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Abstract

When conventional methods such as standard setting combined with inspection for pollution control cannot be implemented in large cities of developing countries, changing the modal structure in favor of modes that pollute less per person and per unit distance transported may be a better option. This is certainly true for Kolkata (India), whose acute pollution problems have not yet been resolved. By measuring, for each mode of transport used, pollution generated per person transported and per unit distance traversed, we are able to rank the modes. This, combined with knowledge of the present modal composition, yields several policy prescriptions.

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Polluting Behaviour of Different Modes of Transport in Big Cities and Policy Implications for Pollution Reduction:

The Case of Kolkata, India

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I. The Transport Pollution Problem in Kolkata

Kolkata is one of 23 megacities in this world and the twelfth largest, with a population of 15 million in the Kolkata Metropolitan Area (or KMA (Map A), whose area is 1380 square kilometers) and 4.58 million under the jurisdiction of the Kolkata Municipal Corporation (or KMC (Map B), which covers 196 square kilometers or 14 per cent of KMA) in 2001.[1] The population density in KMC was therefore around 23367 persons per square kilometer (as against 10869 in KMA) in 2001 – hence KMC has a little more than twice the population density of KMA. Further, the daytime population in Kolkata is far greater than the resident population – around 0.47 million persons enter the KMC area every day (CMDA, 2001).

This enormous population lives (or works) in an area whose length is greater than its breadth, the latter being somewhat broader in the south. It is confined in the east by marshlands, though some 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 city has grown in a somewhat haphazard manner. Although it does have a central business district covering 14 square kilometers with an inner core of 4 square kilometers, this area is used for a variety of purposes. There are offices, wholesale and retail markets, doctors' and lawyers' chambers, restaurants, residences, schools, universities and so on, so that there is a huge population of people moving into and within the district in the daytime. The CBD is surrounded by residential areas that are not always self sufficient in terms of markets and other services. In recent years, however, offices, shopping malls and educational institutions are cropping up in combination with additional residential areas in other parts of the city, especially in the east and south. In the KMC area a high density of buildings and population has been combined with a minimum of roads and streets. The roads are of unequal width and this width does not depend on their positions. The commercial areas are served more by streets than main roads and the residential areas are mostly provided with extremely irregular lanes and passages rather than streets. A substantial proportion of the population (1.5 million or 33 per cent) lives in slums that are located all over the city. There are also a good number of pavement dwellers (recorded in 1987 at 55,571 by a Calcutta Metropolitan Development Authority (CMDA) survey) (Ghosh, 1999 and Chatterjee, 1999).

These features of the city imply that there is a very large flow of traffic mainly along the north-south stretch on a road space that is a mere 6 per cent of the total area, compared to 16 percent in Bombay and 23 percent in Delhi[2]. Kolkata has a diverse fleet: Among motorized forms of transport, the city has buses, trams, autos (or three wheelers), taxis, shared taxis[3], 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[4], school buses and minibuses[5]. Non-motorized forms of transport are rickshaws (both hand-pulled and cycle rickshaws), bicycles and walking. Unlike in some other cities in the developing world, in Kolkata these non-motorized forms are useful in local vicinities but not of much use when it comes to traveling long distance.

The traffic, in combination with a low wind speed caused by the density of buildings, ensures a very high level of pollution on the streets. There have been attempts to ease the traffic by building a parallel north-south corridor (Eastern Metropolitan Bypass) in the east, by passenger ferry services across the river Hoogly[6] and by the introduction of the metro (all three in the early 1980s) and, very recently (2002 and after), by building several flyovers - but the situation remains grim. An enormous quantity of transport plies along the earlier corridor even as the number of vehicles is increasing rapidly on the bypass, and even though the metro is quite popular. The number of vehicles has increased much faster than the rise in population – between 1982 and 2002 the number of registered vehicles rose from around 2.6 lakhs to around 8.2 lakhs (i.e. more than 3 times) when the population rose by a factor of 1.38 in the same period (data from the Motor Vehicles Department, as well as Banerjee and Das, 2001, p. 291, Ghosh, 1999 and Census of India, 2001). The result is low speeds[7] and congestion. Lax laws and underdevelopment have exacerbated congestion problems – they allow encroachment on roads or processions and rallies, for example. Moreover, the scarcity of parking lots has led to the KMC and traffic police legalizing on-street parking (for a fee) on a good number of roads. The CMDA survey (Chatterjee et al, 1999) shows that the carriageway occupied by parked vehicles was between 24 and 38 per cent. This reduces the effective road space to around 4 per cent.

Congestion, combined with unsatisfactory inspection and a high average age of vehicles are responsible for an unhealthy level of air pollution. Table 1 gives the levels of concentration of SPM and SO_2 and Table 2 gives the same for NO_2. In the latter table we have compared the pre-2001 period with the post-2001 period, as 2001 appears to be a benchmark year when NO_2 levels went up significantly. There has been no such jump for the other pollutants.

Table 1: Annual Average Concentration (μg/cm) of SPM and SO_2 in Kolkata's Air

Period	SPM			SO_2		
	Industrial	*Commercial*	*Residential*	*Industrial*	*Commercial*	*Residential*
1980-92	476	425	377	64	63	37
1992-2003	398	338	249	36	36	15
2004	315	265	218	10	10	8

Notes:
1. The averaging for 1980-92 is over 1980-1992 with data on 1988 and 1989 missing
2. The WHO limit for SPM is 75 and for SO_2 is 50
3. The values are approximated to the nearest whole number

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

Table 2: Annual Average Concentration (μg/cm) of NO_2 in Kolkata's Air

Period	NO_2		
	Industrial	Commercial	Residential
1992-2000	37	41	19
2001-4	85	77	53

Notes:
1. The WHO limit is 100
2. The values are approximated to the nearest whole number

Source: CPCB website

Several points may be gleaned from the data:

- SPM is uniformly greater in the industrial area compared to the commercial area.
- The same is not the case for SO_2 and NO_2 – the industrial and commercial areas are more or less the same when it comes to these pollutants.
- Pollution is less in the residential area, but the difference is less marked for SPM
- The concentration of SPM has on the whole declined steadily over the years, though the decline has been less in the residential areas.
- The levels of SO_2 has also fallen significantly, but the fall is less, again, in the residential area
- On the other hand the levels of NO_2 have risen substantially from 2000-01, and have risen far more in the residential area.

