Two-and-Three-Wheelers in India

June 2009

FINAL REPORT

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For:
International Council for Clean Transportation (ICCT)
& The Institute for Transport and Development Policy (ITDP)

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1 Background

India, like other developing countries, is characterized by its rising population, mounting urbanization and motorization, and low per-capita income. Its total urban population burgeoned over the past three decades, rising from 109 million in 1971 to 160 million in 1981 (+47%), 217 million in 1991 (+36%), and 285 million in 2001 (+31%) (Census, 2001). The largest cities have grown especially fast. By 2001, India had three mega cities: Mumbai (Bombay) with 16.4 million inhabitants, Kolkata (Calcutta) with 13.2 million, and Delhi with 12.8 million. Chennai (Madras), Hyderabad, and Bangalore each had more than 5 million residents. And the populations of 35 metropolitan areas exceeded one million residents each, almost twice as many as in 1991 (Census 2001). The rapid growth of India's cities has generated a corresponding growth in travel demand and increased levels of motor vehicle ownership and use.

As Indian cities have grown in population, they have also spread outward. A lack of effective planning and land-use controls has resulted in rapid, rampant sprawl extending beyond old city boundaries and into the distant countryside. This greatly increased the number and length of trips for most Indians, forcing further reliance on motorized transport. Longer trips make walking and cycling less feasible, while increased motor vehicle traffic makes walking and cycling less safe. Most public policies in India encourage sprawl and new commercial development often takes place in distant suburbs. For example, Tidal Park is a software center on the outskirts of Chennai; Gurgaon is a large new industrial area outside Delhi; and Pimpri-Chinchwad is a center outside Pune (Bertraud, 2002). Similarly, Bangalore is planning several technology parks on its fringe as well as several circumferential highways in the suburbs, both of which will induce further decentralization. In most cases, there is inadequate transport infrastructure to serve these new suburban developments and the residences located around them. Ramachandran (1989) characterizes Indian suburbs as an "uncontrolled mix of industrial development, dumps and obnoxious uses," with the "extension of urban settlement causing conditions in the overtaken villages to deteriorate, both physically and socially." This leap-frog development, typical of suburban sprawl, tends to follow major highways out of Indian cities to the distant countryside.

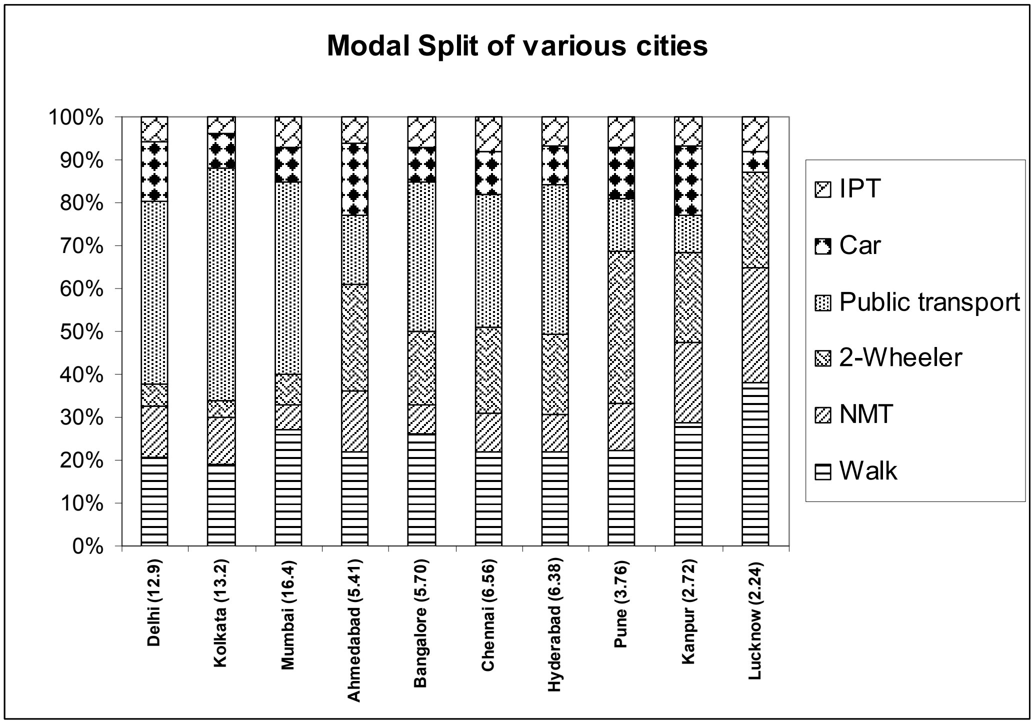
Low-density decentralization causes enormous problems for public transport. It generates less focused trips along well-traveled corridors and, thus, is more difficult for transport to serve. In India, it has led to rapid growth in car and motorcycle ownership and use and resultant congested roadways that slow buses, increase bus operating costs, and further discourage public transport use. As cities grow and trip distances become

Traffic Congestion in an Indian City

longer, walking and cycling account for about half of all trips in medium-sized cities and about a third in the largest cities. There is considerable variation, however, even within city-size categories. Among mega cities, for example, walking and cycling are much less common in Mumbai than in Delhi, perhaps due to Mumbai's superior public transport system. Among smaller cities, Kanpur and Lucknow have much higher proportions of walking and cycling than Pune, which has a very high level of motorcycle ownership and use due to its large middle class, as well as an extensive charter bus services organized by Pune's industrial firms for their employees. By comparison, residents of Kanpur and Lucknow have lower incomes and a resultant much lower level of motorcycle use and minimal bus service. Instead, they rely on a mix of paratransit modes such as auto rickshaws, cycle rickshaws, jeep taxis, and tempos (large auto rickshaws). (J. Pucher et al., 2005).

As of 2006, private motorized transport (mainly cars and motorcycles) accounted for a small but rapidly growing percentage of travel, about 10–20% of all trips (see Figure 1). Figure 2 dramatizes the rapid 16-fold growth of motorcycle ownership between 1981 and 2002. Private car ownership increased almost seven-fold during the same period. The sprawling, low-density development around Indian cities makes cars and motorcycles increasingly necessary, especially given the unsatisfactory alternative of slow, overcrowded, undependable, and dangerous public transport services. At the same

Figure 1 Percent Distribution of Urban Trips by Means of Travel for Selected Indian Cities, 2006.



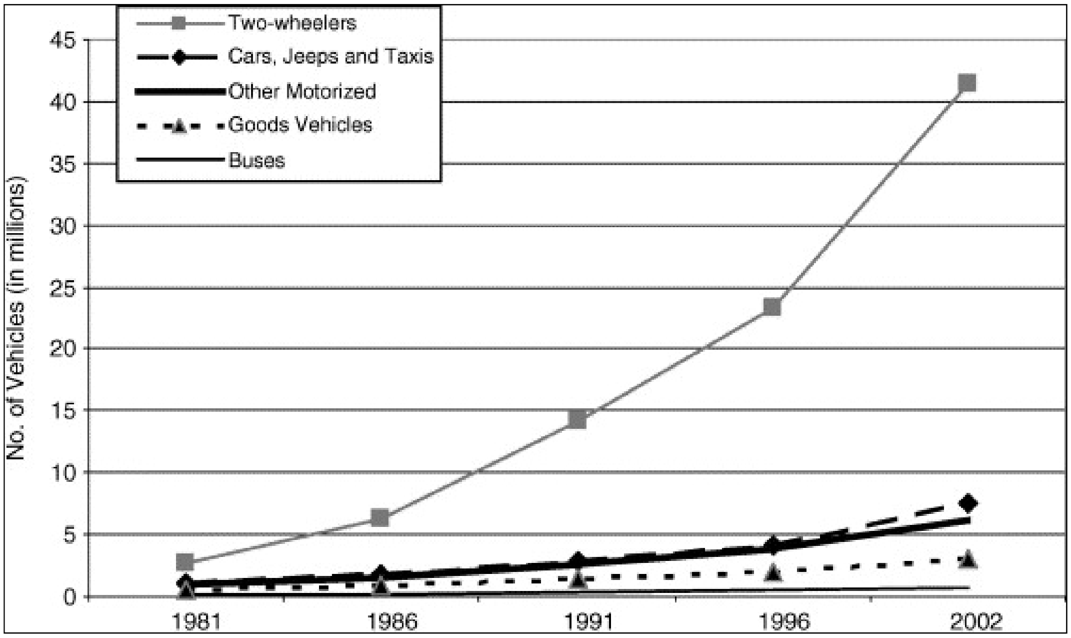
Source: Various CDPS from http://www.jnnurm.nic.in/nurmudweb/missioncities.htm

time, rising incomes among India's middle and upper classes make car and motorcycle ownership increasingly affordable. Cars which cost upward of $6,000 and motorcycles which require an outlay of around $1,000 are the two major choices for private vehicle ownership and serve two different sections of the market. Level of service (comfort) and travel time are the principal priorities for those in the high income population group, while initial capital investment and operating costs are the major deciding factors for those in the middle income class. Because of this, cars and two-wheelers have separate niche markets and, in general, they are not competitors. The Tata Nano, the new $2,500 car launched by Tata, aims to capture some of the two-wheel market. However, its success will hinge on whether consumers are willing to pay its operational and maintenance costs that are greater than those of a two-wheeler.

The three-wheelers on the other hand provide for the mobility needs of people not owning a private transport mode and inadequately served by the public transport system. They are discussed in detail in the following section.

Three-wheeled scooter rickshaws (TSR) play an important role as paratransit modes in most cities in India. According to official statistics, 86,185 were registered in Delhi in 2001. The number registered in 1996 was 80,208 and 87,785 in 1999

Figure 2 Growth of India's Motor Vehicle Fleet by Type of Vehicle, 1981–2002 (In Millions).



(Source: J. Pucher et al., Transport Policy 12 (2005) 185–198)

Note: "Other Motorized" includes tractors, trailers, motorized three-wheelers (passenger vehicles) such as auto rickshaws and other miscellaneous vehicles that are not separately classified.

(Mohan et. al. 2003). It is estimated that the population of Delhi increased by 20% between 1996 and 2001, but the above statistics show that the availability of TSRs increased by only 7% in the same period. Also, they have unique safety and pollution problems. They have high emission levels but cannot be substituted easily by modern vans or buses because of economic and financial constraints. However, the three-wheeled scooter taxis are now coming equipped with four-stroke petrol engines or CNG engines which make emissions per passenger less than those of cars. Yet, research into safety, efficiency and environment friendly technologies for these vehicles is not a priority in India or any other country.

According to Mohan and Roy (2003), TSRs should be the preferred personal transportation mode and should be encouraged in urban areas provided they run on LPG/CNG or four-stroke petrol engines equipped with catalytic converters. Ample availability of TSRs (and taxis):

- Encourages public transport use which can easily get passengers from point-to-point in a hurry
- Encourages non-ownership of private vehicles because point-to-point transportation is easily available for special occasions.

A Three-Wheel Rickshaw in New Delhi

- TSR/taxi drivers do not cheat when supply is abundant and fare structure is reasonable, so passengers are not scared of hassles and arguments.

Greater use of TSRs reduces the need for parking places. A private car needs a minimum of two parking places – one at home and one at its destination. Whereas, a TSR just needs one parking place in the city and if it does 10 trips a day, it reduces the need for nine parking places at home and the destination.

A TSR is preferable to a car, can carry the same number of people on average, takes one-third the parking area and one half of the space on the roadway. Since its weight is one-third of that of a car, it is responsible for less deterioration to the road, requires less tire/rubber use, and takes one-third the national resources to produce. All this reduces indirect pollution. Since TSRs have a small engine (175 cc vs. 800 cc for Maruti), they pollute much less per passenger than most cars. Their small engine size holds speeds to roughly 50 km/h, in keeping with urban speed limits. This also helps control the speeds of others. Because of lower speeds and lighter weights, they can't easily produce fatal accidents among pedestrians and bicyclists. Therefore, TSR use should be encouraged as much as possible in urban areas of India.

2 An Industry Overview

The motor vehicle industry in India underwent a sea of change during 1985-1991 when economic reforms aimed at encouraging competition were introduced. During this period, the two-wheeler industry saw the largest proliferation of brands in the consumer durables industry. From then on the rate of growth of two-wheelers increased rapidly over the next two decades. (Pucher et al, 2005).

The following tables show the production and sales trends of various automobiles in India.

Table 1 Automobile Production Trends

Year of Observation, (Number of Vehicles)						
Category	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
Passenger Vehicles	723,330	989,560	1,209,876	1,309,300	1,545,223	1,762,131
Commercial Vehicles	203,697	275,040	353,703	391,083	519,982	545,176
Three-wheelers	276,719	356,223	374,445	434,423	556,126	500,592
Two-wheelers	5,076,221	5,622,741	6,529,829	7,608,697	8,466,666	8,026,049
Grand Total	6,279,967	7,243,564	8,467,853	9,743,503	11,087,997	10,833,948

Source: http://www.siamindia.com/

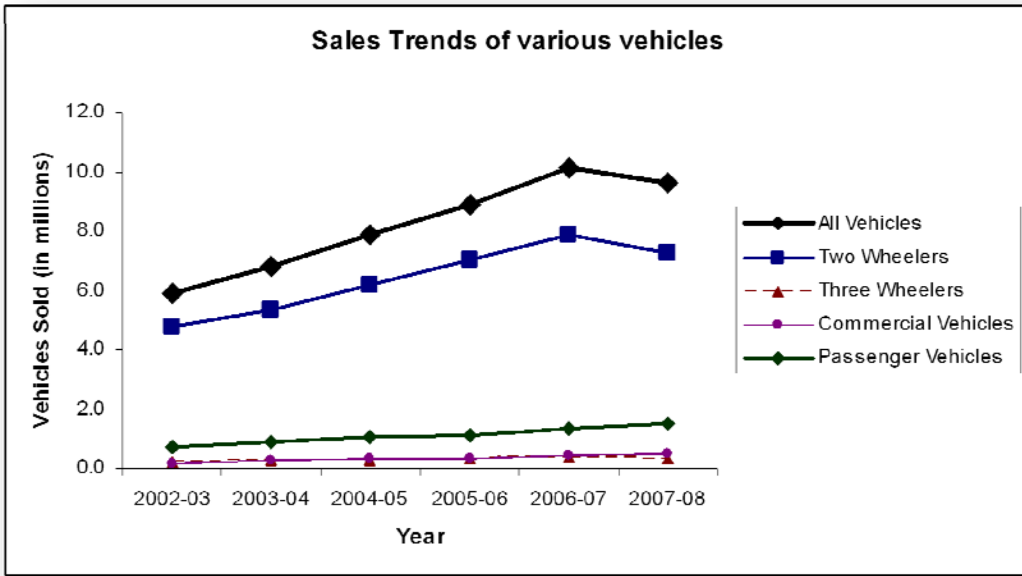
Table 2 Automobile Domestic Sales Trends

Year of Observation, (Number of Vehicles)						
Category	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
Passenger Vehicles	707,198	902,096	1,061,572	1,143,076	1,379,979	1,547,985
Commercial Vehicles	190,682	260,114	318,430	351,041	467,765	486,817
Three-wheelers	231,529	284,078	307,862	359,920	403,910	364,703
Two-wheelers	4,812,126	5,364,249	6,209,765	7,052,391	7,872,334	7,248,589
Grand Total	5,941,535	6,810,537	7,897,629	8,906,428	10,123,988	9,648,094

Source: http://www.siamindia.com/

The sales trends shown above have been represented in the following figure.

Figure 3 Sales Trends of Different Vehicle Types



From the total numbers, the percentage share of each vehicle type is calculated and presented in the following table.

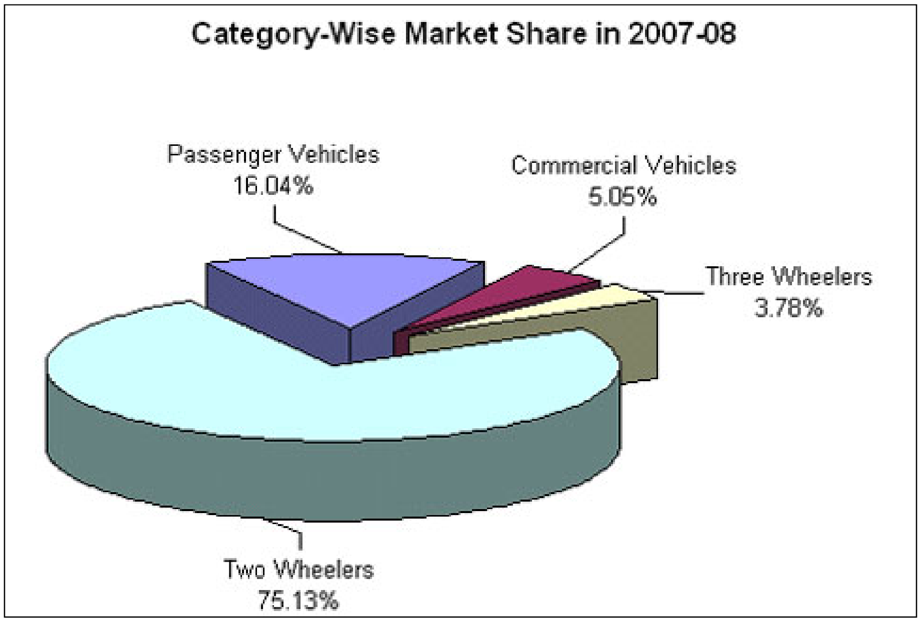
Table 3 Domestic Market Share for 2007-08 for Various Vehicles

Vehicle Type	Market Share
CVs	5.05%
Total Passenger Vehicles	16.4%
Total Two-wheelers	75.13%
Three-wheelers	3.78%

Source: http://www.siamindia.com/

The following figure gives the above data as a pie chart.

Figure 4 Vehicle Category Wise Market Share (2007-08)



Domestic Sales

The cumulative growth of the passenger vehicle segment between March and April 2007 was 20.70%. Passenger cars grew by 22.01%, utility vehicles by 13.21% and multi-purpose vehicles by 25.20% in fiscal year 2006-07.

The commercial vehicles segment grew by 33.28%. Growth of medium and heavy commercial vehicles was 32.84% and light commercial vehicles recorded a growth of 33.93%.

Three-wheelers sales grew by 12.22% with sales of goods carriers increasing by 13.52% and passenger carriers by 11.33% during March and April 2007 compared to the corresponding period the previous year.

The two-wheeler market grew by 11.42% during March and April 2007 over the same period last year. Motorcycles grew by 12.79%, scooters by 3.48%, and mopeds registered a growth of 6.95%.

(Source: www.siamindia.com)

2.1 Driving forces of Two-and-Three-Wheeler Industries

The market factors that drive demand and influence customer preferences for two-and-three-wheelers are discussed below.

Two-Wheelers

Three major forces have bearing on this industry: the manufacturers, financial institutions and the regulators (Ministry of Environmental Regulations and civil society groups).

Manufacturers: Producers launch various models and lobby government to provide better facilities for two-wheelers.

Financial Institutions: These firms drive the market by creating low interest loans which in turn allow more people to purchase two-wheelers.

Ministry of Environment Regulations and Civil Society Groups: There are no regulations on two-wheeler ownership/sales in a city with the exception of rules governing emissions. India's emission norms are among the most stringent in the world (Iyer, BAQ, 2008). Therefore, the Ministry of Environmental Regulations, which sets emission norms, and civil groups like Centre for Science and Environment and other such NGOs that lobby for stricter norms also add up to the driving forces of the industry.

