Transportation Demand Management in the Form of Influencing Modal Choice for Pollution Control:
Feasibility, Costs and Benefits
The Case of an Indian Megacity, Kolkata

FINAL PROJECT REPORT

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Funding: **South Asia Network of Economics Research Institutes (SANEI)**

Organization: **Indian Council for Research on International Economic Relations, New Delhi (ICRIER)**

Acknowledgements

So many persons have helped in this project that there is some danger of our not remembering some of them. Let us try, however.

We would first like to thank the South Asia Network of Economics Research Institutes (SANEI) and the Indian Council for Research on International Economic Relations (ICRIER) for funding and organising the project. The administration of Bengal Engineering and Science University, Shibpur was kind enough to perform the function of the base institution for the project.

Snigdha Chakravarty and Dipankar Kundu of the Indian Statistical Institute, Kolkata and Debashish Bagchi of Bengal Engineering and Science University, Shibpur helped us get started. Subhas Chakravorty, Transport Minister in the West Bengal State Government, gracefully provided us with a letter of authorisation for conducting our measurements and surveys.

Sumit Chowdhury, Ajoy Paul and their laboratory team at Envirocheck handled the measurement of vehicular pollution. In accessing vehicles we were assisted by several owners of petrol pumps, as well as Sukumar Bhattacharyya, Managing Director, CSTC and Bidyut Chakravorty , Hoogly Nadi Jalapath Paribahan Samabay Samiti.

Data on the occupancy of various transport modes was collected with help from S K Gupta, Suranjan Sengupta, Nachiketa Ray, Aniruddha and many others at the Society for Socio-economic Studies and Services, Bidhannagar.

Animesh Halder, formerly of the CMDA, A K Das, Chief Operations Manager, Metro Rail and Ajit Bhattacharya, Transport Department provided us with valuable information on the transport network in Kolkata. We were also assisted by several others at CSTC and Metro Rail Bhavan. Bikram Sen, Director, Census Department assisted us with census data.

Prasid Chakravorty and his team were wonderfully meticulous with the household and commuter surveys and continued to help us in setting up the numerous tables. They have done far more than was expected of them.

We received assistance from Sandip Chakrabarti to ready our presentations. Debashish Sikdar assisted in organisational matters.

We cannot even begin to thank the 3000 interviewees who patiently (and sometimes impatiently) went through a harrowing questionnaire.

Abstract

Policy making and institutional support for the control of vehicular pollution in the megacities of developing countries has become a critical issue in this century. Whilst the developed nations have used technology-forcing standards or market mechanisms (such as taxes) as their main tool, transportation demand management (TDM) may have greater relevance for cities in poorer countries: and the choice of a less polluting mode of travel is the most crucial as well as complex aspect of TDM.

This project determines, for the city of Kolkata (India), the degree of pollution by different (existing) modes and the total air pollution created due to the present modal structure. With the help of a survey of 3000 individuals residing in and /or commuting in the city, we look at the factors that determine modal choice. We then find out the extent to which we can make transport users shift to less polluting modes, and hereby evolve several feasible alternatives that would reduce air pollution. We thus determine the benefit (in terms of emissions reduction) and costs of changing the modal structure. This leads us to concrete policy prescriptions.

I. Introduction/Justification

Pollution caused by motor vehicles in urban areas became a development-related problem in the 1950s, but only for developed countries like the U.S.(Krier and Ursin, 1977). It required a rapid growth in the number of motor vehicles in the latter years of the twentieth century[1] and a rapid increase in urban air pollution[2] to get policy makers in the developing countries to wake up to the fact that a great deal needs to be done to correct the extremely unhealthy quality of air in their cities. Although a significant part of the pollution is caused by industry, transport is increasingly becoming the more important reason for the existence of pollutants in air in most big cities (Vasconcellos, 2001, p. 27). Hence the main component of a policy package to reduce air pollution in big cities would be the reduction of pollution from motorized vehicles.

There are a variety of ways in which this reduction can be achieved. The method that has largely been used in the U.S., which has possibly taken the lead in pollution control policies, is to impose a set of emission standards and ensure that they are met with the help of an elaborate inspection-and-maintenance (I/M) regime. The pressure to meet these standards has encouraged technological innovation in the production of 'clean' cars – in other words, control policy was regulatory and 'technology forcing' (Krier and Ursin, 1977; Faiz, Weaver and Walsh, 1996). Countries in Europe followed suit a decade or two later, but their standards have always been relatively mild and 'technology following'. Further, Europe has made greater use of market mechanisms such as taxes on vehicles or fuel (Society of Automotive Engineers, 1987). It must be noted, however, that market mechanisms also require the use of an I/M regime, as taxes are imposed on actual emissions or related variables.

Major developments in technology in the areas of increased fuel efficiency, emissions reduction and cleaner fuels have certainly had a clear positive impact on emissions per unit distance traveled – and these have occurred due to the imposition of standards. Taxes, too, have encouraged innovation. Further, taking the state of the art as a given, a set of rules and taxes, backed up by an effective I/M regime, would keep out heavily polluting vehicles and perhaps reduce the demand for transportation. However, they are not sufficient conditions for reducing transportation demand. As long as the owner of a vehicle meets the required standards and pays all her taxes, she can drive it as much as she wants and hence the *total* pollution produced is beyond control. There may be factors *other* than standards or taxes that encourage travel demand and hence counter the conventional policies. Moreover, let us not forget that conventional methods of emission control (standards and/or taxes) require an elaborate monitoring machinery. Also, some aspects of these methods (such as the scrapping of old vehicles or fitting them with expensive pollution controlling gadgetry) are anti-poor and infeasible in developing countries.

Another policy that has the objective of making travel easier and reducing travel time, but has a peripheral impact on vehicular emissions, is Transport Systems Management (TSM) – which includes, for example, the construction of new roads or flyovers and electronic traffic signaling. However, TSM is usually expensive and sometimes

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[1] During 1990-5 the demand for automobiles has increased by 200 per cent in the developing world (World Resources Institute, 1996).

[2] A ranking of the 24 megacities in terms of the degree of air pollution , with 17 of them belonging to the developing world, show that 7 cities have 3 or more pollutants exceeding WHO guidelines – and 5 of these cities are in the developing world (WHO/UNEP, 1992).

infeasible for old cities whose structures cannot easily be converted. Moreover, TSM can have the effect of actually inducing travel demand, by making travel more attractive.

Hence, for those developing countries which have one or several big cities and are grappling with the problem of transport-related pollution, it is essential to look at transportation demand management (TDM) as a substitute or major complement of conventional policies. Of the variety of TDM measures,[3] shifting transportation needs to less polluting modes (or modes that are less polluting per person, because they carry more people) is the most major and complex field for policy formulation. Major, because the other measures are either less feasible or less effective, and complex, because it involves coercion rather than imposition. Hence creating incentives rather than setting up and enforcing rules is what the state has to be involved with. It appears to be an area where policy formulation has to be elaborate, and has to involve an understanding and study of human behaviour, both cultural and economic.

Although our study will use data from a single city, Kolkata, we expect it to throw light on policy making in most big cities of the developing world – as many of the relevant features of all such cities are common – such as inadequate infrastructure, a wide array of vehicles, a significant dependence on public transport, a predominance of work-related trips, and so on (Vasconcellos, 2001, pp. 28-29).

[3] Modal shifts, auto-free zones, no-drive days, land use policies, work week reduction, flexible work hours and peak hour charges

II. The Study Area: Kolkata

Demography

We shall be concentrating on the Kolkata Municipal Corporation (KMC), which constitutes what is generally understood as 'Kolkata', although there is a larger area called the Kolkata Metropolitan Area (KMA) (see Maps A and B). The latter occupies 1380 square kilometres, and the KMC covers about 14 per cent of this, i.e.196 square kilometres. Table 1 shows the population increase in KMA and KMC between 1911 and 2001.

Table 1: Population of KMC and KMA, 1911 - 2001
(in millions)

Year	KMC	KMA
1911	1.02	-
1921	1.05	2.25
1931	1.17	2.54
1941	2.17	4.31
1951	2.70	5.08
1961	2.93	6.62
1971	3.15	8.30
1981	3.30	10.11
1991	4.39	11.86
2001	4.58	15.00

Source: Chowdhury, S. (1999), p. 50 and Census, 2001.

During 1921 - 81, the population of KMA has increased nearly 5 times. The population of KMC has increased more slowly (3 times). In recent years (1991-2001) we see that there has been a decline in the rate of growth, especially in proper Kolkata, perhaps because of a process of saturation – the economic advantages are being outweighed by the disadvantages of overcrowding (Ghosh, 1999). The population density in KMC turns out to be around 23316 persons (as against 10869 in KMA) in 2001 – hence it is a little more than twice the population in KMA. Another characteristic of Kolkata is that the daytime population is far greater than the resident population – around 4.7 lakh persons enter the KMC area (CMDA, 2001). Thus one found around 725,000 persons per square kilometre occupying the inner core area (compared to 100,000 in New York) in 1996. There is a strong economic dependence of the surrounding areas on the KMC, which is why there is a large flow of population into the city and out of it (Bose et al, 1997 and Bandopadhyay, 1996).

Over the years, the number of females to males has increased continually as Kolkata has become a city where families rather than male workers live. The majority of residents are still male but the number of females per thousand males has increased steadily to 829 in 2001. The participation rate, because of the inflow of families, declined over the years from 63.1 in 1921 to 38.5 in 1961 and to 30.5 in 1981. It has, however, increased in recent years to 37.6 – a reflection, perhaps, of the greater participation of women (Census Report, 2001 and Ghosh, 1999). The average size of households has been found to be 3.9 in a 1996-7 survey (CMDA, 1999, p. 22). A survey carried out in 1977 in KMA shows that 54% of the population belonged to the labour force in that year, but 48% were employed and only 28% (which is 58% of the employed) were in the organized or formal sector. Also, of the employed, 12.5% and of the organized sector, 8% were female (Banerji, 1985). Another source tells us that in 1981 only 26% of the workers were registered – hence nearly 3 times were unregistered (Ghosh, 1999, p.54). Thus 'a core of organized employment, industrial and non-industrial, is surrounded by a wide penumbra of unregistered informal employment. This is how Calcutta is kept reasonably employed, though in a poorly paid and deplorable manner for a large part of the working population' (Ghosh, 1999, p.54). Surveys have revealed that persons in the informal sector earn much less than those in the formal sector. Around 25% of the women workers in the informal sector hold skilled jobs (Banerji, 1985).

Economy

Kolkata was an industrial city that has slowly evolved into a commercial city, partly because of the decline of industry in West Bengal and partly because of the natural shift of big cities in the direction of the service sector. The occupational pattern in the Kolkata Urban Agglomeration (which is larger than KMC and includes Howrah, the city adjoining KMC) during 1921-81 are given in Table 2. The importance of manufacturing would be much less for the KMC area as KUA includes Howrah, which was and still remains a manufacturing town. Yet even this Table indicates nearly 54% in the service sector.

Table 2: Occupational Patterns in the Kolkata Urban Agglomeration, 1921-81 (percentages)

	1921	1931	1951	1961	1971	1981
Household and Non-household Industries including Manufacturing, processing	25.4	19.5	38.0	37.6	39.1	44.4
Transport and Communication	10.3	8.9	12.3	10.0	11.6	10.3
Trade and Commerce	16.6	15.9	21.8	21.7	18.5	21.4
Other Services	43.4	52.6	27.4	30.6	29.9	21.8
Agriculture and Exploration of minerals	4.3	3.1	0.5	0.1	1.0	2.1

Source: Chowdhury, S. (1999), p.53

The census data for 2001 (not presented here) on the composition of workers in KMC is more current and relevant (as it is on our study area) but the categories are not so easy to decipher. In particular, it clarifies that agriculture and household industry are unimportant, as they should be in an urban area, but there is no break-up in terms of manufactures, transport and services. It shows that in KMC there are currently 38% who are employed, and 16% of these are women. It is improbable that the percent

employed has dropped since 1977; hence we may doubt the 1977 data (see the previous section) which appears high. A higher percentage of women are employed compared to 1977. Of all workers, 95% are 'main' and 5% 'marginal'. Of the main workers, .3% are cultivators, .2% agricultural labourers, 3% are in household industry and the remaining in 'other' activities. For what constitutes 'other', we can go back to the 1981 KMU data in Table 2. One would expect that the decline of industry in the past 25 years has reduced the percentage in manufacturing and hence increased it further (from 54%) in transport, trade and other services.
A survey of more than 20,000 households conducted by CMDA in 1996-7 allows us to add to the information regarding occupations – Table 3 gives the distribution of households by broad occupational groups in KMC. This indicates that whilst around 35% are sales and service workers, a significant proportion of the 33% from the first three categories (professional and technical, administrative and managerial, clerical and related) would also fall in the 'services' sector. On the other hand, 23% of the households are in production and related activities.

Table 3: Distribution of Households in KMC by Broad Occupational Groups 1996-7

Professional and Technical	8.9%
Administration and Managerial	5.7%
Clerical and Related	18.8%
Sales Workers	22.1%
Service Workers	13.0%
Farmers, fishermen etc.	1.0%
Production and Related	22.6%
Not Reported	8%

Source: CMDA (1999), p. 75

The same survey gives the income distribution of the households in KMC (see Table 4). We see that 99% had a monthly per capita income of Rs.5000 or less, and there was a concentration of per capita incomes in the Rs. 300-2000 range – thus the majority of households were in the lower or lower-middle categories.

Table 4: Distribution of Persons According to per capita Household Incomes, KMC, 1996

Monthly p.c. Income Class	Percentage of Persons	Average Monthly per capita Income	Cumulative Percentage
<=100	1	16	1
101-200	1	177	2
201-300	8	268	10
301-500	26	423	36
501-750	22	642	58
751-1000	16	909	74
1001-2000	17	1396	91
2001-3000	6	2316	97
3001-5000	2	3839	99
5001+	1	7392	100

Source: CMDA, 1999, p. 80

Structural Features

The city has an elongated shape, with a much longer north-south stretch (see Map A). The southern part is somewhat broader compared to the north. It is confined in the east by marshlands, though much of these are being reclaimed for real estate, and in the west by the Hoogly River, on whose other bank is the city of Howrah. The business district, as expected, is located around the centre of the area, and covers around 14 square kilometres with an inner core of 4 square kilometres.. However, there are offices in Salt Lake and other areas, universities spread all over the city and with time shopping malls are springing up in the south, north and Salt Lake. Like any other big city, the city has a variety of residential areas - affluent, upper middle class, middle class, lower middle class and slums. The affluent areas are located near the Central Business District (CBD) and real estate prices drop as one moves away from the CBD. New residential areas are cropping up in the extreme south and east. Houses are being rapidly replaced by apartment complexes for the affluent and middle classes. Localities are mostly segregated, but exist side-by-side (Bandopadhyay, 1996).
Like a typical large city in India, Kolkata is dotted by slums. The slum population in the city jumped from 22 to 41% (Table 5) between the 1970s and 1980s, after which the percentage has in fact reduced. However, 33 % in 2001 is still very significant.

Table 5: Slum Population, 1961-2001, KMC

	1961	1971	1981	2001
Total Population	2927289	3148746	3305006	4580544
Slum Population	647218	775947	1350000	1490811
Percent Slum	22%	22%	41%	33%

Source: CMDA, 1981 and Census, 2001

The most affluent amongst the slum residents, other than the slum lords, are electrical workers and mechanics of the lowest paid category. The remaining are labourers or in domestic service, in handicrafts or in sales and clerical jobs. The majority of the slum population lives below the poverty line. In 1981, 50% had an average income of around Rs. 80, 18% around Rs. 130 and 17% around Rs. 40. Only 2.6% earned above Rs. 300 (CMDA, 1981).

Kolkata also has a large population of pavement dwellers. The 1971 census recorded 48,802 pavement dwellers. In 1987, a CMDA survey recorded 55,571 such persons. There were 56% males and 44% females, 56% adults and 44% children. They are mostly unskilled labourers or small traders. The estimate of the proportion of beggars varies from 8 to 10% (Ghosh, 1999, pp. 57, 59).

The Motorized Passenger Transport System in Kolkata

Much of the movement of the Kolkatans is in the north-south direction rather than in the east-west, although the latter is increasing due to the development of the Salt Lake area as a commercial area, in addition to its residential characteristic. The road space, as a percentage of the total area, is a mere 6% compared to 16% in Bombay and 23% in

Delhi[4]. There have been attempts to ease the traffic by building a parallel north-south corridor in the east (Eastern Metropolitan Bypass), by passenger ferry services across the river Hoogly (which started operating in 1981), by the introduction of the metro (in 1985) and very recently (2002 and after) by building several flyovers - but the situation remains grim. The earlier corridor and the CBD remain popular. Lax laws and underdevelopment have exacerbated congestion problems – they allow encroachment on roads or processions and rallies, for example.

Among motorized forms of transport, the city has buses, trams, autos (or three wheelers), taxis, the metro, a circular rail, water-ferries and local trains for public transport, and there are two wheelers and cars for private transport. There are a variety of buses – the state has regular, special and executive fleets, and private buses may be categorized as ordinary, chartered, school buses and minibuses. Non-motorized forms of transport are rickshaws, bicycles and walking. Unlike some other cities in the developing world, these non-motorized forms are useful in local vicinities but not of much use when it comes to travelling long distance. The growth of the city as well as the greater need for motorized transport has caused a rapid increase in the number of motor vehicles in the city - Table 6gives the number of registered vehicles in 1982-3, 1992-3 and 2002-3. The number of vehicles was a mere 50, 000 or so in 1951 – it rose to around 500,000 in 1991 – a ten-fold rise in a period when the population rose by 39% (Dutta, 2001). During 1982-92 there has been an enormous jump in the number of vehicles (97.2%); in particular the rise is phenomenal for autos, though this is because they were nearly non-existent in 1982. Motorcycles also rose by a large amount. On the whole, in 1992-2002 the rate (at 59%) remains high but has reduced, compared to 1982-92.

Table 6. Number of Registered Vehicles in Calcutta and Their Increase.

Types	1982-83	1992-93	2002-03	Percentage of total, 2003	% Change (1982-92)	% Change (1992-02)
1. Motor Cars & Jeeps	132409	197063	305050	37.14	48.8	54.8
2. Motor Cycles	73071	226824	363818	44.30	210.4	60.4
3. Goods Vehicles (Truck & Vans)	25593	35512	66812	8.13	38.75	88.1
4. Taxi	10121	20279	35100♦	4.27	100.3	-
5. Buses	4213	6098	8867	1.08	44.7	45.4
6.Minibus	4023∗	6964∗	1196	0.14	73.1	-
7. Auto rickshaws	19	6304	14662	1.78	33078.9	132.5
8. Tractors	3713	4470	4804	0.58	20.4	7.5
9. Others	-	5601	20982	2.55	-	274.6
10. Total	2,61,927	5,16,511	821291		97.2	59.1

Source: Motor Vehicles Department, Govt. of West Bengal and Banerji and Das, 2001, p. 291
∗ The figures include luxury taxis and are therefore not comparable to column 4.
♦ The figure includes luxury taxis and is therefore not comparable to columns 2 and 3.

We see that (see column 5 in Table 6) motor cycles (including scooters) constitute the major percentage of the vehicles, followed by cars and jeeps. Figure A presents this

[4] Some estimates are lower at 4 or 5%

data in a bar diagram. The number of registrations has some connection with, we may expect, the modal split on the roads – but the proportions may very well be different, and this data does not include mass transits such as trams, the metro, the circular rail, suburban trains and ferries.

There is another data set collected by CMDA which gives numbers of vehicles actually running on the roads for 2001. Here, too, rail and ferries (public transit) as well as cars and two-wheelers have been left out. Table 7 gives the details. These are, of course, calculations made by CMDA on the basis of observations regarding the passengers served daily, and occupancies. This data tells us that private buses dominate the bus/tram scenario, and that autos and taxis are close in terms of numbers.

We also have data on passengers served by each mode on a regular weekday (see Table 8). This data, again, does not include cars and two-wheelers. Figure B gives a pie chart of the distribution of the volume of passengers in Kolkata in the different transit systems, Figure C in different surface transit modes (buses and trams), Figure D in different rail systems and Figure E in different para-transits including cycle rickshaws. Figure F gives a total picture, covering all modes. As yet, para-transits (autos and taxis) serve the same number as rail systems. The first is most polluting and have low occupancies. The second has high occupancies and zero pollution. The maximum, though, is surface transit at 62% - it causes pollution but carries many people. Private buses dominate the surface transit modes, the suburban rail system dominates rail systems and autos dominate para-transits in terms of passengers served.

Figure A

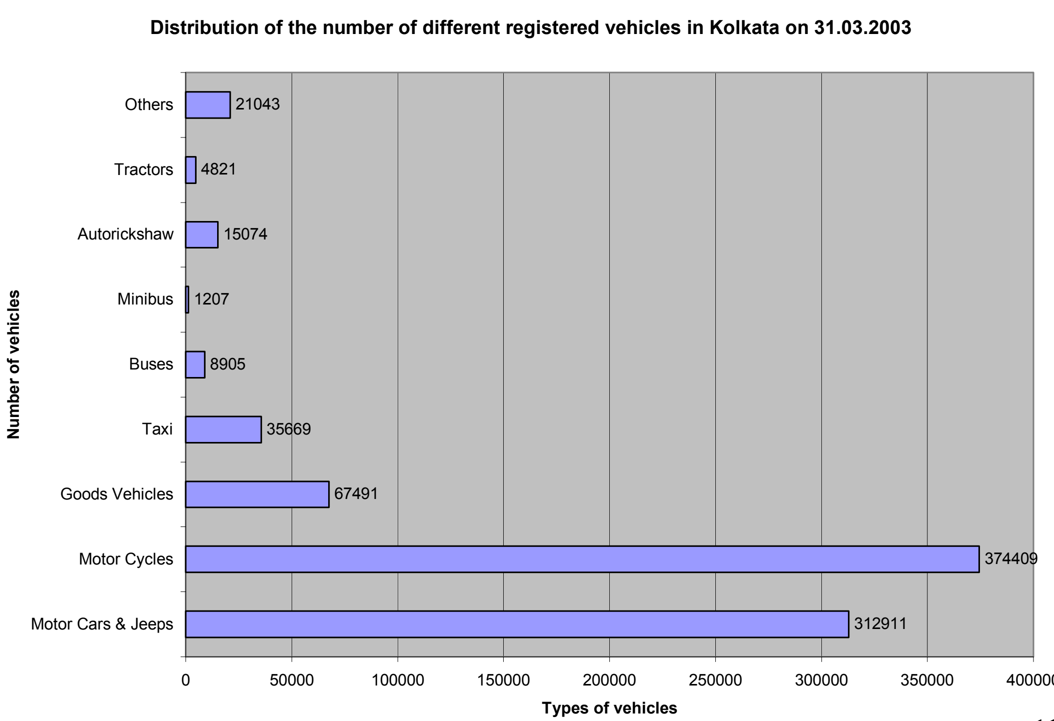


Table 7: Transit Modes and Private Vehicles, 2001

Modes	Number	Percent
Private Bus	7000	1.5
Public Bus	1550	0.33
Tram	200	0.04
Mini Bus	1560	0.33
Chartered Bus	2150	0.46
Taxi	22000	4.78
Auto Rickshaw	25000	5.44
Private Car*	150000	32.64
Two wheeler*	250000	54.40
Ferry*	30	0.007

Source: CMDA (2001), p. 210 and
* from newspaper reports

Table 8. Movement of Passengers within KMA, 2001, lakhs

Mode	Volume of Passengers
Private Bus	85.00
Public Bus	12.50
Minibus	12.50
Tram	2.00
Ferry	2.40
Chartered Bus	2.70
Suburban Rail	32.50
Metro Rail	2.00
Circular Rail	0.20
Taxi	11.00
Auto rickshaw	16.50
Cycle rickshaw	7.50
Total	187.00

Source: CMDA (2001), p.210

Table 9: Break-up of Total Trips in KMA Average Weekday, 1997-98, lakhs

Category of Trips	**Interzonal**	**Intrazonal**	**Total**
Transit Passenger Trips	65.60	45.40	110.60
Private Car Trips	0.94	0.78	1.72
Two Wheeler Trips	1.21	1.42	2.63
Slow Vehicle Trips	2.83	11.33	14.16
Para Transit Trips			
Taxi	2.14	1.50	3.64
Auto Rickshaw	3.03	6.87	9.90
Cycle Rickshaw/Rickshaw	1.30	5.94	7.24
Others	0.16	0.37	0.53
Walking Trips	5.60	57.36	62.96
Total	**90.43**	**135.72**	**226.15**

Source: CMDA (2001), p. 91

Distribution of the volume of passengers of Kolkata in different transit systems in 2001

