Final Report

Project Code 2010EM04

Analysing Sustainable Urban Transport: A City level Modelling Approach

Prepared for

Norwegian Ministry of Foreign Affairs

The Energy and Resources Institute

...towards global sustainable development

Suggested format for citation

T E R I. 2014
Analysing Sustainable Urban Transport: A City level Modelling Approach
New Delhi: The Energy and Resources Institute. 109 pp.
[Project Report No. 2010EM04]

For more information

Project Monitoring Cell
T E R I
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail pmc@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delhi (0)11

Project Team

Advisors

Mr. Shri Prakash

Dr. Ritu Mathur

Research Team

Dr. Atul Kumar (PI)

Ms. Priyamvada Kayal (Co-PI)

Dr. Ritu Singh

Ms. Namita Khurana

Mr. Rishu Kumar

Ms. Megha Kumar

Ms. Seema Singh

Ms. Akshima T. Ghate

Mr. Sumit Sharma

Mr. R. Suresh

Ms. C. Sita Lakshmi

Table of Contents

List of Figures

List of Tables

Acronyms

HH	Household
IPT	Intermediate Public Transport
NMT	Non-Motorized Transport
NSM	Non-Slum Mandatory
NSNM	Non-Slum Non-Mandatory
SM	Slum Mandatory
SNM	Slum Non-Mandatory
PCTR	Per Capita Trip Rate
PMC	Patna Municipal Corporation
PRDA	Patna Regional Development Authority
PUAA	Patna Urban Agglomeration Area
PT	Public Transport
PV	Private Vehicle

Acknowledgement

This report is written as a part of the end product of Analyzing Sustainable Urban Transport: A City Level Modelling Approach project under the Program of Activities, Framework Agreement between the Norwegian Ministry of Foreign Affairs (MFA) and The Energy and Resources Institute (TERI), briefly referred to as the Norwegian Framework Agreement (NFA).

We are very obliged for the support by the government officials of Patna to provide us with the appropriate information and copy of various documents which has helped in the project. These include the Department of Traffic police for accident related documents, Regional and district Transport office for data on registered vehicles in all category, City Pollution Control Board for pollution related data and Office of Municipal Corporation for ward wise information on land use and socio-economic status.

We also extend our gratitude to the survey team of Vision Infinity without whom the data collection and data entry process would be incomplete.

Executive Summary

Historically a city transforms from an agrarian economy to an industrial and service economy during the industrialization and urbanization process. During this it goes through several physical and social changes within the urban structure. This also encompasses the increase in the distances between different activities and their location thereby, increasing the movement of people and goods. In order to ease the movement of people and goods it is essential to meet the accessibility and mobility needs of the same efficiently and in a sustainable manner.

The study provides a city level framework which would help in designing and recommending policy measures to improve the accessibility and mobility pattern of a city. The framework is then implemented on a city as a pilot study to exemplify the framework which could be then applied to a similar city for sustainable mobility measures. The study aims to develop an understanding of current transport infrastructure and travel characteristics of the city. It will also highlight the current transport issues as well as strong points in the city pertaining to transport so as to provide policy recommendation.

The framework includes several parameters and indicators to understand the travel pattern and transport characteristics of a city. The framework emphasises on the interdependence of land use allocation to different activities and the travel demand generated due to the same thereby impacting the travel distance,, speed and time.

Primary data was collected through a set of surveys which included information from end users as well as service providers, whereas, the secondary data was gathered through local governing bodies like municipality and traffic police.

The framework provided an understanding about the transport scenario in the exemplified city along with the interaction and interdependence of land use and transportation. This facilitated in proposing several measures that could be implemented so as to improve the mobility of the exemplified city in a sustainable manner. These include

1. Policy implementation of high frequency air-conditioned buses with decreased time travel to shift the private vehicle user to public transport.
2. Road design improvement through continuous, uninterrupted and shaded footpaths, road crossings, and street lighting to encourage walking among the residents.
3. Adequate street lighting in the collectors of the city is essential and installation of solar streetlights independent of the grid will provide continuous light and a sense of security among the residents.
4. Providing CNG based IPT to decrease the air pollutant emission from the same as the accessibility to IPT better than PT.
5. On-street parking fare should be implemented with stringent rules on number of hours of parking to shift from on-street to off-street parking facilities.
6. Including e-rickshaw as a mode of transport for shorter distance should be implemented with stringent safety, speed and other regulations in place.

7. Incorporation of transit oriented development and mixed use development in the planning process is among the best practices to reduce the travel distance and travel time and number of trips.
8. Multi modal transport system should be incorporated as many transport modes run within the city. This will increase the connectivity and accessibility to mass transit modes of transport.
9. Allocation and distribution of land for various purposes should be done as early as possible to implement mixed use and transit oriented development along the metro lines and at metro stations.

1 Objective and Scope

The objective of the study is to develop a city level transport analysis framework that will help in designing and recommending appropriate strategies as well as policy interventions for reducing energy consumption and addressing other issues related to sustainable urban mobility. Further, the framework is applied to an Indian city as a pilot study. Using this framework, various recommendations of urban transportation are proposed.

The scope of the study is to create a sustainable urban mobility framework by integrating land use and transport system and to analyse their impact on social, economic and environment of the city. The study looks deeper into the transport movement of the people for different purposes within the city Analysis sheds light on the relationship between movement of people and different land uses involved along with the modes used by them. The purpose of the analysis is to propose interventions that would minimize the travel demand and distance of the people so as to reduce the mobility and improve their accessibility.

2 Literature Review

2.1 Rationale and Background

The development process of an urban agglomeration is inevitable and is measured by the spatial and structural alterations in the same. These transformations are visible in both developed and developing countries and are governed by population growth and the economic geography of the urban settlement (WDR, 2009). Typically there are four phases of urban development from its growth to decline depending on the growth of core and periphery (Hall and Hay, 1980; van den Berg et al., 1982 and van den Berg, 1987) which is related to the economic and social development of a country as mentioned by Friedrichs (1985) and Hayashi (1992). The first phase in the life cycle of a city is urbanization and its successor includes sub-urbanization, de-urbanization and re-urbanization. Ideally cities in the developed world have experienced all the phases described below but developing world is still experiencing the urbanization phase. Therefore it is essential to know the development phases in order to move towards sustainable development.

In the urbanization phase urban growth occurs at the core and residents are located in the vicinity or a low density suburb which are majorly dependent on the core. The economic transition occurs from agricultural to an industrial society. During this phase the slum or low income group population increases drastically as the rural population migrate for better jobs in industries. During the sub-urbanization phase the suburbs grow faster than the core and the jobs to move in the suburbs thereby, declining the core of the urban agglomeration. The other two phases are de-urbanization and re-urbanization in which the economic growth of suburbs continues in the former stage and in the latter one the densification of the core is the main aim which is very rarely observed.

As mentioned above, urbanization process has its positive as well as negative side. Where the positive side of urbanization is the economic boon, but it also brings social disparity and environmental imbalances.

In global south, urbanization process is proliferating thus resulting in increased population (as a result of the combined effect of natural growth and migration), rapid motorization, low per capita income, congestion, waste disposal, lack of land management, traffic congestion, pollution, poverty, crime and social unrest (Zegras, 2005; Pucher et al., 2005; Planning Commission 2012).

Being part of the global south and one of the fastest growing economies, urbanization is unavoidable in India. It is a by-product of industrialization which is apparent from the fact that industry and service sector share has been higher than the agricultural since 1980's. Since the locations of these are in and around the city, it increases the employability of the urban agglomeration thus making it a magnet for rural population to migrate. This is evident from the increased urban population in India from 17.3% in 1951 to 27.8% in 2001.(Planning Commission, 2011) and so has increased the number of million plus cities from 35 in 2001 to 50 in 2011which is likely to be 87 by 2031(Report on urban infrastructure and services, March 2011).

One of the by-products of urbanization is rapid motorization which is evident in the increase in car ownership in developed countries (Pucher et al., 2007). Increase in vehicle ownership is visible in developing countries but of 2-wheelers instead of cars (Cervero, 2103). Rapid motorization poses high pressure on infrastructure which is unable to meet the demand, therefore creating a gap between the demand of transport system and the supply of transport infrastructure. In India the new born million plus cities are facing this problem due to rapid urbanization and exponential growth of population. Along with this, spatially distributed activities create demand for mobility thereby increasing motorization.

Therefore, sustainable development along with urbanization has become imperative. Furthermore, sustainability in transport sector has been an issue of concern as the use of car and 2-wheelers increase due to rapid motorization and so does the consumption of fossil fuel and tailpipe emission. Another factor that enhances the above consumption and emission is the location of activities. Spatial distribution of activities or land use allocation impact the travel pattern which in turn affects the fuel consumption and tailpipe emission. Therefore, to achieve sustainable development from transport perspective it has become essential to incorporate land use allocation of activities in the planning process so as to minimize the travel distance and demand of the people.

In reference to aforementioned need for sustainable development it becomes essential to understand the interdependence of land use and transport which are the deciding factor of an urban form. Transport elements, users and geographical characteristics define the urban form which governs the travel pattern including the mobility of goods and people and accessibility to the trip end.

Historically, several ideal urban system were developed and tested these include; Linear City by Soria y Mata (1892), Garden City by Ebnezer Howard (1898), Broadacre City by Frank L. Wright (1935), and Radiant City by Le Corbusier (1924) and All these systems differ in their spatial structure, residential density, distribution of land uses and prevalent transport mode and can be characterized under three urban spatial structures.

1. Point structures: In this structure the system is concentration in the center and is usually the inner core of the city.
2. Linear structures: These are city types built along a line, usually a large transport infrastructure.
3. Area structures: These are city types with low density development which lack a clear spatial hierarchy and central structure.

However, the ideal urban systems fail to succeed as different urban agglomeration develops at a different rate and one of the major factors that brings down the above system is population growth depending upon the level of economic activity of the urban setting.