Three-Wheelers

The three-wheelers cater to the mobility needs of those not using private transport and not being served by the existing public transport system. In this way, they serve the needs of a section of the society by acting as cheap taxis. They have smaller engine capacities and higher mileage rates than the regular car taxis.

The major driving force behind the three-wheelers is the policy makers who decide various issues, such as the total number allowable in the cities and fare policies, etc. There is a general tendency among policy makers in various Indian cities to phase out three-wheelers which they see as competition to public transport, air polluters, slow and unsafe. This informal transport alternative is not always backed by sufficient data to counter these claims. Also, the fact that three-wheelers cater towards mobility of a particular section of the population (i.e., those not using private transport or the existing public transport system) is also ignored while forming the policies.

3 Government Policies Towards Two-and-Three-Wheelers

India is a federal state, which means that the total powers on various policy matters are shared between the central or national government and the states. Generally, policies on various issues are developed by the central government, but implemented by the states. Regulating a particular mode of transport by specifying limits in a city, such as implementing helmet laws or regulating emissions, are in the hands of the state government, resulting in varying policies from state to state.

The transport sector policies in India are made by two ministries of the government:

1. Ministry of Shipping, Road Transport & Highways (MoSRT&H)
2. Ministry of Urban Development and Poverty Alleviation (under which Urban transport is a subdivision)

In the various policies of these ministries, no specific guidelines for two-and-three-wheelers are mentioned. Rather, the policy measures are aimed at increasing mobility by encouraging public transport and not encouraging the use of private modes of transport (NUTP, 2005). Since two-wheelers come under the category of privately owned vehicles, the policies are indirectly designed to discourage two-wheeler usage. Among private transport rules, no specific preference for a two-wheeler over a car or a car over a two-wheeler is mentioned. Two-wheelers have benefits in terms of road space, cost, mobility and release of green house gases. However, safety, emissions and equality of the problems associated with two-and-three-wheelers need to be addressed.

Three-wheelers in India act as intermediate public transport (IPT), a feeder system to public transport in large cities. They are the only available transport for people not owning vehicles in places where public transport is unavailable. A successful public transport system with high ridership requires a good network of three-wheelers. However, the policy guidelines of the ministry of urban development (as given in the National Urban Transport Policy (NUTP), 2005) encourage public transport while ignoring any mention of three-wheelers. The policies of other ministries such as issuing low-interest loans to the poor are encouraging people to buy more three-wheelers as employment opportunities. The following sections discuss the various government incentives and the tax policies toward two-and-three-wheelers.

3.1 Government Incentive Policy

Incentives are provided in the form of low interest loans to buy new vehicles. The government, through various public sector banks, gives loans to people at interest rates about half to one-third less than that of private financiers. The various policies of the government toward the vehicle loans are explained below.

Two-wheeler Loans

A loan of up to 90% of the on-road price of the vehicle or Rs. 60,000, whichever is less, can be received at an interest rate of 13.25 to 16.25%. The repayment period varies from 1 to 5 years, based on the interest rate. The eligibility criterion for this is that the gross annual income of the person getting the loan should not be less than Rs. 60,000 /-.

Four-wheeler Loans

A loan of up to 90% of the on-road price of the vehicle or three years gross income of the loan seeker, whichever is less, can be borrowed from banks at interest rates of 11.75 to 13.5%, depending upon the bank. The life of the loan various from 1 to 6 years based on the interest rate. The eligibility criterion is a gross annual income not less than Rs. 1,00,000/- and also, the person claiming the loan should have a residential telephone in their name.

In the case of second-hand four-wheelers, loans are given only for vehicles less than three years old. The maximum amount of the loan is Rs. 5.00 lakhs. The maximum repayment period is five years.

Three-wheeler Loans

The loan policies for three-wheelers are similar to the ones for two and four-wheelers. However, as a measure of poverty alleviation and employment generation, the government has waived the requirement of security deposits for the unemployed poor, if they provide the appropriate income certificate. This has lead to an increase in the three-wheeler ownership of people with low incomes.

Incentives to Women

To improve the standard of life for women, the government provides loans at a special interest rate 1% less than that charged men. The rest of the requirements are identical.

A Four-Wheel Rickshaw

Private Financiers and Grievances of Three-Wheeler Owners

The interest rates on loans received from private financiers is in the range of 30 to 40%, but the requirements for obtaining a loan are less stringent than that offered by public sector banks. Also, public sector banks do not loan money for second-hand three-wheelers. Therefore, anyone wanting to buy a new three-wheeler should first buy an old one and exchange it for a new one. In general the second hand or the old vehicle costs around Rs. 100,000/- and a new one costs around Rs. 300,000/-. Also, this transaction is done through private dealers who charge around Rs.25,000 to Rs. 50,000. Hence the total cost to buy a new three-wheeler adds up to about Rs. 450,000. Out of this, loans from the public sector banks are given only for the new vehicle, i.e., Rs. 100,000/-. This practice forces people buying three-wheelers to obtain loans from private financiers at high interest rates. As a result, operators who own a fleet of three-wheelers and rent them everyday find it easier to buy new three-wheelers than individuals wanting to buy their own.

3.2 Tax Policies Towards Two-and-Three-Wheelers

The road user-tax on two-and-three-wheelers is controlled by state governments which each have different rates. States collect the road user tax for two-wheelers as a lump sum for a period of 15 years at the time a new vehicle is registered. Some states collect

Table 4 Road User Tax in Different States (As a Percentage of the Vehicle Cost)

State	2-Wheeler Tax		3-Wheeler Tax
Andhra Pradesh	9%		9%
Delhi	2%		2%
Karnataka	9%		9%
Madhya Pradesh	5%		6%
Orissa	5%		5%
Punjab	<50 cc	1.50%	Rs 150/ Yr
	>50cc	3%	
Uttar Pradesh	Rs 1600 (around 4%)		Rs 380/ Yr
Tamil Nadu	6%		Rs 280/ Yr
Bihar	Rs 900-1500*		Rs 990-1920*

*-- Exact amount depends on the weight of the vehicle

Source: http://www.morth.nic.in/related_catmain.asp?rellinkid=27&langid=2

tax on three-wheelers on a yearly or quarterly basis. The following table gives the tax in some selected states, to get an idea of the variations in tax collected in different states. A vehicle registered in one state which later needs to operate in a different state is subject to that state's registration and road user tax.

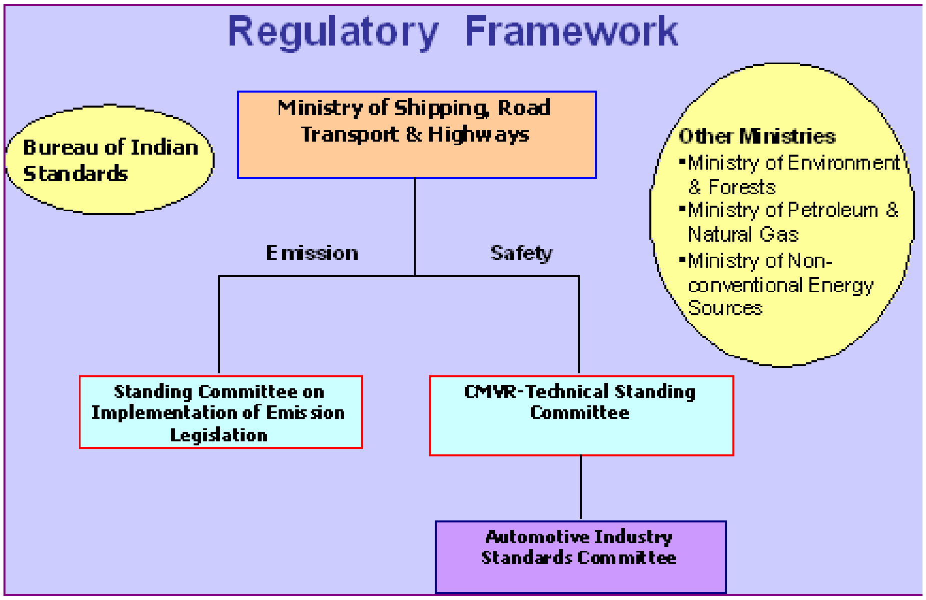
4 Regulatory Framework at Policy and Individual Levels

The regulatory policies developed by the central government will be discussed in section 4.1. The remaining sections discuss their effect on individual users.

4.1 Regulations Related to Users

In India, the rules and regulations related to driving licenses, motor vehicle registration, traffic control, construction and maintenance of motor vehicles, etc., are governed by the Motor Vehicles Act 1988 (MVA) and the Central Motor Vehicles Rules 1989 (CMVR). The Ministry of Shipping, Road Transport and Highways (MoSRT&H) acts as a nodal agency to devise and implement provisions of the Motor Vehicle Act and CMVR.

Figure 5 Regulatory Framework for Automobiles in India



Source: http://www.siamindia.com/scripts/regulatoryframework.aspx

In order to involve all stake holders, MoSRT&H has established two committees to advise on issues of safety and emissions, namely:

- CMVR- Technical Standing Committee (CMVR-TSC)
- Standing Committee on Implementation of Emission Legislation (SCOE)

CMVR- Technical Standing Committee (CMVR-TSC)

This committee advises MoSRT&H on technical aspects related to CMVR. It is comprised of representatives from various organizations, including the Ministry of Heavy Industries and Public Enterprises (MoHI&PE), MoSRT&H, Bureau Indian Standards (BIS); testing agencies such as Automotive Research of India (ARAI), Vehicle Research Development and Establishment (VRDE), Central Institute of Road Transport (CIRT); industry representatives from Society of Indian Automobile Manufacturers (SIAM), Automotive Component Manufacturers Association (ACMA) and Tractor Manufacturers Association (TMA); and representatives from state transport departments. Major functions of the committee are:

- To provide clarity and interpret the central motor vehicle rules which have technical bearing on MoRT&H.

- To recommend international/foreign standards that the government can use in lieu of those set out under the CMVR permit use guidelines for components/parts/assemblies.
- To make recommendations on any other technical issues having direct relevance to the implementation of the Central Motor Vehicle Rules.
- To recommend new safety standards for components for notification and implementation under Central Motor Vehicles Rules.
- To make recommendations on lead time for implementing safety standards.
- To recommend changes in Central Motor Vehicle Rules in view of modifications in automobile technologies.

CMVR-TSC is assisted by another committee called the Automobile Industry Standards Committee (AISC), comprised of members from various stakeholders, in drafting technical standards related to safety. The committee's major functions are:

- Prepare new safety standards for automotive items
- Review and recommend amendments to existing standards
- Recommend adoption of such standards to CMVR Technical Standing Committee
- Recommend commissioning of testing facilities at appropriate stages
- Recommend the necessary funding of such facilities to the CMVR Technical Standing Committee, and
- Advise CMVR Technical Standing Committee on any other referred issues

The National Standards for Automotive Industry are prepared by Bureau of Indian Standards (BIS). The standards formulated by AISC are also converted into Indian Standards by BIS. The standards formulated by both BIS and AISC are considered by CMVR-TSC for implementation.
(http://www.morth.nic.in/index2.asp?langid=2&sublinkid=204)

Standing Committee on Implementation of Emission Legislation (SCOE)

This committee considers issues related to emission regulations. Its major functions are:

- To discuss future emission norms
- To recommend norms for in-use vehicles to MoSRT&H
- To finalize the test procedures and the execution strategy for emission norms
- Advise MoSRT&H on any issue relating to implementing emission regulations.

Based on the recommendations from CMVR-TSC and SCOE, MoSRT&H issues notification for necessary amendments / modifications in the Central Motor Vehicle Rules.

In addition, other ministries, including Ministry of Environment & Forest (MoEF), Ministry of Petroleum & Natural Gas (MoPNG) and Ministry of Non-conventional Energy Sources, are also involved in shaping regulations governing emissions, noise, fuels and alternative fuel vehicles.

These are policies of the government and hence affect users at aggregate levels. Regulations related to individual users are explained in following sections. Emission regulations on new and in use vehicles are detailed initially, followed by methods of enforcement. The actual emissions are explained in section 4.4. After the regulations are in place and if the emissions cannot be adequately controlled, alternative technologies must be explained. Those available technologies are discussed in section 4.5.

4.2 Regulations Related to Emissions

Since the two-wheelers (75% in 2007-08) and three-wheelers (4% in 2007-08) constitute about 80% of the total number of vehicles in India, their emissions also form a significant proportion of total vehicle pollution. The primary pollutants are particulate matter, hydro-carbons and nitrogen oxide. Left unchecked, these pollutants can produce serious health consequences.

Emission Standards by the Government

The emission standards were first adopted in 1991 and have been continuously upgraded since then. The first major revision occurred in 1996, the second in 2000, the third in 2005 and the next in 2010.

The following table provides the chronological order of emission standards and also various pollutants. These norms are for new vehicles.

Table 5 Emission Norms for Two-and-Three-Wheelers in India (Fuel—Petrol)

YEAR	PETROL 2-W		PETROL 3-W	
	CO	HC+Nox	CO	HC+Nox
1991	12 to 15	8 to 9	30	12
1996	4.5	3.6	6.75	5.4
2000	2	2	4	2
2005*	1.5	1.5	2.25	2
2010*	1	1	1.25	1.25
*DF	1.2	1.2	1.2	1.2

DF*: Deterioration Factor, Note: All units are in gm/ km

(Source: N.V. Iyer, Managing Two- and Three-Wheeler Emissions--National Workshop on the Improvement of Urban Air Quality of Pakistan, 13 - 15 December, 2004, Lahore, Pakistan)

Table 6 Emission Norms for Two-and-Three-Wheelers in India (Fuel—Diesel)

YEAR	DIESEL 2 and 3 Wheelers		
	CO	HC+Nox	PM
1991	14.3	20	
1996	5	2	
2000	2.75	0.97	0.14
2005*	1	0.85	0.1
2010*	0.5	0.5	0.05
*DF	1.1	1	1.2

DF*: Deterioration Factor

(Source: N.V. Iyer, Managing Two-and-three-wheeler Emissions---National Workshop on the Improvement of Urban Air Quality of Pakistan, 13 - 15 December, 2004, Lahore, Pakistan)

The following tables give the standards to be followed by vehicles already in use.

Table 7 Emission Standards for In-Use Petrol/CNG/LPG Driven Vehicles

VEHICLE TYPE	CO, % vol	HC, ppm
2&3 wheelers (2/4-stroke), pre-2000	4.5	9000
2&3 wheelers (2-stroke), post-2000	3.5	6000
2&3 wheelers (4-stroke), post-2000	3.5	4500
Bharat Stage II compliant 4-wheelers	0.5	750
4-wheelers other than Bharat Stage II compliant	3	1500

(Source: N. V. Iyer, Environment Friendly Vehicles – the Indian Experience-, National Workshop on Urban Air Quality Management and Integrated Traffic Management for Karachi, September 13 - 14, 2006, Karachi.)

Table 8 Emission Standards for In-Use Diesel Vehicles

Method of test	Maximum smoke density	
	Light absorption coefficient, (1/m)	Hartridge Units
Free acceleration test for turbo charged engine and naturally aspirated engine	2.45	65

(Source: N. V. Iyer, Environment Friendly Vehicles – the Indian Experience-, National Workshop on Urban Air Quality Management and Integrated Traffic Management for Karachi, September 13 - 14, 2006, Karachi.)

Maximum limits for critical ingredients like benzene in petrol have been specified at 5% m/m in the country and 3% in the metropolitan areas. To address the excessive pollution in the four metro cities of Delhi, Mumbai, Kolkata and Chennai, 0.05% sulfur content in petrol and diesel has been set since 2000-2001. The benzene content has been further reduced to 1% in Delhi and Mumbai.

These progressively rigid standards resulted in significant technological advances and the introduction of exceedingly low emission vehicles. This arrested further deterioration of air quality, but resulted in insignificant reductions in ambient pollution levels of PM10 and CO. (Note: Significant contributions of PM10 come from diesel vehicles and CO from passenger cars)

Also, the benefits obtained from cleaner, new vehicles are negated by the pollution contributed by large numbers of older vehicles that are poorly maintained and have no emission controls (Source: N.V. IYER, 2001).

4.3 Methods to enforce the emission regulations

Two levels of checks are needed to ensure that the above mentioned standards are met:

1. Verify that vehicle manufacturers are complying with emission standards
2. Confirm that owners are maintaining their vehicles up to the required standards

The enforcement methodology is explained in this section.

1. **Check on the manufacturers**:

   This is generally done in the following ways:

Type Approval and Conformity of Production (COP) Tests

These tests are done on each vehicle coming out of the manufacturing plant to ensure tail pipe emission standards are being met. Once new vehicles are sold, emission tests are not required for the first year.

Type Approval Tests

All new vehicles need a type approval certificate stating that the model is among those listed in Rule 126(A) of the Central Motor Vehicle Rules (CMVR), 1993. This test needs to be carried out by a government-recognized testing agency (eg iCAT in Manesar, Haryana).

Conformity of Production (COP) Test

The same agency that does the type approval generally does the COP test. However, the manufacturer can go to another agency if desired. The COP period for a vehicle/engine model is every six months from April to September and October to March, or production of 25,000 vehicles/engines if the vehicles are anything other than two-and-three-wheelers. However, if production of a model including its variants in a year (i.e. two consecutive COP periods of six months each) is less than 5,000 in the case of other vehicles (other than two or three-wheelers) the COP interval shall be one year.

The sampling size is one day's average production, subject to a minimum of 10 and maximum of 100. For low-volume production vehicles (<250 numbers in six months) sampling size shall be minimum 5 numbers for Bharat Stage II/ Bharat Stage III vehicles/engines. In case of CBU Bharat Stage II/ Bharat Stage III vehicles, where import is less than 5 numbers at a time, the sample size may be limited to three.

If the vehicle/engine meets the requirements of COP, the test agency issues a COP certificate to the manufacturer. The certificate will cover the vehicle/engine model and its variants planned or produced during the COP interval. The test agency will also send the copies of the certificate to other testing and nodal agencies.

If the vehicle/engine fails to meet the requirements, the testing agency sends copies of the test report to the nodal agency and the manufacturer. The nodal agency makes a decision and conveys it to the manufacturer and test agencies within four weeks of its report and after calling for a standing committee meeting to advise the nodal agency. The vehicle/engine manufacturer gets an opportunity to appeal his case before the committee. Based on committee recommendations, the nodal agency may withdraw the type approval certificate and issue a stop-work order on the vehicles/engines.

Fuel Economy Labeling of Vehicles

Fuel economy labels are affixed to manufactured products to describe energy performance (usually in the form of energy use, efficiency, or energy costs). These labels give consumers the information necessary to make informed energy efficient purchases. In India this is only mandatory for a few items like air conditioners and refrigerators but not for vehicles. In the case of vehicles a "voluntary disclosure of fuel economy" method is followed. The vehicle manufacturer displays the fuel economy label along with the vehicle's model name, fuel used (Petrol/ Diesel/ CNG) and the mileage (certified km per litre).

Standard Test Conditions

Approved agencies conduct tests on all the vehicles under "standard test conditions". Among many parameters, standard test conditions include: two persons in the car/two-wheeler, air conditioning switched-off (for cars); standard (non-adulterated) fuel; gear changes in a predetermined pattern and at predetermined acceleration levels; standard air pressure in the tires; wind speed; etc. Test conditions at the certification agency are identical for all vehicles, irrespective of manufacturer, so the customer can make correct comparisons of fuel efficiency, across car models. Some test centers like iCAT are authorized to carry out these tests and only labeling done there is valid (Maruti Suzuki India Limited, 2008).