If we recognize the fact that there are little or no industrial emissions in the commercial area whilst there are emissions from motor vehicles in both industrial and commercial areas, and also the fact that there are fewer emissions from public transport in residential areas compared to commercial areas, we can arrive at several conclusions. We can say that for Kolkata, industry has been more responsible for SPM emissions compared to transport, whilst that is not true for NO_2 or SO_2. Thus we can also say that industry is more responsible for the ***decline*** in the SPM emissions, in other words, the decline in SPM reflects developments in the industrial sector rather than the transport sector. Secondly, we can say that the lesser decline of both SPM and SO_2 in residential areas, where there are no factories and where there is a greater proportion of private cars, two wheelers and taxis (all low-occupancy vehicles or LOVs), implies the greater contribution of LOVs to air pollution. Thirdly, we can also say that transport has its share of responsibility for the significant rise of NO_2 emissions during 2001-04, and that the greater proportionate rise in the residential area reflects the greater role of private vehicles or taxis. Thus in sum, there has been a decline in certain pollutants and a rise in certain others, but the decline is possibly because of developments in the industrial sector whereas transport and its modal structure is becoming more responsible for the rise.[8]

II. The Case for Influencing Modal Choice

The Central and State Pollution Control Boards have taken several steps in conjunction with the Motor Vehicles Department and the Kolkata Police. 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 vehicle companies are following the specifications on engine design, new vehicles can have very little impact on air quality with so many old vehicles and with a 25-year life. An attempt to make LPG compulsory for public transport also failed due to the intervention of the vehicle unions. There are a small percentage of 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. Hence regulatory policies and the provision of low-emission fuels have been of little use because they cannot be implemented.

Under the circumstances, it is necessary to explore an alternative approach that is more coercive and less regulatory. This approach essentially controls the quantity, mode or time of travel (and by doing so, reduces the total amount of pollution from transport), and is called transport demand management (TDM).

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 facilities
   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 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.

A crucial advantage of TDM is that most of the above measures would not require any monitoring, and those that would, such as parking restrictions, would be easier because the state would not have to monitor all cars, and violation of the rule would be more visible. Secondly and most importantly, TDM controls the ***demand*** for travel rather than the quantity of pollution ***per vehicle***. Given that there is a limit to controlling the latter, especially under circumstances that have already been discussed, TDM should be more effective in controlling the ***total*** quantity of pollution created by motorized vehicles in Kolkata. One may add that the government would be less wary of TDM because it is not so directly regulatory or regressive, and it would not attract the ire of transport unions.

Much of the suggested methods for A, however, apart from the economic disincentives, would, for Kolkata, be difficult to implement. The possibilities of land use planning would be very limited in an old city. Changing the current school system is impossibility, especially in a city where there is a huge variation between schools in terms of quality. Companies and other institutions would normally be unwilling to reduce the workweek or change work hours merely in order to reduce their employees' transport demand. The economic disincentives and peak hour charges 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. 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 for Kolkata and cities like Kolkata.[9] But if we are to look at ***how*** we wish to influence modal choice in the city, we need to know, first, what its present modal structure is and the extent of pollution caused by this structure, both in totality and by each mode. For the latter objective we need pollution per unit distance and per person caused by each mode, for which we have to first determine pollution per unit distance, and then determine the average occupancy of the modes. If we get a list of modes in accordance with the amount they pollute per unit distance per person, we can provide a certain direction to transport policy for the reduction of air pollution in Kolkata.

III. Modes of Transport and Transport Network in Kolkata

The modes of transport can be divided into four categories in terms of the quantity of pollution they emit and the number of passengers they carry (HOV or LOV). Rickshaws and bicycles are low occupancy and emit nothing. Trains, trams and the metro are high occupancy and also have zero (on-road) emissions. Buses and the ferry also carry many passengers but emit substantially. Autos (or three wheelers), taxis and share taxis, though they are public transport, carry few and emit a great deal. We can add the two forms of motorised private transport – cars and two-wheelers – to the last group. As mentioned earlier, 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 3 gives 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, 2000). During 1982-92 there has been an enormous jump in the number of vehicles (97.2%); the rise is particularly 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 3: 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. Cars & Jeeps	132409	197063	305050	37.14	48.8	54.8
2. Two Wheelers	73071	226824	363818	44.30	210.4	60.4
3. Goods Vehicles (Truck & Vans)	25593	35512	66812	8.13	38.75	88.1
4. Taxis	10121	20279	35100♦	4.27	100.3	-
5. Buses	4213	6098	8867	1.08	44.7	45.4
6.Minibuses	4023*	6964*	1196	0.14	73.1	
7. Three Wheelers	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	261927	516511	821291		97.2	59.1

* 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.

Source: Motor Vehicles Department, Govt. of West Bengal and Banerji and Das, 2001, p. 291

We see that (see column 5 in Table 3) three wheelers constitute the major percentage of the vehicles, followed by cars and jeeps (however, this data does not include mass transits such as trams, the metro, the circular rail, suburban trains and ferries.. Figure A presents this data in a bar diagram.

Another data set collected by CMDA gives numbers of vehicles actually running on the roads for 1997-8 (CMDA, 2001). Rail and ferries (public transit) as well as cars and two-wheelers have been left out by CMDA, but we have some data from newspaper reports on the latter three for 2004 (see Table 4). These are, of course, calculations made on the basis of observations regarding the passengers served daily, and occupancies. Also, there may be a slight bias in favour of the cars, two wheelers and ferries as their data is a bit more current. But the data supports what we have gathered from Table 3. It tells us that private vehicles (and hence LOVs) are far greater in number compared to public vehicles (mostly HOVs but also LOVs), that autos and taxis, which are similar in number, come much after the private vehicles and that buses as a whole constitute an even lower percentage. It should be noted, however, that public vehicles (such as buses) cover much greater distances compared to others (such as private cars) in the course of a day. Hence the pollution caused by them (on that count) would be higher than is implied by the numbers in Table 4.