2.2 Land Use and Transport Interaction

The travel pattern of goods and people are governed by the interaction and interdependence of spatially distributed activities and transport infrastructure. It has been deduced from a study by Pucher et al. (2005) that travel pattern is highly governed by the urban form of a city. A linear city corresponds to high density and high transit ridership whereas a low transport infrastructure. It also corresponds to the age of the city especially in India; the old

city corresponds to high density, mixed land use, low land allocation of land for transportation thus becoming sustainable from transport perspective but faces the problem of waste management, congestion and more. Furthermore, the study highlights that a radial city corresponds to low density, low transit ridership and high transport infrastructure investment within the city.

Keeping all the above mentioned parameters and problems of urbanization it has become essential to develop the city in a sustainable manner which includes and meet the mobility and accessibility needs of the city as well as overall development. In context with such a development Cervero (2006) had initially proposed the 3D's to achieve sustainable mobility which included Density, Diversity and Design. Later, Ewing and Cervero (2010) included two more D's which could influence the travel demand of the people comprising Distance to transit and Destination accessibility. Other studies revealed two more D's mentioned by Ewing and Cervero, these were Demand management and Demographics. Following paragraphs give a brief description about the 7D's, and their role in achieving sustainable mobility in an urban agglomeration.

Density: it is defined as concentration of population, job or dwelling unit that reside on a particular area of land and is indirectly related to the mobility pattern and number of trip generated in the area itself and for different purpose.

Diversity: It means the availability of different types of land use which corresponds to several activities like school, hospital, banks, parks, jobs and markets along with residences. Diversity means availability of basic amenities in the vicinity thus by promoting non-motorized transport. Usually this generates high amount of trips with shorter distances.

Design: It mainly corresponds to the street design that is availability of footpath, street lighting, pedestrian crossing, number of intersections, and more. The involvement of street design in context of mobility means increasing the walking and biking of the people thus by reducing the vehicular load on the street.

Distance to Transit: Distance to transit is essential to attract people to use the public or mass transit system in an urban area. The level of use of mass transit or public transit depends on the ease to access the boarding points from the residence. Furthermore, this distance should be walk-able or should be well connected by para-transit or other feeder syst4em.

Destination Accessibility: It is the ease with which people can access a trip end. In achieving this both land use and transport component are essential along with the time to travel (peak and non-peak hours), and personal factors like need ability and opportunity (Geurs and Wee, 2004).

Demand Management: It corresponds to the availability of parking facility as per the needs of the people or the city. With the increase in the number of on street vehicles it is essential to manage the parking of the same so as to avoid on street parking problem.

Demographics: It has an important role fine the travel pattern of the residents in several manners. For example, if a locality has high number of working and school going population it would generate high travel demand during the peak hours as compared to a locality with high elderly or retired population who might prefer the non-peak hours to commute and complete their errands during the same time to avoid overcrowding.

In a border perspective all the influencing factors play an important role in deciding the travel pattern and transport demand of the people. The above elements become essential to consider as they are the influencing factors in travel demand and travel pattern of the residents. Figure 2.1 indicates schematically the implication of the aforementioned elements to move towards sustainable mobility.

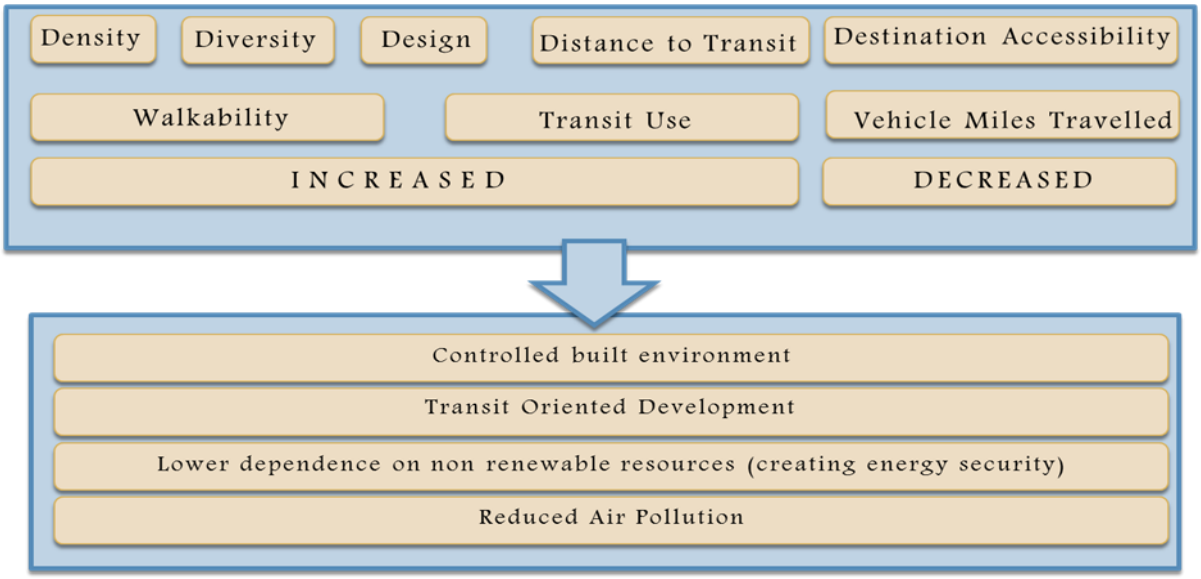


Figure 2.1 Design Elements of Integrated Land Use and Transport Planning

Source: Cervero, 2006

2.3 Institutional Inefficiencies and Policy Measures

With the growing demand for urban travel it becomes essential to manage this demand appropriately with the help of personnel with adequate qualifications and experience which are mostly missing. Such institutional inadequacies like deficit of trained and educated civil-service workforce; corruption free and transparent procedure are common in developing countries Crevero (2013). He further expands the lack of experience in the field of urban management, urban planning, financing, budgeting, accounting and work supervision in the developing world. In addition to inexperience personnel; institutional fragmentation causes lack of coordination and communication between different urban decision making and research institutions thus, resulting in the delays of projects and wastage of resources.

Policies govern the location of activities (job, recreation and residential), mode of travel (public and private vehicles) and transport infrastructure. In many cases, the operation of bus services are given on a public-private partnership (PPP) which has a negative impact on the user as the operator prioritizes profit over comfort and safety of the rider which are the direct influencing factors of reducing occupancy across different income groups.

Another issue that the policy makers of a developing country face is the short sightedness, that is lack of long term vision thus influencing policies and scenarios which will be more sustainable and useful for todays' as well as future generation (Suzuki, Cervero,and Kanako, 2013). Suzuki et al. (2013) summarized policies related to land use and transportation into two main categories; one, land use policies aiming to reduce the need to

travel and two, transport policies aiming to improve accessibility with a wider range of transport alternatives. The former should include policies that implement a reasonable amount of proximity between residences and employment and other amenities and services so as to decrease the trip length and encourage a multi-purpose trip. The latter policy should aim at increasing the use of non-motorized or less energy extensive means of transport such as walking, biking, public transport, car-pooling and use of multi transport service.

Existing land use policies like low floor area ratio within the city as compared to that in urban fringes in India catalyses sprawl and discourages development in the urban centre pushing residents and firms to the out skirts of the city (Pucher et al., 2005). Land use and transport integration and development of the policies for the same should take into account the gender issue in transportation. The policies should be framed in accordance with the 'shelter-transport-livelihood' link especially for a low income woman, says Peter (2013). Certain land use policies should be in place which can regulate the density and concentration by implementing regulations on housing location, road and space layout, transit oriented development, car free developments suggests Banister (2008).

Transport policies should emphasize on modal shift from personalized and single occupied vehicular rides to public and mass transit along with car-pooling opportunities, road pricing and parking control (Banister, 2008). Demand management accentuates on reallocating spaces, effective and creative use of available capacity and restricted access.

Suzuki et al. (2013) discuss that, land use and transit integration requires long-term planning process with a vision to expand the urban agglomeration in the right direction. Although, the planning and implementation process of transit systems in developing countries faces several complications and hindrances with regards to regional and local coordination, policies and regulations to distribute population densities, finance, restricted or contradicting national regulations and lack of policies promoting redevelopment of built and/or abandoned sites.

Policy inadequacies specific to India include lack of safety provisions for pedestrians and bicycle riders and higher provisions to motorized traffic; traffic management policies for implementing advance technology and stricter regulations; improvement in the speed, safety, capacity, priority to public transport; stricter regulations on safety , route planning and coordination while incorporating privatization of bus services; design interventions to feature the needs of buses, pedestrians and bicycle riders; integration among different government agencies to integrate policies and better funding opportunities to reduce motorization (Pucher et al., 2005).

Other policy interventions can be incorporated from examples around the globe compiled by Ghate and Sundar (2013) which include Japan's parking certificates or renting areas for car parking (car parking no more a luxury but a burden) and car prohibitive taxes like car acquisition charges, car weight tax, car annual tax, additional car tax; London's congestion charges in CBD and intensive public transport provision; Hong Kong and Singapore's dissociation of economic growth and automobile production by following the motto of " mobility for all" and not "mobility for automobile". They also mention of creating benchmark for car growth with respect to the infrastructural development which means that car growth should be proportional to existing transport infrastructure and future development to minimize traffic congestion.

'Avoid Shift Improve' ASI policy approach has been gaining importance globally as a measure to achieve sustainable mobility. The ASI approach emphasizes on decreasing travel demand, reducing the use of private vehicle and improving transport technology to reduce emission and smooth traffic flow.