2. Check on the Users

The following measures have been adopted for the in-use vehicles. (Source: N. V. Iyer, 2006, Karachi)

Sound Inspection & Maintenance Program

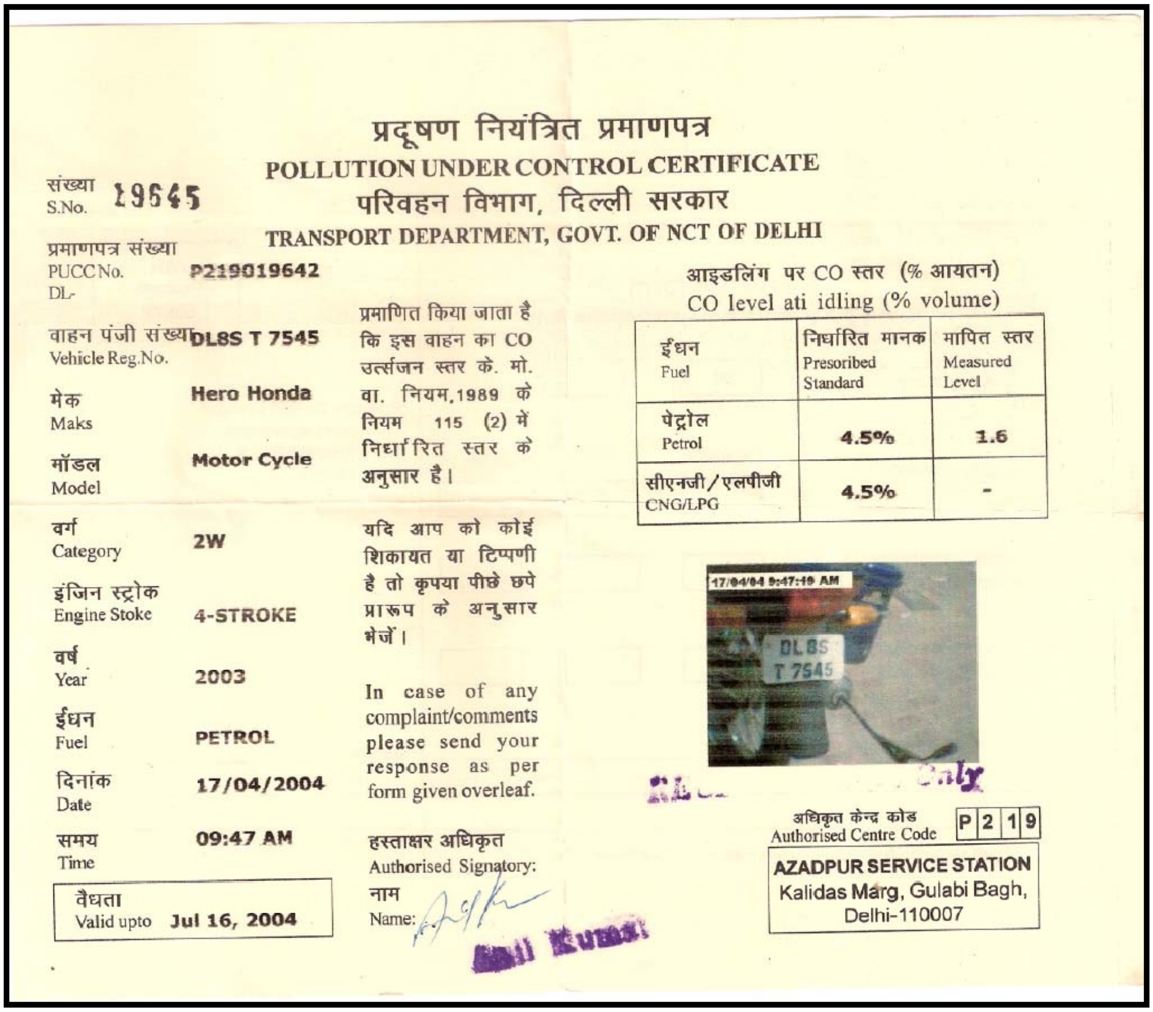
To check that the vehicles are observing the prescribed norms the PUC (Pollution under Control) certificate is mandatory for all the vehicles. All vehicles are required to pass an emission inspection every year and obtain a certificate that states all emission standards are being met.

The PUC certificate is issued after the following procedure:
State transport departments authorize some emissions checking centers in various cities. These are generally placed in fuel filling stations or mobile vans that contain the required equipment for testing. The price charged for this is nominal at Rs. 35/- (less than $1 U.S.). Figure 6 shows an example of a typical PUC certificate issued in Delhi. Even though the certificate is for 2004, the same procedure is still followed even with exceptions for changes in the prescribed standards.

This certificate is valid for one year. A dated photograph of the vehicles number plate is placed on the certificate as a benchmark for calculating the mandatory one-year period. If the measured level of pollution from the vehicle is greater than the prescribed limit, the owner is supposed to get the vehicle repaired and apply for a new PUC certificate.

- However, the present system has the following failings and hence needs to be improved:
    - No government supervision of the large number of privately owned centers
    - No quality assurance to verify correctness of certificates, test equipment not calibrated periodically
    - Certificate issuing system not foolproof
    - Fraudulent practices followed by many centers, certificates issued without testing
    - Test centers are allowed to carry out repairs; this creates vested interests
    - Noise pollution caused by the vehicles is unchecked during the test.

Figure 6 Typical certificate Issued After Pollution Check



प्रदूषण नियंत्रित प्रमाणपत्र
POLLUTION UNDER CONTROL CERTIFICATE
परिवहन विभाग, दिल्ली सरकार
TRANSPORT DEPARTMENT, GOVT. OF NCT OF DELHI

संख्या S.No. 19545

प्रमाणपत्र संख्या PUCC No. DL- P219019642

वाहन पंजी संख्या Vehicle Reg.No. DL8S T 7545

मेक Maks Hero Honda

मॉडल Model Motor Cycle

वर्ग Category 2W

इंजिन स्ट्रोक Engine Stoke 4-STROKE

वर्ष Year 2003

ईंधन Fuel PETROL

दिनांक Date 17/04/2004

समय Time 09:47 AM

वैधता Valid upto Jul 16, 2004

प्रमाणित किया जाता है कि इस वाहन का CO उर्त्सजन स्तर के. मो. वा. नियम,1989 के नियम 115 (2) में निर्धारित स्तर के अनुसार है।

यदि आप को कोई शिकायत या टिप्पणी है तो कृपया पीछे छपे प्रारूप के अनुसार भेजें।

In case of any complaint/comments please send your response as per form given overleaf.

हस्ताक्षर अधिकृत Authorised Signatory:
नाम Name:

आइडलिंग पर CO स्तर (% आयतन)
CO level ati idling (% volume)

ईंधन Fuel	निर्धारित मानक Presoribed Standard	मापित स्तर Measured Level
पेट्रोल Petrol	4.5%	1.6
सीएनजी/एलपीजी CNG/LPG	4.5%	-

17/04/04 9:47:19 AM

DL8S T 7545

अधिकृत केन्द्र कोड Authorised Centre Code P 2 1 9

AZADPUR SERVICE STATION
Kalidas Marg, Gulabi Bagh,
Delhi-110007

Introduction of Pre-Mixed Two-Stroke (2-T) Oil

- At present only the city of Delhi has made this mandatory. Other cities need to follow the example to achieve lesser emissions.

Phasing Out Old Vehicles

- Replacing these with new ones meeting latest emission standards or
- Replacing by those running on alternate fuels

Upgrading old vehicles

- Retrofit with catalytic converters (effective only on post-1996 vehicles)

4.4 Current Fuel Usage and Emissions

The following tables give the total fuel being consumed in various cities in India. The cities are categorized according to their population.

Table 9 Category Wise Fuel Consumption/ Day (In Kilo Litres)

City Category	Population (in lakhs)	Car	2W	3W	Bus	Total
1	<5	36	8	5	6	55
2	5-10	603	414	362	280	1,659
3	10-20	1,003	1,058	602	376	3,039
4	20-40	436	393	393	140	1,362
5	40-80	921	901	553	833	3,208
6	>80	4,782	1,605	2,869	7,442	16,697

Source: MoUD report, 2008

Table 10 Category Wise Emissions/Day (in Tons)

City Category	Population (in lakhs)	Car	2W	3W	Bus	Total
1	<5	6	3	0	0	10
2	5-10	90	133	24	21	268
3	10-20	158	342	125	27	652
4	20-40	64	127	37	9	238
5	40-80	143	300	143	60	647
6	>80	556	365	451	375	1747

(MoUD report, 2008)

Cars and two-wheelers consume the majority of the fuel for all cities in Category 1 to 5 and account for approximately 65 to 90% of the total emissions produced by all modes of transport. In Category 6 cities, while cars and two-wheelers account for less than 50% of the total fuel consumption by all modes, the total emission produced by these two modes is more than 60%. This is due to high levels of congestion resulting in slow speeds and thus higher emissions.

In Category 5 and 6 cities, intermediate public transport vehicles account for 18 to 23% of the fuel consumption, respectively, while they contribute to approximately one quarter of the total emissions by all vehicles.

It is expected that mandatory fuel economy standards and an official fuel economy labeling program will help in reducing these emissions (Centre for Science and Environment, 2008).

4.5 Alternative fuel technologies available

Adopting strong emission standards and enforcing them is one way of controlling air quality. Another way is to explore the possibility of alternative fuels and technologies. This section discusses the various options available in terms of fuel technologies.

Two-wheelers are not attractive candidates for fuel changes. However, the three-wheelers can be successfully converted to CNG (India) and LPG (India and Thailand). The following are the features of these conversions:

CNG Auto-Rickshaw:

- Uses a four-stroke, air cooled, spark-ignited engine
- Has a CNG cylinder (22-liter water capacity) able to hold ~ 3.5 kg of CNG at 200 bar pressure
- Delivers a fuel efficiency of ~ 45 km per kg of CNG
- Complies with all notified safety standards
- Is provided with a three-liter "limp-home" petrol tank
- Priced at US $2,000, about 25% higher than the corresponding petrol version (12,5% higher with Delhi incentives)

LPG auto-rickshaw:

Opinion is divided on whether LPG is a truly environment friendly alternative to advanced engine technology and clean fuels. This is because the total hydrocarbon (THC) emission of an LPG vehicle is higher (~15 to 30%) than that of corresponding petrol vehicle and also the carbon monoxide, nitrogen dioxide and nitric oxide emission levels are comparable to those of corresponding petrol versions. Users also may not be attracted to LPG if the fuel economy benefit is too small. The other danger of promoting LPG in India is that LPG for kitchen use attracts a subsidy (price ~Rs. 24/kg-US$ 0.60, subsidy ~ Rs. 17/kg-US $0.42 /kg). Since the auto LPG price would be based on market forces, its price is likely to be higher and variable.

The other alternatives available in terms of the fuel technology are
Electric three-wheeler auto-rickshaw program
Electric two-wheeler scooter program

However, large-scale commercial production and usage is yet to be achieved in this segment and hence no conclusions can be drawn.
(IYER, 2001; George et al.,2002)

4.6 Traffic Flows and Congestion Data - Traffic Flows

Vehicular traffic flows and their modal splits observed in the CBD areas of some selected cities are presented in this section. The ranges given here are collected from traffic volume count surveys done in these cities as a part of various comprehensive mobility plans, BRT feasibility plans and other studies. Since a variety of vehicle types make up the total traffic, the modal split is also presented to get an idea of which vehicles are actually contributing to the flows mentioned. Since this study is specific to two-and-three-wheelers, only their modal splits and that of cars, the other major personalized mode, are presented separately. All other vehicles are put together in the others column.

Table 11 Traffic Flows and Vehicular Modal Splits of Selected Cities

City	Population (in millions)	CBD-Mid block Flow (pcu/ day)	2W	3W	Car	Others*	Total
Delhi	>10	50,000-60,000	6	8	18	86	100
Hyderabad	5-10	50,000-60,000	24	9	12	67	100
Pune	2-5	40,000-50,000	45	9	15	46	100
Jabalpur	1-2	30,000-40,000	37	2	2	59	100
Rajkot	1-2	30,000-40,000	35	1	16	64	100
Patna	1-2	30,000-40,000	20	10	12	70	100
Vijayawada	1-2	30,000-40,000	29	25	7	46	100

* Others include public transport, non-motorized transport, and other modes like tractors, goods vehicles, etc.

Sources: TRIPP Report, 2008

As a city's population increases, the traffic in the CBD also swells because a large population means a larger city and more business activity, leading to more trips. Also, for the four cities in the same population range of one to two million, the flows are also in the same range, i.e. 30,000 to 40,000 PCU/day. This suggests that the traffic pattern in cities with similar populations is comparable. Also, apart from Rajkot, with a three-wheeler use of 1%, and Vijayawada, having a high three-wheeler usage of 25%, all the other cities have a similar three-wheeler modal share between 8-10%, which is also observed in the modal share section 10.1.

Two-Wheeler Modal Share Trends

In the case of two-wheelers, even though there is no exact trend, the general inclination is that two-wheeler modal shares grow with city size but after a certain point decrease as city size increases. This can be attributed to short trip lengths (Discussed in Section 10.2) in smaller cities that grow as the city-size increases, resulting in longer trips that encourage people to shift to motorized transport. Since two-wheelers are more affordable to middle income Indians (which constitute a high proportion of the population) people shift from NMT to two-wheelers. As the city size and, hence, the trip lengths increase more people prefer the comfort cars provide in the tropical Indian conditions and higher speeds that lead to lesser travel times. Section 10.3 presents some other aspects regarding the two-wheeler modal shares.

4.7 Traffic Flows and Congestion Data - Congestion Data

The volume/capacity (V/C) ratio measures congestion in various cities. For 2007, it is calculated by taking peak-hour volume counts (four hours in the morning peak and four hours in the evening peak) at screen line (imaginary lines cutting across the major arterials connecting the CBD) points of various cities.

The following table gives the average V/C ratios in the arterials of cities categorized according to their population. The future V/C ratios of these cities have also been estimated for a do-nothing scenario, i.e. assuming that the vehicles grow at the same rate and the road infrastructure remains the same.

Table 12 Expected Average Peak Hour Volume-Capacity Ratio for Cities by Category Under Do-Nothing Scenario

City Category	Population (in millions)	2007	2011	2021	2031
Category-1	<0.5	0.24	0.33	0.69	1.48
Category-2	0.5-1	0.73	0.78	1.2	1.64
Category-3	1-2	0.81	1.24	1.8	1.97
Category-4	2-4	0.97	1.05	1.16	1.32
Category-5	4-8	1.12	1.51	2.01	2.54
Category-6	>8	1.21	1.79	2.4	2.9

Source: MoUD report, 2008

It can be observed that in some cities the V/C ratios are greater than 1, which means vehicles exceed the road capacity. This may be due to two reasons.

i) *Roads operating at level of service (LOS) F*: IRC 106 defines this as the state of forced or breakdown flow. This state occurs when the amount of traffic approaching a point exceeds the amount that can pass through it. Queues, which operate in extremely unstable, stop-and-go waves, form in such locations. Vehicles may progress at a reasonable speed for several hundred meters and may then be required to stop in a cyclic fashion. Due to high volumes, break-downs occur and long queues and delays result. The average travel speeds are between 25 and 33 % of free flow speed.

ii) *Use of incorrect capacity values:* The capacities of various roads are specified in terms of pcus/hr/lane. However, the PCU values adopted are static throughout the network and therefore might not be representing the arterial traffic completely. If the PCU values are incorrect, the capacity values will be wrongly estimated and this leads to incorrect V/C values increasing more than 1 in large cities and V/C's in small cities in the range of 1.24. This translates into a calculation that 76% percent of road space is unused

4.8 Measuring Traffic Flows

Appropriate methodologies must be adopted before accurate measures of traffic volume can be obtained when planning, designing and operating a road system. Expressing traffic volume as the number of vehicles passing a given section of road per unit of time is inappropriate when several types of vehicles with widely varying static and dynamic characteristics are present in the traffic stream. This problem can be addressed by converting the different types of vehicles into equivalent passenger cars and expressing the volume as passenger car unit (PCU) per hour.

PCU values:

The PCU has been defined by the United Kingdom Transport and Road Research Laboratory as follows:

> *On any particular section of road under particular traffic conditions, if the addition of one vehicle of a particular type per hour will reduce the average speed of the remaining vehicles by the same amount as the addition of, say x cars of average size per hour ,… then one vehicle of this type is equivalent to x PCU.* (Arasan et al., 2008)

The Indian Road Congress (IRC) sets the parameters related to roads and publishes them as codes of practice in two of its code books -- IRC-SP 41 and IRC 106. IRC SP 41 gives the PCU values of at-grade intersections and IRC 106 gives the PCU values at mid-block sections. In both cases, the recommended PCU values are tentative. The following tables give the values in these codes.

Table 13 PCU Values at Intersections (IRC SP 41:1994)

Vehicle Type	PCU value
Two-wheelers	0.5
Three-wheelers	1

Table 14 PCU Values for Mid-Blocks (IRC 106: 1990)

% Mode share	Less than 5%	10% and above
Two-wheelers	0.5	0.75
Three-wheelers	1.2	2.0

The values for percentage traffic composition between 5% and 10% will be interpolated the above values.

Also, these code books state that the PCU value varies as a function of the physical dimensions and operational speeds of that particular vehicle classes. Speed differentials in urban areas are generally low and hence PCU values are predominantly functions of the physical dimensions of vehicles. However, empirical evidence shows that there are other factors influencing the PCU value of a vehicle. Research done in India on PCU values and extracts from the papers published in peer reviewed journals are discussed in the following section.

Factors Influencing PCU Value

i. Effect of Road Width

Sikdar et al.(2000) found that road width influences the PCU values. If traffic volume and its composition remain unaltered, an increase in road width will provide more freedom for vehicles to choose their speed. By the same logic, the PCU for individual vehicles will increase with road width.

Also, PCU for a vehicle decreases with an increase in its proportion in the traffic stream. For a given road width, increase in volume will cause more density. Due to this, vehicles will move at reduced but uniform speed resulting in lower speed differences between a car and a vehicle type. It will result in a smaller PCU value for the vehicle type.

ii. Effect of Traffic Volume

Arasan et al. (2008) found that the PCU value of a vehicle type varies significantly with variation in traffic volume. Their paper proposes that the PCU value of any mode increases with a rise in the total traffic volume and after a certain level, reduces with further increase in volume. Hence, it is appropriate to treat the PCU value of a vehicle type as a dynamic quantity instead of considering it as a fixed one.

The authors also found that PCU values can be accurately estimated through comprehensive study of the interaction between vehicles in traffic. Study of vehicular interaction under heterogeneous traffic conditions involves modelling the traffic flow at the micro-level, over a wide range of roadway and traffic conditions, as well as the collection of extensive traffic data in the field. A study was carried out in the city of Chennai and the results obtained are explained below.

Table 15 Modal Share of Traffic (Chennai, 2006)

Mode	% Volume
Buses and Trucks	3
Bicycles	10
Motorized Two-wheelers	41
Motorized Three-wheelers	16
Cars	28
Light Commercial vehicles	3

Source: Arasan et al., Road and Transport Research, March 2008.