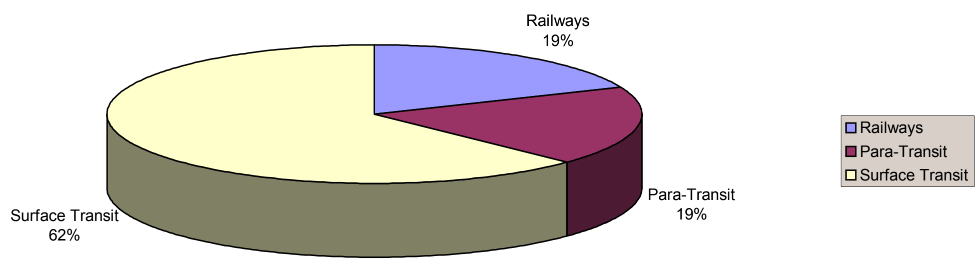


Figure B

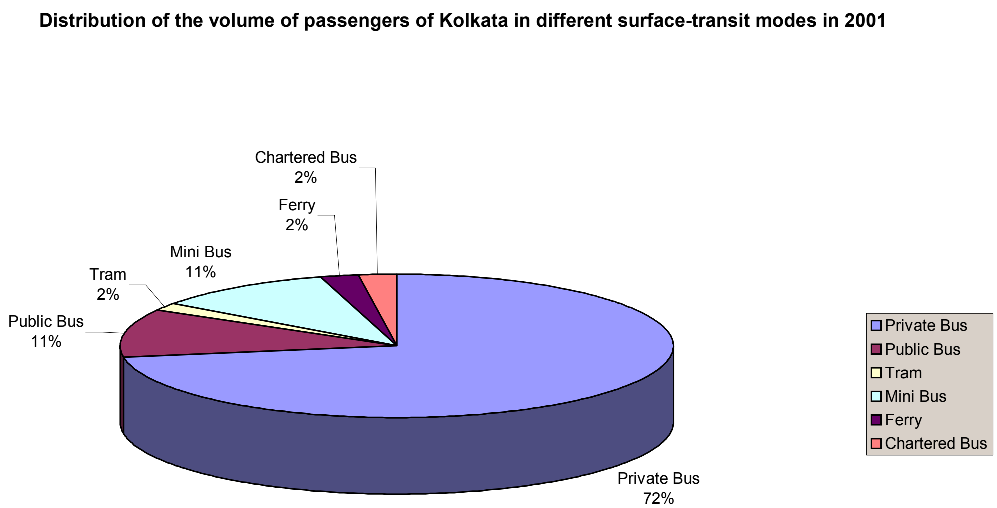

Distribution of the volume of passengers of Kolkata in different surface-transit modes in 2001
Chartered Bus 2%
Ferry 2%
Mini Bus 11%
Tram 2%
Public Bus 11%
Private Bus 72%
Private Bus
Public Bus
Tram
Mini Bus
Ferry
Chartered Bus

Figure C

Distribution of the volume of passengers of Kolkata in different forms of railways in 2001

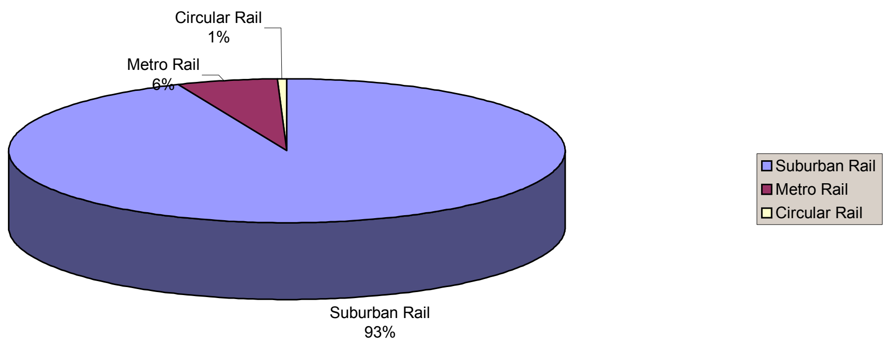


Figure D

Distribution of the volume of passengers of Kolkata in different para transit modes in 2001

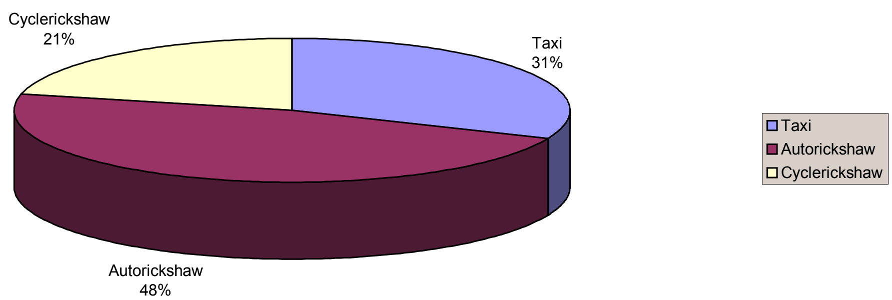


Figure E

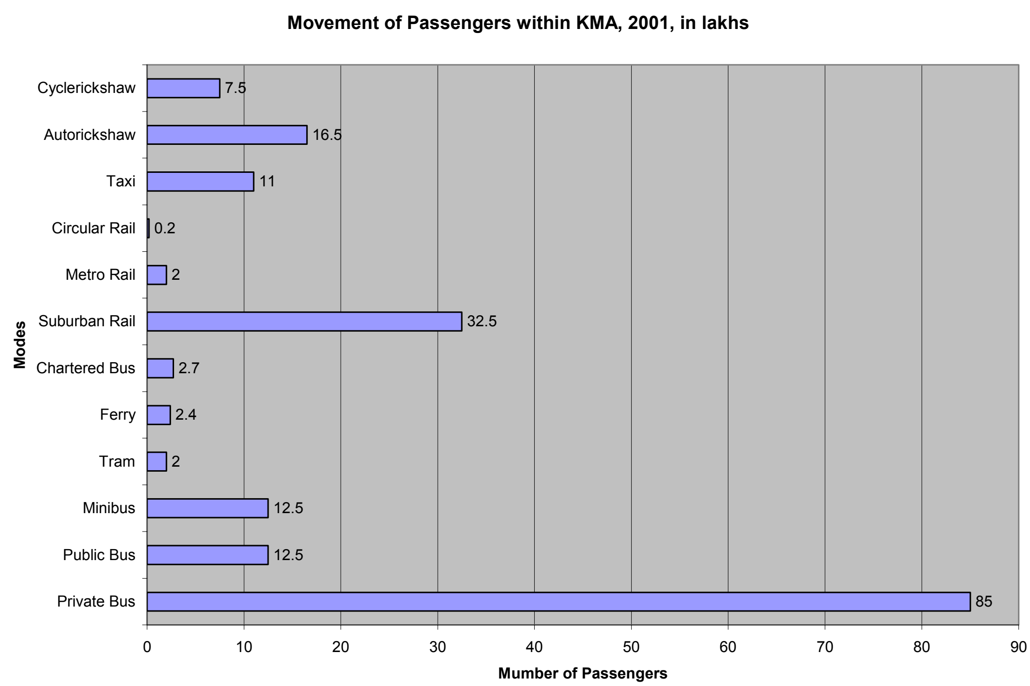

Movement of Passengers within KMA, 2001, in lakhs
Cyclerickshaw
Autorickshaw
Taxi
Circular Rail
Metro Rail
Suburban Rail
Chartered Bus
Ferry
Tram
Minibus
Public Bus
Private Bus
7.5
16.5
11
0.2
2
32.5
2.7
2.4
2
12.5
12.5
85
Modes
0
10
20
30
40
50
60
70
80
90
Mumber of Passengers

Figure F

A 1997-8 survey of 21,000 households in KMA reveals a variety of characteristics of household travel. For the purpose of the survey the KMA was divided into 42 traffic zones (the KMC into 16 zones). It is concluded that on an average weekday around 22.6 million trips were generated within KMA of which 11.06 million were transit passenger trips and 6.29 million trips were walking trips (see Table 9). Hence 5.25 trips were made with personal vehicles (cars and two-wheelers).

It is important to note that in spite of the rapid rate of increase, Kolkata had only 31 vehicles per 100 people in 1995-6. In that year, vehicle registration in Kolkata was 600,000, compared to 2.5 million in Mexico City, 2.7 million in London and 8 million in Los Angeles in 1988-9. In other words, the *potential* for a sustained increase in the number of vehicles is enormous for Kolkata (Ghosh et al, 1996, Bose et al, 1997, ESS, 1999). Further, as we have seen, privately owned vehicles are growing faster than mass transit modes and the greatest increase is in the number of two wheelers.

Whilst the availability of public transport is low to medium in developing countries, there is a predominance of public and non-motorized forms in terms of the passengers served. The same is true, at least with respect to public transport, in Kolkata. Although buses in the city constitute only about 1% of the fleet, more than 60% of mass transit trips were by bus and 19% by rail. Moreover, as we have seen, most of the buses are private - the drop in the number of public buses has been occurring steadily in the past 40 years. Trams, which are state owned, have also been reduced, mainly because they exacerbate congestion problems - and their contribution is minimal. Ferries and chartered buses, on the other hand, are increasing in importance.

As regards the proportionate use of diesel and gasoline in Kolkata, whilst the demand for gasoline in 1999 was 167 thousand tonnes of oil equivalent, for diesel it was 135 thousand tonnes. However, with the price differential (Rs. 39.86 per litre for petrol and 26.55 for diesel), the demand for diesel is expected to rise much faster.

A study undergone by CMDA in 1997 on the arterial roads of Kolkata city shows that on 5% of the road length, vehicular travel speed was less than 5 km. per hour, for 50% of the length the speed was below 20 km and on 14% the speed was more than 30 km on an average weekday (see Table 10). An approximate average calculated from Table 10 gives a speed of around 20 kilometres per hour.

This is certainly an improvement over another estimate made in 1989 which gives an average speed in peak hour traffic as 14 kilometres per hour whilst the maximum (on Park Street) is 25 kilometres (Banerji and Das, 2001). However, the speed remains low enough to have a very negative impact in terms of emissions, as is proved by the estimated relationship between emission and speed, especially for speeds within 50 kilometres per hour (Banerji and Das, 2001, p. 293).

Another feature of travel conditions in the city is the scarcity of parking lots so that cars are forced to park on the roads, effectively reducing the width of the roads and hence enhancing traffic congestion. The KMC and the Traffic police have legalized on-street parking by specifying parking fees on a good number of roads. The CMDA survey shows that the percentage of carriageway occupied by parked vehicles was between 24 and 38%. This reduces the effective road space to around 4%.

Table 10. Speed Profile of the Major Arterial Roads in Calcutta
Average Weekday, Year-1997

Serial No.	Average Travel Speed (Km/Hour)	Total Road Length (Km)	Percentage	Cumulative Percentage
1.	Less than 5	15.2	4.93	4.93
2.	5.0 to 9.0	7.4	2.40	7.33
3.	10.0 to 14.0	38.8	12.60	19.93
4.	15.0 to 19.0	94.0	30.52	50.45
5.	20.0 to 24.0	68.7	22.30	72.75
6.	25.0 to 29.6	40.8	13.24	85.99
7.	30.0 to 34.0	22.7	7.38	93.37
8.	35.0 and above	20.4	6.63	100.00
	Total	**308.0**	**100.00**	

Source: CMDA (2001), p. 77

Travel Behaviour

The main reason why people travel in Kolkata is work-related. Table 11 gives the trip purpose in Kolkata as well as some other cities in the developing world. It shows that work and education are by far the major reason why people in the city travel – and that this is less true for some other cities.

Table 11: Trip Purpose, Selected Cities

City	**Trip purpose**			
	Work	School	Work and School	Other
Alger (Algeria)	25	50	75	25
Bangkok (Thailand)	34	18	52	48
Kolkata (India)	44	29	73	28
Delhi (India)	46	31	77	25
Hanoi (Vietnam)	45	19	64	36
Jakarta (Indonesia)	39	20	59	41
Santiago (Chile)	36	32	68	32
Sao Paulo (Brazil)	41	34	75	25

Source: Vasconcellos (2001), p. 18

In the survey of 21,000 households in KMA we see that in Kolkata (see Tables 12 – 14) work trips constituted 53.7% and educational trips 25.43% of total trips – hence nearly 80% of the total trips were profession-related. Around 80% of the work trips and 93% of educational trips were less than 5km in length. An approximate calculation from Tables 13 and 14 gives the average trip length for work trips as 4 kilometres, and for educational trips as 2 kilometres. Taking the relative percentages of work and education trips (which constitute the major part of all trips) from Table 12, we can postulate that the average trip length in general is 3.4 kilometres. Table 15, though it is only for work trips, finally brings together *all* modes, unlike Table 6 which does not have the modes that are not registered with the motor vehicles department, and Tables 7 and 8 which do not include some modes. It has been calculated that out of the daily total of 227 lakh trips, 144 lakh (63%) were by mass transit and a significant amount (62.96 lakhs or 28%) purely walking trips (see Table 9).

Table 12. Distribution of Trips by Trip Purpose, KMA
Average Weekday, 1997-98
Number of Trips (lakhs)

Category	Interzonal	Intrazonal	Total	Percentage of Total
Work Trips	54.99 (60.81)	66.45 (48.96)	121.44	53.70
Educational Trips	14.55 (16.09)	42.97 (31.66)	57.52	25.43
Cultural Trips	2.13 (2.34)	3.06 (2.25)	5.19	2.29
Social Trips	11.42 (12.63)	8.62 (6.35)	20.04	8.86
Shopping Trips	3.26 (3.61)	5.77 (4.25)	9.03	4.00
Health Trips	1.09 (1.20)	1.64 (1.21)	2.72	1.20
Other Trips	3.00 (3.32)	7.21(5.31)	10.21	4.52
Total	**90.43 (100.00)**	**135.72 (100.00)**	**226.15**	**100.00**

Note: Figures within brackets indicate the percentage
Source: CMDA (2001) p. 91

Table 13. Trip Length Distribution of Work Trips in KMA
Average Weekday: 1997-98

Trip Length	No. of Trips	Percentage of Total	Cumulative Percentage
Less than 1 km	33.97	27.97	27.97
1 km to 3 km	41.40	34.09	62.06
3 km to 5 km	19.21	15.82	77.88
5 km to 8 km	11.45	9.43	87.31
8 km to 10 km	3.73	3.08	90.39
10 km to 12 km	2.82	2.32	92.71
12 km to 15 km	2.81	2.31	95.01
15 km to 20 km	2.58	2.13	97.14
20 km to 25 km	1.35	1.11	98.25
Above 25 km	2.12	1.75	100.00
Total	**121.44**	**100.00**	

Source: CMDA (2001), p. 9

Table 14. Trip length Distribution of Educational Trips in KMA Average Weekday: 1997-98

Trip Length	No. of Trips (in Lakhs)	Percentage of Total	Cumulative Percentage
Less than 1 km	24.01	41.75	41.75
1 km to 3 km	24.42	42.45	84.21
3 km to 5 km	5.07	8.81	93.02
5 km to 8 km	2.35	4.08	97.10
8 km to 10 km	0.50	0.87	97.97
10 km to 12 km	0.34	0.60	98.57
12 km to 15 km	0.32	0.56	99.13
15 km to 20 km	0.30	0.52	99.65
20 km to 25 km	0.09	0.16	99.81
Above 25 km	0.12	0.19	100.00
Total	**57.52**	**100.00**	

Source: CMDA (2001), p.92

Table 15. Modal Distribution of Total Work Trips in KMA Average Weekday: 1997-98 (lakhs)

Type of Trips	Interzonal	Intrazonal	Total
Suburban Rail	9.34	1.46	10.80
Metro Rail	1.09	0.24	1.33
Circular Rail;	0.09	0.03	0.12
Bus	32.76	11.40	44.16
Tram	0.50	0.17	0.67
Office Pool Car	0.20	0.07	0.27
Chartered Bus	0.28	0.06	0.34
Ferry	0.67	0.14	0.81
Sub Total	**45.59**	**13.91**	
Private Car	0.52	0.32	0.84
Two Wheeler	0.98	0.79	1.77
Slow Vehicle	2.21	12.03	14.24
Paratransit			
Taxi	1.61	1.72	3.33
Auto rickshaw	1.07	1.15	2.22
Cycle Rickshaw/Rickshaw	0.41	0.44	0.85
Others	0.06	0.31	0.37
Sub Total	**52.45**	**30.67**	**83.12**
Walking Trips	2.54	35.78	38.32
Total	**54.99**	**66.45**	**121.44**

Source: CMDA (2001), p. 93

The survey also looks at several other features of travel: such as factors affecting the choice of mode, vehicle ownership and the distribution of trips by gender (Tables 16, 17 and 18).

Table 16. Factors Affecting the Choice of Mode for Travel in KMA
Year: 1997-98

Reason for the choice of journey mode	**Percentage of total trips**
Lesser Journey Time	10.24
Lesser Journey Cost	75.84
Cost of Link Trips	0.30
Better comfort of journey	5.50
Better reliability in service	1.18
Absence of alternative modes	1.75
Others	5.19
Total	**100.00**

Source: CMDA (2001), p. 94

Table 17. Households Owning Different Categories of Vehicles in KMA, 1997-98

Categories of vehicles	**Total number of Households**	**Percentage of Total No. of Households**
Bicycle	6,30,821	31.45
Two Wheeler	1,13,874	5.67
Motor Car	34,775	1.73
Households without any vehicle	12,26,482	61.15
Total	**20,05,952**	**100.00**

Source: CMDA (2001), p. 95

Table 18. Sex-wise Distribution of Total Trips Generated within KMA
Average Weekday: 1997-98
Total No. of Trips (lakhs)

	Interzonal	**Intrazonal**	**Total**
Male	67.90 (75.09)	96.00 (70.73)	163.90 (72.47)
Female	22.53 (24.91)	39.72 (29.27)	62.25 (27.53)
Total	**90.43 (100.00)**	**135.72 (100.00)**	**226.15 (100.00)**

Note: Figures within brackets indicate the percentage.
Source: CMDA (2001), p. 95

Interestingly, the most important reason (by a large margin) for choosing a mode appears to be the cost. The second priority is the time required. The majority of households (93%) do not own a motor vehicle. However, the ownership of two-wheelers and also cars has increased rapidly in the post-1998 years due to the need for travel flexibility, and the ease of obtaining bank loans for the purchase of vehicles. The sex-wise distribution of trips indicates that around three-fourths of the travelers are male and one-fourths are female.

Air Pollution in Kolkata and the Contribution of Motor Vehicles

There are three major sources of air pollution in Kolkata – one, industry, two, motor vehicles and three, domestic cooking. Air pollution in the city is measured by NEERI (National Environmental and Engineering Research Institute) and CPCB (Central Pollution Control Board), which have a combined metering system, and also SPCB (State Pollution Control Board). Three types of areas are identified for measurement – residential, commercial and industrial. We can say that the main source in the residential areas is cooking, whilst it is vehicles in the commercial areas and factories in the industrial areas, although there are other sources in each of these areas. Annual average concentrations of the three types of pollution which are regularly measured (SPM, NO_x and SO_2) are given in Table 19.

Table 19. Annual Average Concentration (μg/m) of Pollutants in Kolkata's Air

	Residential					**Commercial**					**Industrial**				
	μ	μ′	cv	Std (N)	Std (W)	μ	μ′	cv	Std (N)	Std (W)	μ	μ′	cv	Std (N)	Std (W)
SPM	377	259	30	140	75	425	979	14.5	NA	NA	476	536	14.7	360	75
NO_x	50	16	72	60	100	62	136	71	NA	NA	50	37	68	80	100
SO_2	37	12	27	60	50	63	91	31.7	NA	NA	64	32	29.7	80	50

Notes:1. The averaging is over 1980-1992 with data on 1988 and 1989 missing.
2. Std (N) - Standards for National Ambient Air Quality Measure (NAAQM) are set by the MoEF and metered by NEERI and CPCB, GOI.
3. Std (W) – the standards set by the WHO.
4. μ stands for the mean value.
5. μ′ stands for mean values in 1995-96 period.
6. cv represents the measure of coefficient of variation.
7. NA stands for non-availability of information.

Source: Banerji and Das (2001), p. 287

The standards (national and international) are also presented for comparison. We see that the standards for SPM are far lower than the mean values in Kolkata. That is not the case for NO_x and SO_2 . If we compare the mean values over 1980-92 and that in 1996 we see that in this period the residential areas pollution has gone down, perhaps due to the use of better cooking fuels, but it has gone up significantly in the commercial areas, most probably due to the increase in motor vehicles. In the industrial areas there has been an increase in SPM but a decrease in the two other pollutants, perhaps due to technological changes in production processes.[5]

It is to be noted that the climate of the city greatly affects the quality of the air. Temperature, rainfall and wind velocity affect the degree of dispersal of the pollutants. It is typical for pollution to be less in the summer months (April to June) due to higher

[5] The SPCB gives current (2004) data on ambient air quality at 179.3 μg/m for SPM, 61.2 μg/m for NO_2 and 5.29 μg/m for SO_2 – the SPM and SO_2 are significantly lower than in Table 19.

wind velocity and significantly less in the monsoon (July to October) due to heavy rainfall. Thus whether the measurements are yearly averages or taken in a particular season, makes a critical difference. Moreover, peak and off-peak hour measurements would obviously be different. The measurements presented in Table 18 are very balanced as they are 24-hour, yearly averages – but they do not give the maximum levels. Finally, the impact of the pollution on human health (the dose-response relationship) depends on age, other health characteristics and lifestyle, including food and smoking habits.

We may thus conclude that the increase in vehicular population in the city has had a significant impact in terms of an increase in the three types of pollutant measured. Banerji (2001) estimates that of the total quantity of air pollution in Kolkata, motor vehicles account for 24.26%. This is lower than the 30% load factor calculated by Agarwal (1996) and possibly higher than the combined (vehicles plus industry) load – 33% - suggested by Basu (1992).

Emission Standards and Other Policy Measures

The Air (Prevention and Control of Pollution) Act was passed as late as 1981,but since then air pollution regulation has improved rapidly. In 1984 NAAQM (National Ambient Air Quality Monitoring) set up monitoring stations in Kolkata. A variety of organizations are involved in regulatory activities, including the Central Pollution Control Board, the State Boards, the Motor Vehicles Department, the Kolkata Police and the Ministry of Petroleum and Natural Gas. Standards have been imposed on both on-road and new vehicles since 1989. The norms were made tighter in 1996. Since October 1, 2004, Euro II (or Bharat II) norms have been in force. Low-lead and unleaded petrol were introduced in 1994 and 1995 respectively, and unleaded petrol became compulsory in 2000. Low sulphur diesel was supplied from 1996, and the concentration reduced further since 1999.

Thus, the standards are there and fuels have been improved. However, several policies to curb vehicular pollution in recent years have failed. In 1999, an attempt to phase out Taxis older than 17 years was quashed by the taxi union. The phase out age of all vehicles was proposed at 15 years but then increased to 25 years by the state government – a number that can have no regulatory impact. Clearly, phasing-out policies would be difficult to implement and are unethical because they are regressive in nature. Though the specifications on engine design are being followed by the vehicle companies, with so many old vehicles and with a 25 year life, new vehicles can have very little impact on air quality. An attempt to make LPG compulsory for public transport also failed due to the intervention of the vehicle unions. There are a few three wheelers in the city that are running on LPG, but vehicle owners are largely biased against LPG and they are being helped by the fact that there are very few LPG outlets in the city.

Most importantly, the Bharat II norms have no meaning because monitoring in the city is insufficient, inefficient and corrupt. The ‘pollution under control’ certificates provided by testing stations are meaningless.

III. Transport Demand Management as a Policy Alternative

Under the circumstances, transport demand management (TDM) assumes a special importance for Kolkata. The government would not be wary of it, as it would not cause them to lose votes on a major scale. It would not face union trouble or be regressive in any manner.

The following are the components of TDM:

A. Systems for reducing vehicle trips or trip length, which consist of

   a. land use management like mixed-use planning
   b. locality-based assignment of students to schools
   c. reducing the work week by increasing hours of work or introducing at-home work
   d. economic disincentives on travel, such as fuel taxes or other taxes based on the quantity of vehicle use

B. Temporal shifts in demand, which will induce ‘peak spreading’, and can be achieved through

   a. flexible or staggered work schedules
   b. special peak hour charges on certain roads

C. Modal shifts to vehicles that pollute less per person, which may be encouraged by, for example,

   a. improvements in the services of higher occupancy vehicles (HOVs)
   b. ridesharing
   c. parking restrictions, fines and charges
   d. fringe parking facilities or parking near mass transit stations such as metro stations
   e. special lanes or roads for HOVs
   f. auto-free zones or zones where lower-occupancy vehicles (LOVs) cannot enter
   g. no-drive days for certain vehicle classes or license plate numbers
   h. bicycle and pedestrian pathways/footpaths
   i. various taxes on LOVs and tax concessions or subsidies on HOVs.

Much of the suggested methods for A, apart from the economic disincentives, would be difficult to implement. The economic disincentives would have an undesirable negative impact on the economy, but they may otherwise be easily implemented and taxes enhance state coffers that can be used for other pollution control measures. The same applies for B – the second measure, being a charge, can be implemented, but the net impact is uncertain. In comparison, C, as it is not supposed to reduce the necessary quantity of travel, would not harm the economy and can be implemented (though not all the methods are useful in Kolkata’s context – for example, ridesharing cannot be implemented on a large scale in most big cities in the developing world (see Vasconcellos, 2001, p. 288 for a discussion on this).

Thus, of the various measures under TDM, influencing modal choice appears to be the most significant, as well as the most feasible and least harmful. From the available data on Kolkata it is clear that in 1997-8 a lot of travel occurred on foot (see Table --) and amongst the travel that occurred using motor vehicles, the major part was by mass transit, which pollutes less per passenger. However, two things are occurring. First, there is perhaps a tendency for persons who were travelling by mass transit to shift to faster, more flexible LOVs. Second, the pollution created is directly connected to the modes that are actually on the road, and though such a large percentage uses mass transit, the vehicles servicing them are proportionately much less compared to LOVs, as reflected by the number of registrations, and by the scant data on the actual number of vehicles on the road. The aim of our policy makers should therefore be in the direction of making mass transit in Kolkata so attractive that those who are at the margin of shifting to LOVs do not do so, and that only those forms of mass transit be developed which (amongst mass transit modes) pollute the least.

IV. Objectives

The following are the objectives of this project.

A. To determine the quantity of pollution (of the different pollutants: Suspended Particulate Matter (SPM), Nitrous Oxide, Sulphur Dioxide, Carbon Monoxide and Hydrocarbons) caused by each vehicle type (bus (various categories), three-wheeler, taxi, minibus, ferry, car (diesel/petrol) and two-wheeler) in Kolkata (per unit distance traveled). We leave out the metro, suburban trains, trams and the circular rail as these, being run on electricity, do not pollute on location. As there are no standard gadgets for such tests and they are not undertaken for some of the above gases, we had to convert gadgets that are used to measure industrial pollution for our purpose.

B. To determine the average occupancy of the different modes, so that we can divide the estimates obtained above by occupancy, to get emissions per unit distance and per passenger transported. The occupancy data will be useful later, too, at the stage of planning a complete transport system.