AVOID the need to travel meaning reducing the travel distance, travel time and number of overall trips made. This can be achieved through integrating land use and transport planning which could be attained through higher densities and smaller distances between activities can reduce the travel demand and also through virtual mobility. Integrated land use and transport planning incorporates compact cities and transit oriented development (TOD). These types of developments emphasizes on mixed use and high density development where high density could be achieved through high floor are ratio (FAR) and mixed use development concentrates on appropriate distribution of various activities, affordable housing and transport facilities. The travel demand can also be reduced by implementing virtual mobility in daily lives. This is done by promoting telecommuting, e-work or work from home, e-trade and e-governance.

The SHIFT component of the policy measure looks into the shifting towards more sustainable means of transport including non-motorized, public and mass transport system. This could be achieved through the development of Comprehensive mobility plans (CMPs) which includes implementation of multimodal transport system like metro or BRTS depending on the requirement of a particular city. Further improvement in bus route, bus stop accessibility, pricing, safety, and security in the system would further promote the use of public transport. In case of non-motorized means of transport importance should be given to provide adequate amount of infrastructure and dedicated lanes for the modes. Finally, decreasing the demand of private vehicle use should be the aim by making public transport more attractive, feasible, comfortable and safer. Moreover, decreasing the number of private vehicles on road can be achieved through promoting carpooling and dedicating lanes for high occupancy vehicles (HOV).

Finally the IMPROVE component of the policy measure focuses towards reducing the vehicular emission and enhancing the traffic flow. This could be achieved through promoting alternate fuel vehicles and clean fuels as well as high efficiency vehicles. Further, by implementing intelligent transport system (ITS) in the city's traffic system would ease the flow of traffic by intimating the traffic about congestion and accident as well as guiding the traffic by providing possible alternate routes.

2.4 Land Use and Transport: Crisis in Global South

Some adverse effects of built environment and transportation are mentioned below which are categorized and exposed by Cervero (2013):

Primacy and mono-centricity: Disproportionate concentration of population and economies among the cities; where some of them are home for specialized job opportunities and efficient market transaction Cervero (2013). This geographic unevenness of economy increases with the increase in the area of country (WDR, 2009). These economic bumps in a country also attract a huge inflow of low skilled and uneducated rural inhabitants for job opportunities leading them to informal economy including informal transport system.

"High primacy and mono-centricity means economies accrue from concentration and agglomeration can quickly turn into diseconomies."

Density and decentralization: Even though the population densities in the Global South is increasing their density gradient is decreasing at a much faster rate, as it is fuelled by monetary inflow and rapid motorization mimicking the sprawl of developed countries. The sprawl carried out by both formal and informal settlements as the satellite towns and slums respectively (Cervero, 2013). The decentralized sprawl and low density development has deteriorating effect on public transport (Pucher et al., 2005).

Road densities and road hierarchy: The growth rate of traffic is higher than the supply of infrastructural facilities to support it, thus creating a gap between the supply and demand of transport infrastructure in the sector. In addition to the gap between demand and supply there is lack of road hierarchy for organized flow of traffic and an inadequate maintenance of the infrastructural facilities (Pucher et al., 2005). Furthermore, the geographical constrains like topography, natural features (rivers, mountains) plays an important role in the infrastructural developments (Crevero, 2013).

Spatial mismatches: extreme socio spatial segregation is equivalent in urban areas of developing countries due to high income disparities. The low affordability rate of the urban poor, compels them to trade between location of residence (mostly in the outskirts of a city) and total travel time and expenses which is equivalent to 3-4 hours/day (Pucher et al., 2005) and 20-25% of their daily wage (Crevero, 2013) respectively.

Economic Loss: Rapid motorization and gap in the supply of infrastructural facilities has resulted in high traffic congestion. This is further boosted by informal economy generators like street hawkers and vendors creating bottle neck situations on the roads. The time loss incurred during traffic congestion has an indirect impact on the overall economy. Slow speed and time loss due to traffic congestion affects GDP ranging from 2 to 5 percent in Asia as reported by European Commission in 2011. This dip in GDP adds burden on current as well as future generations (Ghate and Sundar (2013) ;Crevero, 2013). Congestion also steers the preference of modal choice within an urban agglomeration. Buses are mostly preferred by the most vulnerable class of society as they don't have a choice. Traffic congestion and inflexibility of buses due to their size, turning radii, changing lanes and more becomes less popular among the higher income groups as they have an option of driving a car (Crevero, 2013).

2.5 Sustainable Urban Mobility and India

2.5.1 Sustainability and Transport

Transport Implications on Energy Security

The report has already established the relation between urbanization and motorization in the developing world. Furthermore, the growth rate of motorization also increases with the economic development in a country and rise in income. This indicates the increase in fuel consumption which is majorly petroleum products in developing countries due to lack of alternative fuel and vehicle popularity. This poses a major threat on energy security the developing nations. International Energy Agency (IEA) defines energy security as 'the

uninterrupted availability of energy sources at an affordable price' (OECD and IEA, 2013). According to IEA the long term energy security is investing in timely energy supply while keeping in mind the economic and environmental requirements. Whereas the short term requirements for energy security is to meet the supply-demand balance of energy system. The U.S. Energy Information Administration (EIA) predicts the world energy consumption by transport sector to increase at a rate of 1.1% and its share will be around 63% of the total growth in energy consumption by 2040. During the period of 2010-2040 the energy demand of transportation sector by non-OECD countries of Asia will rise from 20% to 36%, which is more than the energy demand of America by 2025 (EIA, 2013).

Transport sector consumes 28% of the commercial energy used in India in 2010-11 (TERI, 2014) and has seen three-fold increase in energy consumption in 2001-2010. Transport sector is majorly dependent on petroleum products and road transport consumes almost 94.5% of the total energy demanded by the transport sector in 2010-11.The energy consumed by passenger vehicle is about 58% in 2011. This demand poses serious threat on India's energy security as the fuel used is dependent on the supply by countries that produce it.

2.5.2 Transport and Safety

Traffic congestion, vehicle speed, road design and network are key elements in providing road safety to both pedestrians and vehicular passengers. It has been calculated that the fatality rate in India has increased 3 times in the last three decades (Pucher et al., 2005). They concurred that level of traffic injuries are directly proportionate to the vehicular speed. In 2011, it was calculated that around 37% of the total road fatalities occur in urban India, where the level of motorization is high (Ghate and Sundar, 2013).

Pucher et al. (2005) listed several factors that hamper road safety in context with increased vehicle ownership, these include; inadequate road supply and quality, unsafe driving behaviour and vehicles, lack of proper traffic signals, lack of pedestrian infrastructure, narrow and crowded right of ways and overcrowded buses.

3 Framework and Methodology

A comprehensive framework has been developed for the study to elucidate the interrelation between Land use and Transportation so as to understand the travel demand of the people and the pattern of their movement with in an urban agglomeration. The framework encompasses two main components, as - The Indicators and The analytical free ware tool. The Indicators mainly help in deducing the transport characteristics of the city that is under consideration; and further guide to understand its impact on the social, economic and environmental components of a city and its occupants. Furthermore, with the help of indicators the results of primary survey analysis is exemplified at a city level to interpret real picture of travel pattern, travel demand and relation between the land use and travel demand.

The decisive objective of this framework is to assist planners and decision makers to understand the mobility needs in a city with population of over a million, which is undergoing rapid urbanization and facing a transformation in the mobility needs of all categories of demographics in the city. Figure 3.1 shows the schematic diagram of the framework.

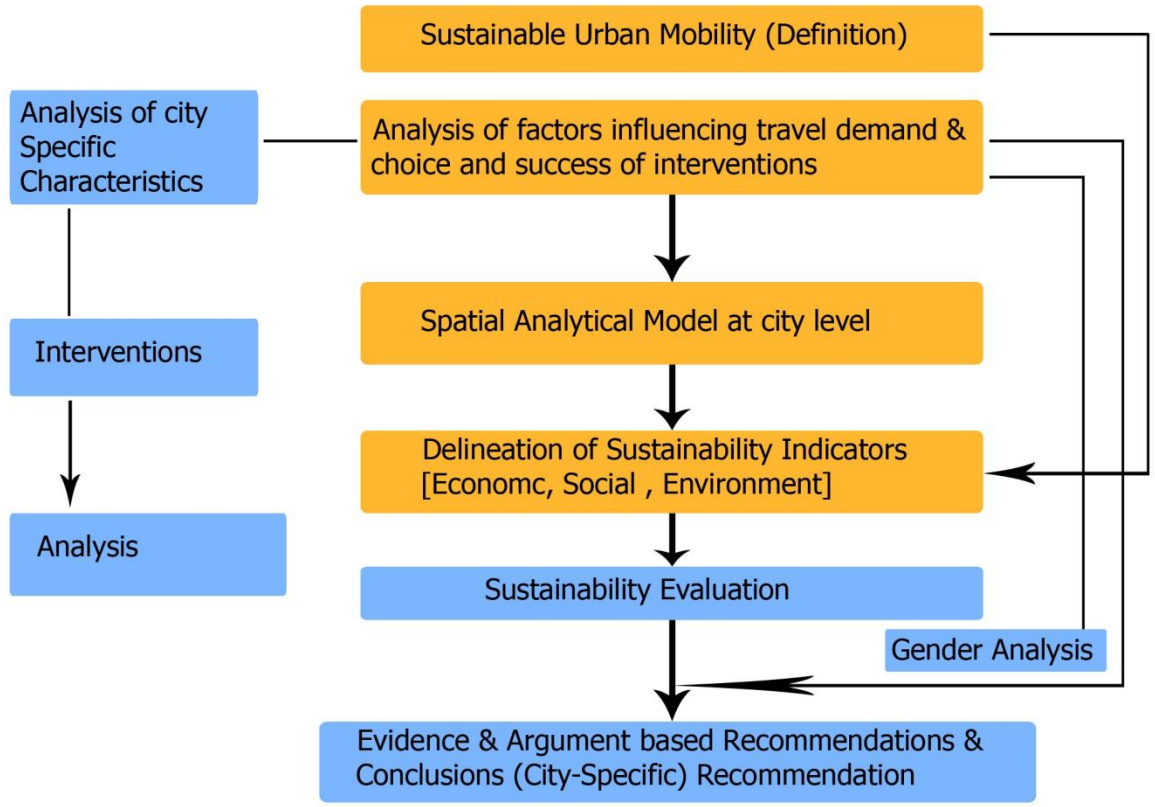


Figure 3.1 Schematic diagram of the Framework

Source: TERI's Analysis

3.1 Framework Approach

This framework is structured to first focus on the definition of Sustainable Urban Mobility; description of which feeds into several significant modules, where - Social, Economic and Environmental Indicators comprise a wide section.