Table 16 PCU Values Observed at Various Volume Levels

Volume (veh/ hr)	PCU Value	
	M3W	M2W
500	1.1	0.29
1000	1.4	0.43
1500	2.07	0.55
2000	1.55	0.53
2500	1.07	0.52
3000	0.79	0.42
3500	0.7	0.38
4000	0.58	0.36

Source: Arasan et al., Road and Transport Research, March 2008.

The study shows that the PCU values increase with an increase in traffic volume and, after a certain level is reached, reduces with the increase in volume. At low volume, spacing (both longitudinal and lateral) between vehicles is greater; cars (the reference vehicles) are able to maneuver through the gaps easily facilitating fast movement. An increase in traffic volume at this stage significantly reduces spacing resulting in a steep reduction in speed. This trend continues up to a certain volume at which the speed of the traffic as a whole drops and, consequently, the speed difference between cars and other vehicle types narrows. At this stage, a further increase in volume results in a relatively lower rate of change (decreases) in the speed of cars and in a relatively lesser impact, due to the introduction of the subject vehicle. This results in the decreasing trend of the PCU value of the subject vehicle at higher volume levels.

iii. Effect of Traffic Density, Modal Split and Lane Width

In a separate study carried out in Delhi by Tiwari et al. (2008), traffic density, modal split and lane width were found out to be affecting the PCU value and PCU values for Indian highways based on empirical data are developed. Traffic data is collected and analyzed for various locations, traffic densities and lane widths and PCU values for modes are derived. The PCU values for two-wheelers and three-wheelers developed in this study, along with the average percentage composition of these modes, are presented in the following table:

Table 17 PCU Values Developed for Two-Wheelers and Three-Wheelers in Various Road Conditions

Road Type	%2W Composition	2-W PCU	%3W Composition	3-W PCU
Single lane	43	0·25	6	1·34
Intermediate lane	23	0·51	7	1·31
Two lanes without paved shoulders	18	0·91	2	9·16
Two lanes with 1·5m shoulders	10	2·81	15	2·15
Two lanes with 2·5m shoulders	24	2·29	3	18·66
Four-lanes divided	20	1·99	4	11·44

Source: Tiwari et al., 2008.

The study's authors found that PCU values of motorized three-wheelers have very high values when the modal share of three-wheelers becomes less than 5%. This shows that vehicles having much lower average speeds than the other vehicles in the traffic stream, affect the capacity of the road even at low densities. Also, observers found that the 85th percentile road width occupied by each mode varies based on the width of the road and, hence, the PCU value is different for different road widths, i.e. lesser road widths force vehicles to form tighter 85th percentile widths and hence occupy less space and vehicles occupy more area on wider highways as is evident from the higher PCU value on wider highways as compared to single lane highways.

The above values are derived from the data at rural and suburban highways, where free flow high speed traffic exists. Therefore in a typical urban scenario, where the traffic is of the forced-flow, low-speed type, these values may not be applicable directly and some corrections are to be made to get the correct values.

iv. Effect of Area Occupancy

Mallikarjuna et al. (2006) studied traffic behavior as a three-dimensional phenomenon, including two-dimensional for the roadway (longitudinal and transverse) and one dimension for the time and found that the area occupancy of a vehicle has an effect on the PCU value. *Area occupancy* expresses how long a particular size of the vehicle is moving on a section of the road. It is measured over time and over space (length and width of the road). In this study the entire road width, irrespective of the number of lanes is considered as well as different sizes of vehicles. The following equation has been used to calculate the area occupancy of a vehicle.

$$\rho_A(A) = \frac{\sum_{i=1}^{N} \frac{L - x_i}{v_i} * w_i * l_i}{T * W * L}$$

Where,

ρ_A is area occupancy measured over space and time across the entire road width

L is the length of the road section under consideration

x_i denotes the distance between the vehicle and any of the two reference lines, measured along the road length

$L - x_i$ denotes the actual distance traveled by the i^{th} vehicle over the observed road section

w_i is the width of the i^{th} vehicle

W is the width of the road and it is assumed to be constant for the entire road section

T is the time period of observation

Cellular Automata models have been developed for modeling traffic because they are more representative of mixed traffic than regular car following and lane changing models. In this model the gap acceptance parameters and speed variation parameters are taken in such a way that they represent mixed traffic conditions. From these models, the PCU values for trucks, buses and two-wheelers at different area occupancy values have been developed. The PCU values for two-wheelers at various modal shares are presented in the following table.

Table 18 PCU Values of Two-Wheelers at Different Area Occupancy Values

% No. of 2W	Area Occupancy	PCE(max)	PCE(Min)
10	0.036	0.1	0.1
	0.038	0.44	0.1
	0.05	1	0.52
20	0.029	0.1	0.1
	0.038	0.76	0.1
	0.05	0.79	0.53
40	0.028	0.1	0.1
	0.038	0.46	0.1
	0.05	0.46	0.34
60	0.025	0.1	0.1
	0.038	0.48	0.12
	0.05	0.88	0.12
80	0.021	0.22	0.22
	0.038	0.6	0.25
	0.05	0.87	0.25
100	0.021	0.26	0.26
	0.038	0.45	0.36
	0.05	0.6	0.36

Source: Mallikarjuna et al.

Observers report that, depending upon the traffic conditions, the two-wheeler PCU value ranges from 0.36 to even 1 in some instances and hence a standard value, as adopted in the current code books, will not be correct. Also, the PCU value decreases with the increase in proportion of two-wheelers in the traffic stream.

From all the above studies it can be concluded that the currently adopted PCU values do not represent the actual situation in the field and, hence, a more robust way of estimating the PCU values need to be developed. However, the factors listed above may not be all inclusive and there may be other factors affecting the PCU value. This requires extensive studies to find the exact factors influencing the PCU values and based on the findings of the study, PCU values of various vehicles under various circumstances need to be developed.

4.9 Road Space Requirements and Travel Time for Different Modes of Traffic in Different Types of Locations

The road space requirements are calculated in terms of the passenger car units (PCU) of vehicles. IRC 106 states the Guidelines for the Capacity of Urban Roads in Plain Areas. This discusses the basis of the PCU values adopted to find the capacities of urban roads. It states that "the PCU value is a function of physical dimensions and operational speeds of respective vehicle classes. In urban situations the speed differential among various classes is generally low, and as such the PCU factors are predominantly a function of the physical dimensions of the various vehicles. Nonetheless, the relative PCU of a particular vehicle type will be affected to a certain extent by increase in its proportion in the total traffic" and it recommends the following PCU values be adopted.

Table 19 PCU Values From IRC 106: 1990

Vehicle type	**Percentage composition of vehicle type in traffic stream**	
	Less than 5%	**10% and above**
Two-wheelers (Motor cycle or scooter etc.)	0.5	0.75
Three-wheeler (Auto-rickshaw)	1.2	2.0
Passenger Car	1.0	1.0
Light Commercial vehicle	1.4	2
Truck or Bus	2.2	3.7
Cycle	0.4	0.5
Cycle Rickshaw	1.5	2
Hand Cart	2	3

The values for percentage traffic composition between 5% and 10% will be interpolated the above values.

However this may not be true all the time. The assumption that speed differentials in urban areas are minimal is questionable. Also, various researchers have shown that the PCU value depends on many other factors apart from the physical dimensions and proportion of various vehicle classes. Therefore the road space requirements vary from one location to another. Extensive empirical data needs to be collected and modeled to know the road space requirements.

Capacities of Roads with Standard Lane Widths

IRC 106 guidelines, Table 33, states the capacities of various types of roads specified here. All the capacities given are in terms of the number of lanes in a particular road. The standard lane widths followed are 3.75m for single lane roads and 3.5m per lane for roads with two or more lanes.

Table 20 Capacities of Roads of Various Widths

Road Type (Both directions Combined)	Capacity (PCU/ hr/ direction)
1-Lane	350
2-Lanes Undivided	750
2-Lanes Divided	750
3-lanes	1000
4-Lanes Undivided	1500
4-Lanes Divided	1800
6-Lanes Undivided	2400
6-Lanes Divided	2700

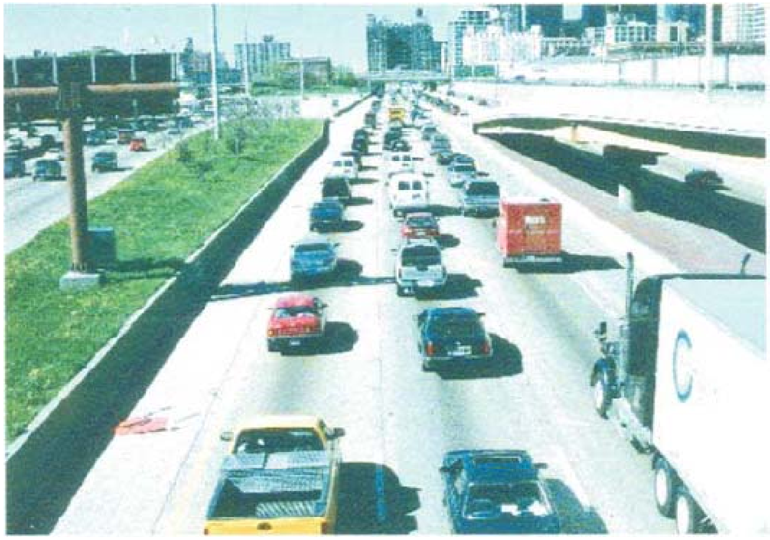
(Source: IRC 106)

However, the actual capacities in the field can be different, mainly for two reasons. First, at many locations in India, the lane width specifications are not followed and many roads with widths not conforming to the 3.5m per lane standard are constructed. Second, the capacities listed above assume that vehicles observe the lane disciplines. Due to mixed/ non-homogeneous traffic conditions, as explained in the following figures, lane discipline is rarely followed in India and so the actual capacities can be different to those mentioned in Table 33.

Homogeneous and Non-Homogeneous Traffic

Homogeneous traffic has strict lane discipline and traffic types whose physical dimensions do not vary much. This is illustrated in Figure 7.

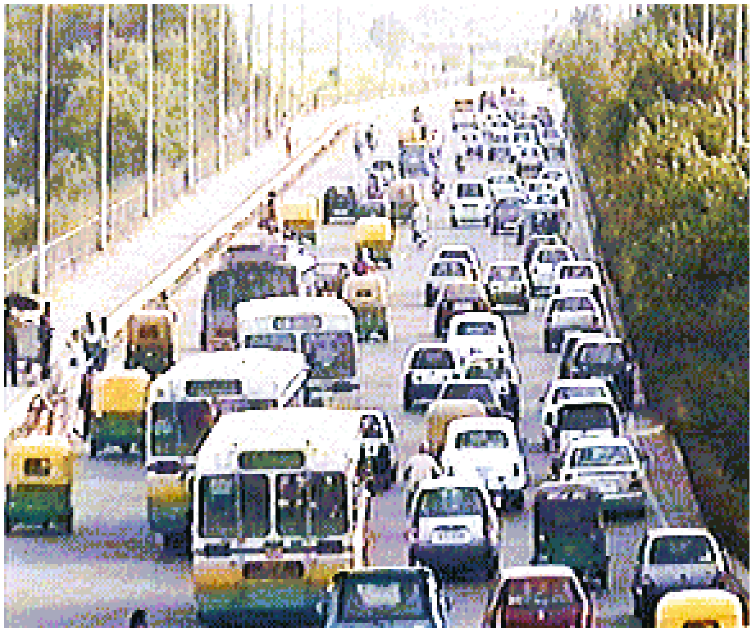
Figure 7 Homogeneous Traffic



Source: Tiwari et al., 2007

Non-homogeneous traffic is usually represented by passenger cars and heavy vehicles. as well as motorized two-wheelers, motorized three-wheelers, mini trucks, minibuses, bicycles, pedestrians, animals, animal-drawn carts, and vendor push-pull carts. There physical dimensions, operational, and acceleration and deceleration characteristics vary greatly because non-motorized traffic entities share the road with motorized vehicles. Further, in this traffic soup motorized two-wheelers that typically have 100 cc engines operating side by side with passenger cars that typically have 1,200 cc engines. A facility has non-homogeneous traffic when its peak hour volume has less than 85% passenger cars and has less than 90% passenger cars and heavy vehicles (Tiwari et al. 2008). Figure 8 shows a typical non homogeneous traffic condition observed in Delhi, India.

Figure 8 Non-Homogeneous Traffic (Delhi, India)



Source: Tiwari et al., 2007.

Actual Capacities Observed on Indian Roads with Non-Standard Lane Widths

To compare the actual flow and the capacity values given in IRC 106, observations from a study done on two intersections on the arterials of Delhi are selected and the peak hour volume counts on the four approaches of each of these two intersections. The following table gives the road widths, actual flow and the capacities of each of the roads according to IRC 106.

Table 21 Capacity Vs. Flow Observed in Delhi

Name of the Intersection	Approach Nos.	Approach road width (m)	No. of Lanes marked	Capacity (pcu/hr)	Total incoming flow (pcu/hr)
IIT Intersection	1	7	2	1800	1430
	2	10	2	1800	2593
	3	14	3	2700	4200
	4	14.5	3	2700	4018
Nehru Place Intersection	1	9.5	2	1800	1561
	2	11	2	1800	2121
	3	11.5	3	2700	4049
	4	11	3	2700	2598

Source: TRIPP, IIT Delhi.

Out of the eight approaches, only one has lane widths marked according to the IRC guideline of 3.5m per lane. At all the other locations the marked lane widths do not conform to standard specifications. Also, converting the traffic into PCUs and comparing the actual traffic with the road capacities, according to IRC 106, shows that in seven of the eight approaches, the volume of traffic is exceeding capacity. This clearly demonstrates the fact the within the 2/3 lanes provided more than 2/3 vehicles are passing because vehicles are failing to following lane disciplines which leads to , better use of available road space.

The problem of unmarked standard lane widths is not a serious one because people are not going in the marked lanes anyway. However, incorrect capacity standards, if any, need to be corrected because people may over estimate the required road space because of the lesser capacities given in the code books.

Suggestions for correct prediction of capacities:

The continuity equation of traffic flow for homogeneous traffic is

$$k = q / u_s$$

where q =traffic flow across a lane or lanes (vehicles/h)

u_s=space mean speed (km/h)

k=traffic density in a lane or lanes (vehicles/km)

The above equation assumes constant spacing and constant speed, i.e., under uncongested conditions with moderate to slightly high traffic volume.

Since maximum flow in any section gives the capacity of that particular section, if the above equation is validated for non-homogeneous conditions, by varying k and u_s based on the actual road conditions, capacity of a particular road can be ascertained. However, the equation is for homogeneous traffic and the capacity is to be found for non-homogeneous traffic. This needs to be done by finding commonalities existing between theories of homogeneous and non-homogeneous traffic and deriving the required parameters from those commonalities.

Tiwari et al. (2008) present one such study done on the validation of continuity equation for non-homogeneous traffic. In this study, the validation is done taking traffic density (k) as the parameter. A modified continuity equation is used in this study to reflect non-homogeneous traffic in such a way that the parameters are adjusted but the traffic characteristics maintain the basic relationship as in the original equation.

Here the total density is taken in terms of sum of individual densities, where individual densities are vehicles of a particular type (mode) per unit area. Flow is taken in terms of number of vehicles of the mode considered for density and speed as the space mean speed of the same mode of vehicles, which cross the total length of the area considered in density.

The equations used here are:

For Individual Mode Densities:

$$K_j = (q_j / W) / u_{s,j}$$

Where,

j=traffic entity type, e.g., 2=heavy vehicle, 3=motorized three-wheeler

k_j=average number of traffic entities of type j per unit area of highway, e.g., motorized two-wheelers/(km m)

W=cross-sectional width for measuring flow, e.g., m

Flow q_j=Number of traffic entities of type j crossing the cross-sectional line of width W during a time interval, e.g., non motorized two-wheelers/h; and

Speed $u_{s,j}$=space mean speed of traffic entities of type j that completely traverse the length of the highway area (km/h)(the space mean speed of non-homogeneous traffic is the weighted harmonic speed of each traffic type's space mean speed)

An assumption here is that W is constant throughout the highway segment for all traffic entity types.

Total Density of all modes, i.e. sum of densities of individual modes, since all the modes use the same available road space.

$$k_{nt} = \sum_{j=1}^{N} k_j$$

Where,

k_{nt}=average number of non-homogeneous traffic entities per unit area of highway, e.g., entities/(km m)

and N= total number of entity types in the non homogeneous traffic stream.

The average density from actual densities observed on a mid-block section in the field is compared to the density derived from flows and space mean speeds. It was found that these two match each other for the above equations. Therefore, by using the above modified equations, continuity equation is also valid under non-homogeneous conditions.

The actual concern here is to find out the capacity, which is the maximum total flow in a section. The flow equation to be used is:

$$\frac{q_{nt}}{W} = \sum_{j=1}^{N} \frac{q_j}{W}$$

Where, q_{nt}= Total non homogeneous traffic flow.

q_{nt} / W = flow per unit width

The maximum total flow is the sum of maximum flows of each mode derived by maximizing the flow equation. In this way maximum flow per unit width is derived which gives the capacity per unit width.

This gives one method of finding the capacities of lanes with non-standard lane widths in non-homogeneous traffic conditions.

5 Traffic Demand Modeling Methods Specific to Two and-three-wheelers and Heterogeneous Traffic

5.1 Current Modeling Practices Followed in India

The modeling method currently adopted in India is largely the four-step process, except in some research institutions where discrete choice modeling and activity based modeling are adopted. The general practice to be followed currently is to model the peak hour traffic using software like TransCAD, CUBE Voyager, TRIPS, etc.

The procedure for this is as follows:

i. Trip Generation: Deriving the trip generation equations (trip production and trip attraction) from household interviews (HHI) and preparing the production and attraction table for all the zones of the city from those equations.

ii. Trip Distribution: Distributing the trips among zones using the gravity method for trip distribution and calibrating it based on observed trip lengths in the city.

iii. Mode Choice: Mode choice modeling by techniques like revealed/stated preference surveys is not carried out in detail in most of the referred studies. (Comprehensive Mobility Plans of Jabalpur, Rajkot, BRT Feasibility studies of Vishakhapatnam, Vijayawada). The mode share derived from the HHI data is applied for the whole city. (In some cases, it is taken zone by zone and in others at the aggregate level for the whole city).

iv. Trip Assignment: Trip assignment techniques like user equilibrium generally are used to assign the trips on the network using the shortest path algorithm. The shortest path is decided either on distance or time as criterion (as specified by the user). The software initially assigns trips to a particular path and based on the capacity of the roads, delays are calculated and alternative paths are explored iteratively before converging on to a single path for each trip.

However, this software has some inherent features which do not exactly reflect the mixed traffic conditions. Thereby implying that, the two-wheelers and three-wheelers are not properly accounted for in the modeling process. These aspects have been listed below. No specific methodology for two and three-wheelers is adopted. PCU value is assumed to be taking care of them (IRC-106).

5.2 Errors in Current Modeling, Applicable for Two and Three-Wheeler Traffic

1. ***PCU Value Constant for the Entire Network***: For traffic assignment, origin-destination (O-D) matrices of various modes according to their modal shares are prepared and while assigning the matrix to the network, the PCU values of the modes are specified. Therefore, the PCU values given here are static throughout the network. As specified in section 5.2.2, the PCU values need to be dynamic for them to be representative of the actual conditions. This implies that the correct PCU values cannot be incorporated in the present modeling procedures.