Modal structure is presented from a totally different angle in Tables 5 and 6, which present data on passengers served and trips by mode in the KMA region (Figure B represents Table 5 in the form of a bar chart).[10] We see that (a) a lot of travel (29% in terms of trips) occurs on foot, (b) amongst public transit, buses (dominated by privately owned ones) serve the maximum number of people (62%) and (c) personal vehicles (cars and two wheelers) account for only 2% of total trips. All these features are encouraging in terms of the pollution generated by travel, as buses do pollute but are high occupancy and hence pollute less per person, and private vehicles are low-occupancy and therefore pollute more per person transported. However, there are three features that must be noted with care.

Table 4: Transit Modes and Private Vehicles, 2001/2004

Modes	*Number*	*Percentage*
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 reports in Anandabazar Patrika, 2004

First, the *potential* for a sustained increase in the number of vehicles is enormous for Kolkata (Ghosh et al, 1996, Bose et al, 1997). Second, as we have seen, privately owned vehicles (i.e. LOVs) are growing faster than mass transit modes and the greatest increase is in the number of two wheelers (see Tables 3 and 4). Third, the pollution created is directly connected to the modes that are actually on the road, and though such a large percentage uses mass transit (Tables 5 and 6), the *vehicles* servicing them are proportionately much less compared to LOVs (Tables 3 and 4), as reflected by the number of registrations, and by the scant data on the actual number of vehicles on the road. Although more than 60% of mass transit trips were by bus, they constitute only about 1% of the fleet. Thus the supply of mass transit appears to be enormously low compared to its demand.

Table 5: Movement of Passengers within KMA, 2001, (in lakhs)

Mode	*Volume of Passengers*	*Approximate Percentage*
Private Bus	85.00	45
Public Bus	12.50	7
Minibus	12.50	7
Tram	2.00	1
Ferry	2.40	1
Chartered Bus	2.70	2
Suburban Rail	32.50	17
Metro Rail	2.00	1
Circular Rail	0.20	0
Taxi	11.00	6
Auto rickshaw	16.50	9
Cycle rickshaw	7.50	4
Total	*187.00*	*100*

Source: CMDA (2001), p.210

Table 6: Trips in KMA, Average Weekday, 1997-98, (in lakhs)

Category of Trips	*Trips*	*Approximate Percentage*
Transit Passenger Trips	110.60	52
Private Car Trips	1.72	1
Two Wheeler Trips	2.63	1
Slow Vehicle Trips	14.16	7
Taxi	3.64	2
Auto Rickshaw	9.90	5
Cycle Rickshaw/Rickshaw	7.24	3
Others	0.53	0
Walking Trips	62.96	29
Total	*213.38*	*100*

Source: CMDA (2001), p. 91

The above three factors imply that there are significant possibilities of making mass transit in Kolkata (especially the forms that pollute less) so attractive that those who are at the margin of shifting to LOVs do not do so, and those who have already shifted to personal vehicles return to mass transit modes.

IV. The Measurement of Pollution

We determined, for each unit distance travelled, the quantities of emission of the major pollutants, viz., particulate matter (PM), sulphur dioxide (SO_2), nitrous oxides (NO_x), carbon monoxide (CO) and hydrocarbons (HC), caused by the different modes of transport.[11] Other than the non-motorized forms of transport, we have also left 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.

Emissions depend on the fuel used, the structural features of the vehicle, it's age and the way it is maintained. Keeping these factors in mind, we divided the modes into five broad categories for the purpose of pollution measurement – buses, cars, two-wheelers, three wheelers and ferries. Buses were divided into three sub-categories - state bus, private bus and private minibus. The first two are basically the same except for the fact that they are maintained differently. Mini Buses are smaller and have different engine capacities. All three run on diesel. Cars constitute taxis/rented cars and private cars. The former run on diesel and the latter on petrol – moreover, private cars are maintained better. Finally, all two wheelers and three wheelers run on petrol and the ferry runs on diesel.

Table 7: Description of Sample for the Measurement of Pollution

Mode		*Pre- 1991*	*1991-2000*	*2000 Onwards*		
				Euro I	*Euro II*	*Non Euro*
Bus	*State*	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			

Source: Primary Survey

For each category we have taken vehicles belonging to three time slots – 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) engines. This is in keeping with benchmarks used for changing vehicular air pollution standards in India (Central Pollution Control Board, 2006). Table 7 shows how the sample was divided between the various categories and time slots.

The measurements were made in the year 2004. The vehicles were accessed with the help of the relevant authorities (for state buses and ferries) or petrol stations. As each ferry has two engines, emissions from both the engines were measured. Appendix A gives a description of the techniques used to measure the five types of pollution.

The emissions per unit time have been calculated based on measurements of emission concentrations and the volume of exhaust gas let out in a certain amount of time. This gives us emissions per unit time for a certain speed or in the static state. Now, given the relationship between speed and emission changes (Watkins, 1991, Table 2.4, p.32), we obtained emissions per unit time for different speeds and from here, emissions per unit distance for different speeds.

As vehicular movement differs significantly depending on whether it occurs during office hours or not, 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 kilometres per hour. This results in an average speed of 11.25 kilometres during office hours. For movements outside office hours, it is assumed that the vehicle idles 20% of the time, moves with an average speed of 20 kilometres per hour 60% of the time and 45 kilometres per hour in the remaining time. This gives us an average speed of 21 kilometres outside office hours. Also, both 'average' emissions data and 'worst case' emissions data have to be considered. These assumptions lead to four mass emissions depending on whether the emissions are average or 'worst case', and the two speeds. For ferries, though, there are no speed variations.

