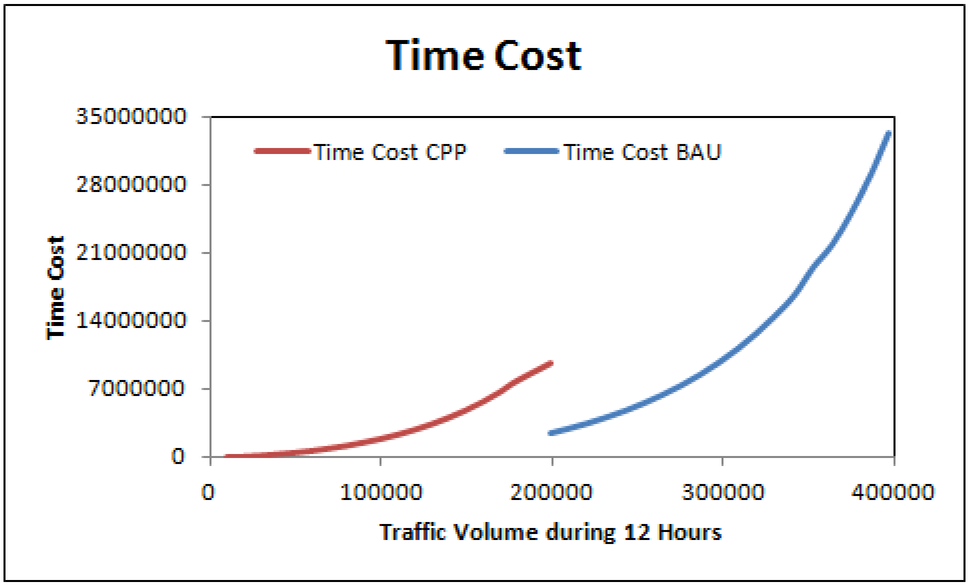
CCP Scenario Y = 35.8869 - .0000984X

Where Y is the speed level
X is the traffic volume entering daily (during 12 hours).

To estimate the external costs from congestion, three parameters were considered for the calculation of external cost which were - Fuel consumption, Value of time and Pollution Emissions.

The methodologies mentioned in the previous section were used to calculate the monetary impact of these externalities involved calculation of value of time, cost of fuel consumption and the cost of pollution converted into monetary terms. The results from the calculation of these parameters are as follows :-

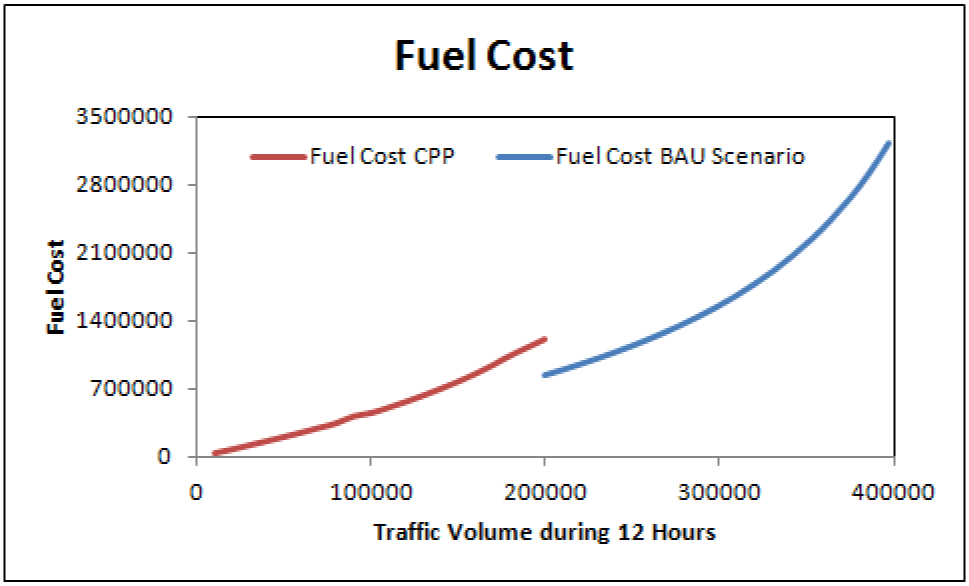
• **Value of Time Cost -** This is the additional time or the time loss when travelling through the congested area. The difference between the speed levels i.e. speed level during congestion and free flow speed level.



The above graph shows the business - as - usual scenario in which as the volume increases the time cost also increases at an increasing rate. This shows that without the congestion price policy levied the daily traffic volume (12 hours) increase up to 3, 97,000 lakhs the number of hours lost are then equal to the 29874.25 hours lost and the time cost is Rs 3,33,39,663.
It shows the congestion pricing policy case in which the volume will decrease by levying a congestion price. Also, the time cost decreases with the decrease in the volume. With Congestion Pricing the traffic volume of the cars decreases to 10,000, the number of hours lost then falls equal to 46.07 hours lost and the time cost is Rs 51415.71

• **Fuel Cost**
This is the additional fuel loss due to congestion. To calculate the fuel consumption a fuel consumption rate was used. The fuel consumption was worked out using the fuel consumption rates for cars at the speed (assumed) at which they are travelling these rates were then converted into monetary value using the prices of fuel of 2005.