   Probable Solution: If modeling software accepts a program which takes dynamic PCU values as a function of the different variables on which it depends, this problem can be overcome. However, the current modeling packages like Emme3, TransCAD (which are among the most used softwares in India) do not have such features and hence more research needs to be done before a solution can be found.

2. ***Modal Share Constant for the Entire Network***: The modal share specified in the O-D matrix is generally calculated at the aggregate level for the entire network. However, this might not be true under actual conditions where there is an elevated chance that the modal split is different in different locations. In some areas, the proportion of cars may be more and in some other areas, the proportion of two-wheelers and three-wheelers may be more.

   Probable Solution: To counter this, from the data collected through household interviews, separate mode shares for all the zones should be calculated and mode choice modeling carried out. This must be used while forming the O-D matrix. However, there is no report of such work done in India as per the data available for the current study.

3. ***Link Speeds but not Vehicle Speeds are Considered***: The speed of the vehicles is taken in terms of link speeds. This assumes that the speed differential among various vehicles is negligible and hence the link speed will be the speed of all the vehicles. This may be true for homogeneous traffic conditions where the number of modes in the traffic is few. But in mixed traffic conditions, with the presence of two-wheelers, three-wheelers and cars which have different engine capacities and also with the presence of non-motorized transport on the road, this may not

be true all the time and, hence, giving link speeds instead of vehicle speeds leads to errors in the modeling results.

Probable Solutions:

i. If segregated lanes for different vehicles are provided (eg: BRT systems), the error is minimized to some extent because heavy vehicles use the bus lanes, NMT uses the bicycle lanes and so on. In this case, the speeds of cars, two-wheelers, three-wheelers and other motorized modes, if any are sharing the road might not be highly different to each other.

ii. Even though macroscopic modeling software does not have the option of mode-wise speeds, microscopic simulation software like VISSIM, AIMSUN have this option. Therefore macroscopic modeling can be used for the entire network to get a general idea of traffic loads at various points and at the critical locations; microscopic simulation can be carried out to get accurate results.

4. ***People Do Not Use the Shortest Path Available***: The algorithms used in various modeling software assign the O-D matrix to the network based on the assumption that people use the shortest path to reach their destinations. However, research shows that people do not always use the shortest path available and they are likely to use some major corridors along their route even if this increases their trip lengths. This may be due to reasons such as lack of knowledge of familiarity with shorter routes which may pass through unpopular areas, superior Level of Service (LOS) on the major corridor, presence of gated communities which do not allow external traffic to pass through. Ideally, to solve this problem, the links of the network need to be given priority.

   Probable Solution: There are no conclusive method for nullifying this error and further research needs to be done out to discover a solution.

Even though the problems mentioned are faced in some other countries where solutions have been found, those solutions need to be adapted to Indian conditions and incorporated in the design standards so that they are available to people doing macroscopic modeling for cities.

6 Road/ Intersection Design Guidelines

The design guidelines for roads in India are formulated by the Indian Roads Congress (IRC). The following four codes are found to be giving the road/intersection design guidelines specific to two-and-three-wheelers.

i. **IRC 3-1983** gives the "dimensions and weights of road design vehicles"
ii. **IRC 86: 1983** gives the geometric design standards for mid-blocks or through sections
iii. **IRC SP-41: 1994** g***ives the "design*** guidelines for at-grade intersections"
iv. **IRC 92- 1985** gives the "guidelines for the design of interchanges in urban areas"

The salient features in these guidelines, which are applicable to two-and-three-wheelers are discussed below.

i. ***IRC 3-1983***, gives the dimensions and weights of road design vehicles'.

Three vehicles taken as a standard for design are:

i) Single unit (meaning one passenger car unit)
ii) Semi-trailer
iii) Truck-trailer combination

Two-and-three-wheelers are not mentioned among the design vehicles. The PCU value is assumed to be taking them into account. However, as explained in the PCU section these values can be wrong in some circumstances thereby implying that the guidelines might not be accurate in all the cases.

ii. ***IRC 86: 1983 gives the geometric design standards for mid-blocks or through sections:***

For this purpose all the urban roads have been divided into four categories:

1. Arterial: A general term denoting a street primarily for through traffic, usually on a continuous route.
2. Sub-arterial: A general term denoting a street primarily for through traffic, usually on a continuous route but offering somewhat lower level of traffic mobility than the arterial.
3. Collector street: A street for collecting and distributing the traffic from and to the local street and providing access to the arterial streets.
4. Local street: A street primarily for access to residence, business or other abutting property.

Based on these road classifications, parameters like the design speed, right of way (ROW), sight distance, and horizontal and vertical alignment parameters are recommended. Also, the cross sectional elements of roads like the road widths, design traffic volume, carriage width, footpath and bicycle track provisions are specified. The design traffic volume is mentioned in terms of PCU and the PCU values for two-wheelers and three-wheelers are as mentioned below. As explained in the PCU section 5.2.2, these values might not be correct under all circumstances and hence need to be revised.

Table 22 PCU Values From IRC 86: 1983

Three-wheeler (Auto-rickshaw)	1.00
Two-wheeler (Motor/Scooter)	0.50

The design speed is the primary criterion for all the standards developed and the designs will comprise all vehicle types, thereby implying that the two-wheelers and three-wheelers are also taken into account. Also, whenever the length of wheel base of a vehicle is required, it is normally taken as 6.1m or 6.0m for commercial vehicles. Since the lengths in case of two-and-three-wheelers are less than this, they are being accommodated in the design.

In all the cases, no separate design standards for two-and-three-wheelers' specific environments are developed. A tentative passenger car unit (PCU) value is developed for various vehicles (in all the cases and they use the same PCU values) and the traffic from all the modes is converted to these units. The rest of the design is developed assuming that a certain number of cars use the road and a certain level of service (LOS) and dimensions are available. Since the PCU value itself can be wrong (explained in section 5.2.2), the whole design process is likely to be inaccurate.

iii. ***IRC SP-41: 1994*** takes the following as design parameters:

- Design speed
- Design traffic volume
- Design vehicle
- Design radius of curves at intersection
- Width of turning lanes at intersection
- Acceleration/ deceleration lanes
- Super elevation and cross slope
- Visibility at intersections
- Channelizing Island

- Curb
- Traffic rotary

Among all the parameters, the design vehicle, design speed and the traffic volume are the central parameters and, based on their values, the other parameters' values are specified. These parameters are discussed in detail in this section.

Design Vehicle

The code specifies that the intersections along the arterials and sub-arterials in the urban areas and those in the Central Business District (CBD) need to be designed for a single unit truck (with allowance for turning vehicles encroaching on the other lanes in the CBD). A single unit truck has the dimensions of 2.58m width and 9m length. Since the two-wheelers and three-wheelers have lesser dimensions compared to a single unit truck, an intersection designed for such a vehicle is assumed to be able to accomodate the two-and-three-wheelers

Design Speed

A design speed of 80kmph for arterials, 60kmph for sub-arterials, 50 kmph for collector streets and 30 kmph for local streets are recommended. Since the desired speeds of two-wheelers and three-wheelers are less than 60 kmph even in arterials, the design speed specified in the codes cater to them also.

Traffic Volume

As explained in the Traffic Flows and Congestion Data Section, the traffic volume should not be tallied as the total number of vehicles passing a point, but should be counted as total PCUs passing through a point. This makes the PCU values very important and the accuracy of the PCU values determines the accuracy of the intersection design. The PCU values recommended in the code are given in the table below.

Table 23 PCU Values (IRC SP 41: 1994)

Three-wheeler (Auto-rickshaw)	1.00
Two-wheeler (Motor/Scooter)	0.50

iv. ***IRC 92- 1985 gives the Guidelines for the Design of Interchanges in Urban Areas***

In this book, various guidelines on when to construct an interchange and what factors to consider -- terrain, traffic coming in, importance of the intersection, etc. -- are discussed. Also, the types of interchanges for various situations and their geometric details are specified. However, all the vehicles are divided into two categories -- motorized and non-motorized and designs are developed for them. But, in mixed traffic conditions two-wheelers and three-wheelers form a high proportion of motorized traffic and based on their vehicle capabilities, speeds, etc. the interchanges designed for cars and trucks can become non-negotiable. For example, if the vertical curves are banked very high, cars with engine capacities of 800cc and above may be able to negotiate it, but two-wheelers with a 100cc engine can find it difficult.

7 Conflicts with Other Vehicles, Bicycles and Pedestrians

A ***traffic conflict*** is defined as a situation in which two road users approach each other in such directions and with such speeds as to produce a collision unless one of them performs an emergency evasive maneuver. More rarely, a traffic conflict may involve a single road user on a *collision course* with a fixed obstacle or an animal. (The Way Forward, 2005)

The normal lane widths are 3.5m per lane and the maximum width of any vehicle is 2.4m. Also typical urban traffic is distinguished by mixed-use, inclusive of two-and-three-wheelers with widths less than or equal to 1.5 m. This leads to more vehicles using the road than there are available lanes during periods of heavy traffic. Because of this phenomenon, vehicles try to out maneuver each other.

A large share of non-motorized vehicles (NMVs) and motorized two-wheelers (MTW) make up the transport system of Indian cities. In such cities, 45% to 80% of the registered vehicles are MTWs. Cars account for 5% to 20% of the total vehicle fleet in most LMC large cities. The road network is used by at least seven categories of motorized vehicles and NMVs. Public transport and para-transit are the predominant modes of motorized travel in mega cities and carry 20% to 65% of the total trips excluding walking trips. Other modes make up for the rest of the traffic and set the stage for conflict.

A study done in Delhi observed the conflicts between various vehicles under mixed traffic conditions and reported the relationship between fatal crashes and conflict rates at mid-block in 14 locations in Delhi. The data revealed that the presence of only a few non-motorized vehicles is enough to cause conflicts with motorized. While the study did not provide a conclusive relationship between mid-block conflicts and fatal crash sites, an important conclusion is that traffic-planning emphasis on conflict rates may not result in reducing fatalities on urban roads along mid-block segments.

From the total conflict data, the conflicts involving two-and-three-wheelers are separated and are presented in the table below.

Table 24 Conflicts of Two-and-Three-Wheelers with Other Vehicles in Delhi

	Car	Bus	2W	3W	Bicycle	Total
3W	24 %	17 %	17 %	25 %	17 %	100 %
2W	22 %	27 %	18 %	13 %	20 %	100 %

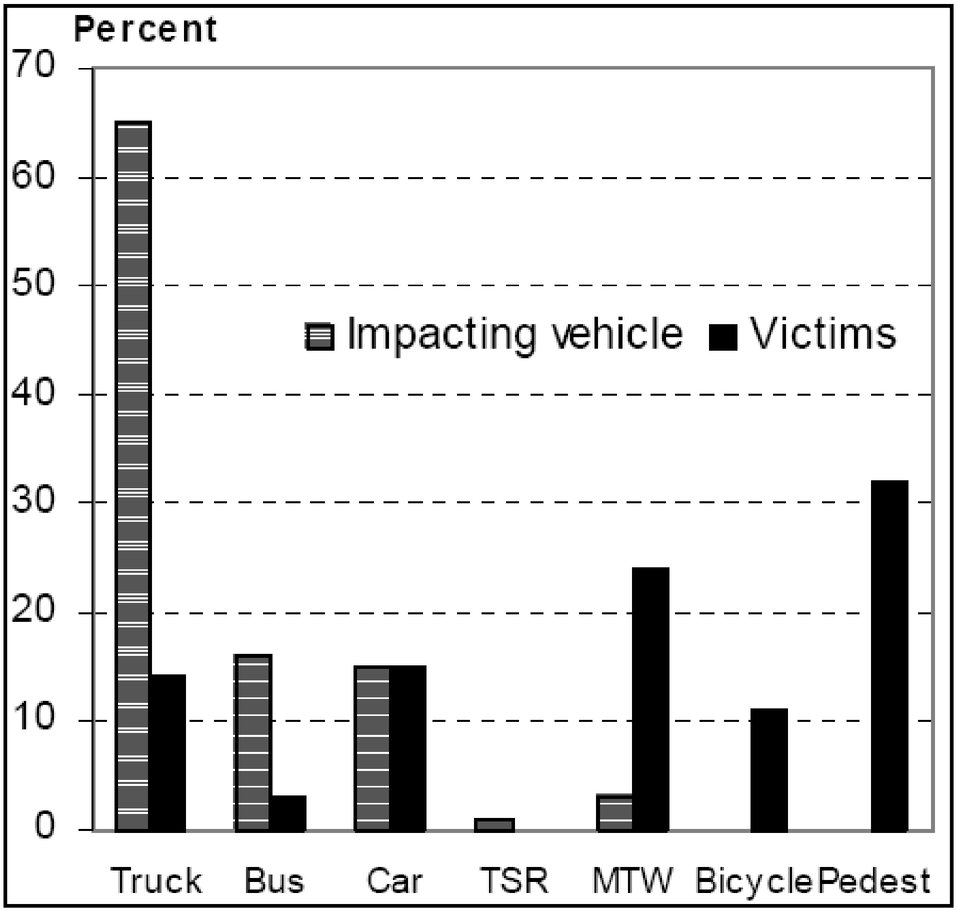
Source: Tiwari et al, Accid. Anal. and Prev., Vol. 30, No. 2, pp. 207-215, 1998

The results show that most conflicts involve three-wheelers engaged with other three-wheelers, followed by three-wheelers in conflict with cars. Two-wheelers are most often involved in skirmishes with buses followed by cars, bicycles and other two-wheelers. This can be explained by the speeds of two-wheelers, buses and cars that calls for segregation of this heavy traffic by methods like exclusive bus lanes. The phenomenon of vehicles colliding most with like vehicles is thought to be due the process of natural segregation. Even without segregated lanes for different modes, vehicles are aligning themselves into clusters of their own. For example, all NMTs operate in the left most lanes, buses in the right most lanes and cars and two-and-three-wheelers in the middle is a common phenomenon.

Figure 9 shows the consolidated results of a detailed study done in 14 locations on national highways around the country (Reference). This demonstrates that even on national highways two-wheelers constitute over 20% of the fatalities and all vulnerable road users put together, which includes the three-wheelers, constitute more than 65%.

Figure 9 also indicates that trucks are involved in the vast majority of fatal crashes. In the absence of detailed multi-disciplinary crash investigation data, we can only surmise that this disproportionate involvement must have to do with a higher presence of trucks on national highways and the greater mass of trucks compared with other road users. In the event of a crash, the road user with a lower mass usually suffers more severe injuries.

Figure 9 Proportion of Road Users Killed from Impacting Vehicles on Sampled National Highways



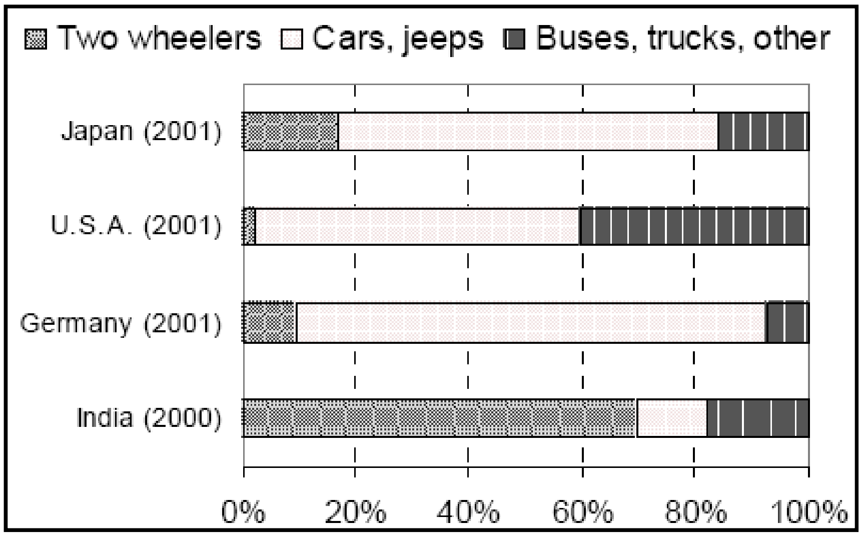
(Source: The Road Ahead, Dinesh Mohan)

8 Safety Data and Prevention Measures

8.1 India in Comparison with Developed Countries

Road traffic crashes are chiefly caused by a high-energy transfer between two vehicles or by a high-speed vehicle hitting a low speed vehicle or a pedestrian. Therefore, the type of vehicles on the road is important in determining the crashes caused and the preventive measures needed. The following figure compares the type of vehicles registered in India as compared to some developed countries.

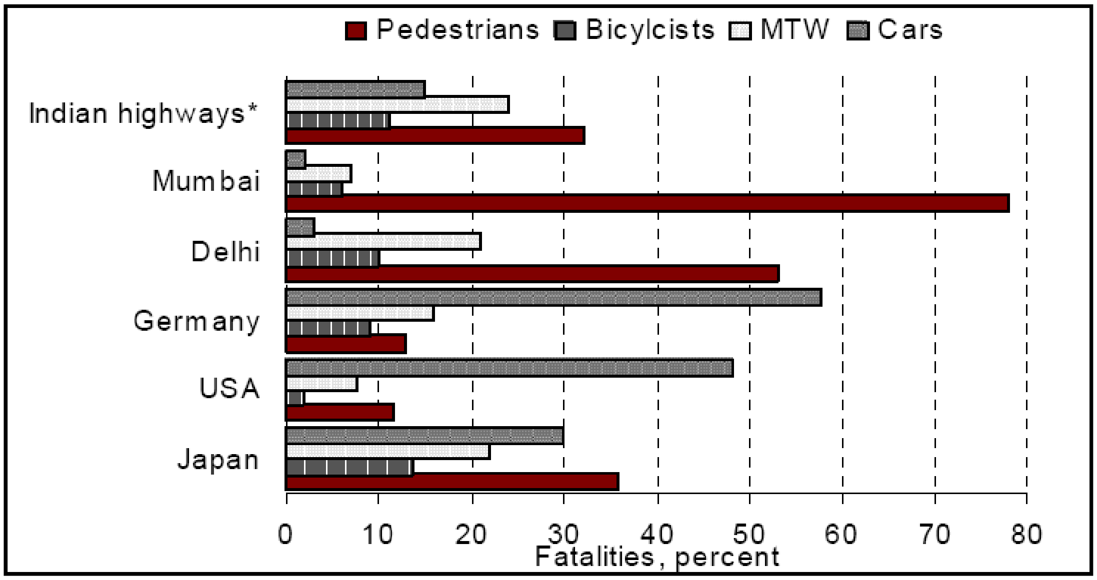
Figure 10 Proportion of Vehicles Registered in India, Germany, Japan and USA



(Source: Mohan D., 2004)

The above data shows that the car population as a proportion of total motor vehicles is much less in India than in the highly motorized countries (HMCs) (13% vs. 56 to 80%) and that the proportion of motorized two-wheelers (MTW) is much higher (70% vs. 5 to 18%). In Figure 8, the fatalities in India are compared to these countries to see whether the difference in the number of vehicles is causing any change in the number of fatalities.

Figure 11 Proportion of Different Types of Road Users Killed in Delhi, Mumbai, National Highways in India and in Highly Motorised Countries



***-- Average for 14 locations, MTW – motorised two-wheelers**

(Source: World report on road traffic injury prevention, 2004)

This figure shows that pedestrians, bicyclists and MTW riders, who constitute the vulnerable road users (VRUs), constitute 60 to 80 per cent of all traffic fatalities in India. This flows logically from the fact that this class of road users forms the majority of those on the road. In addition, because metallic or energy absorbing materials do not protect VRUs, they sustain relatively serious injuries even at low velocity crashes.