C. To select a representative sample of 750 households and 280 non-resident commuters (amounting to 3000 individuals) with the help of appropriate sampling techniques. As the city has around 13 million residents, the sample cannot be a random one covering 20 per cent of the population. It has to be stratified, and carefully chosen in order to be representative. The households should be well distributed residentially, and should represent all relevant income and professional groups. It would be necessary to obtain a good idea of the population in Kolkata, in terms of various socio-economic features, to understand what the sample should be like.

D. To determine the total pollution caused by our sample from the present modal choices and distances traveled of these households, and from here extrapolate for the city.

E. To identify the factors that are more important in determining the choice of a particular mode. For this we consider three groups of factors: (a) socio-economic characteristics of travelers, such as incomes (b) features of trips, such as distance and (c) modal features, such as ease of access, and relate them to modal choice.

F. To determine several ways in which the modal structure may be changed. Feasible modal structures would be determined from the sample with the help of a carefully formulated questionnaire. For an individual who uses taxis, for example, new incentives for changing the travel mode to less polluting modes will be suggested (the 'incentives' may include disincentives for travelling by taxi) and her response as to whether she would then shift to another mode (and if so, which one) taken.

G. To determine the benefit in terms of emissions reduction for each of the alternative modal structures.

H. To then see, for each feasible modal change, what requires to be done by the state to implement it, and the cost involved.

I. From the cost figures and the benefits we arrive at the most cost effective (i.e. least cost per unit benefit) modal structure for the city. If the process of change is a long drawn one, we take present values.

V. Pollution Measurement

The following is a list of pollutants by vehicle types and various engine/fuel combinations.

Table 20: Pollutants for Different Vehicles

Engine Type	Fuel Type	Vehicle Type	Pollutants
Otto Cycle	Petrol	Cars, Motor Cycles, Buses	HC,CO, NOx, Pb
Diesel	Diesel oil	Buses, Cars	NOx, SO_2, Soot Particles
Two-Stroke Cycle	Petrol	Auto, Motor Cycles	HC, CO, NOx, Particles

Our first objective is to determine the quantities of emission of the major pollutants per unit distance travelled, viz., particulate matter (PM), sulphur dioxide (SO_2), nitrous oxides (NO_2), carbon monoxide (CO) and hydrocarbons (HC), caused by the following modes of transport:

1. State Bus
2. Private Bus
3. Minibus
4. Ferry
5. Three-Wheeler (or Auto, as it is called in India)
6. Two-Wheeler (Scooter, Motor Bike)
7. Taxi
8. Private Car

As it has become compulsory to use unleaded fuels, lead is not being measured.

We are leaving out the Circular Rail, Metro, Trams and Suburban Trains as these run on electricity and therefore do not cause pollution in the area they are operating in. For each mode, we take three samples of vehicles for three vehicle ages – pre-1990s, post-1990s but not Euro II, and Euro II.

A. Emission Monitoring Design

Presently,

(a) Only the concentration of CO in petrol driven vehicles is monitored,
(b) PM is measured as smoke density on a relative scale unit for diesel driven vehicles:direct concentration is not measured, and
(c) SO2, NOx and HC are not measured at all.
Therefore monitoring methods have been derived from methods used in measuring industrial emissions of the same compounds.

(i) **Emission Volume:** Emission from the tail pipe of the vehicle can be considered as emission from a chimney stack. This analogy has been subsequently followed in measuring emission volumes and the concentration of PM, SO_2 and NOx

(a) Stack emission velocity was measured following ASTM[6] and CPCB[7] standards. This method involves the measurement of average gas velocity using a calibrated Pitot tube at a number of traverse points. The method is often difficult to apply directly for tailpipes. A special attachment was therefore developed. A special steel pipe of length 1m. and diameter 100 mm, attached with a collar, was constructed. This pipe was fitted to the exhaust pipe of the vehicle with the help of adapter systems of various sizes. The pipe was attached to a monitoring nozzle as is the case for industrial stacks. The average gas velocity in a duct was measured by using an S-type pitot tube through the monitoring port[8].

(b) However, another method was developed to measure emission volumes during static and mobile conditions. A special Anemometer was procured for the purpose. An Anemometer is an instrument with very light vanes set on a cylinder. As the vanes rotate due to gas flow, the velocity is automatically measured and knowing the time and area, total flow volume can be determined. Biram's Anemometer (OSK 15058) was placed at the end of the pipe to monitor gas volume. The instrument was also fixed in a special module and was fitted with tail pipes of different moving vehicles. This gave us emission volumes in a mobile condition.

(ii) Particulate Matter: As mentioned above, particulate matter is not directly monitored in present emission stipulations. Therefore, similarly, the methodology for measuring particulate matter from a stack has been applied here.[9] This mainly consists of isokinetic sampling of particulates from gas. Particulates are collected in a dried and weighed special glass fibre thimble and weighed again after collection for a stipulated period. A special attachment for holding the thimbles was used for this purpose.

(iii) Sulphur Dioxide: Sulphur dioxide was monitored following the methods used by CPCB[10] and ASTM[11]. A known volume of gas was drawn through a midget impinger containing Hydrogen Peroxide. The Sulfur dioxide present was oxidized to Sulfate and then titrated with Barium Perchlorate solution using a thorium indicator. Gas waspassed through a filter to prevent particulates from causing interference.

(iv) Oxides of Nitrogen: It was monitored following the method used by ASTM[12]. The filtered gas sample was admitted into an evacuated flask containing an oxidizing absorbing solution consisting of H_2O_2 in dilute Sulphuric Acid. The oxides of nitrogen were converted to nitric acid by gas phase oxidation due to oxygen in the sample and

[6] ASTM - D-3154
[7] CPCB/COINDS/18/1984-85
[8] ASTM D3154-72
[9] CPCB/COINDS/18/1984-85 and ASTM D3685-78

[10] CPCB/COINDS/18/1984-85
[11] ASTM D3449-79
[12] ASTM 1608-77

the nitrate ion was reacted with phenol disulfonic acid to produce a yellow compound which was measured colorimetrically with the help of a spectrophotometer. Calibration curves, prepared from samples of known nitrate content, were used to determine the amount of nitrate in the sample with results expressed as nitrogen dioxide.

(v) CO and HC: CO and HC were monitored directly with the help of a Gas Analyser (Indus PEA 205) that has been designed and manufactured for testing emissions from automotive engines. The analyser uses the principle of Non-Dispersive Infra-Red (NDIR) method for measurement. The method is based upon the simple fact that a chemical substance shows marked selective absorption in the infrared region. This property was used for measuring concentration in a detector cell by comparing with a reference cell containing non-infrared absorbing gas.

(vi) Polycyclic Aromatic Hydrocarbon (PAH): HC concentrations in emissions from diesel-run vehicles are generally low. Most of the HC not properly burnt forms PAH which either becomes particulates or gets adsorbed in the particulates. Therefore PAH was extracted from the particulates following the standard method[13] and measured.

B. Selection of Vehicles for Monitoring

Emissions depend on

i) the fuel used,
ii) the type of vehicle and
iii) the age of the vehicle.

Vehicles in Kolkata use diesel and petrol. The vehicles used can be divided into 5 broad categories: Buses, Cars, Two Wheelers, Three Wheelers and Ferries. These broad categories have then been divided into subcategories.

Buses have been subdivided into 3 categories – Private Buses, State Buses and Mini Buses. The first two are basically the same, but the maintenance and age of the vehicles differ. Mini Buses are smaller and have different engine capacities. All three categories run on diesel.

Cars have been grouped into two categories, commercial (taxi) and personal. The basic difference is that that i) commercial cars are run on diesel and ii) personal cars are maintained better.

Finally, all two wheelers and three wheelers run on petrol and ferry launches run on diesel.

For each mode we have considered vehicles in three major categories – those registered prior to 1991, those registered between 1991 and 2000, and those registered after 2000 with both Euro I and Euro II (same as Bharat Stage II) norms.

[13] Parivesh , Nov 2003- CPCB

This because the new standards basically divides the vehicles into two categories, vehicles registered before and after the year 2000 and Bharat Stage II (same as Euro II).

C. Monitoring Details

Emission monitoring was carried out between July and September 2004. For State buses and ferry services, the concerned authorities helped arrange vehicles for monitoring. For all other vehicles, arrangements were made with the help of petrol stations.

In some cases two emission samples from the same vehicle were taken. Mostly, single emission monitoring was carried out with a greater stress on measurements from several different vehicles. As each ferry has two engines, emissions from both the engines were measured. Table 21 provides the details of monitoring carried out

Table 21

Number of Samples Monitored

Vehicle Category		**Pre 1991**	**1991 - 2000**	**2000 onwards**		
				Euro I	**Euro II**	**Non Euro**
BUS	Govt	2	2	2	2	
	Private	5	2		1	
	Private Mini	2	2		4	
CAR	Taxi + Rented Car	4	4		2	
	Private Car	1	4		5	
Three Wheeler		4	7			1
Two Wheeler		2	4			6
Ferry			4			

Several issues need to be discussed before using the results.

(a) For private commercial vehicles (especially buses) the age, as measured from the date of registration, is not always a useful criterion, as the owners often carry out modifications (which may include changing engine parts and sometimes the engine itself) during the operating period. . Therefore the age of the vehicle can be a wrong indicator of the emission potential. Such modifications were reported for even new CSTC buses – leading to Euro II buses having worse emissions than Euro I. Therefore a history of bus maintenance is more important than the age of the bus in the context of emissions. However, such information is usually unavailable.

(b) This study found that in general pre 1991 vehicles were less polluting than the vehicles registered between 1991-2000. It was found from discussions with bus operators that due to the 1st October 2004 deadline for new emissions regulations pronounced by Calcutta High Court, they have become active in improving their vehicles. It may be mentioned that earlier the High Court ordered that all vehicles be fitted with Bharat Stage II engines although later this order was changed so that the vehicles had to simply satisfy the new emission standards (that is, they were no longer required to change the engine). Therefore there is greater concern over improving the older vehicles. This seems to be the reason for better emission quality.

(c) It was found that State buses generally do not run for more than 7 to 8 years. On the other hand about 25 percent of private buses are more than 25 years old.

(d) The level of fuel adulteration also impacts emissions (particularly hydrocarbons). It has been reported that 3-wheelers mix waste lubrication oil and this lowers monitored values.

D. Emission Results

As vehicular movement differs significantly between office hours and non-office hours, it was felt that mass emissions for these two different scenarios should be presented separately. For the office hour scenario, it is assumed that for 25% of the time the vehicle idles and for the rest of the time moves with an average speed of 15 km/hr. This results in an average speed of 11.25 km (the distance between Jadavpur and Dalhousie, measuring 8 km, was covered in 42 minutes) during office hours.

For non office hours, it is assumed that the vehicle idles 20% of the time, moves with an average speed of 20 km/hr 60% of the time and moves with an average speed of 45 km/hr in the remaining time. This gives us an average speed of 21 km (the distance between Jadavpur and Dalhousie was covered in 23 minutes) during non-office hours.

Also, both ‘average’ emissions data and ‘worst case’ emissions data should be used.

These assumptions lead to four mass emissions scenarios:

Scenario A: Mass emissions of pollutants per vehicle per kilometer based on average monitoring values and office hour vehicular movements.
Scenario B: Mass emissions of pollutants per vehicle per kilometer based on worst case monitoring values and office hour vehicular movements.
Scenario C: Mass emissions of pollutants per vehicle per kilometer based on average monitoring values and non-office hour vehicular movements.
Scenario D: Mass emissions of pollutants per vehicle per kilometer based on worst case monitoring values and non-office hour vehicular movements.

These scenarios do not apply for ferries as there are no speed variations.

The mass emissions have been calculated based on emission concentrations and the volume of exhaust gas. Emission concentration data for different speeds has been calculated from the established relationship between speed and emission (Watkins, 1991, Table 2.4, p.32). The volume of emissions has been calculated based on anemometer readings under certain specific conditions. Emissions velocity has been measured using the pitot tube and theoretical emission volumes from the combustion of hydrocarbon fuels.

Tables 22-25 present the four scenarios. Table 26, then, takes an average speed of 16 kms per hour and average emission levels. Table 27 gives the data for ferries. We then take, for each mode, averages of the three time periods to obtain single values of emissions for each pollutant (Table 28). For executive state buses we have used the post-2000 data only as these buses are usually the newest in the field.

Finally, for each mode, we derive single values of the 'level of pollution' by taking

(a) the sum of the pollution level of the five pollutants (measure I)
(b) a weighted sum based on weights determined on the basis of consultations with pollution experts: these weights correct for the relative impacts of the five compounds on human health. They are 2.5 for PM, 1.25 for NO_x, .65 for CO, .4 for HC and .2 for SO_2) (measure II).

Table 29 gives the pollution for each mode, in grams and per unit distance, using the two measures. We will subsequently be using our results from the modal occupancy study (which follows) to obtain pollution per unit distance and per person.

Table 22: Scenario A

Emissions of Pollutants in gm/km during office hours at average emissions

PRIVATE BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.149	0.195	0.989	2.600	0.753
1991-2000	0.301	0.053	1.049	13.002	0.680
POST 2000	0.029	0.069	0.921	0.000	0.108
PUBLIC BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.035	0.22	0.84	0.64	0.76
1991-2000	0.293	0.23	1.26	0.959	0.89
POST 2000	0.035	0.09	0.78	0.959	0.19
MINI BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.201	0.217	0.904	2.248	0.772
1991-2000	0.213	0.192	0.744	2.130	0.750
POST 2000	0.026	0.086	0.661	1.597	0.206
TAXI	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.102	0.080	0.750	2.711	0.579
1991-2000	0.093	0.150	0.728	1.808	0.659
POST 2000	0.028	0.078	0.603	3.013	0.179
PRIVATE CAR	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.009	0.048	0.258	0.468	0.221
1991-2000	0.058	0.074	0.367	2.030	0.367
POST 2000	0.046	0.025	0.316	0.624	0.366
AUTO	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.028	0.008	0.071	13.097	6.014
1991-2000	0.025	0.005	0.057	2.328	1.351
POST 2000	0.019	0.004	0.049	0.146	4.270
TWO WHEELER	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.025	0.006	0.029	19.922	6.977
1991-2000	0.021	0.013	0.029	7.592	2.295
POST 2000	0.006	0.007	0.024	3.098	0.547

Table 23: Scenario B

Emissions of Pollutants in gm/km during office hours at worst emissions

PRIVATE BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.21	0.34	1.07	6.50	0.94
1991-2000	0.40	0.058	1.14	13.00	1.01
POST 2000	0.029	0.069	0.92	0.00	0.11
PUBLIC BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.043	0.33	0.89	0.64	0.80
1991-2000	0.311	0.27	1.33	0.959	0.93
POST 2000	0.046	0.10	0.92	1.109	0.26
MINI BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.22	0.23	0.94	2.248	0.817
1991-2000	0.22	0.20	0.76	2.130	0.795
POST 2000	0.031	0.10	0.70	1.597	0.272
TAXI	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.135	0.091	0.809	5.949	0.699
1991-2000	0.117	0.224	0.781	7.139	0.740
POST 2000	0.031	0.082	0.624	5.098	0.179
PRIVATE CAR	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.009	0.048	0.258	0.468	0.221
1991-2000	0.106	0.137	0.472	2.030	0.417
POST 2000	0.074	0.032	0.350	0.781	0.510
AUTO	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.031	0.010	0.082	18.118	9.307
1991-2000	0.028	0.006	0.063	2.547	5.427
POST 2000	0.019	0.004	0.049	0.146	4.270
TWO WHEELER	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.030	0.006	0.031	20.044	8.335
1991-2000	0.041	0.023	0.036	12.451	3.989
POST 2000	0.020	0.010	0.033	3.341	1.949

Table 24: Scenario C

Emissions of Pollutants in gm/km during non- office hours at average emissions

PRIVATE BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.073	0.125	0.683	1.393	0.369
1991-2000	0.147	0.034	0.724	6.967	0.333
POST 2000	0.014	0.044	0.636	0.000	0.053
PUBLIC BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.017	0.139	0.578	0.344	0.373
1991-2000	0.144	0.149	0.871	0.516	0.439
POST 2000	0.017	0.059	0.541	0.516	0.091
MINI BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.098	0.138	0.618	2.248	0.376
1991-2000	0.104	0.122	0.509	2.130	0.366
POST 2000	0.012	0.055	0.452	1.597	0.101
TAXI	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.051	0.052	0.526	1.476	0.287
1991-2000	0.046	0.097	0.511	0.984	0.327
POST 2000	0.014	0.051	0.423	1.640	0.089
PRIVATE CAR	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.004	0.032	0.189	0.254	0.111
1991-2000	0.029	0.050	0.268	1.101	0.1845
POST 2000	0.023	0.017	0.231	0.339	0.1837
AUTO	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.014	0.006	0.052	7.103	3.022
1991-2000	0.012	0.003	0.042	1.263	0.679
POST 2000	0.010	0.002	0.036	0.079	2.145
TWOWHEELER	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.013	0.004	0.021	10.823	3.511
1991-2000	0.010	0.008	0.021	4.125	1.155
POST 2000	0.003	0.005	0.018	1.683	0.276

Table 25: Scenario D

Emissions of Pollutants in gm/km during non-office hours at worst emissions

PRIVATE BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.104	0.215	0.735	3.483	0.462
1991-2000	0.198	0.037	0.785	6.967	0.497
POST 2000	0.014	0.044	0.636	0.000	0.053
PUBLIC BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.021	0.213	0.618	0.560	0.392
1991-2000	0.153	0.171	0.919	0.840	0.458
POST 2000	0.023	0.064	0.638	1.271	0.127
MINI BUS	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.106	0.143	0.642	2.248	0.40
1991-2000	0.110	0.126	0.522	2.130	0.39
POST 2000	0.015	0.063	0.481	1.597	0.13
TAXI	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.067	0.059	0.568	1.968	0.347
1991-2000	0.058	0.146	0.548	2.460	0.367
POST 2000	0.015	0.053	0.438	1.640	0.089
PRIVATE CAR	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.004	0.032	0.189	0.254	0.111
1991-2000	0.053	0.092	0.346	1.101	0.209
POST 2000	0.037	0.021	0.256	0.423	0.256
AUTO	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.016	0.007	0.060	9.826	4.677
1991-2000	0.014	0.004	0.046	1.381	2.727
POST 2000	0.010	0.002	0.036	0.080	2.145
TWO WHEELER	**PM**	**SO2**	**NOx**	**CO**	**HC**
PRE 1991	0.015	0.004	0.023	10.889	4.195
1991-2000	0.021	0.016	0.027	6.764	2.008
POST 2000	0.010	0.007	0.024	1.815	0.981

Table 26: Emissions of Pollutants in gm/km taking average speed of 16 km/hr and at average emissions

PRIVATE BUS	PM	SO2	NOx	CO	HC
PRE 1990	0.102	0.155	0.807	1.831	0.518
1990-2000	0.207	0.042	0.856	9.156	0.468
POST 2000	0.020	0.055	0.752	0.687	0.074

PUBLIC BUS	PM	SO2	NOx	CO	HC
PRE 1990	0.024	0.172	0.683	0.452	0.524
1990-2000	0.202	0.185	1.029	0.678	0.617
POST 2000	0.024	0.073	0.640	0.678	0.128

MINI BUS	PM	SO2	NOx	CO	HC
PRE 1990	0.137	0.171	0.732	2.248	0.526
1990-2000	0.145	0.151	0.603	2.130	0.511
POST 2000	0.017	0.068	0.535	1.597	0.141

TAXI	PM	SO2	NOx	CO	HC
PRE 1990	0.072	0.065	0.620	1.940	0.404
1990-2000	0.065	0.121	0.602	1.293	0.460
POST 2000	0.020	0.063	0.499	2.155	0.125

PRIVATE CAR	PM	SO2	NOx	CO	HC
PRE 1990	0.006	0.036	0.197	0.309	0.143
1990-2000	0.038	0.055	0.279	1.339	0.237
POST 2000	0.030	0.019	0.241	0.412	0.236

AUTO	PM	SO2	NOx	CO	HC
PRE 1990	0.018	0.006	0.054	8.622	3.882
1990-2000	0.016	0.004	0.044	2.591	0.872
POST 2000	0.012	0.003	0.037	5.135	2.757

TWO WHEELER	PM	SO2	NOx	CO	HC
PRE 1990	0.016	0.004	0.022	13.159	4.511
1990-2000	0.013	0.009	0.022	5.015	1.484
POST 2000	0.004	0.005	0.018	4.574	0.354

Table 27: Emissions of Pollutants in gm/km for Ferry Taking an Average Speed of 10km/hr

	PM	SO2	NOx	CO	HC
1991-2000	2.75	2.89	12.17	49.39	10.74

Table 28: Emmisions of Pollutants by Mode, gms/km

Modes	Emissions of				
	PM	SO_2	NO_X	CO	HC
Private Bus	0.1096	0.084	0.805	3.891	0.353
State Bus	0.0833	0.143	0.784	0.602	0.423
Mini Bus	0.0996	0.130	0.623	1.992	0.393
Taxi	0.0523	0.083	0.573	1.796	0.329
Private Car	0.0246	0.036	0.239	0.686	0.205
Auto	0.0153	0.004	0.045	5.449	2.503
Two-wheeler	0.011	0.006	0.020	7.582	2.116
Executive State Bus	0.024	0.073	0.640	0.678	0.128
Ferry	2.75	2.89	12.17	49.39	10.74

Table 29: Total Emissions by Mode, Measures I and II, gms/km

Modes	Emission by	
	Measure1	Measure2
Private Bus	5.2426	3.9674
State Bus	2.0353	0.7773
Mini Bus	3.2376	2.5057
Taxi	2.8333	2.1626
Private Car	1.1906	0.8953
Auto	8.0163	4.6383
Two-wheeler	9.7350	5.8284
Executive State Bus	1.5450	1.3665
Ferry	77.9400	59.0650

VI. Survey of Modal Occupancies

The emissions data is for each kilometer traveled, but different modes not only emit differently but also carry different quantities of people. Hence, we need the emissions per unit distance and per passenger transported, for which we need average occupancies of each mode.

There is some scanty or not very reliable data on the average occupancy of modes in the city. Agarwal (1996) gives occupancies in 5 categories for three cities (see Table 30). We see that they are very similar in all categories except for buses, where the occupancy is somewhat higher in Delhi. The Kolkata Transport Department has given us some data on 'passengers served per trip' which is presented in Table 31. Note the strong discrepancy in the data from these two sources. An average occupancy of 100 for buses seems improbable. Again, the same occupancy for three wheelers in the three metros also appears improbable as in Kolkata all three wheelers have fixed runs and are on sharing basis, with auto drivers rarely starting a run unless the auto has 4 to 5 people in it.

Table 30 : Occupancy in the Three Megacities

Cities	***Occupancy***				
	2-whls	**Car**	**Taxi**	**3-whls**	**Bus**
Delhi	1.7	2.4	2	1.8	47
Mumbai	1.6	2.6	2	1.8	42
Kolkata	1.6	2.6	2	1.8	40

Notes: 2-whls: Two-wheelers
3-whls: Three-wheelers.
Source: Agarwal (1996), p.26
.

Table 31: Passengers Served per Trip Kolkata Transport Department

Mode	Passengers Served per Trip
Bus	100
Minibus	50
Taxi	2.5
Auto	4
Private Car	1.5
Two Wheeler	1.05

Source: Kolkata Transport Department

We therefore decided to carry out a field survey of modal occupancy. We selected 10 well-distributed locations – they are roughly indicated in Map C.

We have initially left out the modes that do not pollute, as we do not need the occupancies for the calculation mentioned above. However, we will need occupancy data for these modes too for a complete planning exercise.

The samples were collected over six time segments for a weekday, a Saturday and a Sunday, as travel behaviour differs for each of these. The time segments are

- 7:15 – 8:15 AM
- 10:15 – 11:15 AM
- 1:15 – 2:15 PM
- 3:15 – 4:15 PM
- 6:15 – 7:15 PM
- 8:30 – 9:30 PM

For each mode and location, six samples were taken on each of these time segments and days, three in the direction towards the CBD and three in the opposite direction. Hence, for each mode, 1080 observations were attempted, though the scarcity of some modes like trams meant fewer observations in these cases. Apart from calculating total averages, we also looked at a variety of averages which give us some insight into the travel behaviour of Kolkatans.

We first calculated averages using both directions, that is both towards the city centre and away from it. Table 32 gives averages over locations for each time segment The last column gives a weighted average with a weight of 5 for weekdays and 1 each for Saturday and Sunday. We see that for buses and trams, the occupancy varies between peak and non-peak hours to a small extent on work-days.