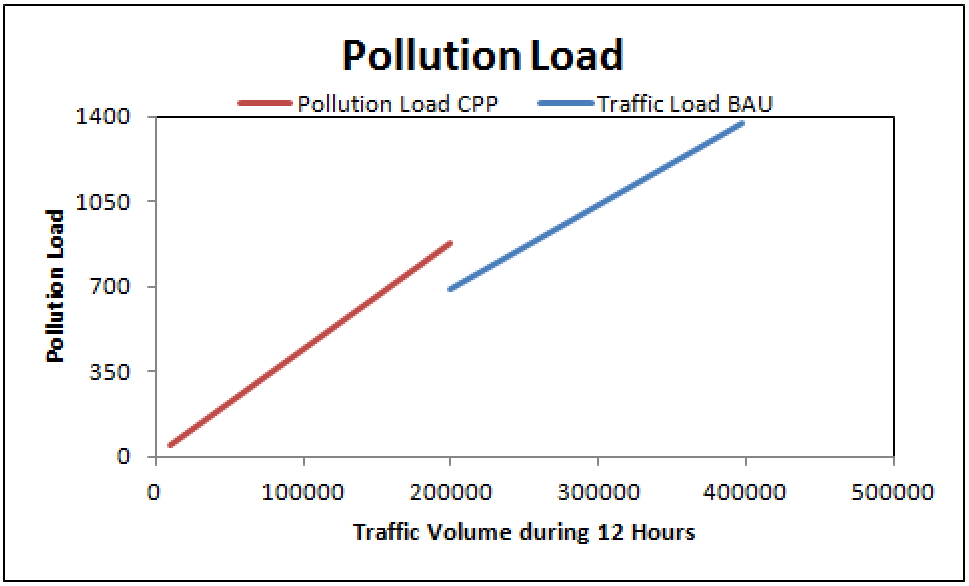
Thus, the tables below shows the results of fuel consumption and the fuel cost for the volume entering the Connaught Place Area are as follows :-



The above graph shows the Business-as-usual scenario, the fuel costs are increasing as the number of cars increases. As the volume increases to 3, 97,000 (daily i.e. 12 hours) the fuel consumption by petrol cars is 63187 litres and for diesel cars it is 15797 litres, and the fuel cost is Rs 3226505. The above graph shows the congestion pricing policy case, with the congestion price levied as the volume of cars decreases the fuel consumption and the fuel cost both decreases. With volume decreasing to 10000 vehicles the fuel consumption by petrol cars is 34467 litres and 6039 litres for diesel cars and the fuel cost is Rs 40506.

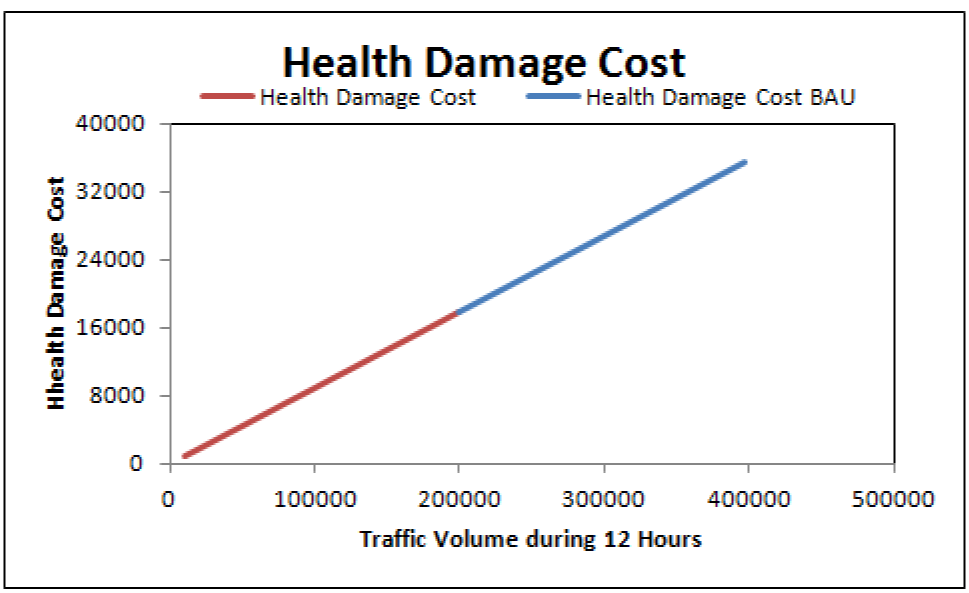
• **Pollution Cost**

The pollution generated was calculated using the equations for cars for different speeds, the pollution emissions of petrol and diesel cars were used to calculate the total pollution load and this pollution load was then converted into monetary value through damage cost i.e. cost associated with these pollutants.