However, the fact that the differences in fleet compositions are affecting the traffic and crash patterns enormously cannot be denied. Therefore, the preventive measures which are applicable in the HMCs might not be of the same use in India and the situation in India needs to be looked at separately to understand the preventive measures required here.

8.2 Situation in India

Table 18 shows the number of two-wheelers and three-wheelers as a proportion of all vehicles registered in Indian cities. Studies from different cities also show that bicycles constitute 10% to 35% of all trips in most cities of India. This shows that the vulnerable road users constitute the vast majority of traffic on the roads in Indian cities.

Table 25 Share of Motorised Two-Wheelers and Three-Wheeled Scooter Rickshaws (14).

City	Percent		City	Percent	
	MTW	TSR		MTW	TSR
Ahmedabad	77	7	Jaipur	74	2
Bangalore	73	6	Kanpur	79	2
Kolkata	44	2	Lucknow	80	3
Delhi	66	3	Chennai	73	4
Cochin	60	13	Nagpur	78	6
Mumbai	41	12	Patna	69	5
Hyderabad	87	7	Pune	74	8

(Source: Mohan D., 2004)

Table 26 shows the proportion of different road users killed in Delhi and Mumbai. In both cities, the car occupants constitute less than 5% of all the fatalities and vulnerable road users more than 80%. Similar data for all cities are not available, but considering that road user proportions are similar in most cities, we can safely assume that fatality patterns will also be similar.

Table 26 Proportion of Road Users Killed at Different Locations in India

	% Fatalities of various modes								
Location	**Truck**	**Bus**	**Car**	**3-W**	**2W**	**Rickshaw**	**Bicycle**	**Pedestrian**	**Total**
Mumbai	2	1	2	**4**	**7**	0	6	78	100
New Delhi	2	5	3	**3**	**21**	3	10	53	100
Highways*	14	3	15	**0**	**24**	1	11	32	100

(* - Average of 14 locations, tractor fatalities not included)

(Source: World report on road traffic injury prevention, 2004)

8.3 Fatality Index for Various Cities

A fatality index has been developed for various cities to compare the situation across different cities. The average number of fatalities per one million people per year is taken as the indicator. Table 27 gives the values for various cities in India. All the cities are segregated in to five categories based on population. The fatalities are collected and the average of all the cities is taken to get a general picture of the fatalities in various types of cities.

Table 27 Average Fatalities Per One Million Population Per Year in Various Cities in India

City Category			Category-1	Category-2	Category-3	Category-4	Category-5
Population (in millions)			<1	1-2	2-5	5-10	>10
Accident data: Fatalities per 1,00,000 population (Time Trends)	2002	2W	260	110	140	80	80
		3W	70	20	40	20	10
		Total	10	10	10	10	0
	2003	2W	270	120	140	90	80
		3W	110	20	50	20	10
		Total	0	10	10	10	0
	2004	2W	270	110	160	90	80
		3W	90	30	50	30	20
		Total	10	0	0	10	0
	2006	2W	310	320	50	30	80
		3W	90	80	30	10	20
		Total	20	20	0	0	0

Source: Ministry of urban Development (MoUD) report, 2008

The data here shows a continuous increase in the number of fatalities in cities with a population of less than two million. However, in cities with a population greater than two million, the number of fatalities is reduced between 2004 to 2006. This can be attributed to increase in traffic and higher V/C ratios, leading to reduction in average speeds and hence reduction in the number of fatalities. No data on time trends of modal split are available and hence no correlation between modal split and mode-wise fatalities could be obtained.

It is also observed that, the two-wheelers contribute to between 17 and 51% of total fatalities while the three-wheelers contribute to roughly 3 to 8%. Hence, three-wheelers are relatively safer and immediate concentration on the preventive measures should be put on two-wheelers. These are discussed in the following section.

Causes of Accidents

Empirical research shows that the following are some of the major contributors toward accidents in India:

- Motorized vehicles colliding with pedestrians and non-motorized vehicles in urban areas

- Speed differentials between diverse vehicles operating on the roads under mixed traffic conditions
- Night time driving
- Wrong-way drivers on divided highways
- Unsafe vehicle front designs

(Source: Road Safety in India: challenges and opportunities, Dinesh Mohan, Omer Tsimhoni, Michael Shivak, Michael J. Flannagan, Report No. UMTRI-2009-1, January 2009)

These aspects need to be taken into consideration while planning the safety measures or the accident prevention measures. The following section discusses the prevention measures which are currently being discussed and the ones which are recommended for future discussion.

8.4 Prevention Measures

The road safety measures to be taken up by the central government come under the Department of Road Transport and Highways. The department has set up a Road Safety Cell, to take care of matters relating to the National Road Safety Plan. It prepares and implements the Annual Road Safety Plan. It also compiles road accident data and interacts with states on issues of road safety.

Schemes Under the Road Safety Cell

The following important action plans are administered by Road Safety Cell:

- Publicity program
- Grants-in-aid to volunteer organizations for road safety program
- National Highway Accident Relief Service Scheme
- Refresher training for heavy vehicle drivers in unorganized sector
- Setting up model driver training schools

(Source: MORTH, 2008 (http://morth.nic.in/index1.asp?linkid=77&langid=2))

Activities Implemented by the Road Safety Cell

As a part of the above plans, the following activities have been taken up by the Road Safety Cell (Annual Report, 2008):

- A public awareness campaign was carried out in the electronic/print media. The campaign included calendars depicting road safety messages, broadcasts of radio jingles, computerized animation displays, etc. Television spots on road safety are telecast on the National Network of Doordarshan. The jingles in different languages are broadcast on various channels of All India Radio in order to create awareness on various aspects of road safety. Publicity materials like calendars, pamphlets, posters, etc. are supplied to NGOs and to transport and police authorities in states/union territories for distribution.

- Grants-in-aid were sanctioned to 120 NGOs for undertaking road safety programs .
- The nineteenth Road Safety Week, with the theme “Drive to Care! Not to Dare!” was observed throughout the country involving state governments, voluntary organizations, vehicle manufacturers, state road transport corporations, etc.
- More than 59,000 drivers were trained during 2008-2009 under the scheme of refresher training to heavy vehicle drivers in the unorganized sector.
- Assistance for setting up model drivers' training schools is being provided to state governments/NGOs. A new school has been sanctioned for Nagaland during the period under report. Another new driving training school for Madhya Pradesh is also under process.
- Cranes and ambulances are provided under the National Highways Accident Relief Service Scheme (NHARSS) to states/union territories as well as NGOs for clearing the accident sites and to take accident victims to the nearest medical centers. During 2007-08, 31 cranes were provided to various states / UTs. It is expected that 71 ambulances will be provided to the states/UTs/NGOs during the current year.
- A national award on road safety is given every year to NGOs as well as individuals for commendable work in the field of road safety. The award amount for winners is Rs.1 lakh for NGO category and Rs.50,000 for the individual category. For the runners up the amount is Rs. 30,000 under the NGO and Rs. 15,000 under the individual category.

Review of the Above Activities Taken Up and Suggestions for Future Activities

- While activities like grants to NGO and, cash awards to people doing good work is appreciated, investments in activities like public awareness, safety weeks, and driver education need to be reviewed. Empirical evidence shows that these activities are not likely to be effective in improving safety. (Sources: The Way Forward, 2005) Therefore, diverting these funds to activities recommended by experts on road safety and injury prevention techniques seems the most logical way to approach improving wellbeing.
- The safety measures specific to two-and-three-wheelers mentioned in this section are:

- Traffic calming during off peak hours, when the speeds are likely to be higher and crash probability increases
- Placing roundabouts at intersections
- Restricti free left turns at intersections
- Enforce of helmet laws
- Pedestrian friendly front ends of vehicles
- Improving the crashworthiness of vehicles
- Make vehicles more noticeable to reduce night time crashes
- Random alcohol breath testing
- Rest regulations for truck drivers
- Mandatory use of headlights during day time.

(Mohan et al, 2009)

9 Mode Share and Mode Preference

9.1 Mode Shares of Different Category Cities

The following table gives the modal split of the trips made in various cities, categorized according to population.

Table 28 Mode Share (%) - 2007 (With Walk)

City Category	Population (in millions)	Walk	Cycle	2-W	3-W	PT	Car
Category-1a	<0.5 with plain terrain	34	3	**26**	**5**	5	27
Category-1b	<0.5 with hilly terrain	57	1	**6**	**0**	8	28
Category-2	0.5-1	32	20	**24**	**3**	9	12
Category-3	1-2	24	19	**24**	**8**	13	12
Category-4	2-4	25	18	**29**	**6**	10	12
Category-5	4-8	25	11	**26**	**7**	21	10
Category-6	>8	22	8	**9**	**7**	44	10
National Average		**28**	**11**	**16**	**6**	**27**	**13**

Source: MoUD report, 2008

Table 29 Mode Share (%)-2007 (Without Walk)

City Category	Population (in millions)	Bus*	Mini Bus	Car/ Jeep/ Van	2W	3W	Comm. vehicles	NMT
Category-1a	<0.5 with plain terrain	9	4	17	**30**	**14**	9	17
Category-1b	<0.5 with hilly terrain	6	15	40	**33**	**0**	5	0
Category-2	0.5-1	7	2	17	**32**	**20**	6	16
Category-3	1-2	6	4	19	**33**	**20**	5	14
Category-4	2-4	6	2	23	**36**	**16**	4	13
Category-5	4-8	9	2	20	**37**	**21**	4	7
Category-6	>8	12	3	31	**23**	**23**	3	4

(*- Including and tourist and education purpose buses)

(MoUD report, 2008)

9.2 Trip Lengths of Various Cities

Trip length plays an important role in mode choice. The average trip lengths of the above categories of cities are given in Table 30. As the population of the city increases, the average trip lengths get longer. Since the average trip lengths in cities with populations greater than 2 million is greater than 5kms, using non-motorized transport like bicycles leads to long travel times and increased use of motorized transport like two-wheelers and cars (Tables 11, 24, 25).

Table 30 Average Trip Lengths of Different Category Cities

City Category	Population (in millions)	Average Trip length (km)
Category-1a	<0.5 million with plain terrain	2.4
Category-1b	<0.5 million with hilly terrain	2.5
Category-2	0.5-1	3.5
Category-3	1-2	4.7
Category-4	2-4	5.7
Category-5	4-8	7.2
Category-6	>8	10.4

(MoUD report, 2008)

9.3 Advantages Provided by the Two-Wheelers

The two-wheeler modal shares in vehicular traffic were briefly discussed in Section 5.1 where it was observed that, for all the cities with population less than 8,000,000, two-wheelers cater to between 30 and 37% of the total modes. The average trip lengths in cities with population less than 8,000,000 are less than or equal to 7.2 kms. For trip lengths of this range, two-wheelers provide users with the following advantages when compared to public transport:

i. Door to door service,
ii. Lesser or comparable cost compared to public transport for short trips
iii. Easy maneuverability in high traffic conditions,
iv. Easier trip changing compared to public transport (eg. home, work, shopping, home)

The reduction in the number of two-wheeler trips for cities with population greater than 8,000,000 can be explained by their average trip length of 10.4 kms. For such long trip lengths, people are likely to choose a mode which is either more comfortable or less expensive or more time saving. The people opting for higher comfort shift to cars and people opting for cheaper modes shift to public transport.

9.4 Three-Wheeler Mode Share and Three-Wheel Index in Cities

From the mode share (without walking) (Table 30), it can be observed that for all cities with population greater than 500,000 the three-wheeler mode share is consistently in the range of 16 to 23%, around twice the mode share for public transport. In cities with population less than 500,000 and in plain terrain, the three-wheeler mode share is 14%, which can be explained by short trip lengths and the lesser requirement of para-transit. In hilly areas with population less than 500,000, three-wheeler mode-share is zero, which can be explained by the difficulty in operating the three-wheelers in hilly terrain.

Three-Wheeler Availability Index of Cities

The availability of three-wheelers or the fleet size of three-wheelers plays an important role in determining the number of people opting to use them. Therefore, an index indicating the number of three-wheelers available in a city as a function of their population has been developed and is explained below (table 31).

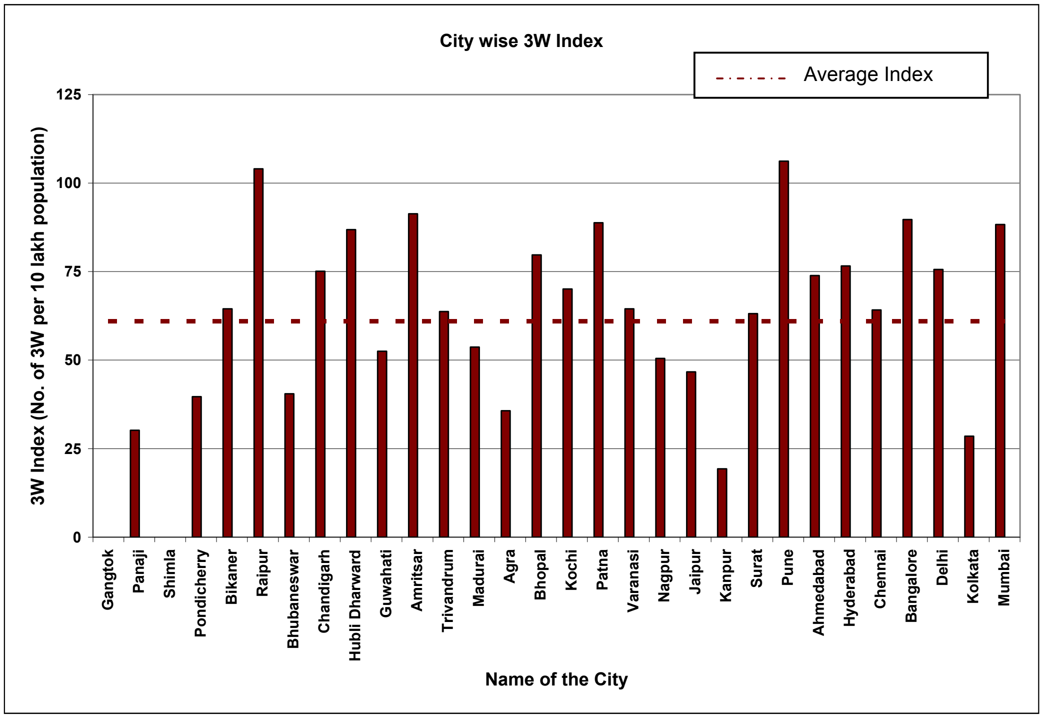
Three-wheeler availability Index = number of three-wheelers registered per 1 lakh population

Table 31 Number of Auto Rickshaws in the Selected Cities

S.No	City	No. of 3Ws (2005)	No. of 3W/ lakh population
1	Gangtok	Nil	0
2	Panaji	293	302
3	Shimla	Nil	0
4	Pondicherry	2017	397
5	Bikaner	4125	645
6	Raipur	7478	1040
7	Bhuvaneshwar	3421	405
8	Chandigarh	7256	751
9	Hubli-Dharwad	8407	868
10	Guwahati	5567	525
11	Amritsar	9903	913
12	Trivandrum	7152	637
13	Madurai	6361	537
14	Agra	4884	357
15	Bhopal	11620	797
16	Kochi	12742	701
17	Patna	16302	888
18	Varanasi	12221	645
19	Nagpur	10666	505
20	Jaipur	12513	467
21	Kanpur	5252	193
22	Surat	19512	631
23	Pune	44590	1062
24	Ahmedabad	43865	739
25	Hyderabad	48898	766
26	Chennai	45016	642
27	Bangalore	77375	897
28	Delhi	104747	756
29	Kolkata	41946	285
30	Mumbai	156261	883

(MoUD report, 2008)

Figure 12 Comparison of Three-Wheeler Index of Various Cities



The auto rickshaw population in selected cities is presented in Figure 12. Cities such as Gangtok and Shimla do not have auto rickshaws. For other cities, the number of auto rickshaws per 100,000 population ranges between 190 in Kanpur to 1,060 in Pune. Pune has the highest number of auto rickshaws per 100,000 population.

Also, from the graph it can be observed that there is no particular relationship between population (indirectly the size of the city) and the availability of three-wheelers. Major metro cities generally have higher number of auto rickshaws compared to smaller cities because they act as a feeder service to public transport and also because of the end-to-end service they provide, which is not always possible for the public transport. It is observed that cities without public transport have a higher number of IPT vehicles. Hence the number of three-wheelers in any city is based on the local conditions, like financial options and road infrastructure. National policies are not having a uniform effect throughout the country.

However, the numbers given here may not accurately give the actual number of three-wheelers operating on the roads (Ref: Autofuel policy study, CRRI). A large percentage of the vehicles registered with the RTOs were found to not be operating so vehicle ownership does not necessarily translate into vehicles on the road.

9.5 Time Series Data on Two-and-Three-Wheeler Mode Share

The data provided here was collected during a research project done by TRIPP, IIT Delhi from 2002 to 2006. Five intersections, among the busiest in Delhi, were selected from various parts of the city. A brief introduction to the importance of these intersections, their connecting roads and the land-use pattern of the area is given here.

Aurobindo Intersection

On Aurobindo Marg, the road along which this intersection is placed, are some very important places in Delhi. Few of the important ones are shopping areas (Delhi Hart, Green Park) hospitals (AIIMS, Safdarjung), educational institutions (IIT Delhi, NCERT), residential areas (Hauz Khas, Green Park) and tourist spots (Qutab Minar).

Hazrat Nizammudin Intersection

This crossing is on Mathura road going toward Noida, Mathura and Agra. This junction is the main entrance for Nizammudin Railway Station and an adjacent a heavy residential area.

ISBT intersection

This intersection is on a busy ring road in North Delhi near the Inter State Bus Terminal. One of the roads connects Sahadra in East Delhi and Ghaziabad to the ring road. The Delhi University campus also is very near this junction.

ITO intersection

ITO has the highest volume at the corresponding time intervals of the five selected intersections. This area is home to some very important offices like Delhi Police Headquarters, DDA, Institute of Engineers and The Times of India. Within a 1.5-kilometer radius of the intersection are India Gate, Pragati Maidan, Supreme Court, Darya Ganj, Delhi Gate, New Delhi Railway station, Connaught Place and Yamuna Bridge, Delhi Secretariat and the ring road.