The numerous key factors that determine travel demand and choice of travel mode of the residents includes their income, location of residence, work and market; accessibility to public transport system, and availability of transport infrastructure. Therefore, a detailed analysis of above discussed aspects lead to propose interventions that can practically be implemented. These factors can even amalgamate with the existing travel pattern of the city to develop guidelines that can be implemented to transform the existing scenarios to the best feasible outcome.

The above mentioned travel characteristics are spatially analysed which is the land use allocation with in an urban agglomeration depending on the division of the same. This analysis in the framework is applied to understand the relation between land use allocation, transport system and travel demand.

This spatial analysis would then help in the sustainability evaluation of the urban transport on the basis of energy used, distance travelled, trip rate and time taken. The analysis of travel characteristics will guide in proposing city specific interventions to move towards sustainable mobility.

The overall evaluation process through Indicators are also be analysed from a gender perspective. This is to recognize the travel pattern, travel mode and its frequency preferred by the two genders based on several conditions. Thus, a detailed evaluation can result in directing user-friendly transportation system.

The basic approach towards the framework was to first gather the current understanding about sustainable urban mobility and the missing link in context with India. Once the understanding was developed and sustainable urban mobility was defined the next step was of data collection. The data was collected in two ways – primary and secondary data. The primary data was collected through several surveys which helped in gaining understanding of the travel pattern for different purposes by different age groups of both the genders. Whereas, secondary data was collected through various government agencies, the two are elaborated further in the following sections. Later, a set of questionnaires are formed to gather the primary information from general public, transport operators, infrastructure providers and others to on the basis of indicators.

To assess the framework, it is essential to apply the framework as to an Indian city as a pilot study so as to know the strengths and weakness of the framework. In order to choose a city certain criteria were taken into consideration which is discussed in the following sections. The next section focuses briefly on the indicators and its background followed by significance of each survey questionnaire and finally the criteria for selecting a pilot city to be a pilot study.

3.1.1 Indicators

There are several tools for measuring the trends compare several activities, evaluate policies and check the performance targets of sustainability. These tools include parameters,

indicators and index. Toth-Szabo et al. (2011) has defined the above mentioned tools as follows

1. Parameter: A property that is measured or observed.
2. Indicator: A parameter or a value derived from parameters, which points to, provides information about, and describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value.
3. Index: A set of aggregated or weighted parameters or indicators

Indicators help in understanding the current transport status and level of service of transport system and in order to achieve sustainable mobility several social, economic and environmental indicators are used with respect to transport characteristics and land use allocation. According to Litmann and Burwell (2006), sustainable transport indicators include traffic speed, travel time, modal split, transport land consumption, transport fatality, emission and pollution, parking facility, affordability, infrastructure availability, and equity in accessibility. For an in depth knowledge and analysis of sustainable transport parameters the above mentioned indicators could be disaggregated by demographics, geographical characteristics, time, mode and trip. They have also compiled several indicators, measurement and the availability of data as mentioned in the Table 3.1 below.

Table 3.1 List of Indicators

Objectives	Indicator	Direction	Data
Economic			
Accessibility – commuting	Average commute travel time	Less is better	3
Accessibility – land use mix	Number of job opportunities and commercial services within 30-minute travel distance of residents	More is better	1
Accessibility – smart growth	Implementation of policy and planning practices that lead to more accessible, clustered, mixed, multimodal development	More is better	1
Transport diversity	Mode split: portion of travel made by walking, cycling, rideshare, public transit and telework	More is better	2
Affordability	Portion of household expenditures devoted to transport by 20% lowest-income households	Less is better	2
Facility costs	Per capita expenditures on roads, traffic services and parking facilities	Less is better	3
Freight efficiency	Speed and affordability of freight and commercial transport	More is better	1
Planning	Degree to which transport institutions reflect least-cost planning and investment practices	More is better	1
Social			
Safety	Per capita crash disabilities and fatalities	Less is better	3
Health and fitness	Percentage of population that regularly walks and cycles	More is better	1

Objectives	Indicator	Direction	Data
Community liveability	Degree to which transport activities increase community liveability (local environmental quality)	More is better	1
Equity – fairness	Degree to which prices reflect full costs unless a subsidy is specifically justified	More is better	1
Equity – non-drivers.	Quality of accessibility and transport services for non-drivers	More is better	1
Equity – disabilities	Quality of transport facilities and services for people with disabilities (e.g., wheelchair users, people with visual impairments)	More is better	2
Non-motorised transport planning	Degree to which impacts on non-motorised transport are considered in transportation modelling and planning	More is better	1
Citizen involvement	Public involvement in transport planning process	More is better	1
Environment			
Climate change emissions	Per capita fossil fuel consumption, and emissions of CO2 and other climate change emissions	Less is better	3
Other air pollution.	Per capita emissions of 'conventional' air pollutants (CO, VOC, NOx, particulates, etc.)	Less is better	3
Noise pollution	Portion of population exposed to high levels of traffic noise	Less is better	2
Water pollution	Per capita vehicle fluid losses	Less is better	1
Land use impacts	Per capita land devoted to transportation facilities	Less is better	1
Habitat protection	Preservation of wildlife habitat (wetlands, forests, etc.)	More is better	1
Resource efficiency	Non-renewable resource consumption in the production and use of vehicles and transport facilities	Less is better	2

Source: Litmann and Burwell (2006)

NOTE: Data availability: 1: limited, may require special data collection; 2: often available but not standardized; 3: usually available in standardized form.

Therefore, indicators have an important role in comprehending the current transport scenario and the missing links in the same. For the exemplified city specific study several indicators are considered depending on the availability of the data to understand the transport characteristics of the city. Some of these indicators include Per Capita Trip rate(PCTR), average trip length, average travel time, mode distribution, trip distribution, travel expenditure, transit accessibility, availability of transport infrastructure, safety indicator, security indicator and congestion indicators. All these indicators are disaggregated by income (slum and non-slum), purpose (mandatory and non-mandatory), and gender (male and female).

3.2 Data Collection

For the purpose of analysis, two types of data are collected; primary and secondary. The primary data is collected with the help of several surveys and the secondary data is collected though already documented database either by the central, state or local government. The secondary database included the land use plan (current and future), road infrastructure, fatality data, road accidents, vehicle registration and more. Following departments were the key government offices involved in the data collection process through secondary information source.

1. Department of Traffic police for accident related documents.
2. Regional and district Transport office for data on registered vehicles in all category.
3. City Pollution Control Board for pollution related data and
4. Office of Municipal Corporation for ward wise information on land use and socio-economic status.

Another set of data collection tool were the primary surveys which included several surveys so as to provide information on transport infrastructure, travel pattern and demand of the people, and traffic information. Following are the list of surveys that were undertaken for the process and are then elaborated to provide an idea of the purpose of the specific surveys.

1. **Household Survey:** The objective of the survey was to gain the demographic, socio-economic profile of both slum and non-slum households in the study area. Along with this it also helped in providing knowledge about the travel pattern of the household, number of trips that are being generated, modes used, ownership of vehicle, type of vehicle, monthly expenditure on the vehicle, their perception about public transport and their preference in order to make a move from private to public transport.
    a. Methodology followed: The list of residential colonies and slum areas as provided from the state government department formed the basis for location identification in each zone for household survey. Multilevel sample methodology is followed for household sample selection. At first level, wards are clustered into four zones – New Capital circle covering 29 wards, Kankarbagh circle covering 11 wards, Bankipore circle covering 12 wards and Patna city wards covering 20 wards. At the second stage, stratified random sampling is used for zone wise sample selection. For this index is formulated with the help of density of land use, road and population across wards. Equal weightage of .33 is assigned to each. Further ward wise composite index is calculated by summing up index values across wards. With 9% precision level and 2.58 Z value, total sample selected is 605. Composite index is multiplied with sample size to determine sample for respective wards. Economic classification of household is done as slum and non-slum. Slum represents low income group where as non-slum represents high and middle income group. Equal sample is selected from both slum and non-slum household.