Table 32: Average Occupancies by Time Segments, Occupancy Survey

Mode 1: Three Wheeler (Passenger)				
Time Segments	**Weekday**	**Saturday**	**Sunday**	**Average**
7:15-8:15 A.M.	3.7	3.2	3.6	3.6
10:15-11:15 A.M.	4.2	4.1	4.0	4.1
1:15-2:15 P.M.	4.1	3.7	4.1	4.0
3:15-4:15 P.M.	3.9	3.9	3.9	3.9
6:15-7:15 P.M.	3.9	3.9	3.9	3.9
8:30-9:30 P.M.	3.2	3.9	3.5	3.3
Mode 2: Two Wheeler				
7:15-8:15 A.M	1.7	1.9	1.6	1.7
10:15-11:15 A.M.	1.9	1.9	2.0	1.9
1:15-2:15 P.M.	2.0	1.9	1.9	2.0
3:15-4:15 P.M.	1.8	1.8	1.8	1.8
6:15-7:15 P.M.	1.9	1.8	2.0	1.9
8:30-9:30 P.M.	1.8	1.9	1.9	1.8
Mode 3: Taxi				
7:15-8:15 A.M.	3.1	2.9	3.3	3.1
10:15-11:15 A.M.	3.3	3.3	3.4	3.3
1:15-2:15 P.M.	3.4	3.4	3.7	3.5
3:15-4:15 P.M.	3.5	3.2	3.7	3.5
6:15-7:15 P.M.	3.7	3.5	4.0	3.7
8:30-9:30 P.M.	3.5	3.4	3.7	3.5
Mode 4: Private Car				
7:15-8:15 A.M.	4.0	3.9	3.6	3.9
10:15-11:15 A.M.	4.0	4.0	4.8	4.1
1:15-2:15 P.M.	4.2	3.9	4.2	4.1
3:15-4:15 P.M.	3.8	3.7	4.2	3.8
6:15-7:15 P.M.	4.3	3.7	4.5	4.2
8:30-9:30 P.M.	4.2	3.7	4.3	4.1
Mode 5: Regular State Bus				
7:15-8:15 A.M.	28.5	36.2	26.4	29.3
10:15-11:15 A.M.	46.7	39.5	31.7	43.5
1:15-2:15 P.M.	32.6	34.0	27.3	32.0
3:15-4:15 P.M.	37.2	36.2	31.5	36.2
6:15-7:15 P.M.	45.7	42.3	36.3	43.9
8:30-9:30 P.M.	42.5	39.2	22.1	39.1
Mode 6: Special State Bus				
Time Segments	**Weekday**	**Saturday**	**Sunday**	**Average**
7:15-8:15 A.M.	27.7	29.7	17.7	26.5
10:15-11:15 A.M.	37.8	29.7	28.4	35.3
1:15-2:15 P.M.	37.2	26.5	26.3	34.1
3:15-4:15 P.M.	24.9	34.2	26.0	25.0
6:15-7:15 P.M.	47.3	31.5	33.0	43.0
8:30-9:30 P.M.	40.3	30.6	36.4	38.3
Mode 7: Executive State Bus				
7:15-8:15 A.M.	8.0	4.7	-	6.4
10:15-11:15 A.M.	23.0	17.6	42.0	24.9
1:15-2:15 P.M.	30.3	21.0	43.0	30.8
3:15-4:15 P.M.	24.3	33.3	33.0	26.8
6:15-7:15 P.M.	36.0	30.7	50.0	37.2
8:30-9:30 P.M.	-	-	1.0	0.1
Mode 8: Ordinary Private Bus				
7:15-8:15 A.M.	36.2	35.4	32.9	35.6

10:15-11:15 A.M.	51.6	52.8	40.7	50.2
1:15-2:15 P.M.	48.0	45.5	40.2	46.5
3:15-4:15 P.M.	47.2	41.8	37.4	45.1
6:15-7:15 P.M.	59.4	51.0	50.4	56.9
8:30-9:30 P.M.	50.7	47.1	46.2	49.6
Mode 9: Chartered Private Bus				
7:15-8:15 A.M.	26.7	30.5	31.3	27.9
10:15-11:15 A.M.	31.8	32.2	34.2	32.2
1:15-2:15 P.M.	27.3	27.8	31.2	27.9
3:15-4:15 P.M.	36.5	28.0	36.0	35.2
6:15-7:15 P.M.	46.5	31.5	50.4	44.9
8:30-9:30 P.M.	38.2	35.2	34.8	37.3
Mode 10: School Bus				
7:15-8:15 A.M.	34.2	32.8	-	33.9
10:15-11:15 A.M.	35.0	31.3	22.7	32.7
1:15-2:15 P.M.	31.8	24.5	67.0	35.8
3:15-4:15 P.M.	30.4	26.9	0.0	29.8
6:15-7:15 P.M.	-	-	-	-
8:30-9:30 P.M.	-	-	-	-
Mode 11: Mini Bus				
7:15-8:15 A.M.	23.3	20.8	19.8	22.4
10:15-11:15 A.M.	35.6	34.2	28.4	34.4
1:15-2:15 P.M.	33.2	31.5	26.3	32.0
3:15-4:15 P.M.	31.2	29.4	26.5	30.2
6:15-7:15 P.M.	36.9	34.2	29.9	35.5
8:30-9:30 P.M.	30.3	29.0	28.5	29.8
Mode 12:Tram				
Time Segments	**Weekday**	**Saturday**	**Sunday**	**Average**
7:15-8:15 A.M.	32.0	28.0	19.0	29.6
10:15-11:15 A.M.	67.3	64.3	29.0	61.4
1:15-2:15 P.M.	51.3	55.3	35.0	49.5
3:15-4:15 P.M.	65.7	57.6	26.7	58.9
6:15-7:15 P.M.	85.0	65.3	56.0	78.0
8:30-9:30 P.M.	42.3	50.6	31.7	41.9

Table 33 gives location-wise averages over time segments for each type of day, and over all types. It is only in the case of buses that the values are significantly different between locations – some locations typically have lower bus occupancies but these locations are not necessarily away from the city centre. The reason for the occupancy differences may be the position of the location vis-à-vis bus routes.

Table 33: Average Occupancies by Location, Occupancy Survey

Mode 1: Three-Wheeler				
Location	Saturday	Sunday	Weekday	Average
1. E.S.I. Hospital-Ultadanga	3.2	3.7	3.5	3.5
2. C.R.Avenue – BB Ganguly Crossing	3.7	3.5	3.8	3.7
3. Deshapriya Park (Rashbehari Avenue)	3.5	4.0	3.9	3.8
4. Tipu Sultan More (Tollygunge)	3.7	4.1	4.4	4.2

5. Shova Bazar (B.K.Pal Avenue)	3.7	3.8	3.3	3.4
6. Exide More (A.J.C.Bose Road)	-	-	-	-
7. Sulekha	4.6	4.4	4.7	4.6
8. Salt Lake Phari	4.6	4.2	4.6	4.5
9. Entally	-	-	-	-
10. Behala Tram Depot (Ajanta Cinema)	3.5	3.8	3.4	3.5
Mode 2: Two Wheeler				
1. E.S.I. Hospital	1.5	1.8	1.9	1.8
2. C.R.Avenue – B B Ganguly Crossing	2.0	2.0	1.8	1.8
3. Deshapriya Park (Rashbehari Avenue)	1.6	1.7	1.8	1.7
4. Tipu Sultan More (Tollygunge)	1.9	1.9	2.1	2.0
5. Shova Bazar (B.K.Pal Avenue)	1.6	1.6	1.7	1.7
6. Exide More (A.J.C.Bose Road)	2.0	2.2	1.8	1.9
7. Sulekha	1.9	1.9	2.0	1.9
8. Salt Lake Phari	1.8	1.7	1.8	1.8
9. Entally	2.1	2.2	2.0	2.0
10. Behala Tram Depot (Ajanta Cinema)	2.0	2.0	1.8	1.8
Mode 3: Taxi				
1. E.S.I. Hospital	3.0	3.8	3.4	3.4
2. C.R.Avenue – B B Ganguly Crossing	2.9	3.6	3.3	3.2
3. Deshapriya Park (Rashbehari Avenue)	2.5	2.8	2.9	2.8
4. Tipu Sultan More (Tollygunge)	3.4	3.9	3.9	3.8
5. Shova Bazar (B.K.Pal Avenue)	3.4	3.6	3.5	3.5
6. Exide More (A.J.C.Bose Road)	3.9	4.2	3.6	3.7
7. Sulekha	2.7	2.8	3.2	3.1
8. Salt Lake Phari	3.7	3.6	3.3	3.4
9. Entally	3.9	4.4	3.6	3.7
10. Behala Tram Depot (Ajanta Cinema)	3.4	4.3	3.2	3.4
Mode 4: Private Car				
1. E.S.I. Hospital	3.1	4.6	4.8	4.5
2. C.R.Avenue – B B Ganguly Crossing	3.9	4.0	3.9	3.9
3. Deshapriya Park (Rashbehari Avenue)	3.0	4.0	3.9	3.9
4. Tipu Sultan More (Tollygunge)	3.7	4.5	4.1	4.1
5. Shova Bazar (B.K.Pal Avenue)	3.7	4.6	3.8	3.9
6. Exide More (A.J.C.Bose Road)	4.8	4.3	3.7	3.9
7. Sulekha	4.0	4.0	4.1	4.1

8. Salt Lake Phari	3.6	3.7	4.1	3.9
9. Entally	4.4	4.6	4.9	4.8
10. Behala Tram Depot (Ajanta Cinema)	3.9	5.1	3.7	3.9
Mode 5: Regular State Bus				
1. E.S.I. Hospital	17.1	10.2	19.0	17.5
2. C.R.Avenue – B B Ganguly Crossing	32.8	25.6	31.0	30.5
3. Deshapriya Park (Rashbehari Avenue)	50.3	47.1	51.3	50.5
4. Tipu Sultan More (Tollygunge)	52.4	45.7	53.1	51.9
5. Shova Bazar (B.K.Pal Avenue)	43.5	36.1	37.2	37.9
6. Exide More (A.J.C.Bose Road)	-	-	-	-
7. Sulekha	40.6	34.1	46.0	43.5
8. Salt Lake Phari	36.7	20.5	27.9	28.1
9. Entally	42.5	22.0	-	32.2
10. Behala Tram Depot (Ajanta Cinema)	54.4	45.9	46.3	47.4
Mode 6: Special State Bus				
1. E.S.I. Hospital	37.7	33.6	38.8	37.9
2. C.R.Avenue – B B Ganguly Crossing	27.1	20.8	23.1	23.3
3. Deshapriya Park (Rashbehari Avenue)	37.7	39.1	48.9	45.9
4. Tipu Sultan More (Tollygunge)	35.6	43.9	42.8	41.9
5. Shova Bazar (B.K.Pal Avenue)	-	-	-	-
6. Exide More (A.J.C.Bose Road)	26.0	21.8	30.6	28.6
7. Sulekha	23.3	19.4	23.9	23.1
8. Salt Lake Phari	36.7	27.4	40.1	37.8
9. Entally	48.5	26.4	-	37.4
10. Behala Tram Depot (Ajanta Cinema)	39.9	35.3	47.8	44.8
Mode 7: Executive State Bus				
1. E.S.I. Hospital	-	-	-	-
2. C.R.Avenue – B B Ganguly Crossing	-	-	-	-
3. Deshapriya Park (Rashbehari Avenue)	42.1	40.5	40.3	40.7
4. Tipu Sultan More (Tollygunge)	-	-	-	-
5. Shova Bazar (B.K.Pal Avenue)	-	-	-	-
6. Exide More (A.J.C.Bose Road)	13.2	-	17.9	17.1
7.Sulekha	-	-	-	-
8. Salt Lake Phari	17.2	-	21.2	20.5
9. Entally	-	-	-	-
10. Behala Tram Depot (Ajanta Cinema)	-	-	-	-

Mode 8: Ordinary Private Bus				
1. E.S.I. Hospital	38.8	33.2	42.5	40.6
2. C.R.Avenue – B B Ganguly Crossing	28.3	29.4	35.8	33.8
3. Deshapriya Park (Rashbehari Avenue)	39.0	36.5	51.6	47.6
4. Tipu Sultan More (Tollygunge)	54.5	54.3	60.6	58.8
5. Shova Bazar (B.K.Pal Avenue)	39.5	41.4	34.2	35.9
6. Exide More (A.J.C.Bose Road)	64.4	64.1	60.5	61.5
7. Sulekha	39.9	29.0	44.4	41.5
8. Salt Lake Phari	46.5	37.9	53.8	50.5
9. Entally	59.0	47.7	62.6	58.9
10. Behala Tram Depot (Ajanta Cinema)	46.0	41.6	42.4	42.8
Mode 9: Chartered Private Bus				
1. E.S.I. Hospital	45.2	45.5	47.9	47.1
2. C.R.Avenue – B B Ganguly Crossing	28.0	24.9	31.3	29.9
3. Deshapriya Park (Rashbehari Avenue)	21.9	39.0	35.6	34.1
4. Tipu Sultan More (Tollygunge)	41.7	30.2	36.0	35.9
5. Shova Bazar (B.K.Pal Avenue)	-	-	-	-
6. Exide More (A.J.C.Bose Road)	23.1	44.0	32.3	32.6
7. Sulekha	20.7	21.0	22.3	21.8
8. Salt Lake Phari	33.0	26.0	34.5	33.1
9. Entally	20.8	14.7	33.1	28.7
10. Behala Tram Depot (Ajanta Cinema)	32.3	42.7	36.7	36.9
Mode 10: School Bus				
1. E.S.I. Hospital	21.5	-	31.6	29.9
2. C.R.Avenue – B B Ganguly Crossing	20.3	-	31.6	29.7
3. Deshapriya Park (Rashbehari Avenue)	35.2	-	29.1	30.1
4. Tipu Sultan More (Tollygunge)	34.4	-	38.1	37.5
5. Shova Bazar (B.K.Pal Avenue)	23.3	-	5.8	8.7
6. Exide More (A.J.C.Bose Road)	48.2	-	52.4	51.7
7. Sulekha	27.2	-	27.8	27.7
8. Salt Lake Phari	25.7	-	27.2	26.9
9. Entally	26.6	-	35.7	34.1
10. Behala Tram Depot (Ajanta Cinema)	39.1	-	33.0	34.0
Mode 11: Mini Bus				
1. E.S.I. Hospital	28.4	27.5	32.3	31.0
2. C.R.Avenue – B B Ganguly Crossing	20.8	18.6	23.0	22.0
3. Deshapriya Park	31.9	28.1	32.2	31.5

(Rashbehari Avenue)				
4. Tipu Sultan More (Tollygunge)	35.3	38.0	39.7	38.8
5. Shova Bazar (B.K.Pal Avenue)	26.4	27.3	23.6	24.5
6. Exide More (A.J.C.Bose Road)	39.0	33.9	40.4	39.2
7. Sulekha	29.7	21.4	29.9	28.6
8. Salt Lake Phari	24.9	17.0	29.1	26.7
9. Entally	34.3	29.7	38.7	36.7
10. Behala Tram Depot (Ajanta Cinema)	28.1	26.2	27.3	27.2
Mode 12: Tram				
1. E.S.I. Hospital	-	-	-	-
2. C.R.Avenue – B B Ganguly Crossing	-	-	-	-
3. Deshapriya Park (Rashbehari Avenue)	52.1	33.0	60.0	55.0
4. Tipu Sultan More (Tollygunge)	44.7	30.5	40.4	39.6
5. Shova Bazar (B.K.Pal Avenue)	-	-	-	-
6. Exide More (A.J.C.Bose Road)	--	-	-	-
7. Sulekha	-	-	-	-
8. Salt Lake Phari	-	-	-	-
9. Entally	63.1	33.5	57.4	54.8
10. Behala Tram Depot (Ajanta Cinema)	-	-	-	-

Note: At locations 3, 5, 6 and 8 East-West movements were taken, and for the remaining, North-South movements.

Table 34 gives averages over time segments and locations, for each type of day, and over all types. It is clear that occupancy in private buses is higher compared to state buses.

Table 34: Average Occupancies, Occupancy Survey

Modes	Weekday	Saturday	Sunday	Average
1. Three Wheeler	3.8	3.8	3.8	3.8
2. Two Wheeler	1.9	1.8	1.9	1.9
3. Taxi	3.4	3.3	3.7	3.4
4. Private Car	4.1	3.8	4.3	4.1
5. Regular State Bus	33.3	37.9	29.2	37.3
6. Special State Bus	35.8	30.3	27.9	33.7
7. Executive State Bus	24.3	18.0	42.0	21.0
8. Ordinary Private Bus	48.8	45.6	41.5	47.3
9. Chartered Private Bus	34.5	30.9	36.3	34.2
10. School Bus	32.8	28.9	-	32.1
11. Mini Bus	31.6	29.9	26.8	30.7
12. Tram	57.3	53.5	32.9	53.2

We carried out the same exercise, keeping the directions (towards city centre and away from it) separate (see Table 35). There is, interestingly, no clear difference between occupancies in any of the modes going towards and away from the CBD. This is quite possible for privately owned or single occupancy modes but for public transport this may be because there is no longer a single city centre.

Table 35: Average Occupancies Towards and Away From City Centre by Time Segments, Occupancy Survey

	Weekday		***Saturday***		***Sunday***		***General***	
	Away	***Towards***	***Away***	***Towards***	***Away***	***Towards***	***Away***	***Towards***
Mode 1: Three Wheeler								
7:15-8:15 A.M.	3.6	3.6	3.1	3.1	3.5	3.6	3.5	3.5
10:15-11:15 A.M.	4.4	4.1	3.5	3.5	4.0	3.5	4.2	3.4
1:15-2:15 P.M.	4.0	4.3	3.7	3.9	4.0	3.6	3.9	4.1
3:15-4:15 P.M.	3.3	3.9	3.9	3.8	3.5	3.8	3.4	3.9
6:15-7:15 P.M.	3.8	3.8	3.9	3.8	3.9	3.7	3.8	3.8
8:30-9:30 P.M.	3.2	3.4	3.3	4.0	3.4	3.5	3.2	3.5
Mode 2: Two Wheeler								
7:15-8:15 A.M.	1.7	1.7	1.9	1.8	1.7	1.8	1.7	1.7
10:15-11:15 A.M.	1.9	1.9	1.8	1.9	1.9	2.0	1.8	1.9
1:15-2:15 P.M.	2.0	2.1	1.8	1.8	1.9	1.9	1.9	2.0
3:15-4:15 P.M.	1.7	1.8	1.8	1.9	1.9	1.8	1.7	1.8
6:15-7:15 P.M.	1.9	1.8	1.7	1.9	2.1	1.8	1.9	1.8
8:30-9:30 P.M.	2.0	1.7	1.8	1.9	1.8	1.9	1.9	1.7
Mode 3:Taxi								
7:15-8:15 A.M.	3.2	2.9	3.2	2.5	3.6	3.5	3.2	2.9
10:15-11:15 A.M.	3.3	3.5	3.4	3.2	3.5	3.3	3.3	3.4
1:15-2:15 P.M.	4.0	3.1	3.7	3.1	4.2	3.3	3.9	3.1
3:15-4:15 P.M.	3.4	3.9	2.9	3.4	3.8	3.7	3.4	3.7
6:15-7:15 P.M.	3.5	4.0	3.5	3.4	3.9	3.6	3.5	3.8
8:30-9:30 P.M.	3.7	3.8	3.4	3.3	3.8	3.1	3.6	3.6
Mode 4: Private Car								
7:15-8:15 A.M.	3.1	3.2	4.2	4.1	2.0	1.9	3.1	3.1

10:15-11:15 A.M.	3.9	4.0	4.0	4.3	2.1	2.6	3.6	3.8
1:15-2:15 P.M.	2.7	2.8	3.9	3.1	3.0	2.4	2.9	2.8
3:15-4:15 P.M.	4.0	2.1	2.9	3.5	1.6	1.9	3.5	2.3
6:15-7:15 P.M.	3.5	3.8	3.0	3.3	2.8	2.6	3.3	3.5
8:30-9:30 P.M.	4.1	3.6	3.2	3.1	3.0	2.5	3.8	3.4
Mode 5: Regular State Bus								
7:15-8:15 A.M.	34.8	37.2	34.2	37.1	26.6	30.1	33.5	36.1
10:15-11:15 A.M.	41.2	44.6	41.2	39.5	24.1	19.5	38.7	40.2
1:15-2:15 P.M.	39.6	46.1	40.5	36.2	18.2	20.4	36.6	41.0
3:15-4:15 P.M.	35.4	32.6	35.6	32.4	22.1	19.4	33.5	30.6
6:15-7:15 P.M.	42.6	44.6	42.5	44.8	24.6	30.1	40.0	42.5
8:30-9:30 P.M.	36.2	32.1	36.5	34.5	18.5	24.1	33.7	31.3
Mode 6: Special State Bus								
7:15-8:15 A.M.	25.3	26.8	33.3	20.1	21.5	18.5	25.9	24.6
10:15-11:15 A.M.	29.6	31.2	30.1	31.2	18.5	20.1	28.1	29.6
1:15-2:15 P.M.	33.2	31.9	21.5	29.6	19.4	22.5	29.5	30.2
3:15-4:15 P.M.	27.5	28.3	30.3	31.6	24.6	19.8	27.5	27.5
6:15-7:15 P.M.	31.5	37.6	35.2	28.5	22.6	25.4	30.7	34.5
8:30-9:30 P.M.	22.3	22.9	21.5	23.6	20.1	16.4	21.8	22.1
Mode 7: Executive Bus								
7:15-8:15 A.M.	-	12.0	-	6.7	-	-	-	11.1
10:15-11:15 A.M.	25.7	20.2	18.0	19.3	42.0	-	26.9	20.05
1:15-2:15 P.M.	33.0	29.5	18.6	24.5	46.0	40.0	32.8	30.3
3:15-4:15 P.M.	18.6	26.3	27.5	34.4	25.0	40.0	20.8	29.4
6:15-7:15 P.M.	36.0	17.0	24.6	67.5	50.0	-	36.4	25.4
8:30-9:30 P.M.								
Mode 8: Ordinary Private Bus								
7:15-8:15 A.M.	33.6	24.2	27.3	39.1	22.3	30.1	31.1	27.2
10:15-11:15 A.M.	39.6	41.2	31.2	35.6	25.4	27.5	36.4	38.4
1:15-2:15 P.M.	44.5	46.5	25.6	37.5	30.1	19.3	39.7	41.3

3:15-4:15 P.M.	37.5	41.0	22.5	31.2	21.2	18.5	33.0	36.4
6:15-7:15 P.M.	48.9	44.3	33.6	40.1	26.3	28.5	43.5	41.4
8:30-9:30 P.M.	42.1	41.6	22.5	27.8	25.4	18.9	36.9	36.4
Mode 9: Chartered Private Bus								
7:15-8:15 A.M.	25.4	29.6	31.0	29.7	25.3	28.5	26.1	29.4
10:15-11:15 A.M.	30.8	36.5	32.4	41.0	29.9	42.9	30.9	38.0
1:15-2:15 P.M.	29.2	27.9	32.8	29.9	40.8	27.6	31.4	28.1
3:15-4:15 P.M.	36.8	30.2	22.9	23.4	37.0	27.6	34.8	28.8
6:15-7:15 P.M.	44.6	43.1	32.5	29.9	56.3	40.8	44.5	40.9
8:30-9:30 P.M.	39.3	33.7	36.7	23.9	38.3	34.9	38.8	32.5
Mode 10: School Bus								
7:15-8:15 A.M.	33.2	34.8	25.6	30.1	-	-	31.9	34.0
10:15-11:15 A.M.	29.6	41.2	30.5	28.4	-	-	29.7	39.1
1:15-2:15 P.M.	31.8	40.5	41.5	44.6	-	-	33.4	41.1
3:15-4:15 P.M.	44.6	43.2	24.5	18.6	-	-	41.2	39.1
6:15-7:15 P.M.	-	-	-	-	-	-	-	-
8:30-9:30 P.M.	-	-	-	-	-	-	-	-
Mode 11 : Mini Bus								
7:15-8:15 A.M.	22.5	26.4	28.4	22.4	19.5	20.1	22.9	24.9
10:15-11:15 A.M.	34.5	33.6	30.1	30.9	28.4	21.7	33.0	31.5
1:15-2:15 P.M.	36.4	31.5	29.6	30.4	22.5	30.1	33.4	31.1
3:15-4:15 P.M.	29.4	30.8	33.4	41.5	28.5	21.4	29.8	30.9
6:15-7:15 P.M.	38.5	36.9	34.6	40.1	20.1	25.6	35.3	35.7
8:30-9:30 P.M.	29.6	32.1	25.6	21.5	19.5	20.7	27.5	28.9
Mode 12: Tram								
7:15-8:15 A.M.	26.0	38.3	16.3	39.5	16.8	21.3	23.3	36.0
10:15-11:15 A.M.	76.5	59.5	62.0	66.3	30.1	26.9	67.8	55.8
1:15-2:15 P.M.	48.8	56.0	56.2	55.7	30.0	22.8	47.2	51.2
3:15-4:15 P.M.	83.8	54.4	49.2	65.6	31.9	22.8	71.4	51.5
6:15-7:15 P.M.	106.0	62.8	58.8	71.6	49.8	61.9	91.2	63.9

8:30-9:30 P.M.	49.0	36.5	24.5	68.0	38.3	30.4	43.9	40.1

VII. Ranking the Modes According to Emissions per Unit Distance and per Person

Using the summary of occupancy results in the final column of Table 34, and using the two estimates (I and II) of average emissions per unit distance by mode (Table 29), we derive the emissions per person and per unit distance (Table 36). The total emission from the ferry becomes very high essentially due to the high value of CO emissions. It did not appear reasonable to take this very high value because of the obviously higher dispersion rate on the river compared to the city's narrow roads. On the basis of discussions with scientists and officers managing the ferry service, we have divided the ferry emissions by a factor of 10.

Table 36: Pollution per Person per Unit Distance, by Mode

Modes	Pollution per person per unit distance	
	Measure 1	Measure2
Auto	2.1095	1.2206
Two-wheeler	5.1235	3.0675
Taxi	0.8335	0.6361
Private Car	0.2900	0.2183
Regular State Bus	0.0545	0.0476
Special State Bus	0.0600	0.0527
Executive State Bus	0.0735	0.0650
Ordinary Private Bus	0.1110	0.0839
Chartered Private Bus	0.1530	0.1160
School Bus	0.1635	0.1236
Mini Bus	0.1055	0.8160
Share Taxi	0.5665	0.4325
Hired car	0.6900	0.5274
Ferry	0.0996	0.0755

We then rank the modes according to the level of pollution per person, per unit distance. Note that we have used the same emissions data for (a) regular and special state buses, (b) ordinary, chartered and school buses and (c) taxis, share taxis and hired cars. This is because the same vehicles with similar maintenance levels are used for these purposes – it is only the occupancy that varies for these vehicles. On the other hand, we have used the same occupancy levels for private and hired cars and an occupancy of 5 for share taxis as these run with this fixed number.

Interestingly, the two sets of values (measure I and II) are different but the rankings turn out to be the same. The two-wheeler is the worst offender, followed by the auto and the taxi, though there are major gaps between the pollution levels of each of these modes. The low-occupancy vehicles have higher values and the high-occupancy buses come last, though the state buses are much better than the private buses. The ferry's pollution level is situated somewhere in-between the buses

Given that the tram, metro, circular rail and local train emit zero pollution on the road, their rank follows that of the buses. Finally, rickshaws, bicycles and walking are non-motorised, and therefore come last in the ranking.