Table 8: Emissions of Pollutants by Mode, gm/km

Mode	*PM*	SO_2	NO_X	*CO*	*HC*	*Total*
Private Bus	0.1096	0.084	0.805	3.891	0.353	5.2426
State Bus	0.0833	0.143	0.784	0.602	0.423	2.0353
Executive State Bus	0.024	0.073	0.640	0.678	0.128	1.5450
Minibus	0.0996	0.130	0.623	1.992	0.393	3.2376
Taxi	0.0523	0.083	0.573	1.796	0.329	2.8333
Private Car	0.0246	0.036	0.239	0.686	0.205	1.1906
Three Wheeler	0.0153	0.004	0.045	5.449	2.503	8.0163
Two Wheeler	0.011	0.006	0.020	7.582	2.116	9.7350
Ferry	2.75	2.89	12.17	49.39	10.74	77.9400

Source: Primary Survey

We then take an average speed of 16 kilometers per hour to obtain average emission levels. We then take, for each mode, averages of the three time periods to obtain single values of emissions for each pollutant (Table 8). Finally, for each mode, we derive single values of the 'level of pollution' by taking the sum of the pollution level of the five pollutants (last column, Table 8). We will subsequently be using our results from the modal occupancy study (which follows) to obtain pollution per unit distance and *per person*.

V. 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 those modes that pollute.

Table 9 : Occupancy in Three Indian Megacities

Cities	*Occupancy*				
	Two wheelers	*Cars*	*Taxis*	*Three wheelers*	*Buses*
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

Source: Agarwal (1996), p.26

Table 10: Passengers Served per Trip (Kolkata Transport Department)

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

Source: Transport Department, Government of West Bengal

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 9). 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 10. 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 shared, with auto drivers rarely starting a run unless the auto has 4 to 5 people in it. We therefore decided to carry out our own field survey of modal occupancy for polluting modes. For this, it may be noted, we required to divide the modes into more categories than was the case when pollution was being measured, because there are certain types, like school buses and chartered[12] buses or 'regular' state buses and 'special' state buses[13], which pollute the same but tend to have different occupancies. On the other hand, in the context of occupancy data private and rented cars are the same, especially as they cannot be distinguished in on-road surveys. We selected 10 well-distributed locations – they are roughly indicated in Map C. The samples were collected over six time segments for a weekday, a Saturday and a Sunday, as travel behaviour differs for each of these. For each mode and location, six samples were taken on each of these time segments and days,

Table 11: Average Occupancies from Primary Survey

Modes	*Weekday*	*Saturday*	*Sunday*	*Average*
Three Wheeler	3.8	3.8	3.8	3.8
Two Wheeler	1.9	1.8	1.9	1.9
Taxi	3.4	3.3	3.7	3.4
Private /Rented Car	4.1	3.8	4.3	4.1
Ordinary State Bus	33.3	37.9	29.2	37.3
Special State Bus	35.8	30.3	27.9	33.7
Executive State Bus	24.3	18.0	42.0	21.0
Ordinary Private Bus	48.8	45.6	41.5	47.3
Chartered Private Bus	34.5	30.9	36.3	34.2
School Bus	32.8	28.9	-	32.1
Mini Bus	31.6	29.9	26.8	30.7

Source: Primary Survey

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 executive buses (which only run on a few routes) meant fewer observations in these cases. Appendix B gives us data on average occupancies of each mode by location.[14] Table 11 gives the end product – occupancies averaged over both time segments and locations for each type of day. A single average is obtained (last column) by taking a weight of 5 for weekdays and 1 each for Saturday and Sunday.

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

Using the summary of occupancy results in the final column of Table 11, and using the estimate of average emissions per unit distance by mode (Table 8), we derive the emissions per person and per unit distance (Table 12). 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.

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 occupancy of 5 for share taxis as these run with this fixed number.

Table 12: Pollution per Person per Unit Distance by Mode

Mode	*Pollution per Person per Kilometre*
Three Wheeler	2.1095
Two Wheeler	5.1235
Taxi	0.8335
Private Car	0.2900
Ordinary State Bus	0.0545
Special State Bus	0.0600
Executive State Bus	0.0735
Ordinary Private Bus	0.1110
Chartered Private Bus	0.1530
School Bus	0.1635
Mini Bus	0.1055
Share Taxi	0.5665
Hired Car	0.6900
Ferry	0.0996

Source: Primary Survey

The two-wheeler is the worst offender, followed by the auto or three-wheeler 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 various types of 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-motorized, and therefore come last in the ranking.

The following list, therefore, gives the complete ranking of all modes of transport, motorized and non-motorized, in terms of the level of pollution per person and per unit distance in descending order.

Table 13: Ranking of Modes

HIGH POLLUTION	
Two-Wheeler	1
Three-Wheeler	2
Taxi	3
Hired Car	4
Shared Taxi	5
Private Car	6

School Bus	7
Chartered Bus	8
Regular Pvt. Bus	9
Mini Bus	10
MEDIUM POLLUTION	
Ferry	11
Executive State Bus	12
Special State Bus	13
Regular State Bus	14
Tram	15
Metro	16
Circular Rail	17
ZERO POLLUTION	
Local Train	18
Rickshaw	19
Bicycle	20
Walking	21

VII. Policy Implications

We obtain a moderately clear scenario of polluting behaviour from the above data. The magnitude of unit emissions for two wheelers is so much higher than for all other modes, as to put this mode in a different category altogether. There is also a significant gap between three wheelers on the one hand and taxis, hired cars and share taxis on the other, with the latter three having similar values. The value for private cars is again lower compared to 'public' cars, perhaps because private cars are better maintained, and then there is again a drop for the buses. The unit pollution drops continuously for the seven types of buses, with lower levels for the state owned buses – perhaps because the turnover rate for state buses is higher. Ferries are in the middle of the list of buses, and the non-polluting modes come last.

The most crucial policy measure, therefore, should be to divert users or potential users of two wheelers towards public HOVs. The transport department should also rethink its policy of giving so many licenses to three wheelers and taxis. Though private cars offend less, there should still be a policy of discouraging the ownership of cars, as they are far worse than the HOVs. Two methods of discouraging the ownership of private vehicles are parking restrictions and higher prices of the fuel used by these vehicles. The third and more important method is to make travel by public transport (preferably HOVs) more attractive.