2. **Traffic Count and Pedestrian Survey:** It is vehicle count survey and covers both passenger and goods vehicle and is done at both outer cordon and inner cordon. With the help of screen lines plots and reconnaissance, locations for inner cordon, at arterial roads approaching towards central business districts, are identified. These are the locations with heavy traffic volumes. This survey is essential to throw light on the number of vehicles using a particular road link or a junction during different hours of the day and also the popularity of the road used for pedestrian movement. The survey covers all vehicle movements on the identified roads that passing through both sides of the roads. Outer cordons cover all the roads that connect the city with adjoining region. The survey at outer cordons focused on vehicles that entered the city.
3. **Transport Operator Survey:** Two types of transport operator survey were done mentioned below.
    a. Transport Operator Survey of bus, auto, manual rickshaw and taxi: The purpose of the survey was to understand the ownership of different modes, their maintenance, employment generation, revenue generated, consumption of fuel and type of fuel, occupancy and seats allocated for women. The survey consists of operators of bus, auto rickshaw, manual rickshaw, and taxi. Majorly unions are surveyed for auto rickshaw, manual rickshaw and taxi.
    b. Transport Operator Survey of truck and LCV: The similar information as mentioned above was collected from the truck and LCV operator along with the loading and unloading destination, distance travelled, make and model of the vehicle, capacity of the vehicle, and personnel employed. 6 operators are selected for survey. The operator are interviewed through structured questionnaire
4. **Inventory of Road:** Complete road network that exist in Patna Urban Agglomeration Area (PUAA) was studied. Majorly three types of roads exists - major, arterial and collectors. Major roads are the National highways. Arterial roads run parallel to major roads and connect to important locations in the city. Collectors connect residential areas to small market places and to major and arterial roads. Total 50 roads are surveyed covering 20 each of major and arterial roads and 10 of collector roads (See Annexure). The information gathered for each road type include the width of the road, availability of cycle track and footpath, street lighting, encroachment on the footpath and their type, on street parking (informal or formal) and bus stops. The survey gave a picture on the availability of foot path, and street lighting some of the major elements to promote walking.
5. **Inventory of Parking Facilities:** The survey provided information of the type of parking, its location, and tariff at the parking lot for different vehicle type, number and type of vehicles parked. This helped in understanding the location of parking infrastructure along with type of vehicle intensive areas. Total 12 locations are selected as sample for parking inventory survey. It is snapshot survey. It is done by interviewing the vehicle drivers of both public and private vehicles
6. **On-board bus and bus stop passenger count Survey:** The surveys was carried out on particular routes inside the bus and another at the stop to gather information

about the occupancy of the bus, reservation for women and the situation of overcrowding in the buses and at what time of the day. Regional Traffic Office provided information on heavy, medium and low traffic roads. Out of total existing 12 operational bus routes, 6 bus routes are selected for the survey, covering one bus of each operator. The latter one also provided information on the availability of different facilities on a bus stop like lighting, shade and seats. This survey was carried out on the major bus routes, 3-4 bus stops are identified for survey. The survey of identified bus stops is done in three slots of 2hrs each, morning, afternoon and evening.

7. **Origin Destination Survey:** The survey facilitated in gathering information about the location of origin and destination, mode of travel, purpose of the travel, time taken and cost incurred. The intent of the survey was to understand the movement of the people from one zone to another. Total 10 locations are selected as sample. The identified locations cover bus terminals, railway station, bus stops and at outer cordon. These are the locations where people are observed catching the connecting mode to reach the destination.
8. **GPS and Speed delay Survey:** The purpose of the survey is to study the level of congestion on different roads with the help of speeds at different locations. This is done by gathering information on speed at the origin and destination of a vehicle. Furthermore, the reason of delay is also mentioned in the same. Major routes with heavy traffic flow are selected as sample for GPS and Speed and Delay. The objective is to identify the bottlenecks in smooth flow of traffic. This survey is carried with the help of GPS machine on two wheeler, manual rickshaw, auto rickshaw, bus, taxi and personal car.
9. **Off-street Parking Demand Survey:** The survey puts light upon the locations where the demand of parking is high but the availability of the resource is insufficient. 24 parking areas across the city covering major locations are surveyed. Along with parking inventory survey, major unauthorized parking locations are identified. Locations selected covers areas near offices, shopping area, cinema halls, colleges, schools, hospitals, railway stations, and apartments.

3.3 City Selection

The above mentioned framework and indicators were then applied to an Indian city so as to exemplify the implementation and authenticity of the framework. While selecting a city several criteria were taken into account which was on the basis of data on demography, population growth rate, per capita income, availability of city development plan, comprehensive mobility plan and master development plan, human development index, Gross State Domestic Product (GDP), pollution, infrastructure, registered vehicles and road network of cities across states. Fifteen cities were initially shortlisted which included both capital and other fast growing cities on the basis of above mentioned data. City mobility plan was another important study which was taken into consideration while selecting the city and it was seen that the mobility plans were only done for some cities under the JNNURM (Jawaharlal Nehru National Urban Renewal Mission) fund, which is mostly

allotted to capital cities. Therefore, it was planned to select capital city from the list of shortlisted city for the study.

Moreover, regular visit to a selected city was required for survey supervision and data collection; hence, it was important to select a city at close proximity to Delhi. Therefore, considering the above criteria, among the 15 cities four cities were shortlisted. The team visited these cities, and interacted with the government officials to know the willingness and requirement of such a study in a particular city. Finally the criteria that were considered while selecting the city for the pilot study were:

a. It has to be the capital of a state
b. The population of the city must be more than a million
c. The city should be easily accessible from Delhi
d. Co-operative government officials for data collection

Considering all of the above conditions Patna was selected to conduct the pilot study as the state government showed their willingness to support the study through making the related public documents and data available.

3.4 Limitation

One of the limitations of the project is the land use data analysis from a user's perspective. The reason being, basic amenities like food, shelter and sanitation are the major concern of the slum dwellers and lower income group than the transport infrastructure or facilities. This conclusion was drawn after the team directly interacted with the residents in these localities i.e. of the urban poor as they are the ones who are most deprived of basic services and amenities.

Furthermore the land use interventions rely on the prior decisions made by the development authority of the urban area. Therefore, to make decisions related to land use in the project mainly relies on the secondary data like the land use planning and the zoning ordinance which will help the project in identifying the current as well as the future planning of the city by the governing agencies. In addition to this, the GPS survey of land use is an extensive survey which requires more time and money. Thus, limiting the study's GPS survey to the type of road infrastructure and their characteristics like the level and type of encroachment was done.

Since the project is a framework that will be further helpful in understanding and implementing a sustainable mobility in different cities, certain surveys and their purpose are added to understand the spatial distribution of a given city and understand the travel pattern of the same.

Another limitation of the framework is the structure of an urban agglomeration which is majorly governed by factors like topography and natural features like forest, lakes, rivers and more. For instance in the exemplary city for this project; Patna, is restricted by natural feature on the three sides with Ganga, Sone and Poonpun. The topography of the city would indirectly and directly affect the policies governing land use and transportation.

In case of indicators, availability of data from respective authority was a barrier to generate a distinct set of indicators pertaining to economic indicators like investment done on road infrastructure.

The data received from the survey was limited due to the fund constrain a small sample was chosen. Along with this the quality of data largely depended on the respondents' answer and willingness to answer. This hindrance in the quality of data occurred mainly when respondents from very high income group denied taking the survey, road inventory to be carried out more extensively and detailed information the travel pattern of the respondents should be captured more precisely.

Lastly, the applicability of a freeware analytical tool and its understanding with reference to an Indian city was a difficult to decode with the available data and knowledge about the tool as it was a pilot attempt to use the tool.

4 Defining Sustainable Urban Mobility

People's travel decisions are based on residential location, job location and activity participation. It is also a physical outcome of interactions between cultural backgrounds and physical needs of a particular society and the potential of land availability (Chawla, 2012). Government planning on land use and transport system is undertaken primarily with the objective of designing land-use systems in order to meet accessibility and mobility needs of the people. This land use system consists of spatial distribution of opportunities supplied at each destination in terms of jobs, shops, health, and residence, and social and recreational facilities; and the transport system typically consists of multi-modal public transport system connecting spatially-distributed destination. Transportation is a means to overcome the space between two destinations, so as to meet the demand generated by displacement of people and goods.

4.1 Accessibility and Mobility

Mobility and accessibility are two main components of transportation system. Ilan Salomon and Patricia L. Mokhtarian (1998) have defined mobility as a demand for activities or travel, where the costs are an integral part of the demand. Travel can be an activity when a person travels for enjoyment and satisfaction whereas travel is a derived demand when a purpose is attached to travel that is reaching a destination. Beimborn et al. (1999) has defined mobility as the ease of movement from one destination to another with the help of transport network and services available within the two destinations. The location of origin and destination largely governs the travel pattern and depends on the placement of activities (Cervero R., 2009). Mobility between origin and destination is measured as the distance travelled by people in person miles travelled, goods in ton-miles travelled and vehicle trips for both people and freight, and is enhanced by increasing the speed and mileage of the vehicle (Litmann, 2003). In other words the demand for travel is the distance travelled by an individual between the origin and the destination using a specific transport mode, which includes a time dimension (as travel time, waiting time and parking time) opportunities (in terms of income, travel budget, education level etc.) and an assurance dimension (in terms of reliability, level of comfort, accidents, risks, and others). Any confrontation of supply and demand for opportunities due to restricted capacities at any one destination results in greater mobility need and disutility.

On the other hand, accessibility is a measure of supply, namely, potential mobility, and is not a descriptor of user behaviour (Jones, 1989). Access is the ultimate goal of most of the transportation, except a small portion in which travelling is the motive with no destination (Litmann, 2003), it means that travelling becomes an activity in itself. Accessibility is also the management of travel demand across different income groups and gender (Cervero R., 2009), which is achieved by providing transport infrastructural and logistic facilities to meet the mobility demand. The supply of infrastructure includes location of activities and various transport infrastructure and service characteristics such as maximum travel speed, number of lanes, public transport schedules, and travel costs. Traditionally, improvements in accessibility were obtained by improvements in transport supply, particularly through the expansion of infrastructure (roads and rail) and associated services. In recent years, such

accessibility gains attained by means of increasing inefficient (automobile-based) mobility are deemed undesirable and unsustainable. Instead accessibility improvements accomplished through better land use planning policies such as mixed-use developments and job-housing balance, as well as by temporal policies such as alternate work schedules, are considered socially more efficient. In addition, non-motorized transport system is consider sustainable along with compact and mixed land use that helps to increase walkable communities in order to reduce the amount of travel required to reach respective destinations.

The above definition frames accessibility as a more sustainable approach of travelling when compared to mobility, but in recent times the definition of mobility has been modified as a combination of the above mentioned components of transport system. In this paper mobility+ would be referred as the current concept of mobility, incorporating the role of transportation and land use in meeting the travel demands of people with a sustainability approach.