VIII. Household and Commuter Survey

The main objective of the survey is to determine the travel behaviour of two categories of persons - (a) those residing in Kolkata city (households), and (b) those who enter the city in the daytime but reside outside it (commuters). By 'city', of course, we mean the KMC area. In addition, our objective has been to look at all aspects that determine the use of a particular mode, and finally, factors that will induce users to change the mode used. These observations would then give us

a. the modal structure in the city as a whole, in terms of the mode-wise kilometres covered by the population of the city as a whole, including those who do not live in the city but commute within it. This information, in turn, will yield the total pollution emitted by the vehicles running in the city.
b. the relationship between modal use and
   (i) socio-economic characteristics of the user
   (ii) the nature of the trip and
   (iii) features of the mode used, and finally

c. alternative *feasible* modal structures for the city, how they can be made operational, their cost and their benefit in terms of pollution reduction.

The choice of the sample has to made with care as, given that the population of the KMC area is more than 4.57 million, this project cannot survey a 20% or 30% random sample. We have therefore taken a purposive sample of 750 households constituting 2720 individuals and 280 commuters residing outside the KMC area. This proportion is based on the data that 4.7 lakh persons enter the KMC area, which has a population of 4.57 million, so that approximately 10.3 % of the number in the households have to be sampled from the commuters.

The households were selected with three main criteria in mind – (a) residential spread, (b) income groups and (c) nature of the locality. Also, we have taken 22.6% households whose main occupation is sales, as this is the percentage of households in sales (CMDA, 1999, p. 75). This is because of all the listed professions (see Table 3), this is the only one that can influence modal choice, so that we wanted to keep a representative sample in the total.

The residential spread has been maintained by covering all the 15 boroughs in the KMC area, and maintaining the same population percentage in the sample as exists in the population itself. Table 37 gives the populations in each of the boroughs in absolute and percentage terms. Hence, 7.12% of the household sample resides in borough 1, 5.18% in borough 2, and so on.

We have data on the per capita monthly household incomes (see Table 4) in the KMC area, a data collected in 1997(CMDA, 1999, p.80) and the residential areas they may correspond to. This is the only authentic data on household incomes in the KMC area. As the data was 7 years old at the point of the survey (conducted in October and November of 2004), we have used an inflation rate based on retail price indices in West Bengal to inflate the income ranges given in Table 4 (Govt. of West Bengal, 2003-4, p.

169) Table 38 gives the ranges, the average income in the range and the percentages of household in this range.

Table 37: Borough Populations, KMC

Borough	Wards	Population	Percentage
1	1-9	3,25,649	7.12
2	10-12,15-20	2,36,767	5.18
3	13,14,29-35	3,41,876	7.47
4	21-28,38,39	2,78,255	6.08
5	36,37,40-45,48-50	2,62,353	5.74
6	46,47,51-55,60-62	3,13,638	6.86
7	56-59,63-67	5,05,358	11.05
8	68-73,84-87,90	2,96,653	6.49
9	74-80,82,83,88	3,64,254	7.96
10	81,89,91-100	4,06,935	8.89
11	101,102,110-114	2,01,040	4.39
12	103-109	2,22,145	4.86
13	115-123	2,47,093	5.40
14	124-132	2,96,044	6.47
15	133-141	2,74,706	6.04

Source: Kolkata Municipal Corporation Records

Table 38: Per Capita Monthly Household Incomes in the KMC Area

Range	Average Income	Percent Households
0 – 125	20	1
126 – 250	221	1
251 – 374	335	8
375 – 624	528	26
625 – 936	801	22
937 – 1248	1135	16
1249 – 2497	1743	17
2498 – 3745	2891	6
3746 – 6241	4792	2
6242 & above	9227	1

We have maintained these percentages in our sample. Thus, for example, 1% or 8 households in our sample earn in the range 0-125 per capita per month. In order that the surveyors are able to cover all the income ranges, there has been an attempt to choose localities according to the following percentages:

Slum: 33%
Lower Income Group: 41%
Middle Income Group: 23%
Upper Middle Income Group: 2%
Higher income Group: 1%

These percentages have been devised on the basis of inferences on the possible localities for each of the income ranges, and also the information that the slum population in the 2001 census was 33%.

The commuters were selected with the same income group proportions, but further, a male-female ratio of 72:28 was maintained, as this is the ratio obtained for commuters in general in the city. The latter had not been necessary for the households as the ratio becomes automatically close to that of the population when one is including every member of a household.

The household and commuter survey questionnaires are given in Appendices A and B. Several observations are required to be made on the questionnaires.

First, the affluence of the family is evaluated in a variety of ways – over and above monthly expenditure and incomes, we have looked at the residential area, the nature and size of the dwelling unit and the ownership of electronic durables. The objective was to ascertain the level of affluence in several ways. After other details on the family, we have interviewed each member separately.

Second, the section on travel behaviour, which is in tabular form, needs some elaboration. Twelve categories of purpose have been identified, a number far greater than recorded in most of the literature on travel behaviour. For each category (such as 'work' or 'friends' or 'children's hobby/tutor), data on a maximum of five locations have been recorded. For sales persons who have multiple work locations, no specific locations were recorded and average distances of multiple locations were taken. For others it was very rare that there were more than five locations, and if there were, these were recorded. The frequency of travel was recorded in days per week, month or year, according to the respondent's convenience, but then all the data was converted to days per year. The total distance of a destination was divided up according to the mode used, and the remaining information (columns 5-8) was collected for *each* of these modes. Note that all the modes (21 including non-motorized forms) are listed according to the level of pollution per person per unit distance as obtained in Sections V and VI (see the end of the questionnaires).

What is 'more polluting' (column 5) is determined by this list. The 'prevention factors' (column 6) are the same as the incentives (10 of them) listed in section q (commuter) and section III (household) of the questionnaires. We can divide up the modes into three categories – very polluting (1 – 6), polluting (7 - 14) and zero polluting (15 – 21). Now, for modes 1-6, we suggest 5 alternatives (bus, metro, local train, circular rail and ferry) and ask what incentives would induce them to shift to these (column 7). We have left out the tram as whatever of this mode remains will also be phased out because it is slow, takes up too much of the scarce road space and creates traffic disruptions due to its relatively rigid movements. It is therefore not a mode that we plan to propose an enhancement of. We have also not considered modes that do not presently exist. Column 8 then lists the required incentives for a shift to each of the 5 alternatives.

Finally, there is a listing of trip combinations – that is, trips that are combined, and if so, whether the combination takes place in one direction, both directions or in a 'circular' manner (that is, for example, one starts with one destination, goes to the second, goes from there to the third, and returns home). Further, the percentage of times (of the minor trip, that is, the one with the lower frequency) that one combines it with the major trip/trips is recorded.

IX. Analysis of Data

A. Correction of Frequency Data and Distance Calculations

The frequency data is clearly an overestimation as combined trips are listed individually. We thus used the information on combination trips to correct frequency in the following manner. We have simply translated distance corrections into frequency corrections). Say, for an individual, the (yearly) frequencies for work I and work II are x and y. Say m% of the minor trip (the one with the lower frequency) is combined with the major trip. Then, the combined trips are the product of y and m – call this k.

There are four possibilities. The first three are for the combination of two purposes, which is the usual case, and the last for the combination of three or more purposes.

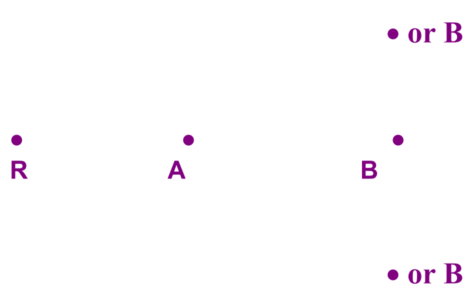
The first scenario is when the location of work II (B) is on the way to that of work I (A):

The frequency correction will then be as follows:

Work I : x (as before)
Work II: y – k

We simply leave out the combination trips from the second purpose (as we do in the case of all possibilities that will follow), and the frequency for Work I remains the same as the distance traveled does not increase (due to the fact that B is on the way).

Second, work II may be located at a point to the right of the vertical line passing through the location of Work I.



If the combination is two-way, the frequency correction is as follows:

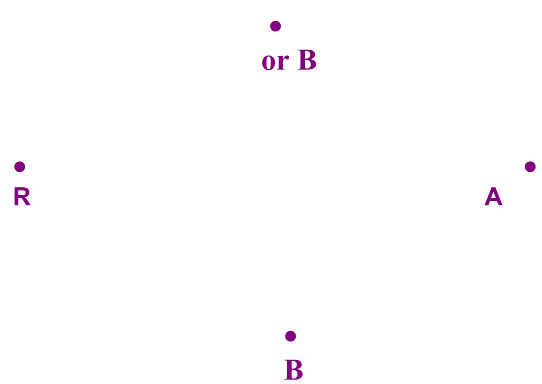
Work I: $(x - k) + k\,(3/2)$
Work II: $y - k$

The assumption being made is that on average, the person has to travel half the distance extra to reach B. Thus, x is divided into two parts: non-combination trips (x-k) and combination trips (one and a half of k). The one and a half times distance is thus translated into a correction of trips.

If on the other hand, the combination is one-way or circular, the corrections are:

Work I: $(x - k) + (k/2)(3/2) + (k/2)(5/4)$
Work II: $y - k$

Here, we are dividing up the distance into two parts (non-combination and combination trips), and the second part is again divided into two parts – the part corresponding to the way that one combines, and the part corresponding to the way that one returns home from B. For the first half of the second part, we assume that B is an extra half distance away from A (on average), and for the second half, as the person goes straight from B back home, so that there is no need to pass through A again, we assume that on average this is one and one-fourth times extra travelling (compared to the distance from R to A) – and hence make the corresponding frequency corrections.
The third case is when B is to the left of the vertical line through A



If the combination is two-way, the correction is:

Work I: $(x - k) + k(5/4)$
Work II: $y - k$.

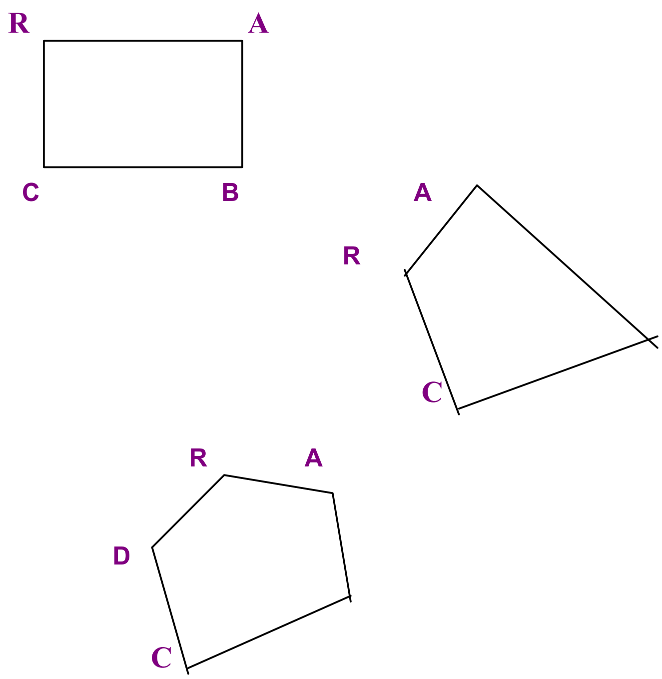
If, on the other hand, it is one-way or circular, the correction is:

Work I: $(x - k) + (k/2)(5/4) + (k/2)$

Work II: y – k

For two-way combinations we have increased the distance of the combined trips by 25%, an amount half of the increase for the second case when B was further from the residence than A. Further, if the combination is one-way, the distance of one journey remains the same, whilst the distance of the other increases, again by an average of 25%. Hence the above formula.

Finally, for three, four, five etc. trips, which are almost always ‘circular, we have devised the following rules



If three trips are combined, and k is the number of combination trips such that k is the product of z, the frequency of the trip with the lowest frequency, and m, the percentage of this trip that is combined, the correction is

Work I: (x – k) + 2k
Work II: y – k
Work III: z – k

Here we are assuming that on average, the movement makes a square (see the diagram).

If four trips are combined (see the diagram again), we enhance the extra travelling with the assumption that not all the distances are the same, hence we have

Work I: (x – k) + 2.5k
Work II: y – k
Work III: z – k
Work IV: p - k

Similarly, for five trips, we have

Work I: (x – k) + 3k
Work II: y – k
Work III: z – k
Work IV: p – k
Work V: q – k,

And so on.

The decision on the average value of the extra distance is somewhat arbitrary, although there is a certain logic behind each of these values – for example, that if the distance between A and B is more than double the distance between R and A or very much out of the line between R and A, .there is little reason for combining the trips. Basically, trip combinations are with the objective of saving travel but also, on a single day, it becomes difficult to travel more than twice of the normal travel distance.

After correcting the frequency data, which gives the number of trips, we multiplied it by two (to and fro) and then multiplied this with the distance (column 2) to get, for each individual in the sample, the total distance traveled, by destination and within each destination, by mode.

B. Verification of Incomes Data

For each household, we have collected information on assets and the nature of residence, in order to confirm that the income data truly reflects the affluence of the respondent (see Tables 39, 40, 41 and 42). Table 39 shows a clear connection between the household per capita income group and the locality of residence. Table 40 indicates that whilst there is no clear connection between income and whether the residence is owned or whether rented, especially in the lower income categories, there is some connection between the nature of the dwelling unit (house, flat or slum) and income, especially in the case of slum residence. The connection between the *size* of the dwelling unit and income is, on the other hand, far more obvious in Table 41. Finally, Table 42 relates the ownership of electronic goods with per capita household income – here, too, the connection is strong. Hence, on the whole, we can say that per capita income does reflect the level of affluence of the household.

Table 39: Locality of Residence and Income Groups of Sample Households

HH Income/capita/month	No. of Households in					
	Rich	Upper Middle	Middle	Lower Middle	Poor/Slum	***Total***
0-125	0	0	0	2	4	6
126-250	0	0	0	2	6	8
251-374	0	0	6	20	30	56
375-624	0	2	23	87	85	197
625-936	1	4	49	64	49	167
937-1248	1	4	43	41	24	113
1249-2497	1	14	62	31	26	134
2498-3745	0	7	19	6	4	36
3746-6241	0	8	9	1	0	18
>6241	2	8	4	1	0	15
TOTAL	5	47	215	255	228	750

Table 40 : Nature of Dwelling Unit and per Capita Household Income, Households

HH Income/Capita/ month	Nature of dwelling unit(No. of HH)					
	Own			Rented		
	House	Flat	Slum	House	Flat	Slum
0-125	2	0	2	0	0	2
126-250	1	0	2	1	0	4
251-374	11	0	7	14	1	23
375-624	63	3	20	43	3	65
625-936	62	6	14	38	12	35
937-1248	50	3	6	28	8	18
1249-2497	60	6	4	31	11	22
2498-3745	19	3	0	8	2	4
3746-6241	7	2	0	7	2	0
>6241	11	2	0	0	2	0
TOTAL	**286**	**25**	**55**	**170**	**41**	**173**

Table 41: Distribution of Sample Households by Area of Dwelling Unit and Income Groups

Income Group	Distribution of households by total covered area occupied in the dwelling unit(sq.ft)							
	<=100	101-150	151-250	251-500	501-750	751-1200	1201+	Total
0-125	2	1	2	0	0	1	0	6
126-250	3	2	2	1	0	0	0	8
251-374	22	11	12	9	1	0	1	56
375-624	51	31	38	49	20	7	1	197
625-936	27	19	38	44	28	3	8	167
937-1248	19	14	17	30	19	13	1	113
1249-2497	15	10	23	33	32	13	8	134
2498-3745	6	1	1	8	10	7	3	36
3746-6241	4	1	1	1	6	4	1	18
>6241	0	0	0	2	3	6	4	15
TOTAL	149	90	134	177	119	54	27	750

Table 42: Asset Ownership and per Capita Household Incomes

HH Income/Capita/month	Assets Ownership (No. of Households)					
	Radio only	Mobile only	Radio + Mobile	Color TV +	Washing Machine+	All
0-125	2	0	0	1	0	0
126-250	1	0	0	1	0	0
251-374	17	0	0	12	0	0
375-624	59	0	14	77	1	2
625-936	39	0	0	89	5	1
937-1248	23	1	3	71	8	3
1249-2497	16	0	8	91	8	5
2498-3745	5	0	0	29	4	3
3746-6241	3	0	0	14	5	1
>6241	0	0	0	14	10	9

C. Socio- Economic Features of Traveler and Modal Choice

As discussed earlier, we see whether socio-economic characteristics of the respondent has any connection with modal choice. Table 43 gives the distance covered by mode for females and males, made comparable by dividing the values by the number of males or of females in the sample. We see in general that the distances are significantly less for women, but women on average travel more by certain modes (executive bus, tram, circular rail and rickshaw) and interestingly, they walk more. Women also tend to travel much less by taxi, minibus, auto, hired car, share taxi, special state buses and the bicycle. Hence our sample indicates a definite relationship between modal choice and sex.

Table 43: Average Distance Covered by Mode, Females/Males, Household and Commuter Data

Modes used	**Male**	**Female**
	Average distance covered by km	
Two-wheeler	592	292
Auto	201	50
Ferry	880	360
Taxi	139	6
Hired car	324	79
Shared Taxi	1010	150
Private car	180	53
School Bus	1238	571
Chattered Bus	1705	983
Ordinary Bus	295	123
Mini Bus	210	26
Executive State Bus	79	145
Special State Bus	274	25
Regular State Bus	481	172
Tram	71	204
Metro	1050	528
Circular rail	7628	9360
Local train	740	220
Rickshaw	150	289
Bicycle	1135	277
Walking	64	268

Secondly, we have divided up our sample into age groups and recorded the kilometres traversed by each age group using each mode (Table 44). Once again, we have made the numbers comparable by dividing the data by the number of persons in the relevant age group. We see here that the maximum use of all modes is in the age group 46-60, mostly followed by the age group 26-45. Children under 5 have a greater tendency of walking, and older people tend to have a preference for certain modes. Whilst there are some modal choices at the extreme age groups, there is no clear relationship between age and modal choice for the more moderate age groups.

Third, we have looked at average distances covered by the income groups used by us for selecting the sample (Table 45). The income categories are odd (not ending with zeros) because we have used inflation rates to change the categories used in a household survey in 1997-8. It must be noted that the first income group (0 – 125) has to be ignored as it includes a large number of persons who are dependants – that is, their modal choice depends more on the income of the spouse/offspring/parent.

Now, once again, there is *some* connection between income groups and modal use, but not a very clear cut one. There seems to be a clearer relationship for some modes like the chartered bus, share taxi, ordinary bus, mini bus, metro, local train and walking.

Table 44: Average Distances by Age Group and Mode, Household and Commuter Data.

Modes used	Age group Average Distance covered in km					
	0-5	6-16	17-25	26-45	46-60	>60
Two-wheeler	65	11	197	904	4171	211
Auto	35	104	199	151	420	118
Ferry	0	628	112	1366	1229	1872
Taxi	64	58	79	106	365	31
Hired car	120	56	311	282	577	10
Shared Taxi	0	16	674	341	3072	1161
Private car	59	71	101	149	514	185
School Bus	0	862	2056	170	622	496
Chattered Bus	0	12	283	1672	3034	480
Ordinary Bus	45	74	337	240	663	97
Mini Bus	54	90	129	140	422	82
Executive State Bus	0	42	35	119	637	162
Special State Bus	60	113	795	138	516	88
Regular State Bus	237	69	109	463	2686	115
Tram	350	49	91	62	232	227
Metro	94	184	964	873	1826	187
Circular rail	0	0	40	9696.8	9696.8	0
Local train	66	60	261	635	1328	155
Rickshaw	99	110	188	205	498	391
Bicycle	56	429	108	995	2429	1282
Walking	337	131	143	121	323	190

We can thus conclude that there are some connections between socio-economic features of the respondents and modal choice, but other than gender, the other connections are not very strong.

D. The Nature of Trips and Modal Choice.

We look at three aspects of the trip itself: purpose, distance and frequency. Tables 46 and 47 give the (a) number of persons and (b) distance covered for all combinations of mode and purpose. Both tables indicate no connection between modal choice and purpose. For all purposes, walking is the most major mode, followed by the ordinary bus (mode 10).

We have also looked at the connection between distance covered and purpose. Table 48 gives the *total* distance traveled (by the sample) for each purpose. Note that the total distance has a strong connection with purpose. The distance traveled to see relatives, interestingly, is higher than that traversed for educational purposes. Traveling to see friends is also very high. Table 49 gives the average distance of destinations by purpose. Work trips have a medium rank in terms of average distance, whilst the

Table 45: Average Distance Covered by Modes and Income Groups, Household and Commuter Data

Modes used	Average distance covered (Income Group)									
	0-125	**126-250**	**251-374**	**375-624**	**625-936**	**937-1248**	**1249-2497**	**2498-3745**	**3746-6241**	**>6241**
Two-wheeler	0	18	170	356	374	629	131	406	2907	1742
Auto	93	32	74	126	176	151	97	158	300	511
Ferry	0	0	244	59	87	480	91	2288	942	1248
Taxi	204	49	33	109	35	90	49	26	66	246
Hired car	12	0	405	57	77	79	539	2036	207	62
Shared Taxi	0	0	6	982	323	1923	26	0	0	0
Private car	12	0	90	80	102	80	291	226	301	227
School Bus	0	0	831	686	1474	361	726	719	848	0
Chattered Bus	5	0	26	111	237	26	477	2186	1965	930
Ordinary Bus	935	94	213	85	56	348	142	406	292	439
Mini Bus	0	23	81	73	87	95	170	403	1317	1294
Executive State Bus	0	252	214	51	108	16	138	0	70	20
Special State Bus	0	0	151	450	157	84	99	59	10	0
Regular State Bus	0	180	77	233	261	42	126	43	1840	936
Tram	40	672	115	28	7	171	197	288	18	0
Metro	1400	71	158	125	365	44	141	402	2339	1245
Circular rail	40	0	0	0	0	0	0	13148	11700	3083
Local train	1707	32	127	16	170	289	454	718	1493	1388
Rickshaw	795	958	225	130	203	95	222	431	222	6727
Bicycle	456	15	618	603	525	448	575	531	207	0
Walking	375	1094	188	112	142	130	106	240	68	63

Table 46: Number of Persons for All Mode-Purpose Combinations, Household and Commuter Data

Mode Used (code)	No. of Individuals												
	Work	Education	Chil.School	Chil. Hobby	Shopping	Friends	Relatives	Health	Entertainment	Hobbies	Station Airport	Others	Total
1	29	4	6	0	14	5	18	5	8	5	2	6	102
2	43	32	16	5	132	106	254	247	121	60	123	44	1183
3	8	0	0	0	0	1	10	0	1	2	4	0	26
4	5	0	1	0	73	18	146	132	163	34	76	7	655
5	8	2	1	0	7	0	32	14	15	13	4	1	97
6	6	1	0	0	1	1	2	1	6	3	0	0	21
7	11	1	3	0	43	15	21	15	32	7	12	2	162
8	3	20	3	0	1	0	0	0	3	0	0	0	30
9	39	2	0	0	15	0	7	2	45	7	0	0	117
10	320	160	38	10	1107	144	1337	467	645	528	467	80	5303
11	18	8	1	1	125	33	154	19	99	34	37	5	534
12	0	0	0	0	1	1	20	0	9	0	3	0	34
13	4	0	0	0	11	7	35	3	9	1	0	0	70
14	5	0	0	0	8	2	28	4	8	3	1	1	60
15	1	1	0	2	7	3	15	13	8	19	1	2	72
16	70	17	0	1	130	15	129	10	68	40	4	16	500
17	7	0	0	0	0	0	1	0	1	1	0	1	11
18	52	26	3	0	37	40	260	14	40	76	26	1	575
19	69	33	26	10	120	64	290	133	39	37	22	33	876
20	79	35	22	1	46	43	29	19	8	6	2	22	312
21	1099	598	295	84	2591	1693	2426	2322	1435	1191	706	267	14707
Total	1876	940	415	114	4469	2191	5214	3420	2763	2067	1490	488	25447

Codes: Two Wheeler:1, Auto: 2, Ferry:3, Taxi:4, Hired Car:5, Share Taxi:6, Private Car: 7, School Bus: 8, Chartered Bus:9, Ordinary Private Bus: 10, Mini Bus: 11, Executive State Bus: 12, Special State Bus: 13,
Regular State Bus: 14, Tram: 15, Metro: 16, Circular Rail: 17, Local Train: 18, Rickshaw: 19, Bicycle: 20
Walking: 21

Table 47: Distance Covered for All Mode-Purpose Combinations, Household and Commuter Data

Mode Used (code)	Distance Covered by K.m												
	Work	Education	Chil.School	Chil. Hobby	Shopping	Friends	Relatives	Health	Entertainment	Hobbies	Station Airport	Others	Total
1	44629.4	3880	2723.8	0	6285.4	761.6	2855.2	92.6	242.6	9846.4	127.8	19812.8	91257.6
2	60442	31044	7263.4	1388.6	15598.6	17880.2	42163.2	5289.8	5098.6	3014.8	7858.4	4653.4	201695
3	18720	0	0	0	0	152.4	1586.2	0	30.4	102.2	255.6	0	20846.8
4	6032.8	0	454	0	9155.8	2935.4	23533.4	2428.2	9359.2	2326.8	4855.6	3535.2	64616.4
5	11130.4	1940.2	454	0	788.6	0	7310.2	2633.8	1590.6	1758.4	255.6	3589.2	31451
6	8530.4	970.2	0	0	112.6	152.4	317.2	18.6	182	153.2	0	0	10436.6
7	15639	970.2	1361.8	0	4870.6	2232.4	3331.2	278	1077.6	357.6	766.6	211.6	31096.6
8	4265.2	19402.4	1361.8	0	112.6	0	0	0	91	0	0	0	25233
9	82843.2	1940.2	0	0	40094.8	0	5089.2	4454.8	62885.2	357.6	0	0	197665
10	420495.8	158531.4	18398.8	2776.6	290123.6	28066.6	292794	134840.4	162581.4	28007.4	30800.2	35451.2	1602867
11	25591.2	7760	454	277.8	14080.8	5027	24428.2	352.2	2984.1	1737.4	2363.8	528.8	85585.3
12	0	0	0	0	40	152.4	3172.4	0	272.8	0	191.6	0	3829.2
13	5687	0	0	0	212.6	1066.4	5403.2	55.6	252.6	51	0	0	12728.4
14	7057.2	0	0	0	2184.6	304.6	5678.8	74.2	242.6	153.2	63.8	105.8	15864.8
15	1421.8	970.2	0	555.4	788.6	457	2316.8	241	242.6	970.8	63.8	105.8	8133.8
16	133499.2	27351.2	0	2176.8	111884.4	10382.8	67832.2	8799.8	88133.2	4169.6	255.6	32863.6	487348.4
17	55823.6	0	0	0	7974.8	0	0	0	7974.8	0	0	7974.8	79748
18	86436	40854.8	2746.6	0	26830.6	6092.6	72592.2	13000	55461.2	5722	3435.8	105.8	313277.6
19	98099.2	32014	11803	2777.2	13959.2	9749.2	46119.6	2465.2	1182.6	1890.6	1405.6	3490	224955.4
20	112316.2	33954.2	9987	277.8	5181.6	6614	4600	352.2	242.6	306.6	127.8	2326.6	176286.6
21	1279069.2	512865.8	133173.4	23133	289783	257391	379261.4	52195.2	55973.6	61174	45141.4	29433.8	3118595
Total	2477728.8	874448.8	190181.6	33363.2	840062.8	349418	990384.6	227571.6	456101.3	122099.6	97969	144188.4	6803518

Codes: Two Wheeler:1, Auto: 2, Ferry:3, Taxi:4, Hired Car:5, Share Taxi:6, Private Car: 7, School Bus: 8, Chartered Bus:9, Ordinary Private Bus: 10, Mini Bus: 11, Executive State Bus: 12, Special State Bus: 13, Regular State Bus: 14, Tram: 15, Metro: 16, Circular Rail: 17, Local Train: 18, Rickshaw: 19, Bicycle: 20, Walking: 21

Table 48: Total Distance Traveled by Purpose, Household and Commuter Data

Purpose	Total distance traveled (km)	Percentage of the total	Rank
Work	2477727.8	36.36	1
Relatives	990384.6	14.53	2
Education	874448.8	12.83	3
Shopping	840062.8	12.33	4
Entertainment	466101.4	6.84	5
Friends	349418.0	5.13	6
Health	227571.6	3.34	7
Children's school	190481.6	2.80	8
Other professional	144188.4	2.12	9
Hobbies	122099.6	1.79	10
Station/Airport	97969.0	1.44	11
Children's hobby	33363.2	0.49	12
Total	6813816.8	100.00	

Table 49: Average Destination Distance by Purpose

Purpose	Average destination distance (km)	Rank
Relatives	9.75	1
Hobbies	7.31	2
Entertainment	6.64	3
Children's hobby	6.15	4
Station/Airport	5.42	5
Other professional	5.11	6
Shopping	4.31	7
Work	4.29	8
Friends	3.79	9
Education	3.38	10
Children's school	2.80	11
Health	1.87	12

distance of relatives' houses tends to be high. The distance of friends' houses, children's schools (when the guardian accompanies the child) and educational centres tends to be low on average, perhaps because these can be chosen whilst relatives and therefore relatives' houses cannot.