Buses and the ferry are medium-level offenders. Their exhaust emissions are quite significant, but they also carry many people. There is a clear advantage of buses vis-à-vis the other public modes that are non-polluting – buses have a variety of routes and hence access is easier and travelers don't have to change their modes so much. Thus buses are indispensable. The difference in the proportions of *passengers* using buses (vis-à-vis other modes) and the number of buses in the vehicle fleet is shocking – there need to be more buses, which would reduce waiting time and crowdedness. Also, the quality of bus travel can be improved significantly by having more comfortable seating, better ventilation or perhaps air-conditioning, less bumpy rides, more standing space, etc. The executive state buses are a case in point. Though the ventilation in these buses is not too great (a large part of the windows are blocked by glass) and the size of the seats is not a comfortable one, the wait time is low, the ride tends to be smoother and standing passengers are not allowed, which also means that that getting off the bus is not as painful as it normally is. Even this has made these buses very popular – but very few routes have executive bus services. It is conceivable that owners or potential owners of two wheelers and even cars may opt for such buses, especially if they are made even more comfortable. In New York City, for example, the metro and bus services have made private vehicles largely redundant.

In conjunction with the above, one also has to consider the relative merits of private and public buses. In the last 40 years, private buses have become the more dominant mode whilst public buses have dwindled. It has been seen that these private buses are very uncomfortable to travel in and their travel speed is very irregular, making travel time very uncertain. If the government prefers to let the private sector run buses, it should at least monitor them more closely.

It would be difficult to conceive of the ferry as a major proposition as their development would require significant expenses in terms of maintaining the waterways, some of which have become unusable. Moreover, access would be a limiting factor. Further, opinions may differ on the matter of dividing ferry emissions by a factor of ten because of the larger expanse in which the pollution is being emitted. Those standing near the exhaust pipes, for example, would get a good dose of the emissions, irrespective of the expanse. Thus in the short run the ferry can be promoted only in a limited manner, and issues such as the reduction of emissions and maintaining or building new waterways have to be looked into.

Coming now to the non-polluting modes, bicycles, rickshaws and walking have their usefulness ***within*** localities but do not seriously substitute for the motorized modes in Kolkata. The city does not have bicycle paths and they would be infeasible as road-space is very limited. Moreover, bicycles and rickshaws tend to increase congestion and are best kept out of roads that carry motorized vehicles. Trams have the problem of fixed tracks and a large bulk and tend to create congestion problems – they are being phased out and should at best be available on a few tracks for reasons related more to heritage than efficiency (for example on Chitpur Road and the Maidan).

On the other hand, the Metro and Rail are enormously useful for the city. Whilst the limited road-space limits the number of buses that can possibly ply, the metro and rail have the potential to provide many more passengers with comfortable transportation. They have the advantage of speed and congestion/pollution-free travel; they can be made more comfortable and their wait-time can be reduced. Their main disadvantage is access – hence apart from increasing and improving these services the government should try to solve this aspect. The auto rickshaw plays a major role, for example, in the access of metro stations, and this is unfortunate because not only do they make for uncomfortable and risky travel, but they also pollute a lot, thereby undoing the benefit of the zero-pollution metro. Presently the state government is planning to develop a light rail system that is to run on raised tracks – this system should ideally move in the east-west direction, bringing commuters to the metro or rail lines that presently move in the north-south direction.

We can thus conclude that over and above encouraging the non-polluting modes – in particular the metro and rail, two aspects are critical for transport policy in the coming years – one, an attractive bus service, and two, non-polluting feeder services that make accessing the rail and metro stations more easy. But over and above improving and enhancing the public transport system in the above manner, the state has to strongly discourage the purchase and use of private vehicles.

Appendix A
Methods Used to Measure Vehicular Emissions.

Although at present the concentrations of CO in emissions of petrol driven vehicles and of SPM for diesel driven vehicles are measured by India's pollution control authorities, the latter is done so only on a relative scale. Further, SO_2, NOx and HC are not measured at all. We have therefore made use of the technology used to measure industrial emission velocities of the above-mentioned compounds (ASTM (American Society for Testing and Materials, 1972, D3154) and CPCB (Central Pollution Control Board, 1984-5, p. 18)). This method involves the measurement of average gas velocity using a calibrated Pitot tube at a number of traverse points. As the position and structure of vehicle tailpipes is different from that of chimneystacks, a special attachment – a steel pipe of length 1metre and diameter 100 millimetres, attached with a collar, was constructed and fitted to the tailpipe with the help of adapter systems of various sizes. This pipe was then attached to a monitoring nozzle. The average gas velocity in a duct was measured by using an S-type pitot tube through the monitoring port (ASTM, 1972, D3154). Biram's Anemometer (OSK 15058) was also used to measure emission volumes during static and mobile conditions. 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 period and area of flow, total flow volume can be determined. The Anemometer was placed at the end of the above-mentioned steel pipe to monitor gas volume. The instrument was also fixed in a special module and fitted to the tail pipes of different moving vehicles. This gave us emission volumes in a mobile condition.

Measurement of SPM

The methodology for measuring particulate matter from a stack has been applied (CPCB, 1984-5, p. 18 and ASTM, 1978, D3685). 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.

Measurement of SO_2

SO_2 was monitored following the methods used by CPCB (1984-5, p.18) and ASTM (1979, D3449). A known volume of gas was drawn through a midget impinger containing Hydrogen Peroxide. The SO_2 present was oxidized and then titrated with Barium Perchlorate solution using a thorium indicator. Gas was passed through a filter to prevent particulates from causing interference.

Measurement of Oxides of Nitrogen

The method used by ASTM (1977, D1608) has been followed. 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 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.

Measurement of 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 Non-Dispersive Infra-Red 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.

Measurement of 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 (CPCB, 2003, p.6) and measured.