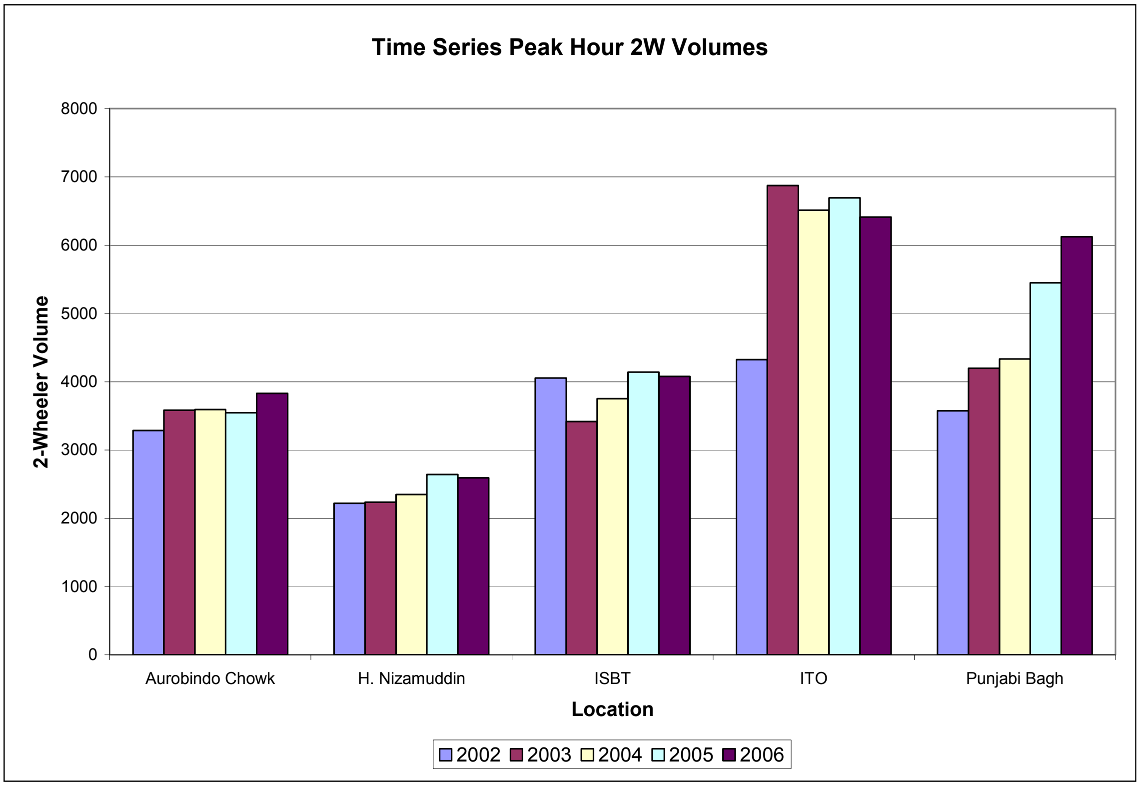
Punjabi Bagh Intersection

This crossing is on the ring road and is used by commuters going to Rohtak. A heavy residential area that creates high traffic volumes is located on both sides of the crossing.

The data collected during the morning peak of 9 to 10 a.m. was analyzed. These intersections are evenly spaced out around the city, so it is unlikely that during the peak hour, the same vehicles are counted more than once.

Figure 13 gives the variation of the total volume of two-wheelers passing through these sections during the peak hour.

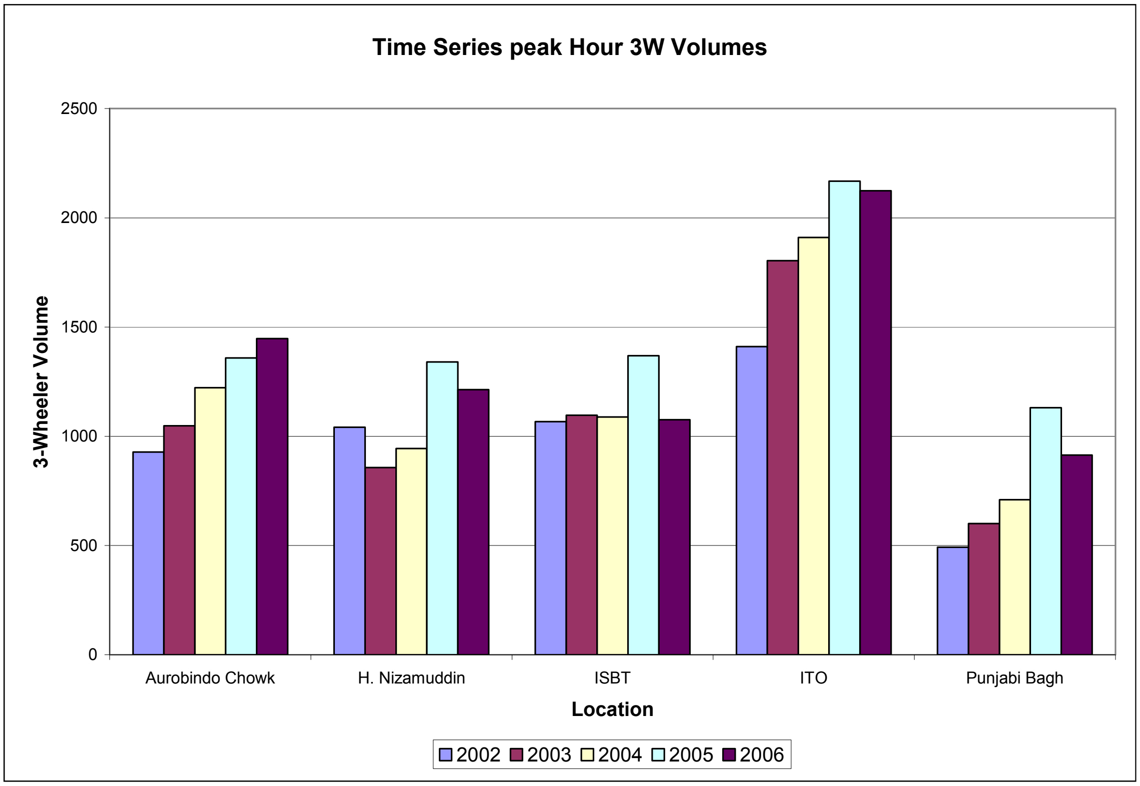
Figure 13 Peak Hour Two-Wheeler Volumes at the Five Intersections Selected in Delhi



Source: TRIPP, IIT Delhi

At three of the five intersections considered, the two-wheeler volumes continuously increased over the five-year period while at ISBT intersection, the volume in 2006 remained almost the same as in 2002. In the case of the ITO intersection, the two-wheeler volumes increased by about 2,000 veh/hr(4,324 to 6,873) from the year 2002 to 2003 and have slightly reduced in the later years. But ITO still has the highest two-wheelers among all the intersections, followed by Punjabi Bagh.

Figure 14 Peak Hour Three-Wheeler Volumes at the Five Intersections Selected in Delhi

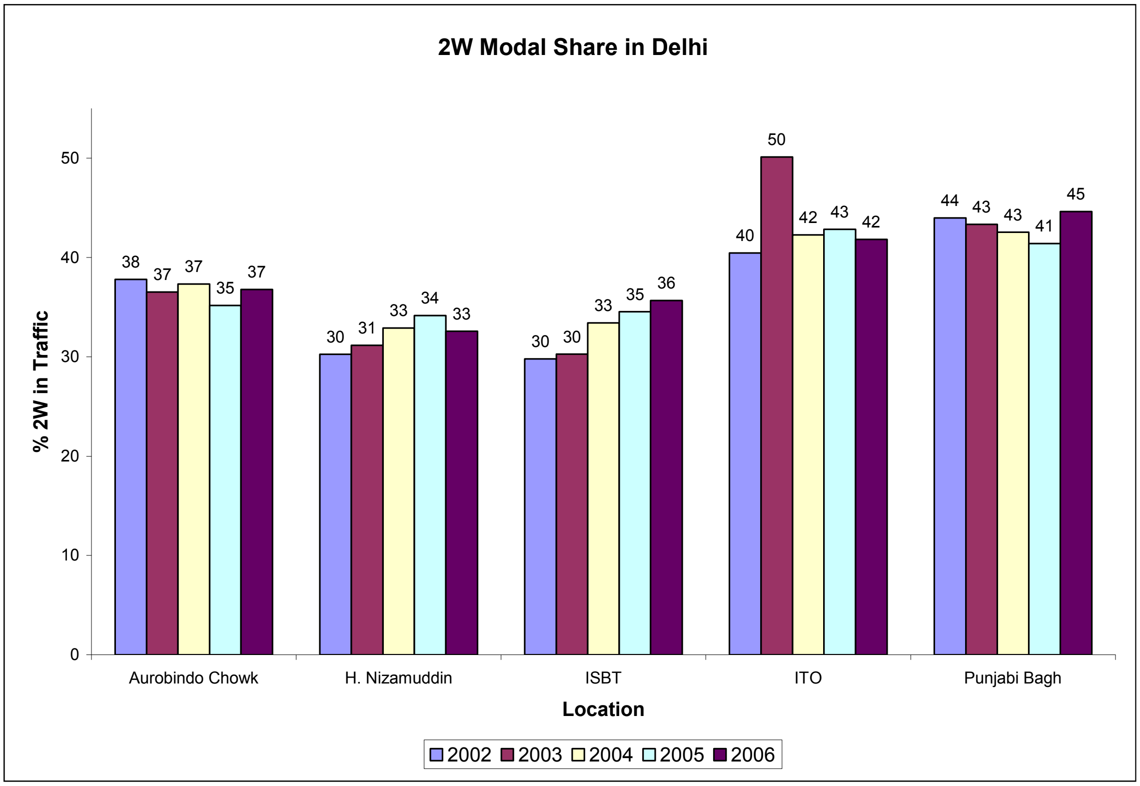


(TRIPP, IIT Delhi)

At four of the five intersections, the number of three-wheelers continuously increasing increased until 2005 and then decrease in 2006. This can be attributed to the age restrictions and the restriction on the total number of three-wheelers in the state by the Delhi government.

The percentage of two-and-three-wheelers in the total traffic is discussed in the following sections. Figure 15 gives the modal share of two-wheelers at the five intersections, in the five years observed.

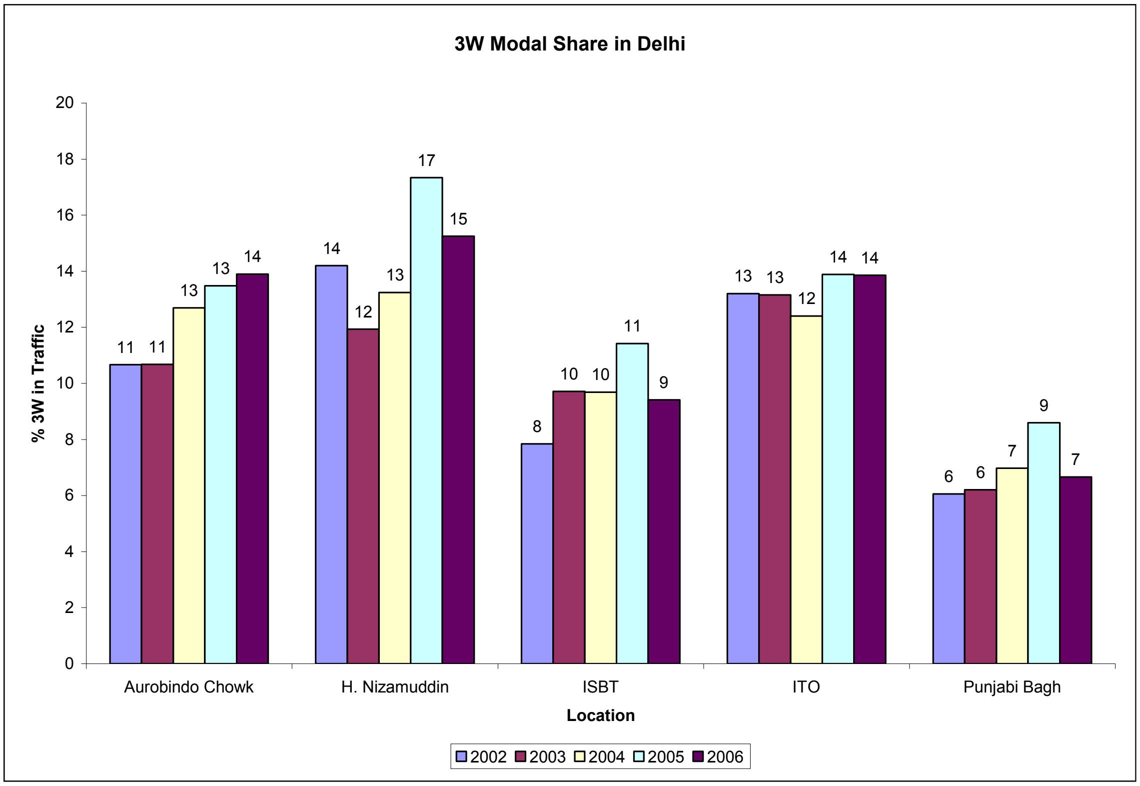
Figure 15 Two-Wheeler Modal Shares at Five Intersections for Five Years in Delhi



(TRIPP, IIT Delhi)

The study revealed no patterns that show the modal share of two-wheelers is changing with time. The three-wheeler modal shares are shown in the **Figure 16**.

Figure 16 Three-Wheeler Modal Shares at Five Intersections Over Five Years in Delhi



(TRIPP, IIT Delhi)

The study shows the modal share of three-wheelers in traffic has increased marginally over the period of observation. To get the overview of the modal share trends of two-wheelers and three-wheelers in the city, their average is taken for each year. The average values of modal shares are presented in the following table.

Table 32 Average Modal Share of Two-and-Three-Wheelers at the Five Intersections

Average Modal Share	**Year of Observation**				
	2002	2003	2004	2005	2006
% 2W	36	38	38	38	38
% 3W	10	10	11	13	12

The two-wheeler modal share remained almost constant throughout the study while the share of three-wheelers has fluctuated within a range of 3%.

In conclusion, it can be said that over time the modal share of two-and-three-wheelers, is staying at relatively the same proportion though the total volume of vehicles/ flow is increasing.

9.6 Purpose Wise for Trips for Various Modes

In this section, data from four sample cities -- Delhi, Hyderabad, Pune and Patna -- were selected from four population categories and analyzed to get a picture of how trips are distributed.

Work Trips

The following table gives the mode split of the four cities for work trips.

Table 33 Mode Split for the Work Trips of Various Cities

City	Population Category	Bus	Car	2 W	3W	Cycle	Walk	Train	Total
Delhi	>10 million	14	17	**20**	10	18	4	18	100
Hyderabad	5-10 million	36	4	**48**	4	5	3	0	100
Pune	2-5 million	23	19	**11**	5	19	7	16	100
Patna	1-2 million	5	15	**18**	5	13	41	3	100

Source: DMRC report: RITES, 2001, BRTS Master Plan, Pune, Primary Survey-Patna, 2009, Hyderabad MMTS Report, L&T Ramboll

Except in Pune, two-wheelers are the preferred option for trips to work in the cities studied. This can be attributed to their affordability and the various advantages mentioned in section 10.3 provided by the two-wheelers.

Education Trips

The following table gives the mode split of the four cities for education trips.

Table 34 Mode Split for the Education Trips of Various Cities

City	Population Category	Bus	Car	2 W	3W	Cycle	Walk	Train	Total
Delhi	>10 million	15	5	2	**23**	9	46	0	100
Hyderabad	5-10 million	62	2	21	**7**	4	4	0	100
Pune	2-5 million	6	7	11	**17**	17	26	15	100
Patna	1-2 million	31	3	7	**23**	14	0	21	100

Source: DMRC report, RITES, 2001, BRTS Master Plan, Pune, 2008 CMP Patna, 2009, Hyderabad MMTS Report, L&T Ramboll

Among education trips in Hyderabad and Patna, school bus and public transport had the highest usage, whereas in Delhi and Pune, three-wheelers have the highest share. Even in Patna, the share of three-wheelers is high at 23%. This is because children and students in most Indian cities use the same auto rickshaw when they have similar origins and destinations.

Social and Recreational Trips

All the other trips, apart from work and education, are grouped into social and recreational trips. The mode share of these trips is given in the table below.

Table 35 Mode Split for the Social and Recreation Trips of Various Cities

City	Population Category	Bus	Car	2 W	3W	Cycle	Walk	Train	Total
Delhi	>10 million	18	21	9	22	4	3	24	100
Hyderabad	5-10 million	50	4	26	12	2	7	0	100
Pune	2-5 million	11	15	21	23	6	14	11	100
Patna	1-2 million	14	19	15	17	15	0	20	100

Source: DMRC report, RITES, 2001, BRTS Master Plan, Pune, 2008 CMP Patna, 2009, Hyderabad MMTS Report, L&T Ramboll

Public transport use for social and recreation trips is low while use of three-wheelers and personalized modes like cars and two-wheelers is high. This is because comfort is the first priority for social trips and cost is secondary.

In conclusion, the data presented here indicates that two-wheelers mainly serve those going to work, while three-wheelers are used for education, recreation and shopping.

10 Parking

This section discusses current parking policies and government plans, existing standards and their drawbacks and the recommendations for future work in this area.

10.1 Parking Policy (NUTP)

The following guidelines set out by the Ministry of Urban Transport in the National Urban Transport Policy (NUTP), act as a broad framework within which parking strategies are developed:

- Levy a high parking fee that truly represents the value of the land occupied to make public transport more attractive
- Provide park and ride facilities for bicycle users with convenient interchanges
- Graded scale parking fees should aim to recover the cost of land-used for parking and electronic metering should be used widely
- State governments should amend building bylaws in all million plus populated cities so that adequate parking space is available
- Bylaws should control parking in residential areas
- Multi-level parking complexes should be mandatory in city centers that have high-rise commercial complexes and will be given priority under the national urban renewal mission (NURM)

In addition to the above guidelines, a city-specific parking policy is also outlined below:

10.2 City Parking Policy

The policy states that each city should develop a comprehensive mobility plan or transport master plan that includes a strategy for parking controls within the city and conforms to the national policy outlined above. The following list provides a summary of components typically used by cities worldwide. The design of parking measures should conform to the adopted strategy of the city.

Components of parking strategy:

- Strategy considering location and land-use
- Characteristics of on-and-off street parking
- Selection of on-street parking options
- Potential for private sector involvement
- Pricing strategies

- Additional consideration

The policy also mentions that parking controls are an effective tool for restricting excessive use of private cars. Public transport and non-motorized transport (NMTs) for shorter trips can be encouraged by restricting the number of parking spaces. No two-wheeler and three-wheeler parking strategy is explicitly proposed but it is understood that the policy tilts more toward encouraging public transport (of which three-wheelers are a subset and act as intermediate public transport (IPT). However, no specific stance to encourage or discourage two-wheelers is taken. Since cars and two-wheelers are both private modes of transport, it is understood that both are encouraged to a lesser degree..

IRC SP 12:1973 gives the ”Tentative Recommendations on the Provision of Parking Spaces for Urban Area.” Only the area to be earmarked for parking in various land-use types are specified but the proportion of parking area for transport modes is not specified. The equivalent car space (ECS) is mentioned for various vehicles as provided in the table below.

Table 36 Equivalent Car Space (ECS) by Type of Vehicle

Vehicle Type	ECS
Car / Taxi	1
two-wheeler	0.25
Auto Rickshaw	0.5
Bicycle	0.1

Source: MoUD Guidelines, June 2008.

This inherently assumes that the amount of parking provided will be location specific and is left to the discretion of the parking provider to divide the land for various modes. However, this may lead to a disproportionate allocation of land. Also, all parking standards are recommended in terms of car spaces provided as part of the built up area. In a country where fewer than 13% of the population own cars, this may lead to over-estimation of required parking area.

10.3 New Vehicle Parking Schemes:

The NUTP sets out specific steps involved from planning to execution of a new parking scheme. This includes:

a. Studies to evaluate the suitability of a scheme

b. Steps involved in the design process
c. Financial options for new parking places

These steps have been explained in detail in the following sections:
(MoUD Guidelines, 2008)

1. Studies to be Conducted to Evaluate the Suitability of a Parking Scheme

The following checklist may be used to assess the suitability of a parking scheme (Y\N).