Going back to our investigation of the determinants of modal choice, if we look at the average length of a trip by mode – this indicates sufficiently significant differences in length.

Table 50: Average Trip Length by Mode

Modes	Average trip length	Rank
Circular Rail	26.45	1
Chartered Bus	16.22	2
Metro	13.87	3
Executive State Bus	13.35	4
Shared Taxi	9.74	5
Local Train	9.70	6
Regular State Bus	8.53	7
Hired Car	8.20	8
Ferry	7.50	9
Special State Bus	6.78	10
Ordinary Private Bus	6.42	11
Two-wheeler	6.27	12
Taxi	5.49	13
School Bus	5.47	14
Local Train	4.56	15
Rickshaw	4.55	16
Tram	4.10	17
Mini Bus	3.96	18
Auto	3.55	19
Private Car	3.50	20
Walking	2.95	21

As regards frequency of trips, there is a clear variation in frequency of trips by mode. Tables 51 and 52 give the total and average frequencies by mode. We can therefore say that modal choice is determined by the frequency of trips.

Thus of the three features of travel, modal choice appears to depend more on trip frequency and distance and less on purpose.

Table 51: Frequency of Use by Mode

Modes	Frequency /year	Rank
Walking	1056553.00	1
Ordinary private Bus	249492.40	2
Auto	56677.30	3
Rickshaw	49249.00	4
Bicycle	38672.30	5
Metro	35129.25	6
Local Train	32286.40	7
Mini Bus	21561.35	8
Two-wheeler	14550.70	9
Chartered Bus	12183.30	10
Taxi	11772.05	11
Private Car	8870.50	12
School Bus	4614.50	13
Hired Car	3834.80	14
Circular Rail	3015.00	15
Ferry	2780.00	16
Tram	1981.50	17
Special State Bus	1877.40	18
Regular State Bus	1859.60	19
Share Taxi	1071.50	20
Executive State Bus	286.70	21

Table 52: Average Frequency of Use by Mode

Modes	Average Frequency /year	Rank
Walking	352.18	1
Ordinary private Bus	83.16	2
Auto	18.89	3
Rickshaw	16.41	4
Bicycle	12.89	5
Metro	11.71	6
Local Train	10.76	7
Mini Bus	7.19	8
Two-wheeler	4.85	9
Chartered Bus	4.06	10
Taxi	3.92	11
Private Car	2.96	12
School Bus	1.54	13
Hired Car	1.28	14
Circular Rail	1.01	15
Ferry	0.92	16
Tram	0.66	17
Special State Bus	0.62	18
Regular State Bus	0.62	19
Share Taxi	0.36	20
Executive State Bus	0.09	21

E. Features of the Mode Itself and Modal Choice

If we rank modal choice by the distance covered, we see that (see Table 56 in the subsequent section) that walking comes first, followed by the ordinary bus, the metro and the local train. On the other hand, we have (from Tables 59 and 60) that less travel time, cost, travel comfort and less wait time are the four most important criteria for travelers. If cost is the second most important criterion, this certainly justifies walking and the use of the ordinary private bus, whose fare per km is still low. The metro is more comfortable and the bus is certainly uncomfortable. Also, the bus takes more time than the metro, both in terms of waiting and travel. Thus whilst time is an important criterion, the budget constraint appears to make the decision for the traveler in this city.

We have chosen two features of travel – access and parking restrictions to see if they have an impact on the mode. Table 53 gives the average access distance from the residence of the traveler. We see that private vehicles, hired cars, the school bus and the non-motorised modes come first. The worst are the ferry, circular rail, metro and local train, in that order. Buses, on average, have medium access, whilst taxis and autos are easily accessed. If we again look at the kilometres traveled by each mode, there is clearly no connection between use and access.

Table 53: Average Distance of Modal Access from Residence

Modes	Average distance from residence (km)	Rank
Two wheeler	0	1
Hired Car	0	1
Private Car	0	1
School Bus	0	1
Rickshaw	0	1
Bicycle	0	1
Walking	0	1
Taxi	0.38	2
Ordinary Private Bus	0.41	3
Mini Bus	0.41	3
Regular State Bus	0.41	3
Auto	0.49	12
Share Taxi	0.75	13
Chartered Bus	1.66	14
Executive State Bus	1.66	14
Special State Bus	1.66	14
Tram	1.91	17
Local Train	3.19	18
Metro	3.57	19
Circular Rail	11.83	20
Ferry	12.22	21

Again, we have looked at parking facilities and whether they restrict or encourage the use of personal vehicles. Whilst the proportion of persons with no vehicles who do not have parking at their place of work is 74.5% (see Table 54), those who have vehicles but do not have parking (so that they have to park on the road or in a paid garage) is

36%. We also see that the use of a personal vehicle is nearly double for those who have parking, compared to those who do not (see Table 55). Thus parking possibly does act as a constraint but it is often not binding – this is partly because parking can occur illegally or legally (for a price) on the city roads, and partly because personal vehicles may be used for non-work purposes.

Table 54: Parking Facilities and Vehicle Ownership

	Whether Parking facility available		
	Yes		No
	Limited	Unlimited	
Who have no Vehicles and no such plan to purchase	142	34	528
Who have no Vehicles and plan to purchase	6	0	6
Sub-Total(Who have no vehicles)	**148**	**34**	**534**
Who have own Vehicles	42	9	29
Total	**190**	**43**	**563**

Table 55: Parking Facilities and Use of Personal Vehicles

Existance of Parking facility	Use of personal vehicle (km traveled by personal vehicle)
Yes- Unlimited	6719.0
Yes- Limited	41992.9
No	25146.6
Not Applicable	28542.3

We may therefore conclude that the features of the mode perhaps do impact modal choice, but some (like cost) are more constraining than others.

In general, therefore, none of the three aspects – features of the traveler, of the trip and of the mode – can be ignored, although some factors in each seem to be more important – like gender, trip frequency, trip distance and cost of travel, whilst others are less so.

F. Derivation of Total Vehicular Pollution in KMC Area

We first obtain the total distance (in terms of person-kilometres – that is, the kilometres covered by each person is counted separately) traveled by our sample of 2720 household members and 280 commuters by each mode. This derivation is given in Table 56 below.

Table 56 – Total kilometres covered by sample individuals

(household and commuter) by mode

Modes	Km covered	Percentage	Rank
Walking	3118565.0	45.83	1
Ordinary Pvt.Bus	1602869.0	23.56	2
Metro	487363.1	7.16	3
Local Train	313280.7	4.60	4
Rickshaw	224955.8	3.31	5
Auto	201695.0	2.96	6
Chartered Bus	197665.7	2.90	7
Bicycle	176286.6	2.59	8
Two-wheeler	91257.6	1.34	9
Mini Bus	85585.3	1.26	10
Circular Rail	79748.0	1.17	11
Taxi	64622.9	0.95	12
Hired Car	31451.0	0.46	13
Private Car	31096.6	0.45	14
School Bus	25233.0	0.37	15
Ferry	20846.8	0.31	16
Regular state Bus	15864.8	0.23	17
Special state Bus	12728.4	0.18	18
Share Taxi	10436.6	0.15	19
Tram	8133.8	0.12	20
Executive State Bus	3829.2	0.06	21
Total	6803514.9		

Interestingly, the greatest distance is covered by walking, followed by the ordinary private bus, and the metro and local train are in the third and fourth positions at significantly lower values. We see that the rickshaw, although it is used largely within localities, is in the 5th position. The most polluting modes, the auto and the two wheeler, are in the 6th and 21st positions respectively. The high pollution modes (1-6) are used for 6.3% of the distance, the medium pollution modes (buses and ferry) cover 28.87% of the distance and the zero pollution modes, 64.78%. Thus we can say that the current modal distribution in Kolkata is not unfavourable, and perhaps the major factor that keeps it thus is the high cost of much of the polluting forms of transport. However, the pollution levels would decrease significantly if one could shift the bus users to the zero polluting modes. Secondly, and this something that is not evident in this table, there is a danger of the medium or zero pollution users shifting to higher pollution modes (we shall observe this in subsequent analyses) in the near future – this, too, is something that has to be prevented.

We have then used the two measures of pollution per kilometre and per person derived in Table 36 of section VI for the different modes. Of course, the non-motorised modes and the tram, metro, circular rail and local train emit zero pollution. Multiplying these values with the distance covered by the sample, we get, for each mode, the total pollution created in grams. This is given in Tables 57 (measure I) and 58(measure II).

Table 57: Total Pollution (grams) emitted by each mode for sample (households and commuters) using measure I

Mode	Pollution	Rank
Tram	0	1
Metro	0	1
Circular Rail	0	1
Local Train	0	1
Rickshaw	0	1
Bicycle	0	1
Walking	0	1
Executive State Bus	281.72 (0.02)	8
Special State Bus	763.71 (0.06)	9
Regular State Bus	864.63 (0.07)	10
Ferry	2077.76 (0.17)	11
School Bus	4125.59 (0.34)	12
Share Taxi	5912.33 (0.49)	13
Private Car	9018.01 (0.75)	14
Mini Bus	9029.25 (0.75)	15
Hired Car	21701.19 (1.79)	16
Chartered Bus	30242.85 (2.50)	17
Taxi	53863.18 (4.45)	18
Ordinary Bus	177918.45 (14.71)	19
Auto	425475.60 (35.20)	20
Two-wheeler	467558.31 (28.70)	21
Total	1208832.58	

Note: percentages are in parenthesis.

Given that the KMC and commuter population is 5.04 million, i.e. 1680 times the sample size of 3000, the above table implies a total pollution of 2030838734.4 gms. or around **2 million kgs** in the KMC area. For measure I we have added the emissions of the different pollutants without discounting for the impact of the different types of pollution on individuals. If we take measure II, which weighs the pollution emissions of the 5 pollutants according to impact, we get Table 41 below. Once again, we can calculate the total pollution impact in the KMC area as 1298068715 grams, that is, **1.3 million kgs.** We may thus say that giving greater weights to particulate matter and nitrous oxides as having more health effects reduces the pollution impact of motor vehicles in the city.

Table 58 : Total Pollution (grams) emitted by each mode for sample (households and commuters) using measure II

Mode	Pollution	Rank
Tram	0	1
Metro	0	1
Circular rail	0	1
Local train	0	1
Rickshaw	0	1
Bicycle	0	1
Walking	0	1
Executive State Bus	249.15 (0.03)	8
Special State Bus	671.30 (0.08)	9
Ferry	1574.55 (0.20)	10
School Bus	3118.65 (0.40)	11
Share Taxi	4514.05 (0.58)	12
Private Car	6790.70 (0.88)	13
Mini Bus	6985.45 (0.90)	14
Regular State Bus	7559.55 (0.98)	15
Hired Car	16589.15 (2.15)	16
Chartered Bus	22930.20 (2.97)	17
Taxi	41104.05 (5.32)	18
Ordinary Bus	134440.65 (17.40)	19
Auto	246192.95 (31.88)	20
Two-wheeler	279939.55 (36.23)	21
Total	772659.95	

Note: percentages are in parenthesis.

We can see that the regular state bus becomes more polluting for measure II compared to measure I, but otherwise the ranks, though not identical, are close. By the total pollution created, the ordinary private bus becomes a major culprit because it is used so much, and the auto and two wheeler become the two most major polluters, in spite of the significantly lower person-kilometres of the two-wheeler.

G. Modal Shift Analysis

Our next objective is to see how we can change the modal structure in order to reduce the total quantity of pollution created by the present structure, as derived in the last section. We are not suggesting just any kind of modal structure, for providing that would not ensure that it is used. We are therefore trying to evaluate what sort of structure would actually be used by the travelers, and for that we have thoroughly evaluated the various features looked for in transport, and how we can entice transport users to shift to less polluting modes by improving on these features.

Let us first present the data on modal shift. This data has been collected in four parts. First, we have identified 10 features of transport that determine their choice (see Table

59) and hence would act as incentives for modal shift. We have evaluated the importance given by the sample individuals to these features. Second, we have asked the respondents to specify, against each of their current modal choices, whether they plan to shift to another mode, and if that mode is more polluting, what incentives will prevent them from shifting (columns five and six of the travel behaviour data in the questionnaire). Third, we have also asked each respondent whether she/he wishes to purchase a personal motorized vehicle, and of so, what will prevent such a purchase. Fourth, we have asked, for the highly polluting modes (1 to 6), what incentives they would require in order to shift to the bus, the metro, local train, circular rail and ferry. The choice of these particular modes has been discussed earlier.

(a) Tables 59 and 60 gives the responses of the household members and commuters on the ‘importance’ of each feature. They had three choices: ‘very important’, ‘medium important’ and ‘not important’. They were also asked to rank the features that they said were very important.

We have taken two weighted averages, one using a weight of 2 for ‘very important’ and 1 for ‘medium importance’, and the other using weights of 2, 2.25, 2.5, 2.75, 3, 3.25 and 3.5 for rank 7 to rank 1 (under ‘very important’), and 1 for ‘medium importance’. The first method tells us that ‘less travel time’ is the most important feature and direct route, travel comfort, cost and less waiting time are very close in terms of importance. Safe travel and good access are less important, whilst waiting comfort, fringe parking and restricted parking are not important criteria. The second method changes the ranks but travel time is still the most important, and cost, comfort and wait time are still important. ‘Direct route’, however, becomes less important. The medium levels for access and safety are retained, and wait comfort, fringe parking and parking restrictions are still unimportant for our sample.

We can therefore say that travel time is of utmost importance, and the time of the journey (i.e. including wait time) is of supreme importance. Of the remaining features, cost and comfort are also quite important.

Table 59: Ranking of Incentives for Modal Choice, Number of Persons, Household and Commuter Data

Factors	Very important	Medium Important	Not Important	Weighted Average*	Rank
Less travel time	2194	646	136	1678.00	1
Direct route	1626	1150	200	1467.33	2
Travel comfort	1626	1144	210	1465.33	3
Cost (incentive/disincentive)	1777	810	389	1454.66	4
Less waiting time	1478	1317	181	1424.33	5
Safe travel	1228	1372	376	1276.00	6
Good access	1223	1350	402	1265.33	7
Waiting comfort e.g. Better shaded bus	289	2179	508	919.00	8
Fringe parking at metro/ Circular rail/ferry/railway station	43	749	1779	278.33	9
Parking restricted/fine (disincentive)	15	782	1770	270.67	10

∗Weights of 2 for 'very important', 1 for 'medium importance' and 0 for 'not important'

Table 60: Ranking of 'Very Important' Incentives for Modal Choice, and Weighted Average Using These and the 'Medium Importance' Values, Number of Persons, Household and Commuter Data

Incentives	Very important factors- Ranks							Medium important	Weighted Average*	Rank
	1	2	3	4	5	6	7			
Less travel time	516	514	687	297	121	45	13	646	366.91	1
Cost	859	344	330	160	49	31	3	810	324.08	2
Travel comfort	390	415	401	288	94	33	0	1144	304.29	3
Less Waiting time	266	602	284	165	108	42	5	1317	290.60	4
Good access	273	325	307	182	90	36	10	1350	252.31	5
Safe travel	168	378	304	204	124	41	8	1372	250.85	6
Direct route	75	303	339	378	86	52	0	1150	236.33	7
Waiting comfort e.g. Better shaded bus	18	56	77	67	29	38	5	2179	148.50	8
Fringe parking at metro/ Circular rail/ferry/railway station	5	3	12	7	6	9	4	749	43.19	9
Parking restricted/fine (disincentive)	2	0	4	2	2	1	2	782	40.38	10

∗Weights ranging from 3.5 to 2 have been used for the 'very important' ranks, and 1for medium.

(b) There were 19 persons (out of 3000) who said that they would purchase a car or two wheeler, both highly polluting modes. There were 5 persons who said that nothing would induce them to refrain from buying the vehicle. For the others, incentives that would prevent these persons from buying are summarized in Table 61.

Table 61: Incentives that would prevent the purchase of a motorized vehicle for personal use.

Incentive	Corresponding no. of persons
Only travel comfort	4
Travel comfort as at least one factor	8
Only less travel time	3
Less travel time as at least one factor	6
Less wait time as one of the factors	2
Safe travel as one of the factors	1
Access as one of the factors	2
Cost as one of the factors	2

It is evident that travel comfort is a major factor in the purchase of a personal vehicle, followed by travel time. The rest are far less important. Hence the main concern for policy makers, if they wish to prevent the purchase of personal vehicles, would be to increase the comfort of and reduce the time taken by public transport.

(c) We next look at the responses, corresponding to each purpose and modal choice within this purpose, regarding a concrete plan to shift to a vehicle that pollutes more than the present vehicle being used, and what would prevent this plan from being implemented.

Table 62 gives the modes ***to*** which a shift is planned, the corresponding distance, the percent of the total distance traveled by this mode (by the sample), and the incentives that would prevent a shift. On the whole, only 1.67% of the total person-kilometres is in threat of shift. In terms of the number of persons, only 106 (3.53%) responded with one yes or more in the sample constituting 3000 persons.

However, some of the specifics are disturbing. We see that the taxi is the mode in greatest threat of being used more – there would be an increase by 67% of person-kilometres traveled by taxi. Then comes the private car, with an increase by 20.5%, and the auto, by 16.8%. From the fourth column of Table 65 which lists the number of times a particular feature has come up, we see that the factors that would prevent the shifts are mostly reductions of wait and travel time and an increase in travel comfort. The cost factor is also important – presumably the shifts would be *prevented* if taxis and cars become more expensive.

As regards the modes ***from*** which the shifting is planned, Table 63 tells us that the school bus is the greatest culprit, followed by regular and special state buses, and the minibus. Also, though the shift from the ordinary private bus is not significant as a percentage, the absolute value of shift is very high. Therefore, buses as a group are being disliked (although school buses, as a category, are very different and the reasons

Table 62: More polluting modes to which shifts are desired, corresponding distances and factors that would prevent shift.

Desired shift modes	Corresponding distances	Percentage Of total sample distance	Factors To prevent shift	Rank
Taxi	43478.40	67.28	27a, 63b, 42c, 63e, 4f, 5g, 45h	1
Private car	6391.52	20.55	2a, 2b, 3e, 1g, 2h	2
Auto	33821.42	16.77	13a, 33b, 23c, 23e, 1g, 21h	3
Hired car	3150.00	10.07	1e	4
Two-wheeler	6410.00	7.02	3b, 1c, 2e, 2h	5
Chartered Bus	13198.00	6.67	3e, 1f, 1g	6
Mini Bus	855.2	0.99	2a, 2b, 1g, 1h	7
Metro	3390.4	0.69	1c	8
Ordinary Bus	3588.00	0.22	1a, 6b, 2c, 1d, 4e, 1g, 4h	9
Total	114282.9			

Table 63: Modes from which shifts are desired to more polluting modes, corresponding distances, and factors that would prevent shift

Modes from which shift is desired	Corresponding distances	Percentage Of total sample distance	Factors To prevent shift	Rank
School Bus	12028	47.66	1c, 2e, 1g, 2h	1
Regular State Bus	4991.08	31.46	2a, 4b, 1c, 1g	2
Special State Bus	3085.48	24.24	1a, 2b, 1c, 2e, 2h	3
Mini Bus	17254.84	20.16	3a, 16b, 11c, 10e, 2g, 7h	4
Tram	732.00	8.99	1b, 1e, 1h	5
Ordinary private Bus	61361.3	3.82	33a, 74b, 49c, 72e, 5f, 2g, 53h	6
Local Train	11984.8	3.82	2a, 3b, 4c, 3e, 2h	6
Hired car	551.6	1.75	1c, 2e, 1g, 2h	8
Taxi	866.6	1.34	1a, 4b, 1c, 2e, 1g, 4h	9
Rickshaw	1178.0	0.52	1b, 1c, 1d, 2e, 1h	10
Metro	151.2	0.03	1b, 2g, 1h	11
Bicycle	48.0	0.03	2e	11
Chartered Bus	50.0	0.02	1a, 1b, 1c, 1e	13

Table 64: Distances for which shifts to more polluting modes are planned, by purpose

Purpose	Distance for which shift is planned	Percentage of the sample distance	Rank
Children's school	6420.0	3.37	1
Work	73741.6	2.97	2
Education	16132.0	1.84	3
Friends	5557.24	1.59	4
Station/Airport	706.00	0.72	5
Health	1642.0	0.72	5
Shopping	5825.1	0.69	6
Relatives	2679.0	0.27	7
Other professional	372.0	0.25	8
Entertainment	1110.00	0.24	9
Hobbies	98.0	0.08	10
Total	114282.9		

Table 65 : Incentives that will prevent shifts to more polluting modes, corresponding distance and rank

Incentives	Corresponding kms	Rank
less waiting time	49118.08	1
less travel time	40962.84	2
travel comfort	38237.44	3
cost	27763.80	4
direct route	25820.10	5
good access	2617.52	6
waiting comfort	936.00	7
safe travel	566.00	8

Table 66: Three most major incentives and their combinations: corresponding kms impacted

Incentives that receive rank 1,2,3 and possible combinations	Corresponding kms impacted
Less waiting time (b)	16903.08
Less travel time (c)	22288.8
Travel comfort (e)	11445.8
b & c	41447.88
b & e	35731.88
c & e	35305.64
b, c & e	69886.12

why persons may want to shift from them may be different) –, we see that wait time, travel time and travel comfort are the major reasons for the desired shift. Also, the need for a direct route and cost are not unimportant here.

If we look at the purpose-wise break-up (Table 64) work and education are the two most important purposes for which shifts are planned by person-kilometres, but by the percent of the sample totals, children's school and work are the highest. Hence shifts tend to be planned for the more regular trips relative to the irregular.

Finally, we have ranked the incentives according to the kilometres corresponding to each time they have come up (Table 65). We see that wait time, travel time, and travel comfort are the three most important incentives. Thereafter (Table 66) we have evaluated the kilometres impacted if we provide these incentives by themselves, in combinations of two, and all three together. We see that 69886 kilometres, which is 61% of the total kilometres in threat, would remain with the current modes when all three incentives are provided.

(d) The final step was to record, for each and every destination and every mode used for that destination that is in the most polluting category (two wheeler, auto, taxi, share taxi, hired car and private car) , what incentives would induce the user to shift to buses, the metro, the circular rail, the local train and the ferry. We have already discussed the choice of these five modes. Tables 67 - 71 give the results.

Of the total kilometres covered by the more polluting modes (430553.2 kms), there are 100069.24 kilometres which cannot be converted to any of the five modes. This is given in Table 67.