4.2 Sustainability and Mobility+

The travel demand of a settlement is governed by various factors like demographics, economic activity, vehicle ownership and maintenance cost, public transit availability and cost, level of congestion, non-motorized transport use conditions, vehicle sharing options, land use development patterns, and health and environmental concerns (Litmann, 2013). Furthermore, urbanization, a by-product of increased economic activity has consequences on the rate of motorization, thus increasing the travel demand and need for transport infrastructure and services (Ghate and Sundar, 2013). The increased travel demand of India can be seen through rise in the number of registered vehicles from 55 million in 2001 to 142 million in 2011, and with this the share of transport sector on GDP has also increased from 3.9% in 2001 to 4.7% in 2011. Whereas, during the same period the growth rate of roads was 3.4% as compared to 9.9% of vehicular growth rate as shown in Table 4.1, thus, creating a gap between the need for transport infrastructure and supply of the same (MoRTH, 2012). Aforementioned rate of motorization poses several mobility challenges like insufficient road capacity, low levels of clean air, high fatality rates and lower access conditions (Tiwari, 2011).

Table 4.1 Compound annual Growth in percentage of Vehicles and Roads

Period	Vehicles	Roads
1951-1961	8.1	2.7
1961-1971	10.9	5.7
1971-1981	11.2	5.0
1981-1991	14.8	3.0
1991-2001	9.9	2.1
2001-2011	9.9	3.4

Source: MoRTH, 2012

Note: Roads include - National Highways, State Highways; Other Public Works Department roads, Rural and Urban roads and various projects. Vehicles include – Two-wheelers, Cars, Jeeps, Taxis, Buses, Goods vehicles, Tractors, Trailers, Three-wheelers (passenger vehicles/LMVs) and other miscellaneous vehicles which are not classified separately.

Therefore, sustainable urban mobility provides an alternate concept to understand the complex movement needs of people and goods in a city and amend the links between transport and land use. For this alternative approach, emphasis is given to the future of cities with respect to existing infrastructure (reality), desirability (what is the need and expectation of the community) and role of transport in order to meet the above expectations of the city (Banister, 2008). Based on empirical research, Banister (2008) quantifies sustainable city parameters with a population of 50,000 and more, with medium density of 40 persons per hectare, and mixed land use developments representing public transport accessibility or public transport mode used significantly. Several settlements of the above mentioned size and transport characteristics helps in creating an urban agglomeration with amenities in close proximity and of a scale which requires least use of personalized vehicles. He further states essential steps required to achieve sustainable mobility, which includes reduction in the amount of travel, number of trips per person, and travel distances; increase in modal split travel and finally the use of efficient transport system.

Further Banister has compiled Marshall's (2001) measures for sustainable mobility – an alternative approach which includes the social dimension, accessibility, focus on people (either walking or in vehicle), local in scale, street as a space and not just a means to travel, change in transport hierarchy with a bottom up approach for modes of transport like preference to cyclist and pedestrians, integrating people and traffic, travel management, and reduced travel times. Further adding to the list is a holistic approach for the city rather than just traffic, scenario development and modelling, integration of social and environmental concerns, type of travel (such as derived demand and valued activity), management of mobility, reducing and slowing the movement, travel time reliability, reasonable travel times and integration of people and traffic.

4.3 Defining Sustainable Urban Mobility

4.3.1 Existing Definitions

In addition to the above mentioned broader sustainable concept, below mentioned are specific definitions of sustainable transport given by various agencies.

The first definition of sustainable development by Brundtland Commission (1987) explains it as 'Development that meets the needs of the present without compromising the ability of future generations to meet their own need'.

The Transport Research Board (1997) a US National Advisory Board on transportation has defined sustainability w.r.t. transportation as 'Sustainability is not about threat analysis; sustainability is about systems analysis. Specifically, it is about how environmental, economic, and social systems interact to their mutual advantage or disadvantage at various space-based scales of operation'.

According to Moving on Sustainable Transport (1999) program launched by Canada Transport defines sustainable transport as 'The goal of sustainable transportation is to ensure that environment; social and economic considerations are factored into decisions affecting transportation activity'.

World Bank Council for Sustainable Development (2001) explains sustainable mobility as 'The ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future'.

Centre of Sustainability (2004) elucidates sustainability as 'the capacity of continuance into the long term future' which means the ability to continue anything for indefinite period is sustainable otherwise it is unsustainable.

In 2006, after the approval of Union Cabinet, a National Urban Transport Policy (NUTP) was formulated. The objective of the policy is to 'ensure safe, affordable, quick, comfortable, reliable and sustainable access to all residents'.

A precise adaptation of Brundtland Commission Report's definition of "sustainability" mentioned above with respect to sustainable transportation is 'a set of transport activities together with relevant infrastructure that collectively does not leave problems or costs for future generations to solve or bear', here the cost does not limit to environmental degradation but also the social and economic impacts of transportation (EMBARQ, n.d.).

The abovementioned definitions address a couple of common agendas of sustainable transport system which are mentioned below.

1. Revolve around stabilizing the costs incurred under economic, social and environment aspects, the three pillars of sustainability.
2. To minimizes the burden on future generations.

Whereas the definitions don't take into account factors like

1. Making the transport system accessible to all segments of society at affordable prices.
2. Land use allocation as an integral part of mobility and accessibility.

4.3.2 Sustainable mobility: A broader concept

Sustainable mobility is not only about reducing one's own travel footprint but also to reduce the same of the society, therefore, a sustainable transport system should not only look into individual's mobility need but also the mobility need of the society at large.

Sustainable transport system goes beyond the concept of consuming lesser amounts of fossil fuels to improve energy security and proactively work towards lowering carbon emissions. It is about taking holistic approach by considering economy, society and environment along with the mobility and accessibility requirement of the people. For instance, a narrow approach towards sustainable transport would be implementation of alternative fuel vehicles like biofuel, hydrogen, electricity etc. without addressing the problem of acquisition, maintenance, operation and parking cost of the vehicle. This kind of technological advancement should not be restricted to automobile modifications but should also be involved in traffic management systems and in dissemination of traffic information. Furthermore, this approach does not include the indirect cost like that of accidents, sprawl, poor health and more. The broader concept of sustainable urban mobility looks into the impact of prevailing transport system on the economy, environment and the community and is meant to create a balance between the above mentioned dimensions of sustainability. The end purpose of sustainable transport is to reduce the travel demand, trip distance, and

trip frequency along with increase in the use of public and mass transit modes of transportation.

Achieving the broader approach of sustainable mobility becomes very complex in case of developing countries where the gap between rich and poor is high along with varied requirements of mobility depending upon the spending capacity of an individual. In most cases, the poor becomes a captive non-motorized transport user thus becoming the most vulnerable to safety issues (Tiwari, n.d.). In addition to the above social constrain there is considerable amount of gap between the need of transport services and infrastructure as compared to the requirement for the same.

4.3.3 Issues of urban transport which should be taken into account

Several authors have mentioned various issues from economic, social and environment perspective that are generated by the movement of goods and people. Most of these issues arise due to excessive use of personalized vehicles. Table 4.2 provides a comprehensive overview on the issues of urban transport system.

Table 4.2 Issues of Urban Transport System

Economics	Social	Environmental
Traffic congestion	Mobility for vulnerable groups	Air pollution
Infrastructure costs	Human health impacts	Habitat loss
Consumer costs (fares, automobiles, etc.)	Community cohesion and street life loss	Hydrologic impacts
Mobility barriers	Community livability	Depletion of non-renewable resources
Accident damages	Aesthetics	Noise
Productive rural land loss	Isolation in suburbs	Urban sprawl
Urban land loss to bitumen surface	Public safety	Storm water run-off problem
Time loss due to sprawl		Photo chemical smog, lead and benzene

Source: Litman and Burwell (2006); Newman and Kenworthy (1996)

4.4 Proposed definition

With reference to the aforementioned definitions, issues and broader concept that are to be considered while working towards achieving sustainable mobility the following, definition has been derived and proposed with the intention to attain the same.

"Sustainable Urban Mobility is a system that incorporates economic viability, environment stability and social equity along with meeting the sustainable transport needs of both current and future generations in an efficient manner".

The above definition deliberates both user and service provider's perspective for attaining sustainable mobility. From a user's perspective, the transport system should be quick, affordable, safe, secure, reliable, comfortable, energy efficient and environmentally benign for every category of traveller. It means that the transport system should reduce the distance

travelled, time taken and use of personal vehicles along with increasing accessibility though different modes for all travellers. From system operator/infrastructure provider perspective, the transport system should be profitable along with meeting out the requirements of travellers across various income group and gender. So, normative view on sustainable urban mobility suggests urban mobility to be financially efficient for user and profitable for the provider, by maximizing the use of existing infrastructure thus lowering the cost incurred and investing adequately on sustainable modes of transport infrastructure.

5 Analysis of Primary and Secondary Data

5.1 Background

Patna, the capital city of Bihar lies south of river Ganges and between Latitude: 25° 37' North and Longitude: 85° 12' East. The city is also surrounded by three small rivers namely Punpun, Sone and Gandak creating a unique and favorable location to flourish historically as well as now. Today, Patna has become an important business and tourism center of eastern India. It attracts tourists because of its historic and religious significance.

5.2 Jurisdictional Distribution of Land and Study Area

Patna district is part of Patna Regional Development Authority (PRDA), which includes two more districts namely Saran and Vaishali, where Patna district or Patna Urban Agglomeration Area (PUAA) comprises more than 50% of the total area under PRDA. The area under Patna Municipal Corporation (PMC) is 73% of the PUAA as shown in Table 5.1. The area of PRDA under the PMC jurisdiction is also the study area for this analysis. Figure 5.1 further illustrates the distribution of study area into wards and zones.