Appendix B:

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 Mor (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 (Rashbehari Avenue)	31.9	28.1	32.2	31.5
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

Source: Primary Survey

Notes :

1. Between 1911 and 2001, the population of KMC has increased nearly 5 times. Due to a high level of saturation, its growth rate has come down to 4 per cent in the decade 1991-2001, but the KMA continued to grow at a rate of 26 per cent in the same period.
2. For Kolkata, some estimates are still lower, at 4 or 5%
3. These are taxis that have a fixed route and carry five to six persons on a trip.
4. These buses usually transport office goers.
5. These are smaller than the regular size for private buses.
6. The ferries do not service the north-south corridor, though.
7. Estimates of average speed vary between 14 to 20 kilometres per hour (Chatterjee et al, 1999, Banerjee and Das, 2001
8. It has been estimated that motor vehicles were responsible for 24-30 per cent of the total air pollution (Banerji and Das, 2001, p. 287 and Agarwal, 1996), but this share has perhaps increased in recent years.
9. Note that modal changes reduce pollution per person per mile traversed because the new modes are less polluting per se (eg. the metro), or because they carry more people (eg. buses).
10. Table 6 compensates for the absence of data on private vehicles in Table 5, though the nature of the data is somewhat different.
11. As leaded fuels are no longer available, lead was not measured.
12. These usually carry a fixed clientele of office-goers and do not allow standing passengers
13. These used to be better maintained relative to 'regular' buses, but have now fallen into disrepair. But they still have a higher fare structure and therefore are expected to have different average occupancies.
14. The data indicates that there are no significant differences in occupation due to location differences: the variation is just greater for high occupancy vehicles like buses.

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Figure A

Distribution of the number of different registered vehicles in Kolkata on 31.03.2003

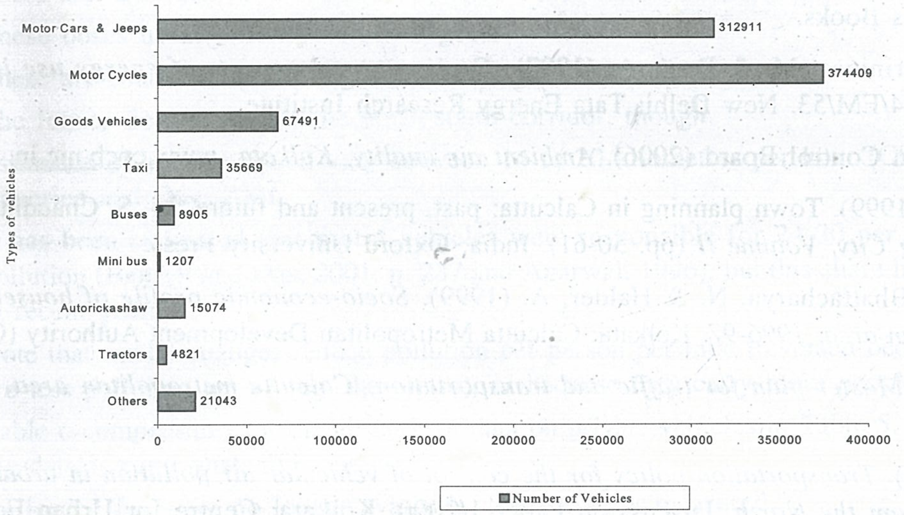
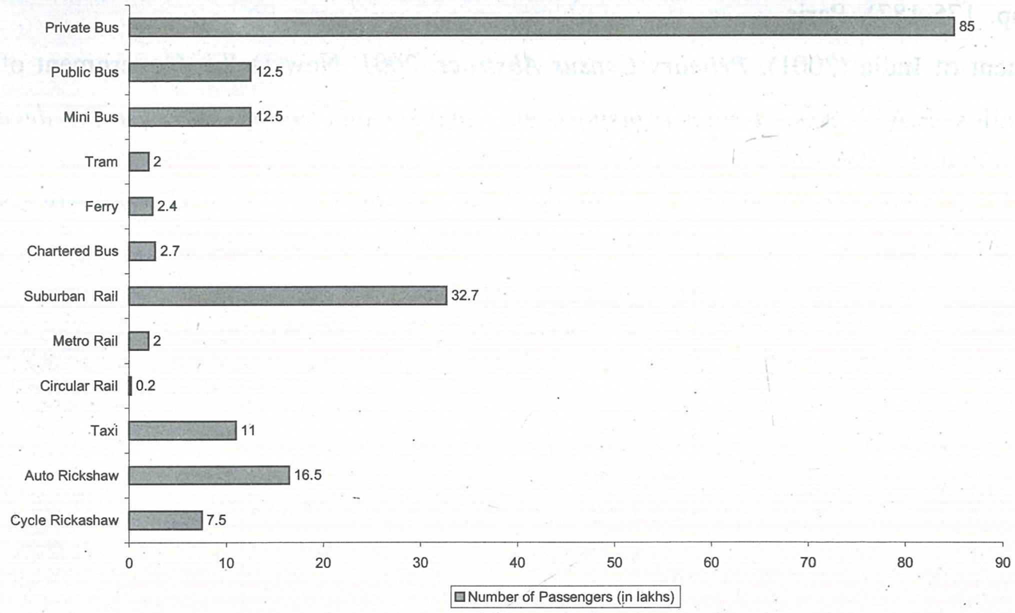
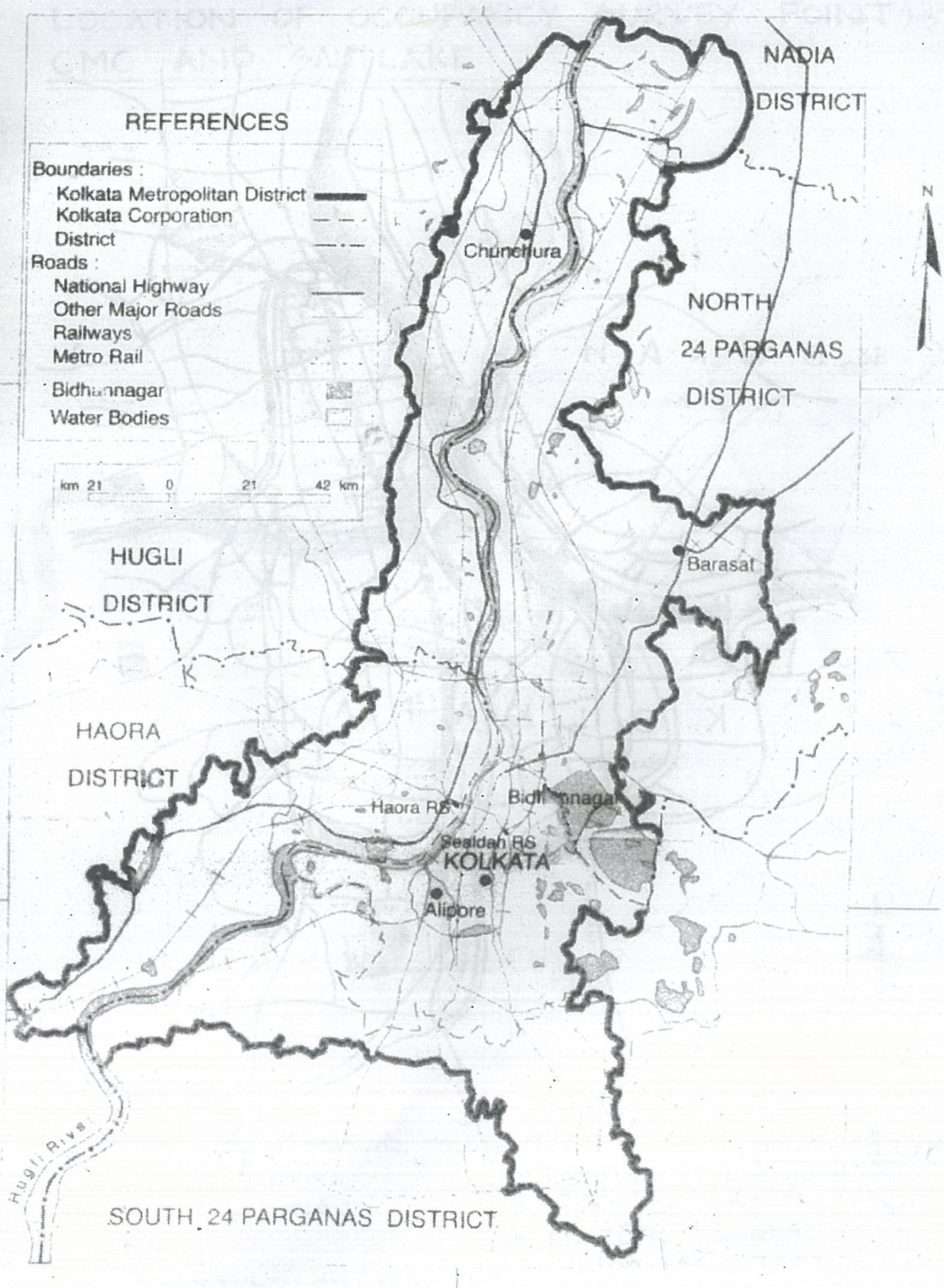