Table 67: Non-shiftable kilometres, by mode currently used

Mode	Total Km travel	Don't want to shift to any mode (in Km.)	As %
Two-wheeler	91257.6	48777.19	53.45
Auto	201695	36809.38	18.25
Taxi	64616.4	3812.367	5.9
Hired car	31451	880.628	2.8
Shared Taxi	10436.6	678.379	6.5
Private car	31096.6	9111.30	29.3
Total	430553.2	100069.24	23.24

Table 68: Five Modes to which the More Polluting Modes Can Be Shifted, Kilometres of Possible Shift and Percentages of the Total Kilometres, by Purpose

Purpose	Total Km covered by modes 1-6	Shift modes									
		Bus		Metro		Rail		Circular		Ferry	
		Km	%	Km	%	Km	%	Km	%	Km	%
Work	146404	32273.4	22.04	103093.74	70.42	57390.2	39.2	52592.74	35.92	18639.8	12.73
Education	38804.6	5626.6	14.5	24563.2	63.3	12921.8	33.3	13115.8	33.8	6420.6	16.55
Children's school	12257	2157.2	17.6	8923	72.8	6128.4	50	4304.6	35.12	2108.4	17.2
Children's Hobby/Tutor	1388.6	661.2	47.62	852.4	61.39	513.2	36.96	425.6	30.65	169.2	12.18
Shopping	36811.6	13705	37.23	21247.2	57.72	18993	51.6	8147.2	22.13	5248.4	14.26
Friends	23962	8941.64	37.32	17845	74.47	10699.6	44.65	9980.36	41.65	3430.4	14.32
Relatives	79510.4	37336.96	46.96	45561.6	85.56	27777	34.94	21674.3	27.26	11808.4	14.85
Health	10710.6	2185	20.4	3448.1	32.19	2353.6	21.97	2008.88	18.76	325.4	3.03
Entertainment	17581	3686.2	20.95	6043.7	34.38	7960	45.28	5566.72	31.66	1924.4	10.95
Hobbies/Club	17457.2	4085.4	23.4	7981.08	45.72	4683	26.83	1895.7	10.86	1327.2	7.6
Station/Airport	13864.4	5097.4	36.77	10843.2	78.21	7937.8	57.25	6392.6	46.11	2509.8	18.1
Other professional	31802.2	6798	21.38	10993.16	34.57	7196.68	22.63	5518.78	17.35	1842.4	5.79
Total	**430553.6**	**122554**	**28.46**	**262395.4**	**60.94**	**164554.2**	**38.22**	**131623.28**	**30.57**	**55754.4**	**12.95**

Table 69: Five Modes to which the More Polluting Modes Can Be Shifted, Kilometres of Possible Shift and Percentages of the Total Kilometres, by Mode

Mode	Total Km covered	Shift modes									
		Bus	%	Metro	%	Rail	%	Circular	%	Ferry	%
Two-wheeler	91257.6	5088.2	5.85	27174.8	29.78	17379.8	19.04	12704.6	13.92	3361.8	3.86
Auto	201695	81563	40.44	136075.44	67.47	95285.6	47.24	58377.9	28.94	30255.6	15.00
Taxi	64616.4	26064.7	40.34	55074.66	85.23	32355.7	50.07	39185.5	60.64	15443.4	23.9
Hired car	31451	2512.8	7.99	27977.1	88.95	13287.9	42.25	14560.9	46.3	2006.4	6.38
Shared Taxi	10436.6	4889.4	46.85	9064.2	86.85	4591.4	43.99	4207.2	40.31	2530.4	24.25
Private car	31096.6	2435.9	7.83	7029.24	22.6	1653.8	5.32	2587.2	8.32	2156.8	6.94
Total	**430553.2**	**122554**	**28.46**	**262395.4**	**60.94**	**164554.2**	**38.22**	**131623.28**	**30.57**	**55754.4**	**12.95**

Table 70: Number of Responses for Each Incentive, Corresponding to Shift to Each of Five Modes

Incentives	Shift Modes (no. of responses)				
	Bus	Metro	Rail	Circular	Ferry
Direct Route	768	2818	2448	1714	650
Less Wait Time	857	1388	1498	1280	245
Less Travel Time	916	2135	1188	873	627
Wait Comfort	20	75	27	34	9
Travel Comfort	719	1593	541	383	304
Safe Travel	389	996	527	208	97
Good Access	131	4360	2461	3136	1314
Cost	530	3901	2150	2043	670
Fringe Parking	0	0	5	4	0
Parking Restriction	0	0	2	0	0

Table 71: Three Major Incentives of Shift for Each of the Five Shift Modes, Shift Achieved for Each and for Combinations

Shiftable Mode & shiftable Km	Shiftable factors (in Km) according to response										
	Less Travel Time only		Less wait only		Direct route only		Less travel & less waiting	Less travel & Direct route	Less wait & Direct route	Less travel less wait & direct route	
Bus(122554)	13969	11.4	7741.32	6.31	9533	7.78	17970	1957.5	2221.12	51136.34	41.72
Metro (262395.4)	Good access		Cost		Direct route		Good access & cost	Good access & direct route	Cost & direct route	Good access, cost & Direct Route	
	22461.58	8.56	31263	11.91	28195.8	10.75	43784.9	25940.6	17496.3	13038.52	4.96
Rail (164554.2)	Good access		Cost		Direct route		Good access & cost	Good access & direct route	Cost & direct route	Good access, cost & Direct route	
	15307.4	9.3	5508.6	3.34	15472.64	9.4	20691.2	24489.9	19198.8	5093.6	3.09
Circular (131623.28)	Good access		Cost		Direct route		Good access & cost	Good access & direct route	Cost & direct route	Good access, cost & Direct route	
	17314.6	13.15	15197.78	11.54	14327	10.88	11649.2	17195.3	13240.24	2512.96	1.9
Ferry (55754.4)	Good access		Cost		Direct route		Good access & cost	Good access & direct route	Cost & direct route	Good access, cost & Direct route	
	16527.4	29.64	9139.2	16.39	6851.3	12.28	1973.64	2312.68	1667.2	898.64	1.79

The second column in Table 68 records the total kilometres traveled by only the more polluting modes for each purpose, and the following columns give the kilometres shiftable to each of the five modes, as well as percentage of the total (in column 2). The last row gives the total over all purposes. We see that the greatest shift is recorded for the metro (60.94% of the total kms traveled by the more polluting modes), followed (not closely) by rail, circular rail, bus and ferry. At 12.95 %, the shift to ferry is the lowest. There is a greater tendency to shift for the less regular purposes like trips to the station /airport, to friends' or relatives' houses and shopping. But major shifts are also recorded for work and children's school. The values are particularly low for education. Note that only 430553.2 kilometres, i.e. 6.33% of the ***total*** kilometres traveled (see Table 56) are by the more polluting modes, although the pollution created by these modes is (see Tables 57 and 58) a significantly greater proportion of the total.

Table 69 presents the same data in terms of the modes (more polluting) currently being used, so that the total in the final row corresponds to the total in the earlier table. We see that very few users of personal vehicles (cars and two-wheelers) are willing to shift to anything much other than the metro, and even that percentage (at 30% for two-wheelers and 23% for cars) is not significant. The possible shift is particularly low for buses and the ferry. The percentages are larger for the other modes (auto, taxi, hired car and shared taxi) to all the five modes in general, although as seen already, a shift to the metro is most easily accepted from *all* modes.

Let us now look at the incentives that would be required to achieve the shifts. Table 70 gives us a count of the number of times each of the ten incentives have come up for the five types of modal shift. This table helps us to identify the more important incentives for each category of shift. For buses, the three most important incentives are less travel time, less wait time and a direct route (travel comfort is a close fourth). For the four other modes, they are access, cost and a direct route, although cost is the third important factor for rail. These results are not unexpected as access is not such a problem for buses, and they take the lowest fares. The time at the bus stop and on the bus is, on the other hand, a problem. Buses (especially the ordinary private bus) are also less comfortable due to uncomfortable seating, unruly crowds and pollution. These problems are far less for the other modes. However, these modes all run on limited routes – hence access is difficult. It is odd that cost has come up for these four modes as a criterion, given that currently the fares for these four modes, apart from the ferry, is equal to or less than the bus fare (bus fares are Rs. 1 on average per passenger kilometre, metro fares 75 paisa, rail or circular rail Rs. 1 and the ferry Rs. 2.30). An absence of a direct route is a common problem for all the modes – this is not surprising for the train-modes but should not have existed for buses. That it does means that there is not enough variability in the routes.

Now, using these ranks, we have set up Table 71, which shows how many kilometres are impacted if we provide the three most important incentives for each of the five modes, and their combinations. The last column gives the kilometres impacted if all three are provided. For buses, the three incentives would achieve a major part of the shift.

Finally, Table 72 gives the kilometres for the persons who have opted for bus as well as metro, whatever else they may have opted for, and the same for metro and rail, bus and rail, and bus, metro and rail. This table will be required when we plan alternative modal structures and will be discussed subsequently.

Table 72: Kilometres Corresponding to More Than One Option (Bus, Metro and Rail)

Mode	Total Km travel	Bus & Metro	%	Metro & Rail	%	Bus & Rail	%	Bus,Metro,Rail	%
Two-wheeler	91257.6	4420.1	4.84	8807.5	9.65	3845.5	4.21	3845.5	4.21
Auto	201695	71089.89	35.25	89628.49	44.44	59632.35	29.57	59382.15	29.44
Taxi	64616.4	10338.76	16.00	20604.24	31.89	7835.24	12.13	7809.24	12.08
Hired car	31451	1847	5.87	1296.4	4.12	1268.4	4.03	1268.4	34.23
Shared Taxi	10436.6	3720	35.64	3840	36.79	3720	35.64	3720	35.64
Private car	31096.6	938.2	3.02	950.2	3.06	890.2	2.86	890.2	17.07
Total	430553.2	92354	21.45	125126.8	29.06	77191.69	17.93	76915.49	17.86

Summary of Shift Results

On the whole, if we compare the results of the various shift analyses, we can say that travel and wait time are very important criteria for transport choice, and cost has also been given importance. For specific modes, access and comfort are concerns. A direct route is a general need, that has an impact on both time and the physical effort of changing modes. Those who can afford it choose personal vehicles because they provide comfort, and reduce the travel time.

X. Alternative Modal Structures.

It may be concluded from the last section that

- The metro is in greatest demand, but only if access and a direct route are provided, and these can happen at a very high cost (yet the users would like to keep fares low)– however, this is just a first-hand observation and we would have to evaluate costs and benefits more exactly
- Buses are not substitutable in terms of accessibility and cost but travel/wait time and comfort are deterrents there
- Access is difficult for rail, circular rail and ferry, and providing a direct route would be impossible for these. Keeping the cost down (for the traveler) would also be a problem for these modes.

Our alternative plans will be developed from these basic observations and Tables 69 – 72. Firstly, we see that all of the kilometres being covered by the more polluting modes cannot be converted, whatever the incentive. Table 67 gives the kilometres that cannot be converted. Thus our alternative plan will be on the following (by mode currently being used):

Mode	Convertible Kms.
Two wheeler	42480.41
Auto	164885.62
Taxi	60804.03
Hired Car	30570.37
Share Taxi	9758.22
Private Car	21985.30
Total	330483.96

As the above are kilometres traveled by the sample, the corresponding amounts for the KMC area would be obtained by multiplying each of the above by a factor of 1680.

Although the bus does pollute at a ‘medium’ level, we retain it because, as we mentioned, it has features that none of the others have, there is already an elaborate bus system in the city as is the case for most cities, and it is cheap. The metro, of course, cannot be ignored as a zero-pollution mode with very attractive features. The rail is given tertiary importance as it provides better access (having a longer stretch) compared to the ferry and circular rail. The ferry, as discussed in the ‘background’ chapter, currently mostly runs across the river, carrying passengers who are coming from or going to Howrah station – but it can be made to run along the river. But from the responses, the ferry appears to remain a less attractive mode.

We are also assuming that the pollution levels calculated by us would remain. In reality, of course, these levels may change in some years, and differently for the various modes. Such changes can also be incorporated in our structure. But this particular project concentrates on modal structure, with the assumption that other policy moves are not taken, or do not work. It is a fact that recent efforts to reduce vehicular emissions in the city have failed (The Telegraph, July 8, 2003, June 3, 4,19, October 1, 2004 etc.).

It may be noted that concentrating on as few modes as possible reduces cost because of economies of scale. On the other hand, as respondents have not been willing to convert to all modes, we have to see the number of kilometres saved. We shall also, therefore, consider cases where all 5 modes are developed.

We shall then be considering the following alternatives:

- Plan I – Shift what is possible to the metro
- Plan II – Shift what is possible to buses
- Plan III – Shift what is possible to the (suburban) rail
- Plan !V – Shift what can be to buses, and the remaining to the metro
- Plan V – Shift what can be to rail, and the remaining to the metro
- Plan VI – Shift what can be to buses, and the remaining to rail.
- Plan VII – Shift what can be to buses, then to rail, and the remaining to metro
- Plan VIII – Shift what can be to buses, and distribute the rest according to their convertibility percentages in the last row of Table 69 .
- Plan IX - Distribute all according to their convertibility percentages in the last row of Table 69.

Calculations of Pollution Saved and Costs for the Alternative Plans

Table 69 is reproduced here for convenience. It gives us the maximum kilometres (of the sample) convertible to the five proposed modes, in terms of each of the current (more polluting) modes being used. We also know from the survey that 100069.24 kilometres of the total 430553.2 kilometres *cannot* be converted to *any* of the modes.

Also, Table 72, which gives the kilometres for the persons who have opted for bus as well as metro, whatever else they may have opted for, and the same for metro and rail and bus, metro and rail, is reproduced. When we will consider a shift to the metro, say, after all the possible kilometres have been shifted to buses, we have to leave out those who have opted for both bus and metro as they have already been shifted to buses. The specifics will be discussed individually for each plan.

Table 69: Five Modes to which the More Polluting Modes Can Be Shifted, Kilometres of Possible Shift and Percentages of the Total Kilometres, by Mode

Mode	Total Km covered	Shift modes									
		Bus	%	Metro	%	Rail	%	Circular	%	Ferry	%
Two-wheeler	91257.6	5088.2	5.85	27174.8	29.78	17379.8	19.04	12704.6	13.92	3361.8	3.86
Auto	201695	81563	40.44	136075.44	67.47	95285.6	47.24	58377.9	28.94	30255.6	15.0
Taxi	64616.4	26064.7	40.34	55074.66	85.23	32355.7	50.07	39185.5	60.64	15443.4	23.9
Hired car	31451	2512.8	7.99	27977.1	88.95	13287.9	42.25	14560.9	46.3	2006.4	6.38
Shared Taxi	10436.6	4889.4	46.85	9064.2	86.85	4591.4	43.99	4207.2	40.31	2530.4	24.2
Private car	31096.6	2435.9	7.83	7029.24	22.6	1653.8	5.32	2587.2	8.32	2156.8	6.94
Total	**430553.2**	**122554**	**28.46**	**262395.4**	**60.94**	**164554.2**	**38.22**	**131623.28**	**30.57**	**55754.4**	**12.9**

Table 72: Kilometres Corresponding to More Than One Option (Bus, Metro and Rail)

Mode	Total Km travel	Bus & Metro	%	Metro & Rail	%	Bus & Rail	%	Bus,Metro,Rail	%
Two-wheeler	91257.6	4420.1	4.84	8807.5	9.65	3845.5	4.21	3845.5	4.21
Auto	201695	71089.89	35.25	89628.49	44.44	59632.35	29.57	59382.15	29.44
Taxi	64616.4	10338.76	16.00	20604.24	31.89	7835.24	12.13	7809.24	12.08
Hired car	31451	1847	5.87	1296.4	4.12	1268.4	4.03	1268.4	34.23
Shared Taxi	10436.6	3720	35.64	3840	36.79	3720	35.64	3720	35.64
Private car	31096.6	938.2	3.02	950.2	3.06	890.2	2.86	890.2	17.07
Total	430553.2	92354	21.45	125126.8	29.06	77191.69	17.93	76915.49	17.86

The pollution saved for each plan using both measures (I and II) of pollution per person per kilometre given in Table 36 is calculated in the following manner.

Plan I

Here the conversion is solely to the metro. 262395.4 kms can be converted (see Table 69). From the kilometres by mode in column 5, we can calculate the saving in terms of pollution to be

Measure I

- 139230.09 gm (27174.8 x 5.1235 gms – consult Tables 69 and 36) due to the shift from two wheelers. Similarly, the savings are
- 287051.14 gm due to the shift from autos
- 45904.72 gm due to the shift from taxis
- 19304.20 gm due to the shift from hired cars
- 5134.87 gm due to the shift from shared taxis

- 2038.48 gm due to the shift from private cars.

Hence a total of 498663.5 gm is saved for the sample. No pollution is added as the metro does not pollute. Thus KMC saves 837754680 gm or **8.4 lakh kgs** per year..

Measure II

- 83360.74 gm due to the shift from two wheelers
- 166096.40 gm due to the shift from autos
- 35030.80 gm due to the shift from taxis
- 14756.81 gm due to the shift from hired cars
- 3920.46 gm due to the shift from shared taxis
- 1535.01 gm due to the shift from private cars

Hence a total of 304700.21 gm is saved for the sample. No pollution is added. Thus KMC saves 511896352.8 gm or **5.1 lakh kgs.**

Plan II

The conversion here is to buses only. The convertible kilometres are 122554. We use column 3 of Table 52 and Table 36 to calculate the saving in terms of pollution:

Measure I

- 26069.39 gm due to the shift from two wheelers
- 172057.15 gm due to the shift from autos
- 21724.92 gm due to the shift from taxis
- 1664.83 gm due to the shift from hired cars
- 2769.84 gm due to the shift from shared taxis
- 706.41 gm due to the shift from private cars

The addition to the pollution would be 12623.06gm due to the pollution from the added buses. We have taken an average of the pollution from the seven types of buses.

Therefore the total amount of pollution saved is 212369.48gm. For the KMC area it would then be 356780726.4 gms i.e. **3.6 lakh kgs**.

Measure II

- 15608.44 gm due to the shift from two wheelers
- 99557.43 gm due to the shift from autos
- 16578.72 gm due to the shift from taxis
- 1272.66 gm due to the shift from hired cars
- 2114.77 gm due to the shift from shared taxis

- 531.94 gm due to the shift from private cars

The addition to the pollution is 9989.11 gm

Hence the total amount of pollution saved is 125674.85gm for the sample and 211133748 gms i.e. **2.1 lakh kgs** for KMC.

Plan III

Her the conversion is to rail only. The kilometres converted to rail are 164554.2 km. The saving in the quantity of pollution would be

Measure I

- 89045.40 gm due to the shift from two wheelers
- 201004.97 gm due to the shift from autos
- 26968.47 gm due to the shift from taxis
- 9168.65 gm due to the shift from hired cars
- 2601.03 gm due to the shift from shared taxis
- 479.60 gm due to the shift from private cars

A total of 329268.13 gm is saved for the sample. There is no addition to the pollution from rail transport. The saving for KMC would be 553170458.4 gms i.e. **5.5 lakh kgs.**

Measure II

- 53313.84 due to the shift from two wheelers
- 116307.51 due to the shift from autos
- 20580.17 due to the shift from taxis
- 7008.84 due to the shift from hired cars
- 1985.88 due to the shift from shared taxis
- 361.15 due to the shift from private cars

A total of 199557.39 gm is saved for the sample. There is no addition to the pollution. The saving for KMC would be 335256415.2 gms i.e. **3.3 lakh kgs**.

Plan IV

Here we convert what can be to buses, and the remaining to the metro.

We can convert 122554 kms to buses. We are then left with

430553.2-100069.24-122554 = 207929.96 kms for the metro.

But as there are persons who have agreed to shift to both the metro and buses (whatever else they may have agreed to shift to), we have to leave them out from those who have opted for the metro. In other words, with the help of Tables 52 and 55, we know that the possible conversion to the metro is

262395.4 – 92353.95= 170041.45 kms.

As this is < 207929, only 170041.45 kms go to the metro. We then calculate the saving in pollution (sum of the saving in pollution due to a shift to buses, and a shift to the metro) as

Measure I

- 116295.38gm due to the shift from two wheelers
- 358266.24gm due to the shift from autos
- 51472.8gm due to the shift from taxis
- 14243.63gm due to the shift from hired cars
- 6097.41gm due to the shift from shared taxis
- 2027.42gm due to the shift from private cars

The addition in pollution (due to the extra buses) is 12623.06 gm

Hence the total amount of pollution saved is 535779.82 gm for the sample, or 900110097.6 gms for KMC, i.e. **9 lakh kgs** for KMC.

Measure II

- 69629.13gm due to the shift from two wheelers
- 207303.59gm due to the shift from autos
- 39279.91gm due to the shift from taxis
- 10888.33gm due to the shift from hired cars
- 4655.36gm due to the shift from shared taxis
- 1526.68gm due to the shift from private cars

The addition in pollution due to the extra buses is 9989.11 gm

Hence the total amount of pollution saved is 323293.9 gm for the sample, or 543133752 gms for KMC, i.e. **5.4 lakh kgs** for KMC.

Plan V

Here we convert what can be to rail, and the remaining to metro. Hence from Table 52, 164554.2 kms can be converted to rail, leaving us with

430553.2- 100069.24- 164554.2= 165929.76 kms.

But the amount that one can possibly convert to the metro, given that 125126.79 kms are options for both metro and rail, so that as we have already shifted what can be to rail, this number is out of bounds for conversion to metro. Hence, the possible kilometres convertible to the metro are

262395.4 - 125126.79 = 137268.61 kms.

The saving, then, in pollution is

Measure I

- 161881.74gm due to the shift from two wheelers
- 351171.9gm due to the shift from autos
- 50982.91gm due to the shift from taxis
- 19267.38gm due to the shift from hired cars
- 5287.27gm due to the shift from shared taxis
- 1546.00gm due to the shift from private cars

Hence the total amount of pollution saved is 590137.20gm for the sample, or 991430496 gms for KMC, i.e. **9.9 lakh kgs** for KMC.

Measure II

- 96922.89gm due to the shift from two wheelers
- 203198.6gm due to the shift from autos
- 38906.06gm due to the shift from taxis
- 14728.66gm due to the shift from hired cars
- 4036.81gm due to the shift from shared taxis
- 1164.17gm due to the shift from private cars

Hence the total amount of pollution saved is 358957.19 gm for the sample, or 603048079.2 gms for KMC, i.e. 6 lakh kgs for KMC.

Plan VI

Here we convert what can be to bus, and the remaining goes to rail Hence 122554 kms are to be covered by bus. We are left with

430553.2- 100069.24- 122554= 207929.96 kms for the rail.

In a similar manner as was done in Plan V, we see that the possible kilometres for rail are

164554.2 – 77191.69= 87362.51 kms.

As this is < 207929.96 kms, only the former (87362.51 kms) goes to rail transport.

Hence the pollution saved is

Measure I

- 73343.97gm due to the shift from two wheelers
- 278961.38gm due to the shift from autos
- 36042.59gm due to the shift from taxis
- 6601.5gm due to the shift from hired cars
- 4150.74gm due to the shift from shared taxis
- 961.03gm due to the shift from private cars

The addition in pollution is (because of the bus transport) 12623.06 gm

Hence the total amount of pollution saved is 387438.15 gm for the sample, or 650896092 gms i.e. **6.5 lakh kgs** for KMC.

Measure II

- 43912.98gm due to the shift from two wheelers
- 161415.42gm due to the shift from autos
- 27504.82gm due to the shift from taxis
- 5046.42gm due to the shift from hired cars
- 3169.08gm due to the shift from shared taxis
- 723.67gm due to the shift from private cars

The addition in pollution is 9989.11 gm

Hence the total amount of pollution saved is 231783.28gm for the sample, or 389395910.4 gms for KMC, i.e. **3.9 lakh kgs** for KMC.

Plan VII

Here we transfer what can be to buses, then to rail, and finally what remains to the metro, taking into account the responses which opt for both bus and rail, both metro and rail and also all three. The process is as follows.

122554 kms gets converted to bus. What remains is

430553 – 100069 – 122554 = 207929 kms.

We get what can be converted to rail, by subtracting the bus-rail options from the maximum amount for rail (see Tables 52 and 55), as

164554 – 77191.69 = 87362.31

What remains, then, is

207929 – 87362.31 = 120566.69 kms.

Now, what is convertible to the metro? We subtract the kilometres which opt for (at least) metro and bus, and the kilometres which opt for (at least) metro and rail from the maximum amount convertible to the metro. However, as this implies the subtraction of those opting for a minimum of metro, rail and bus two times, we add the kilometres which opt for at least metro, rail and bus. That is (consult Table 55), the kilometres possibly convertible to the metro are

262395.4 – 92353.95 – 125126.79 + 76915.49 = 121830.15

As 121830.15 > 120566.69, therefore only the latter is fully convertible to the metro.

Given the three values for bus, rail and metro, we calculate the saving in pollution to be

Measure I

- 179088.89gm due to the shift from two wheelers
- 505147.6gm due to the shift from autos
- 69785.91gm due to the shift from taxis
- 19772.47gm due to the shift from hired cars
- 7730.26gm due to the shift from shared taxis
- 2122.66gm due to the shift from private cars

The addition in pollution, on the other hand, is 12623.06 gm because of the additional bus transport.

Hence the total amount of pollution saved is 771024.73 gm for the sample, or 1295321546.4 gms i.e. **13 lakh kgs** for KMC.

So the total amount of pollution saved is

Measure II

- 107225.27gm due to the shift from two wheelers
- 292293.56gm due to the shift from autos
- 53255.01gm due to the shift from taxis
- 15114.77gm due to the shift from hired cars
- 5902.04gm due to the shift from shared taxis
- 1598.4gm due to the shift from private cars

The addition in pollution due to the buses is 9989.11 gm

Hence the total amount of pollution saved is 465399.94 gm for the sample, or 781871899.2 gms i.e. **7.8 lakh kgs** for KMC.

Plan VIII

We convert what can be to bus transport, and distribute the rest according to their proportions in the last column of Table 52.

Hence 122554 kms are converted to bus, and we are left with 207929 kms.