The above graph shows that in the business - as - usual case the pollution load increases with increase in traffic volume of cars. The pollution load increases from 691 kg to 1373 kg as the volume increases from 199731 to 397000 also on the other hand the speed decreases from 30 to 12 KMPH. The graph shows that in congestion pricing policy case the pollution load decreases with decrease in traffic volume of cars. The pollution Load decreases from 875.2 kg to 43.8 kg as the volume decreases from 199731 to 10000 and also on the other hand the speed increases from 17 to 35 KMPH.

Now, the pollution load estimates were used to generate the health damage cost of these pollutants - CO, HC, NOx and PM. The damage cost were taken and were converted for the year 2005 using inflation in GDP deflator.



The above graph shows that in the business - as - usual case as the pollution load increases with increase in traffic volume of cars, the damage burden or the cost by these pollutants increases due to increase in traffic volume of car increases. The damage cost increases from Rs 17797/kg to Rs 35376/kg as the volume increases from 199731 to 397000. The graph for the congestion pricing case shows that health damage cost decreases with decrease in traffic volume. The health damage cost decreases from Rs 17797.73/kg to Rs 891.08/kg as the traffic volume (daily, 12 hours) decreases from 199731 to 10000.

Thus, the total cost curves are then estimated by adding both the direct as well as the indirect costs. The direct costs - the value of time and Fuel costs and the indirect costs - the pollution cost i.e. health damage cost.

In BAU scenario, the total costs are increasing with the increase in traffic volume as there is no congestion pricing policy i.e. price or charge is levied. Without any policy as the numbers of cars are increasing, the congestion costs are also increasing.

In case of congestion pricing, the total congestion costs are declining with decrease in volume. With the charge the number of cars are reducing, which also saves the time cost, fuel cost and reduces the pollution cost in the city. This estimation of the congestion costs are now used to set an optimal price.

Optimal Level Of Pricing

To arrive at a pricing level that gives maximum benefits to the society, the charge should be set at a level where the external costs are nullified by the charge collected i.e. optimum charge should be set so that the charge collected should recover the external cost.

The methodology adopted for calculation of the optimal level of pricing involved two steps :-

A. The calculation of the external costs - the external costs considered for calculation were value of time, fuel consumption and pollution emissions. The external costs were computed for decreasing level of traffic, where speed is function of volume and both the total and marginal costs were calculated.

B. Obtaining a demand elasticity curve (pricing curve).

The level of pricing was determined by the point where the marginal cost curve intersects the price curve. The graph showed two relationships - the relationship between the price level and the marginal cost curve and the relationship between price level and the volume. On the horizontal axis prices are set and on the vertical axis the volume. With these two relationships we get the total volume of cars are decreasing with increase in pricing and decrease in external costs with decrease in volume of cars. The intersection of these two curves gives the charge needed to recover the congestion costs.

A decrease of 10000 vehicles is taken. The parameters include the fuel consumption, the value of time and pollution generated. It takes into account the increase in operational speeds with the decrease in volumes. Thus the marginal external also decreases with decrease in volume of cars.

Therefore, an optimal charge of Rs 15 is obtained with an optimal volume of 50000 vehicles entering (daily). This charge is obtained where the two curves the marginal congestion cost curve and the pricing curve intersect.

Chapter 5

Limitations and Recommendations

Limitations

1. Old data was used due to easy availability.

2. We were unable to get primary data due to the huge cost associated with collecting data. So instead we had to use Secondary data procured from various Government institutions.

3. Commercial vehicles could not be accommodated because of lack of any proper data on the same.

4. 2-wheelers could not be accommodated even when we had their numbers because of their varying speeds and the range of varying speeds is very high to be accommodated in a single study.

5. Trucks and buses have also been ignored for the convenience of this study.

Recommendations

1. There should be a policy action to reduce congestion in the Connaught Place Area by levying a congestion charge

2. The congestion charge will reduce the car usage – leads to low pollution levels, fuel and time saved.

3. The total savings when charging Rs 15 comes out to be Rs 1,02,18,386 (daily) and the revenue generated is 750000.

4. With congestion charge the revenue generated can be used up for improving the public transport in the city.

5. With the introduction of congestion pricing, public transport systems should be improved in the city.

6. Also, a carpooling strategy is recommended for the destined traffic i.e. a car should carry four persons(four persons /car)

7. Variable rates should be charged for different periods i.e. is a higher rate for peak periods and a low rate for off-peak periods.

Chapter 6

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