Table 5.1 Jurisdictional distribution of Patna District

S.No.	Name of Place	Total Area 2001 (in sq kms)	Total Population 2001 (in lakhs)
1.	PRDA	234.70	21.40
2.	PUAA	135.79	16.97
3.	PMC	99.45	13.66

Source: CDP, Patna

The PMC area is divided into four zones as shown in Figure 5.1 namely

Zone-1: Nuthan Rajdhani Anchal which is the new development area for the city. This zone also includes a part of the existing central business district.

Zone-2: Kankarbagh Anchal comprises of the residential colonies of the city.

Zone-3: Bankipur Anchal is the main central business district of Patna City which includes most of the government offices, colleges and universities.

Zone-4: Patna City Anchal is the old Patna City with historical importance.

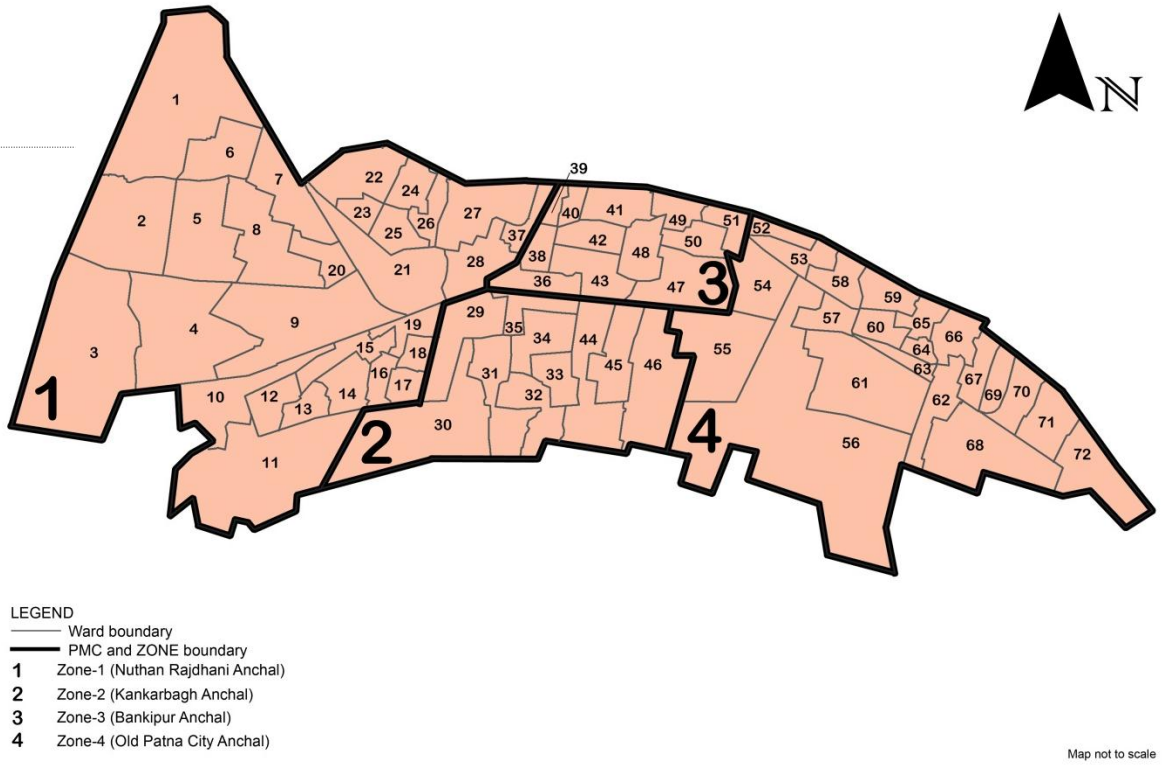


Figure 5.1 Ward and Zone Boundary map of PMC

Source: TERI's Analysis

5.3 Demographic Profile

The area under Patna Municipal Corporation had a population of 9.17 lakhs in 1990-1991 which has increased to 16.83 lakhs in 2001-2011. The growth rate experienced by the city during the 1991-2001 decade was almost 49% which came down to 23% during 2001-2011, which shows that the city is experiencing growth but a slower rate as compared to the previous decade. The sex ratio of the city is 882 females per 1000 males, whereas the sex ratio of children in between 0-6 years is 863 females per 1000 males. Moreover, the children constitute of 11.32% of the total population in the city.

Table 5.2 Demographic distribution among different zones

ZONE	Zone Name	Avg. HH Size	Total Population	Total Slum Population	Total Non-Slum Population	% of Slum Population	% of Non-Slum Population
Zone - 1	Nuthan Rajdhani Anchal	5.4	680874	44437	636437	2.6%	37.8%
Zone - 2	Kankadbagh Anchal	5.7	282332	9706	272626	0.6%	16.2%
Zone - 3	Bakiput Anchal	5.8	254090	16675	237415	1.0%	14.1%
Zone - 4	Patna City Anchal	6.2	466926	13881	453045	0.8%	26.9%

Source: PMC, Patna

The total population of the PMC is being divided into the above mentioned four zones; also, the population is categorized as slum and non-slum dwellers on the basis of the slum settlements in the city. Table 5.2 provides an overview of demographics in the four zones. The highest concentration of non-slum population with respect to total population lies in Zone-1 (37.8%) followed by Zone-4 (26.9%), Zone-2 (16.2%) and Zone-3 (14.1%). In case of slum dwellers the highest concentration of population with respect to total population lie in Zone-1 (2.6%) followed by Zone-3 (1%), Zone-4 (0.8%) and Zone-2 (0.6%). The population distribution among slum and non-slum for the study area is 5% and 95% respectively where Zone-1 and Zone-3 has the highest percent of slum population 6.5% and 6.6% respectively and lowest is in Zone-4 with 2.9%.

The average house hold size of the study area is 5.7 members per household where Zone-4 has the highest house hold size of 6.2 members per household. The average slum household size in the study area is 5.2 members per household where Zone-1 has the highest and Zone-4 has the lowest house hold size with 6.2 and 4.5 members respectively.

5.4 Density

The average density of the study area is 241persons per ha which is been calculates as the average of the ward densities in the PMC, where, the ward density varies drastically from 26 persons per ha in ward 56 of Zone 4 to 693 persons per ha in ward 22 of Zone 1 as shown in Figure 5.2. Furthermore, the zonal density also vary where Zone3 has the highest density of 314 persons per ha followed by Zone 4, Zone 1 and Zone 2 with 300 persons per ha, 198 persons per ha and 168 persons per ha respectively. The zonal density is the average density of the wards in that particular zone.

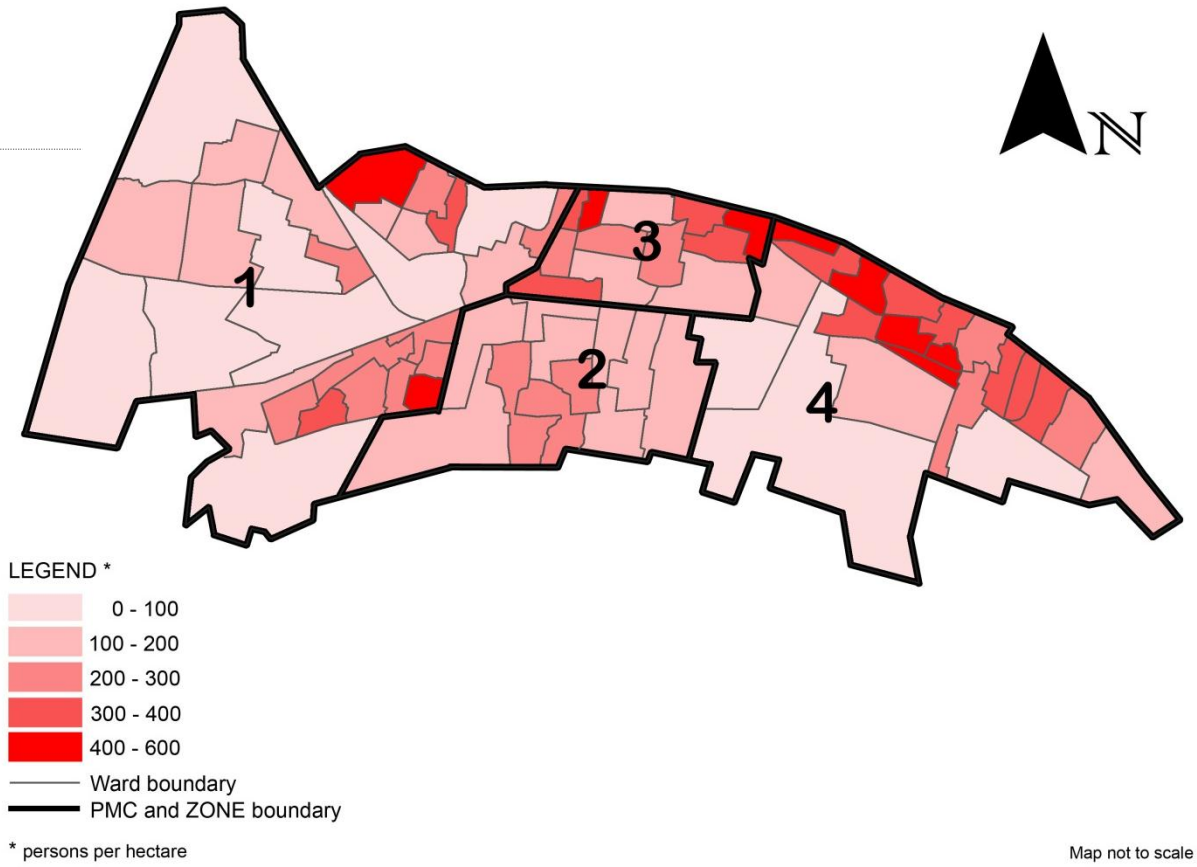


Figure 5.2 Non-Slum Population Density of PMC

Source: TERI's Analysis

The slum density in the study area varies enormously throughout the city. Certain wards have zero slum population and thus zero density whereas, the highest density of slum population in ward 56 with approximately 13800 persons per ha as illustrated in Figure 5.3 below. This clearly shows the lack of per capita land availability for the slum population. Among the four zones the highest slum density is in Zone-3 with 1820 persons per ha followed by Zone-1, Zone-4 and Zone-2 with 1279 persons per ha, 736 persons per ha and 659 persons per ha respectively. Where, in Zone-3 most of the slum population lay along the banks of the river Ganges in the low lying areas as it is the most undesirable to live. Furthermore, the second highest density of slum is in Zone-1 which corresponds to the cheap land availability in the outskirts of the city.