As the percentages of the four other modes (see last row of Table 52) add up to

60.94 + 38.22 + 30.57 + 12.95 = 142.68, the relative percentages of the four modes is given by

Metro – 60.94/142.68 x 100 = 43%
Rail - 27%
Circular Rail - 21%
Ferry - 9%

That is the kilometres for the four modes is

Metro - 207929 x 43% = 89409.47
Rail - 207929 x 27%= 56140.83
Circular Rail - 207929x 21%= 43665.09
Ferry - 207929x 9%= 18713.61

We then calculate the saving in pollution as follows:

Measure I

- 131265.66 gm due to the shift from two wheelers
- 400720.32 gm due to the shift from autos
- 61722.98 gm due to the shift from taxis
- 15237.37 gm due to the shift from hired cars
- 6678.71 gm due to the shift from shared taxis
- 1978.18 gm due to the shift from private cars

The Addition in terms of pollution is 14488.21 gm.

Hence the total amount of pollution saved is 603115.01 gm for the sample, or 1013233216.8 gms for KMC, i.e. **10.1 lakh kgs** for KMC.

Measure II

- 78592.23gm due to the shift from two wheelers
- 231868.8 gm due to the shift from autos
- 47102.02 gm due to the shift from taxis
- 11647.97 gm due to the shift from hired cars
- 5099.18 gm due to the shift from shared taxis
- 1523.7 gm due to the shift from private cars

Addition in terms of pollution is 11402.54 gm

Hence the total amount of pollution saved is 364431.36 gm for the sample, or 612244684.8 gms for KMC, i.e. **6.1 lakh kgs** for KMC.

Plan IX

All five modes are implemented in proportion to their percentages in the last row of Table 52. The total amount that is convertible is

430553 – 100069 = 330484 kms.

Now the percentages add up to

28.46 + 60.94 + 38.22 + 30.57 + 12.95 = 171.14

Thus the kilometres for each are

Bus : 17% ie 330484 x 17% = 56182
Metro : 36% ie 330484 x 36% = 118974.24
Rail : 22% i.e. 330484 x 22% = 72706.48
Circular Rail : 18% i.e. 330484 x 18% = 59487.12
Ferry : 7% i.e. 330484 x 7% = 23133.88

The pollution saved is

Measure I

- 150988.72 gm due to the shift from two wheelers
- 379979.95 gm due to the shift from autos
- 62791.06 gm due to the shift from taxis
- 18713.90 gm due to the shift from hired cars
- 6419.18 gm due to the shift from shared taxis
- 2058.63 gm due to the shift from private cars

The pollution added is, due to the bus and ferry modes, 8092.46 gm

Hence the total amount of pollution saved is 612858.98 gm for the sample, or 1029603086.4 gms for KMC, i.e. **10.3 lakh kgs** for KMC.

Measure II

- 90400.95 gm due to the shift from two wheelers
- 219867.80 gm due to the shift from autos
- 47917.09 gm due to the shift from taxis
- 14305.56 gm due to the shift from hired cars
- 4901.03 gm due to the shift from shared taxis
- 1550.18 gm due to the shift from private cars

The added pollution, due to bus and ferry, is 6298.03 gm

Hence the total amount of pollution saved is 372644.58 gm for the sample, or 626042894.4 gms for KMC, i.e. **6.3 lakh kgs** for KMC.

The returns in terms of pollution saved are given in Table 73 below.

Table 73: Pollution Saved in Proposed Plans, lakh kgs.

Plan	Measure I	Measure II
I	8.4	5.1
II	3.5	2.1
III	5.5	3.3
IV	9	5.4
V	9.9	6
VI	6.5	3.9
VII	13	7.8
VIII	10.1	6.1
IX	10.3	6.3

We now have to determine the costs of each of these plans. The kilometres covered by each mode in each of the plans *for the sample* are given below:

Plan I: Metro 262395

Plan II: Bus 122554

Plan III:	Rail	164554
Plan IV:	Bus	122554
	Metro	170041
Plan V:	Rail	164554
	Metro	137268
Plan VI:	Bus	122554
	Rail	87363
Plan VII:	Bus	122554
	Rail	87363
	Metro	120567
Plan VIII:	Bus	122554
	Metro	89409
	Rail	56141
	CR	43665
	Ferry	18714
Plan IX:	Bus	56182
	Metro	118974
	Rail	72706
	CR	59487
	Ferry	23134

We have obtained the costs (operating plus capital costs) net of revenues per passenger kilometre of the five modes for 1989 (Roy, 1989) which we have updated to 2004 using the price indices for West Bengal (Govt. of West Bengal, 2003-4, p. 163). These costs are

Bus	Rs. 0.30
Metro	Rs. 1.75
Rail/CR	Rs. 0.25
Ferry	Rs. 0.40
LRT	Rs. 0.50 (LRT stands for light rail transit)

If we now look at the incentives desired by the travelers to shift to the five modes, first, greater speeds and frequency of the buses is desired, as well as comfort. Now, the removal of the low-occupancy modes on the road would automatically reduce the congestion and enhance speeds. Also, the greater number of buses would decrease the wait time. Increasing the comfort in the buses would involve an average expenditure of Rs. 125,000 (estimate based on consultations with experts) per bus. If this expenditure has to be repeated every 10 years, the cost is Rs. 18750 per year (for a Present Value of

Rs. 125000), i.e. Rs. 51.36 per day. As we need all costs in terms of person-kilometres, the comfort cost would be

51.36 ÷ (34 x 150) = .01,

given that the average occupancy of buses is 34 (by our survey) and one bus on average runs 150 kms (as reported by state bus officials).

For all the four other modes, access is important. This, we propose, should be provided by a system of light rail transit (LRT) along the east-west corridor (spaced according to the total person-kilometres required) for which we have cost estimates, and which is pollution-free. Now, the average distance for accessing the metro, which runs along the centre of the city is b/4, where b is the breadth of the city, and the average distance traveled on the metro is L/2, where L is the length of the city, hence for each person kilometre of travel on the metro, (b/4 ÷ L/2) person kms has to be traveled on the LRT. There are similar calculations for the rail, circular rail (CR) and ferry, taking average distances of access and the standard length of travel as L/2 for all these modes, as they all traverse (or, in the case of the ferry, are expected to traverse) the length of the city.

Cost was also stated as an important incentive for the modes other than bus, but actually the fares are all very low for the ferry and the two rails, and medium for the metro. It appears that access costs are the concern – hence if access is made easier and by HOVs (LRT), the cost would not remain a factor.

The issue of a direct route, stated for all modes, is not solvable, as it would be impossible to provide direct routes on HOVs. However, if the greater number of buses translates into more routes, if the east-west LRT routes are appropriately spaced and the ferry runs not only across but also along the river, the problem of a direct route would be partially solved. Also, a single ticket purchased at one location for several mode changes might partially solve the problem of both cost and a direct route.

Given the above, the cost of one passenger km for the five modes are as follows:

Bus

Cost: .3 + .01 = .31

Metro

Cost of Metro = 1.75

Access Cost = $\frac{.5 \times b/4}{L/2}$,

given that the average distance of access to the is b/4 where b is the breadth of the city, as the metro runs through the central backbone of the city, and the average distance traveled by a metro user is L/2 where L is the length of the city (the metro runs along the whole length of KMC). So

Cost = 1.75 + .097 = 1.847,

given that the average breadth of the KMC area is 7 kms and the length is 18 kms.

Rail

Cost of Rail service = .25

Access Cost = $\frac{.5 \text{ x } b/2}{L/2}$ = .194,

as the rail runs along one side of the city, so the average access distance would be half the breadth of the city. Hence

Cost = 0.444

Circular Rail

The cost would be the same as for rail, as the capital and operating costs are the same, and access involves the same distance.

Ferry

Ferry cost = .4,

Even if the ferry runs along the breadth of the river, as ferry stops are fewer, a longer distance has to be covered to access the ferry. If this distance is double the distance for rail,

Access cost = $\frac{.5 \text{ x } b}{L/2}$ = .388 ,

So

Cost = .4 + .388 = .788.

We will evaluate cost efficiencies without, at first, looking at revenues. The costs for each plan are then given by

Plan I

262395 x 1.847 = 4.8 lakh rupees or **806 m**. rupees for the city (multiply by 1680).
Plan II

122554 x .31 = 0.4 lakh rupees or **67 m**. rupees for KMC

Plan III

164554 x .444 = .7 lakh or **118 m**. rupees for KMC

Plan IV

(122554 x .31) + (170041 x 1.847) = .4 + 3.1 = 3.5 lakh or **588 m**. rupees for KMC

Plan V

(164554 x .444) + (137268 x 1.847) = .7 + 2.5 = 3.2 lakh or **538 m**. rupees for KMC

Plan VI

(122554 x .31) + (87363 x .444) = .4 + .4 = .8 lakh or **134 m**. rupees for KMC

Plan VII

(122554 x .31) + (87363 x .444) + (120567 x 1.847) = .4 + .4 + 2.2 = 3 lakh or **504 m.** rupees for KMC

Plan VIII

(122554 x .31) + (89409 x 1.847) + (56140 x .444) + (43665 x .444) + (18713 x .788) =

.4 + 1.7 + .44 + .14 = 2.68 lakh or **450 m**. rupees for KMC

Plan IX

(56182 x .31) + (118974 x 1.847) + (72706 x .444) + (59487 x .444) + (23134 x .788) =

.17 + 2.2 + .6 + .18 = 3.15 lakh or **529 m.** rupees for KMC.

Using the above cost figures and the pollution saved by both measures, we obtain the cost efficiency of each plan in kgs saved per million rupees in Table 74.

Table 74: Cost Efficiency of Plans, kilograms per million rupees

Plan	Cost Efficiency	
	Measure I	Measure II
I	**1042**	**633**
II	**5224**	**3134**
III	**4661**	**2797**
IV	**1531**	**918**
V	**1840**	**1115**
VI	**4851**	**2910**
VII	**2579**	**1548**
VIII	**2244**	**1356**
IX	**1947**	**1191**

The above implies the following:

- Plan II (bus only) is the most cost efficient, but also reduces pollution the least
- Plan VI (bus and rail) is the second best in terms of efficiency and reduces pollution by a medium amount
- Plan III (rail only) is 3rd best in terms of efficiency and the pollution reduction is less than for VI – hence this should certainly be abandoned
- Plan VII (bus, then rail, then metro) is fourth most efficient and the reduction in efficiency is significant, on the other hand it achieves the maximum reduction in pollution
- Plan VIII (bus, and distribute the rest according to convertibility) is close to VII in efficiency but the reduction in pollution is less than for VII, so it clearly is to be abandoned
- Plan IX (distribute all according to convertibility) has less efficiency than VIII and the pollution reduction is close to that of VIII, so this is similarly to be abandoned
- The same is true for Plan V (rail and metro)
- Plan IV (bus and metro) is second worst, and the pollution reduction is less than for VIII
- Plan I (metro only) is the worst in terms of efficiency, and the pollution reduction is less than that for IV.

Therefore if we give sole importance to efficiency, we should choose Plan II (bus only). On the other hand, if we balance efficiency with the absolute value of pollution reduction, we can consider both Plans VI (bus and rail) and VII (bus, rail, metro). They are second and fourth in terms of efficiency, and the pollution reduction is the highest for VII and a medium amount for VI.

XI. Summing Up and Concluding Observations

The objective of this project was to determine

(a) the modal choice of users of transport in the KMC area, and from here the modal structure of the city
(b) the pollution caused by this modal structure
(c) feasible changes in this modal structure and how these can be achieved,
(d) the reduction in pollution due to these changes
(e) the cost effectiveness of the alternative schemes and
(f) the implied optimal schemes.

With the above objectives in mind, we have first calculated the tailpipe emissions of all motorized modes of transport running in the city and the average occupancies of these various modes. On the basis of the above, we obtained the pollution (the emissions of the five compounds were summed with and without weights to get total emissions) let out by the modes, per person and per unit distance.

We next conducted a survey of 750 households (constituting 2720 individuals) and 280 commuters (who reside outside the KMC area) in order to obtain every detail of their travel behaviour in the KMC area. From the survey we obtained the total person-kilometres covered using each mode: multiplying this with the pollution per person per kilometer, we obtained the pollution caused by each mode in the sample. As the sample was chosen to be representative of the city as a whole, this data was extrapolated to obtain the pollution emitted by the modal structure in the city.

A peripheral objective of the survey was to look at the connections between modal choice and (a) socio-economic characteristics of the traveler (b) features of the trip such as purpose, distance and frequency and (c) features of the mode. We saw that all of these are important in determining modal choice, though some *specific* aspects within each of the above three were more important than others. Whilst trip purpose does not determine choice, distance and frequency of the trip do. Whilst gender has a strong connection with modal choice, age has a weaker one, and personal incomes are relatively unimportant. Whilst cost is a binding factor, aspects like travel time and comfort are recognized but do not bind.

Our survey looked at various aspects of modal shift. Respondents were asked (a) whether they plan to purchase personal vehicles, (b) whether they plan to shift to more polluting modes, corresponding to each mode they are presently using and what would prevent the shift, and (c) if they are currently using the 'more polluting' modes (two wheeler, auto, taxi, shared taxi, private car and hired car), whether they would be willing to shift to the 'low' or zero pollution modes – viz., buses, the metro, rail, ferry and circular rail. For (b) and (c), the incentives required for the shift were identified. For this purpose ten 'incentives' or 'features' of the mode (such as less travel time or travel comfort) were presented to the respondent. On the basis of the 'shift' survey we developed nine alternative plans, where the more polluting modes are partially replaced by one or more of the five non-polluting (or less polluting) modes. It may be clarified that when respondents did not wish to shift to any of the other modes under any circumstance, the corresponding kilometers were left out. Only *feasible* quantities of shift were considered. When a certain number of kilometers, for example, could be shifted to any of two modes, and a particular plan shifts these kilometers to one of the modes, then the plan automatically takes this into consideration when considering total shift to the *other* mode.

Each of the plans, after being developed, implied a net saving in the total pollution for the sample and the city as a whole. Also, each of the plans imply a net cost. The cost was determined after careful consideration of the incentives required to coerce travelers into shifting to the less polluting/nonpolluting modes.

Hereby, the cost-effectiveness of the plans was determined and on that basis, two plans were considered optimal. The first shifts what can be shifted of the more polluting modes to buses and the rail, and the second shifts them to buses, the rail and the metro. In both, the first priority is given to buses (that is, what can be shifted to buses is done so) , then to the rail, and finally (in the second case) to the metro.

So many facts come to light in this comprehensive study of modal choice. An interesting fact, for example, and that which contradicts statements in existing literature, is that trips to see relatives cover more kilometers than trips for educational purposes. We will, however, confine ourselves to the central theme of this research endeavour.

First, the income structure of Kolkata's population is such that their present modal choice is *far from* the most polluting. The major percentage of travel is by walking, followed by the ordinary private bus. However, a small percentage of travel is being serviced by a large number of low-occupancy and highly polluting vehicles in the city, and their number is growing dangerously. It is the rich and upper middle classes who are causing a rapid enhancement of Kolkata's transport pollution, and therefore it is they who have to be coerced into using low-polluting HOVs. This can only be done by greatly improving the public transport system, mainly in terms of travel time, wait time, travel comfort and access.

Secondly, alternative plans need not concentrate on the metro as the city's sole saviour. It has been conclusively proved that not only is the metro very expensive, but also, the travel that *can* be shifted to the metro would not reduce pollution as much as other plans which concentrate on the bus and rail. The general preference of Kolkata's travelers for buses and the existence of an elaborate bus network in the city should not be ignored. Rather, the transport and other related departments should reconsider the total network, make the private and public services more compatible and strictly monitor the private bus service so that they provide a better product. Kolkata's bus service must be made as attractive as that in the cities of the north to convince the city's affluent to depend on it and forget about their cars, as is the case in some of the larger northern cities. It is not clear why up-market bus services such as executive buses are so limited, especially as they have been very successful in certain routes.

Our work also indicates the significant possibilities of an improved rail service. If our rail service can be made as good as Bombay's, for example, it would solve a major part of our transport problems. The ferry and circular rail have not been favoured on a relative scale. However, this may be because respondents were unduly influenced by their present condition.

Whilst the city has several north-south routes, access to these routes emerges as a major constraint. The use of the rail, circular rail and metro would increase enormously if easy and reasonably cheap access were provided – which means several east-west routes with reasonable gaps in-between. We have suggested a light rail transit for this purpose, superior to the tram that is being phased out because of its innate inefficiencies. However, buses or other modes of transport can also be used for this purpose.

In conclusion, it may be pointed out that a political will to curb the purchase of personal vehicles would be critical in determining the modal structure in the city and the resultant pollution from transport. It would be difficult to make impositions on the nature of the engine or the fuel, at least in the medium run – as evidenced by recent interactions between the judiciary and the state government, which have almost always ended in the relaxation of restrictions and the extension of deadlines. Moreover, improvements in engine or fuel can never lead to zero pollution – they would only reduce the pollution. Hence the promotion of zero-pollution modes and discouraging the purchase and use of personal vehicles becomes imperative for megacities like Kolkata.

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APPENDIX A

HOUSEHOLD SURVEY

Travel Behaviour

Sl No. **(**Target occupational specification & income will be given)
Occupation of Hhh/main-earner) Code : ( )
Total Monthly Income of hh (Rs.)

Borough No. of KMC __________ Ward No. ____________ Date of Investigation :__________

Name of Investigator__________________________________Backchecked by ______________

1. : General Information :

a. Name, Head of the Household : ____

b. Residential Address :
____

c. Area : ___________________________ d. Landmark _________________________________

e. Phone No.(Res.)________________(O)__________________

f. Premises located at : Rich / Upper-Middle /Middle / Lower-Middle/ Poor / Slum Area (tick)

g. Nature of Dwelling Unit : Own/Rented (tick) House/ Flat / Slum (tick)

h. Size of Dwelling Unit :

2. Demographic Particulars of Household Members

Sl. No.	Sex	Age	Occupation (Specify all kinds of occupations)	Income/ month
			O1	
			O2	
			O1	
			O2	
			O1	
			O2	

3. **Household expenditure per month:**

4. **Do you have:** Colour TV (no.)_____

Mobile(no.)_________

Washing machine (no) ________

Radio (no.) ________

. 5 : **Distance & mode used to access :(Use codes)**

Transport Modes	**From Home**	
	Distance	Intermediate mode
Bus stop		
Taxi		
Auto-Rickshaw stop		
Metro station		
Circular Rail Station		
Local Train Station		
Ferry Ghat		
Tram Stop		
Chartered Bus Stop		
Share Taxi		
Bus Terminus		

For Each Family Member

Sl. No. _________(Follows 'Question 2'- 'Demography of HH members')

Ia. Name of the Respondent ____

IIa. Vehicles owned for personal use: Type___________(No.)____
Type___________(No)____

IIb. Whether parking facility is available at your work place? Yes / No / Not Applicable

Limited / Unlimited

IIc. Any plans to purchase a personal car/two-wheeler? Yes/No (Ring around)

IId. If yes, what will prevent purchase?

II.e.**Distance & mode used to access :(Use codes)**

Transport Modes	***From Work Place***	
	Distance	Intermediate mode
Bus stop		
Taxi		
Auto-Rickshaw stop		
Metro station		
Circular Rail Station		
Local Train Station		
Ferry Ghat		
Tram Stop		
Chartered Bus Stop		
Share Taxi		
Bus Terminus		

III. Incentives of shift : Very Important (V) Medium Important (M) Not Important (N)
(Rank the very important factors)

Factors	**Scale**	**Rank**
a. Direct route (no changing)		
b. Less waiting time		
c. Less travel time		
d. Waiting comfort e.g. better shaded bus stop		
e. Travel comfort *		
f. Safe travel		
g. Good access (e.g. less walking)		
h. Cost (incentive/disinc.)		
i. Fringe parking at metro/circular/ferry/train		
j. Parking restricted/fine (disincentive)		

* seating availability, seating comfort, smooth ride, heat (AC/big windows), pollution, ease of getting on/off, closeness to other travelers

IV : **Travel Behaviour** : (Normally within 5 unless considered necessary to record more)

Purpose & Location	Distance (Km) for each mode	Frequency (days per wk/month/year)	Present modes used (use number code)	Any plan to shift to more polluting modes If Yes, change?	If Yes, what will prevent shift?	Alternatives Bus(B) Metro(M) Rail (LR) Circular(CR) Ferry (F)	Factors which will allow shift to
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**

Work A1							
A2							
A3							
A4							
A5							
Education B1							
B2							
B3							
B4							
B5							
Children's School C1							
C2							
C3							
C4							
C5							
Chi. Hobby/Tutor							

D1							
D2							
D3							
D4							
D5							
Shopping E1							
E2							
E3							
E4							
E5							
Friends F1							
F2							
F3							
F4							
F5							
Relatives G1							
G2							

G3							
G4							
G5							
Health H1							
H2							
H3							
H4							
H5							
Entertainment I1							
I2							
I3							
I4							
I5							
Hobbies/Clubs /Religious J1							

J2							
J3							
J4							
J5							
Station /Airport K1							
K2							
K3							
K4							
K5							
Other Professional L1							
L2							
L3							
L4							
L5							

IVa. Trip Combinations

Trip codes (from III): list more frequent trip first)	One/Both Directions or Circular (O/B/C)	Frequency (%of frequent trip)
___________________________		

SHOW- CARD

III. Incentives of shift : Very Important (V) Medium Important (M) Not Important (N)
(Rank the very important factors)

Factors	**Scale**	**Rank**
a. Direct route (no changing)		
b. Less waiting time		
c. Less travel time		
d. Waiting comfort e.g. better shaded bus stop		
e. Travel comfort ∗		
f. Safe travel		
g. Good access (e.g. less walking)		
h. Cost (incentive/disinc.)		
i. Fringe parking at metro/circular/ferry/train		
j. Parking restricted/fine (disincentive)		

∗ seating availability, seating comfort, smooth ride, heat (AC/big windows), pollution, ease of getting on/off, closeness to other travelers

SHOW- CARD

List of Modes	Codes
Two- Wheeler	1
Auto-Rickshaw	2
Ferry	3
Taxi	4
Hired Car	5
Share-Taxi	6
Private Car	7
School Bus	8
Chartered Bus	9
Ordinary Bus (Private Bus)	10
Mini Bus	11
Executive State Bus	12
Special State Bus	13
Regular State Bus	14
Tram	15
Metro	16
Circular Rail	17
Local Train	18
Rickshaw	19
Bicycle	20
Walking	21

Appendix B
Commuter Survey on Travel Behavior

Sl. No :

Name of the Investigator :____
Date of Survey :__________________
Re-checked by: ____

1. : General Information :

a. **Name :** ____

b. **Sex :** Male / Female c. **Age :** _____________

c. Residential Address :
____

d. **Office Address** :
____

e. Phone No.(Res.)________________(O)__________________

f. **Nature of Dwelling Unit :** Own/Rented (tick) House/ Flat / Slum (tick)
g. Do you have: Colour TV (no.)_____ Mobile(no.)______Washing machine (no) _____
Radio (no.) _____

h. INCOME PER MONTH /OCCUPATION:

Occupation	Income
O1	
O2	

i. Household expenditure per month:

j. **Any specific modal requirement of occupation :** Yes / No

k. **If Yes, then specify the modes :** _______________________________________

l. **Vehicles owned for personal use:** Type___________(No.)____
Type___________(No)____

m. **Whether parking facility is available at your work place?** Yes / No / Not Applicable

Limited / Unlimited

n. **Any plans to purchase a personal car/two-wheeler?** Yes/No (Ring around)

o. If yes, what will prevent purchase?

p. Travel Behavior:

Purpose: Use codes	Entry Point (Location)	Mode used to reach Entry Point	Distance to your destination from the entry point for each mode	Mode use (From the entry point to destination)	If E.P & Exit.P. same put –1, or -2	If Exit point is not same Pl. specify the location of Exit point	Mode use (From the Destination to Exit point)	Distanc Exit from Destina with in for modes

(Code for Purpose : Work-**1**,Education-**2,** Chil.School-**3**, Chil.hobby/tutor-**4**, Shopping-**5**,Friends-**6**, Relatives-**7**, Health-**8**, Entertainment-**9**, Hobbies/Club-**10**, Station/Airport-**11**, Other-**12**)

q. Incentives of modal choice: Very Important (V) Medium Important (M) Not Important (N) Not applicable (NA)
(Rank Very Important factors)

Factors	**Scale**	**Rank**
a. Direct route (no changing)		
b. Less waiting time		
c. Less travel time		
d. Waiting comfort e.g. better shaded bus stop		
e. Travel comfort *		
f. Safe travel		
g. Good access		
h. Cost		
i. Fringe parking at metro/circular/ferry/train		
j. Parking restricted/fine		

* seating availability, seating comfort, smooth ride, heat (AC/big windows), pollution, ease of getting on/off, proximity to other travelers

r. **Trip Purpose, Location, Distance, Present mode use etc. (in KMC area)**
(instructions: First note the purpose mentioned above(in p)).

Purpose	Purpose (Codes)	Location of Destination in KMC area	Mode used from Entry point to Destination inside KMC	Distance for each mode	Frequency	Any plan to shift to more polluting modes If Yes, change?	If Yes, what will prevent shift?	Alternatives Bus-B Metro-M Circular-C Local.T-T Ferry-F	
								B- M- C- LT- F-	

								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	
								B- M- C- LT- F-	

r. Trip Combinations :

Combinations				Distance from Entry point to Each destination				Modes used for Each destination				One/Both/ Circular direction	Fre ncy
T1	T2	T3	T4	D1	D2	D3	D4	D1	D2	D3	D4		

List of Modes:

Two-Wheeler	1
Auto	2
Ferry	3
Taxi	4
Hired Car	5
Share Taxi	6
Private Car	7
School Bus	8
Chartered Bus	9
Ordinary Bus	10
Mini Bus	11
Executive State Bus	12
Special State Bus	13
Regular State Bus	14
Tram	15
Metro	16
Circular rail	17
Local Train	18
Rickshaw	19
Bicycle	20
Walking	21