- Is the number of on-street parking spaces appropriate to encourage public transport use and to promote an attractive pedestrian environment?

- Is the number of off-street parking spaces sufficient to provide a balance where there is a reduction in on-street spaces?

- Are public off-street parking facilities located within an acceptable walking distance of actual destinations? (for short-stay parking – i.e. less then four hours – acceptable walking distance rarely exceed 500 meters.)

- Is priority given to residents and short stay parking? (Computer parking can be accommodated, but it should not be at the expense of residents and short stay visitors.)

- Does the parking scheme divide the city into coherent zones, with regulation appropriate to the particular circumstances of each zone (i.e. the strictest regulations are usually required in areas with the highest parking volumes).

- Is the regulation and tariff for public on-street parking higher than for off-street parking?

- Is there adequate enforcement to ensure compliance with the parking regulations?

2. Steps involved in the design process of a vehicle parking scheme

The selection and subsequent design of an appropriate city parking scheme requires a number of stages, summarized below. In each of the steps, the heading indicates the work to be done and the points below it indicate the basis upon which the work is to be done:

Step 1: Diagnose the existing situation

a. Parking supply inventory
b. Parking utilization study
c. Demand analysis and projections

Step 2 Consider potential measures

a. Supply measures
b. Demand measures

Step 3 Select appropriate measures

a. Comprehensive mobility plan

Step 4 Design appropriate measures

a. Consult with stakeholders

3. Financial Options for New Parking Places

Public private partnerships (PPP) are being explored as attractive options to high cost, multi-level parking in city centers when the municipality alone cannot meet construction, development and maintenance needs. In this model, a private entity obtains the right from a government agency to provide a service under market conditions. The arrangement allows asset ownership to remain in public hands, but new investments in addition to operation and maintenance becomes the responsibility of the private operator.

The above practices are for new parking provisions. In already developed parking areas which owned by the municipalities, the operation and maintenance work is already being leased to private entities many cities.

10.4 Existing practices and Drawbacks

IRC SP 12 gives "Tentative Recommendations on the Provision of Parking Spaces for Urban Areas." It specifies the space for different land-uses in terms of square meters or car spaces. The following are the parking spaces recommended for different land-uses.

1 Residential

(i) Detached, semi-detached and row houses:	
Plot area up to 100 square meters	No private or community parking space required
Plot area from 101 to 200 square meters	Only community parking space required
Plot area from 201 to 300 square meter	Only community parking space required
Plot area from 301 to 500 square meters	Minimum one-third of the open area should be earmarked for parking
Plot area from 501 to 1,000 square meters	Minimum one-fourth of the open area should be earmarked for parking
Plot area from 1,001 square meters and above	Minimum one-sixth of the open area should be earmarked for parking
(ii) Flats	
One space for every two flats of 50 to 99 square meters or more of floor area.	
One space for every flat having 100 square meters or more of floor area.	
(iii) Special, costly developed area:	
One space for every flat of 50 to 100 square meters of floor area.	
One and a half spaces for every flat of 100 to 150 square meters of floor area.	
Two spaces for every flat of above a 150 square meters of floor area	
(iv) Multi-storied, group housing schemes:	
One space for every four dwellings, except in cities like Kolkata and Mumbai where the demand may be more	

(IRC SP 12)

2 Offices -- One space for every 70 square meters of floor area.

3 Industrial Premises -- One space for up to 200 square meters of initial floor area. Additional spaces at the rate of one for every subsequent 200 square meters or fraction thereof.

4 Shops and Markets -- One space for every 80 square meters of floor area.

5 Restaurants -- One space for every 10 seats

6 Theatres and Cinemas -- One space for every 20 seats

7 Hotels and Motels

(i) Five and Four star hotels -- One space for every four guest rooms

(ii) Three star hotels -- One space for every eight guest rooms

(iii) Two star hotels -- One space for every 10 guest rooms

(iv) Motels -- One space for every 10 beds

It is also specified that the minimum car parking space is 3m*6m, when individual parking space is required and 2.5m*5m when parking lots for community parking are required. The truck space is specified at a minimum of 3.75m*7.5m. No other space requirements are specified.

The scope of the book itself states that “The recommendations are only tentative and reasonable relaxation from these may be allowed in particular circumstances”. As a result the enforcement of these guidelines is difficult.

No data exists on segregating parking space between cars and two-wheelers. . Further research is needed before concluding whether it is done according to some principle or based on the judgment of the parking spaces’ owner.

10.5 Recommendations for Future Parking Studies

In conclusion, parking is one area in which very little research has been done. Therefore, little evidence is available about conditions on the ground, the problems faced by people, authorities and the ones with licenses of parking spaces. It is strongly recommended that a research project looking at parking issues in cities with varying population, size and other such local issues should be taken up as early as possible.

11 Noise Pollution and Control Technologies

This section takes up noise legislations and standards in India; how well they are being implemented and possible ways to reduce noise pollution levels.

11.1 Legislations on Noise Control in India

Following are various laws in India related to noise control.

1 Environmental (Protection) Act, 1986 (Noise Limits for Motor Vehicles (revision) - 2000)

2 Air (Prevention & Control of Pollution) Act, 1981

3 Factories Act, 1948

4 Motor Vehicles Act, 1988

- **Section 119** specifies that every motor vehicle be fitted with an electric horn and any multi-toned horns that produce shrill, loud or alarming noises are not permissible under law. But this law is not enforced properly
- **Section 120** requires that every motor vehicle be fitted
  With a muffler device which reduces the noise that would otherwise made by escape of exhaust gases from the engine.
  It also specifies that every motor vehicle shall be so constructed and maintained as to conform to the noise standards for motor vehicles.

5 Indian Penal Code – Sections 268, 290 & 291

6 Criminal Procedure Code – Section 133

7 Law of Torts

8 Local Acts/ Rules regulating loud speakers etc.

Among all the regulations in the above mentioned legislations, the one's which are relevant to this study are explained below.

11.2 Ambient Noise Standards (Noise Rules, 2000 and its Amendments)

Noise Standards for Various Land-use developments

In these standards, various areas have been categorized by land-use and individual limits.

Table 37 Noise Limits for Various Land-use Patterns

Category of Area / Zone	Limits in dB(A) Leq	
	Day time	Night time
Industrial area	75	70
Commercial area	65	55
Residential area	55	45
Silence Zone	50	40

Note:-

1. Day time shall mean from 6 a.m. to 10 p.m.
2. Night time shall mean from 10 p.m. to 6 a.m.
3. Silence zone is an area comprising not less than 100 meters around hospitals, educational institutions and courts, religious places or any other area which is declared as such by the competent authority.
4. Mixed categories of areas may be declared as one of the four above mentioned categories by the competent authority.

(Source: www.cpcb.nic.in)

Noise Limits for Vehicles at Manufacturing Stage

The following table gives the noise limits specified for two-and-three-wheelers as a function of their engine capacities. These limits are specified to discourage users from operating vehicles without proper muffler systems.

Table 38 Noise Limits for Two-Wheelers and Three-Wheelers of Different Engine Types

Sl. no.	Type of vehicles	Noise limits db(a)
1	Two-wheelers	
1.1	Displacement up to 80 cc	75
1.2	Displacement more than 80 cc but up to 175 cc	77
1.3	Displacement more than 175 cc	80
2	Three-wheelers	
2.1	Displacement up to 175 cc	77
2.2	Displacement more than 175 cc	80

(www.cpcb.nic.in)

Extensive checks need to be carried out as to whether these limits are enforced. Even though nationwide data is unavailable, there are some numbers from various hospital locations in Delhi. The peak hour levels there are presented below.

Table 39 Noise Levels Near Hospitals in Delhi

Location	**Noise level (dB) - day**	**Noise levels (dB)- night**
AIIMS	87	77
Jai Prakash Narayan hospital	83	103
Kalawati Saran hospital	83	103
Guru Teg Bahadur hospital	82	102
Dr RML hospital	71	-
Safdarjung hospital	88	-
LNJP hospital	80	90
Mool Chand hospital	60	69

(www.cpcb.nic.in-2007)

Hospitals come under silence zones so noise levels there should not exceed 50 decibels during the day and 40 decibels at night. However, the actual levels observed are higher during the night and in both time periods are greater than the prescribed limits at all the locations. The higher noise levels at night can be attributed to increased movement of heavy vehicles (trucks, trailers, etc.), which are banned in the city during the day. This shows that the noise limits are not being observed and further reduction in the noise produced by traffic is to be achieved. The following section discusses the control measures that can be adopted in this regard.

11.3 Noise Control and Regulation Procedures

Reduction in the ambient noise levels can be achieved by the following measures:

Advanced noise control technologies in vehicles

Various techniques for noise control are available and should be considered at the design stage. Most noise sources (except for aerodynamic noise) are associated with vibrating surfaces. Hence the control of vibration is an important part of any noise control program.

Better enforcement of noise laws

Stricter laws for noise levels, the issuance of more pollution certificates to violators and greater enforcement of these laws are required

12 Policy Recommendations

This section discusses the recommendations on the mix of policies needed to promote safe and efficient two-wheeler use in urban settings of India. This section is based on opinions collected by experts involved in research on issues related to two-wheelers and three-wheelers and is presented under two headings, one about the safe and efficient use of two-wheelers and one for the safe and efficient use of three-wheelers.

12.1 Safe and Efficient Use of Two-Wheelers

Safe Use of Two-Wheelers

Policies recommended to improve the safety of two-wheeler users are:

a. Notification of Helmet Law in all States

Helmet laws fall under the jurisdiction of state governments. And not all states have not have declared that helmet usage is mandatory. Even in states where it is mandated, it applies only for the drivers but not for the pillion riders. Research shows that helmets greatly reduce the probability of a fatality in two-wheeler crashes (WHO Report, 2004). Hence, it is recommended that helmet laws be mandatory for both drivers and passengers in all states.

b. Segregation of Heavy Traffic

In urban mixed traffic conditions, two-wheelers have the most conflicts with buses (Table 21). This can be attributed to the difference in mass between the two vehicles. Therefore, it is recommended that separate bus lanes are provided wherever possible to reduce conflicts.

c. Daytime Headlight Usage for Two-Wheelers

Research shows that turning on the headlights during day reduces road traffic crashes (WHO Report, 2004) and hence this rule is recommended to be implemented in India.

d. Making Two-Wheelers More Visible

Two-wheelers are less discernible at night, a fact that leads to accidents. Steps taken to improve this are likely to make them safer.

e. Discouraging Bigger Engine Sizes by Higher Taxation

The motorcycle sales trends show that more and more new vehicles are being sold with higher engine powers (Iyer, 2008). Higher powered engines lead to higher speeds and are likely to cause more accidents and greater potential cost to the society. The current taxation system does not have different taxes for different engine sizes. By levying progressively increasing taxes with increase in engine sizes, this can be overcome to some extent, assuming that higher taxes discourage people from going for higher powered engines.

f. Traffic Calming

Traffic calming at locations with a high incidence of accidents leads to lower speeds and less probability of accidents. This is recommended to be implemented at as many critical locations as possible.

g. Progressive Increase in the Use of Disk Brakes

Disk brakes are a superior technology to drum brakes, which are the most commonly used brakes in India. Disk brakes are currently used only in some high end motorcycles, probably due to cost constraints. Superior braking technology leads to reduced accidents. Progressive introduction of disk brake systems in all the motorcycles is recommended.

h. Introduction of Children's Helmets

At present, only adult helmets are available in the market leaving children with no option. Measures to introduce child-sized helmets will reduce fatalities among children.

Efficient Use of Two-Wheelers

The current occupancy value of cars in Patna (population in the range of 1 to 2 million) is 2.03, while that of two-wheelers with a PCU value of 0.5 to 0.75 has an occupancy value of 1.30 (Source: Primary Survey). The values of other cities follow a similar pattern. This indicates a more efficient usage of road space by the two-wheelers. Even at signalized intersections, during red times, it is common to find two-wheelers weaving through the gaps between bigger vehicles to come to the start of the queue and they are the first to clear the queue during green times as a consequence. This is another instance of efficient space utilization by the two-wheelers.

In this way individual two-wheelers are already using the available road space efficiently. If the issue is better use of road space, the solution can be of two types:

a. Reducing Two-Wheeler Usage

Policies aimed at reducing the usage of two-wheelers altogether and promoting public and non-motorized transport as an alternative is the best idea. Currently, two-wheelers chief advantages are their end-to-end service and the travel time they save. Providing good pedestrian and non-motorized vehicle (NMV) infrastructure, like footpaths and bicycle tracks (currently non-existent in most of the cities), is likely to provide the same advantages as two-wheelers. This would attract some of the trips currently made by two-and-three-wheelers to non-motorized modes. The trips still made by two-wheelers are the ones the user finds better even after the NMV facilities. The NMV facilities are likely to shift short trips, while long trips can be shifted from two-wheelers by providing a reliable and efficient public transport system.

b. Promoting Two-Wheelers as an Alternative to Cars

The second best option is to promoting two-wheelers as an alternative to cars. In the present scenario cars and two-wheelers cater to two different niche markets and steps should be identified and implemented to convert at least some of the car users to two-wheelers .

c. Improved Traffic Management

- ***PCU values and design guidelines***

  As explained in Chapter 5, the existing PCU values and design practices followed in India are erroneous and a detailed study of ways to correct them needs to be undertaken.

- ***Road and Intersection traffic management***

  Under the existing system, normal traffic engineering duties like signal systems at intersections and traffic circulations at rotaries, etc. are left to the traffic police. This results in suboptimal usage of urban road space. These practices need to be reviewed thoroughly and new and efficient practices should be introduced.

d. Parking Issues

Parking is a problematic issue in Indian cities. And proper scientific studies are few. Practices more suited to Indian traffic conditions need to be developed if the road space for two-wheelers is to be used more efficiently.

e. Policies to Reduce Emissions

- **Emission standards based policies:** This topic has been discussed separately for old and new vehicles.

New Vehicles

Emission standards for new vehicles (based on a type approval process) tend to be the driving force to stimulate cleaner vehicle technologies. Experience, both in and outside Asia, demonstrates that this is the most effective method to reduce average emissions over time. There is a need to constantly upgrade technology to improve efficiency of two-wheelers.

Introduction of new technologies should neither be accomplished through promotion nor through a ban on specific technologies. Introduction should be achieved through **"Technology Forcing"** standards for emissions and fuel efficiency with due consideration to cost-benefit ratios. This helps industry find ways to improve its technology to maintain the standards. However, emission-based measures are more difficult to monitor than technology-based options.

New standards should be **"fuel-neutral,"** i.e. the same for all fuels and globally harmonized as far as possible. This helps users select their preferred fuel type while conforming to the standards. Increased efforts are required to adopt alternative propulsion systems and fuels.

Stricter emission standards are apparently pushing Indian manufacturers to build more four-stroke engine vehicles, though changing customer profiles and preferences have also played a part.

In-Use Vehicles

There is a need to take urgent steps towards introducing effective **Inspection & Maintenance (I&M)** systems for two-wheelers (see discussion of current drawbacks in Section 4.3). Where these systems exist but are not effective, improvements should be sought and based on the effective system currently used in countries like Taiwan.

Implementation of I&M system and other in-use vehicle management systems should be backed up by progressively refined fiscal instruments. Steps need to be taken to reduce noise emissions, the one issue which is most neglected.

Vehicle inspection will be ineffective if the vehicles that fail are not repaired promptly. The availability of adequately equipped and trained mechanics, which are in short supply due to the introduction of increasingly sophisticated four-stroke technologies, is a prerequisite for a successful I&M program,

It is necessary to ensure that **fuels and lubricants** (particularly for two-stroke engines) should be of specified quality and without adulteration. Solutions such as phasing out, up-grading and conversion of old vehicles to alternative fuels, appear to have limited possibilities and may be used to specific locations and conditions.

Technology-Based Policies

The following technology based policies are recommended to reduce emissions.

Ban two-stroke engines greater than 10 years old from urban areas:

This has been taken up in Delhi for three-wheelers. Two-stroke engines pollute more than four-stroke engines, a situation that increases with age.. Since banning two stroke engines would deny point-to-point access for millions of people, older vehicles which pollute more are recommended to be excluded. In Delhi, the diesel/petrol using three-wheelers having an age greater than 10 years were banned in March 2000 and are mandated to use cleaner fuels. A similar policy for two-wheelers can be taken up in urban areas, where the concentration of emissions will be high to reduce their emissions.

Ban New Two-Stroke Engine Vehicles

This is likely to have less socio-economic impact than banning all such vehicles, since the cost difference between new two-and four-stroke engines is not significant. If operating and maintenance costs are included, the cost of two-stroke engine may even be more than a four-stroke engine.

All the above methods are best pursued if the following conditions are met:

i. Alternatives for the vehicles being removed are readily available and market-tested.
ii. These alternatives are affordable, which may require the lowering or elimination of import duties or other taxes on new vehicles and
iii. Sufficient credit exists for vehicle owners and drivers to finance the purchase of the newer vehicles.

Economic and Fiscal instruments

Whether or not technology specific measures are adopted, economic policy options exist to encourage removal of older and more polluting vehicles from polluted cities. These options are discussed below:

Tax incentives for vehicle renewal

The structures of taxes and other vehicle charges, such as annual registration fees, should be carefully reviewed and revised if necessary where such structures do not capture the cost of pollution. For example, the import tariffs or sales taxes on cleaner alternatives to three-wheelers (whether new vehicles or parts for vehicle retrofitting) should not be so high as to discourage their purchase since the public health benefits to be gained are high. Similarly, the annual registration fees based solely on the market value of the vehicle, rather than on market value and pollution emitted, would be too low to discourage the use of older vehicles in urban areas. In assessing each of these measures the policy makers need to weigh the socio-economic cost of making it more expensive to own old vehicles against the health benefits of reducing vehicular emissions.

Credit availability for replacing old vehicles

Government help to ensure the availability of credit through regular credit and micro credit markets to facilitate the replacement of older two-stroke engines or auto rickshaws with cleaner ones is likely to encourage the process. This provides an incentive to people owning older vehicles to switch to newer and cleaner vehicles.

(Iyer, 2008, Two-and-three-wheelers, Source book, 2009)

12.2 Safe and Efficient Use of Three-Wheelers

Fatality rates show that travelling in a three-wheeler is very safe compared to a two-wheeler. The vehicle's design makes it stable while on the move.

i. **Fare Structure**

An exact fare structure for three-wheelers is not formulated or properly implemented in many of the cities in India. Even where they are put into practice, grievances like not upgrading fare prices with fuel prices crop up and some operators charge according to what the;y perceive as reasonable. Therefore, people believe the operators are dishonest and always charge more that what is reasonable. (Mohan et al., 2003)

ii. **Reviewing the Limit Imposed on Three-Wheelers**

Delhi seeks to reduce congestion by setting a limit to the total number of three-wheelers permitted to ply the roads. However, such limits are not imposed on any other vehicle type even though they also contribute to congestion. Also, demand for three-wheelers as a para-transit is also increasing with the population while supply remains constant. So, the rationale behind this needs to be reviewed. If the emissions caused by the three-wheelers are the reason for the ban, then the limit must be in terms of the emissions caused or the technology used by an individual vehicle.

iii. **Policies to Reduce Emissions**

The same policies explained for two-wheeler emission reductions in section 13.1.2 can be applied reduce emissions even in the case of three-wheelers.

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