Figure B

Movement of Passengers within KMA, 2001 (in lakhs)

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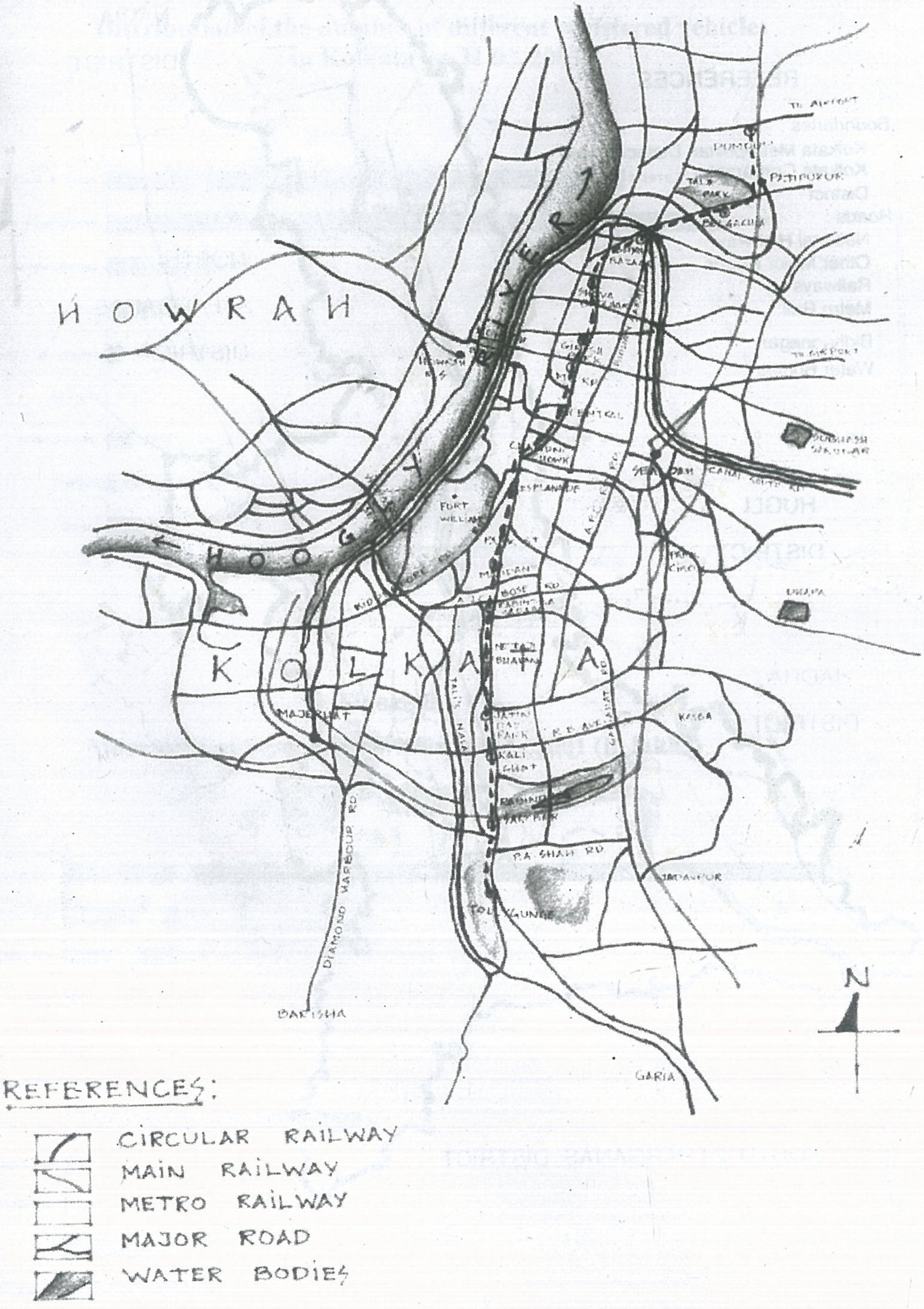
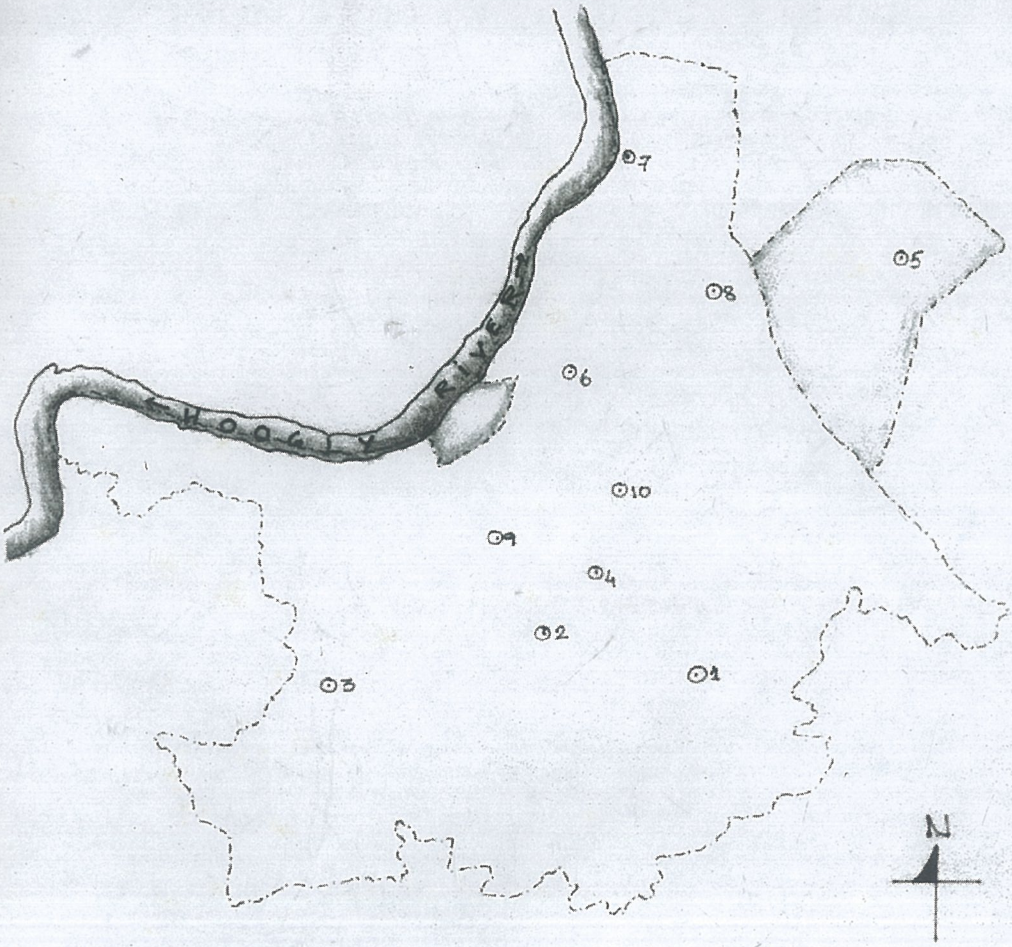
Boundaries :
Kolkata Metropolitan District
Kolkata Corporation
District
Roads :
National Highway
Other Major Roads
Railways
Metro Rail
Bidhannagar
Water Bodies
km 21 0 21 42 km
NADIA
DISTRICT
N
Chunchura
NORTH
24 PARGANAS
DISTRICT
HUGLI
DISTRICT
Barasat
HAORA
DISTRICT
Haora RS
Bidhannagar
Sealdah RS
KOLKATA
Alipore
Hugli River
SOUTH 24 PARGANAS DISTRICT

MAP A


HOWRAH
HOOGHLY RIVER
KOLKATA
DUMDUM
PATIPUKUR
BELGACHIA
FORT WILLIAM
ESPLANADE
PARK ST
MAIDAN
BOSE RD
NETAJI BHAVAN
JATIN DAS PARK
KALI GHAT
R.B. AVE
KASBA
P.A. SHAH RD
TOLLYGUNGE
MAJERHAT
DIAMOND HARBOUR RD
BARISHA
GARIA
N
REFERENCES:
CIRCULAR RAILWAY
MAIN RAILWAY
METRO RAILWAY
MAJOR ROAD
WATER BODIES

MAP B

LOCATION OF OCCUPANCY SURVEY POINTS, CMC AND SALTLAKE



REFERENCES:

1. SULEKHA
2. TIPU SULTAN MASJID, TOLLYGUNGE
3. AJANTA CINEMA
4. DESHAPRIYA PARK.
5. PNB
6. B.B. GANGULY/CHITTARANJAN AVENUE CROSSING
7. B.K. PAL / CHITPUR CROSSING
8. ULTADANGA - ESI HOSPITAL
9. EXIDE CROSSING
10. ENTALLY 'DWARIKS'

MAP C