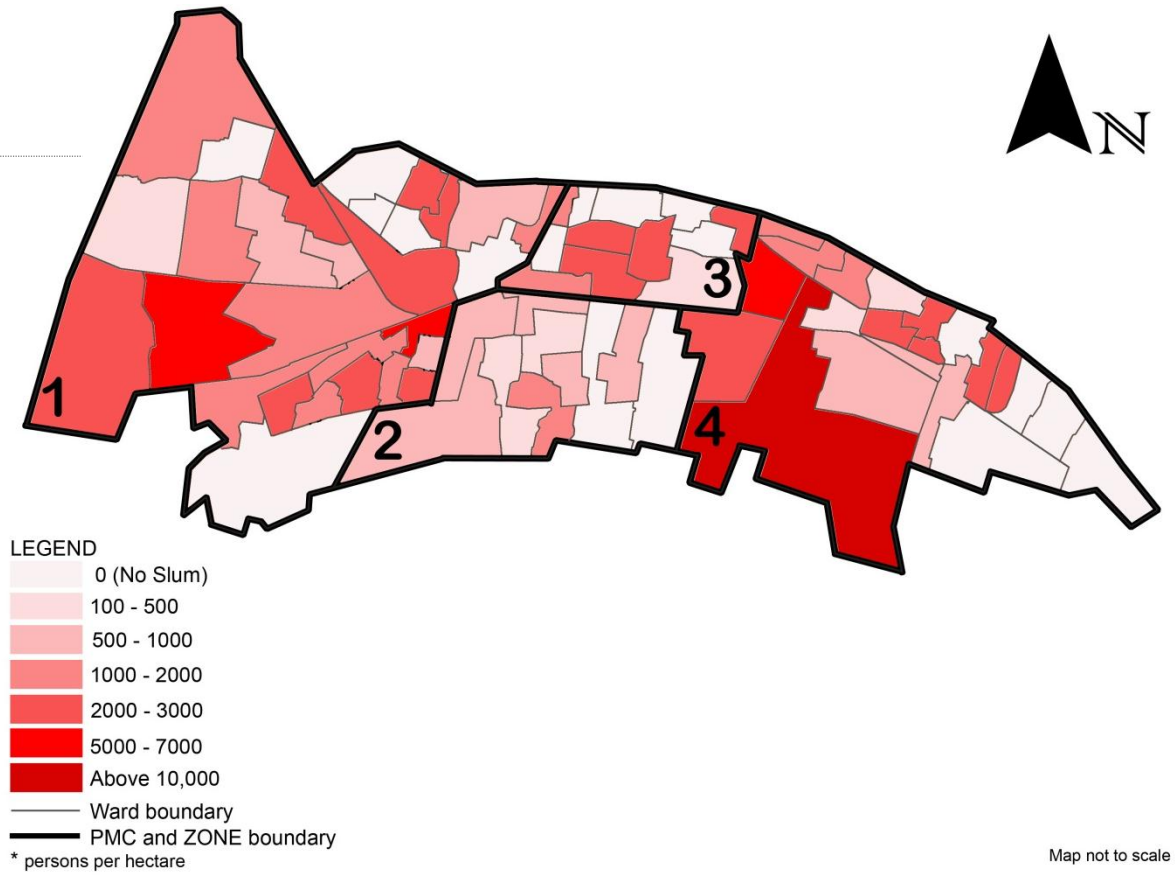


Figure 5.3 Slum Population Density of PMC

Source: TERI's Analysis

5.5 Literacy Rate

The literacy rate of PMC is around 1% lower than that of PUAA which is 84.05% (Census, 2011). The crude literacy rate of male and female in the city is 56% and that of females is 44%. Whereas the literacy rate. Where, the crude literacy rate is the number of literates out of the total population whereas the literacy rate is the ratio of number of literates with respect to the population above the age of 7 years.

So, the literacy rates of all the four zones are approximately similar with highest in Zone-2 and lowest in Zone-4 with 88% and 79% respectively.

5.6 Economic Profile

The working and non-working population distribution in PMC region is 30% and 70% respectively. This clearly shows that a major portion of population is unemployed and falls under the category of children and elderly. According to census the working population is categorized as main and marginal. Main workers are the ones who are employed for more than 6 months in a year whereas; marginal workers are temporarily employed i.e. for less than 6 months. Amongst the total working population almost 84% of the populations are main employees and only 16% of the working populations are marginal workers. The above

two categories of workers are further sub-categorized as agricultural labour, cultivators, household industry and others. The other category consists of professionals, teachers, lawyers, government employees etc. A major proportion of main (89.3%) and marginal (81.6%) workers are employed as other workers. Whereas, among the agricultural labours and cultivators 12% are marginal workers and 6% are main workers. This shows that people engaged in agriculture are employed for less than 6 months. The similar situation is with the HH industry workers where marginal workers are more than the main workers. Overall it is obvious that majority of the working population is engaged in service sector, clearly showing that the city is under the urbanization process and is transforming from rural to urban

The distribution of working population among the different zones clearly shows the highest concentration in Zone-1 with 41% and Zone-4 with 27% the other two zones have an equal distribution of working population about 16%.

5.7 Land Use Distribution

Land use allocation for various activities defines the diversity in the land use within the zone and also in the city on the whole. Figure 5.4 illustrates the current land use distribution within the study area, where equal amount of land is allocated for residential and road infrastructure of approximately 27% and 26% respectively. Agricultural land still shares the 16% of the total land allocated in the city out of with 55% of the land is in Zone-4 which is a swamp and hence unsuitable for any development purpose. The trip attraction land use i.e. the land use that act as the destination of a trip are recreational, institutional, educational, commercial and others which on the whole comprises of approximately 30% of the total land use.

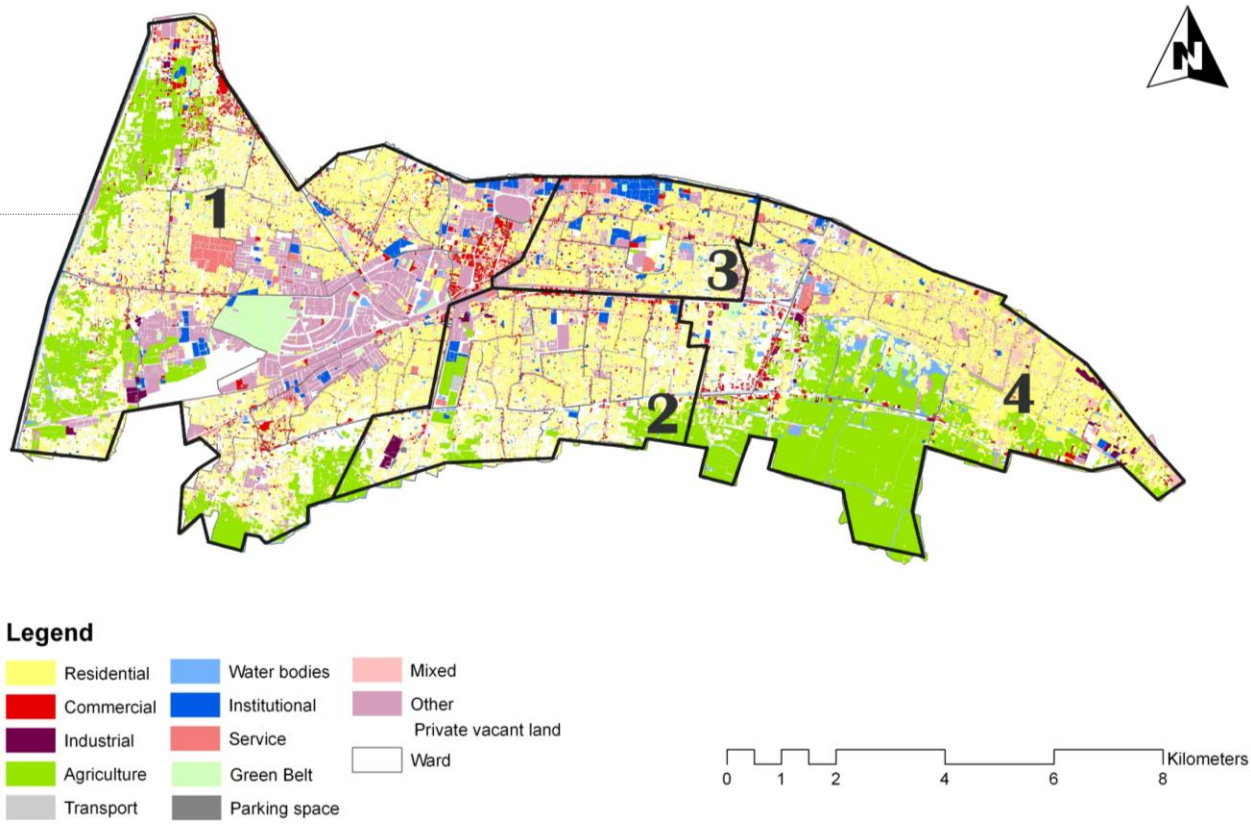


Figure 5.4 Land Use distribution of Patna Municipal Corporation, 2011

Source: TERI's Analysis

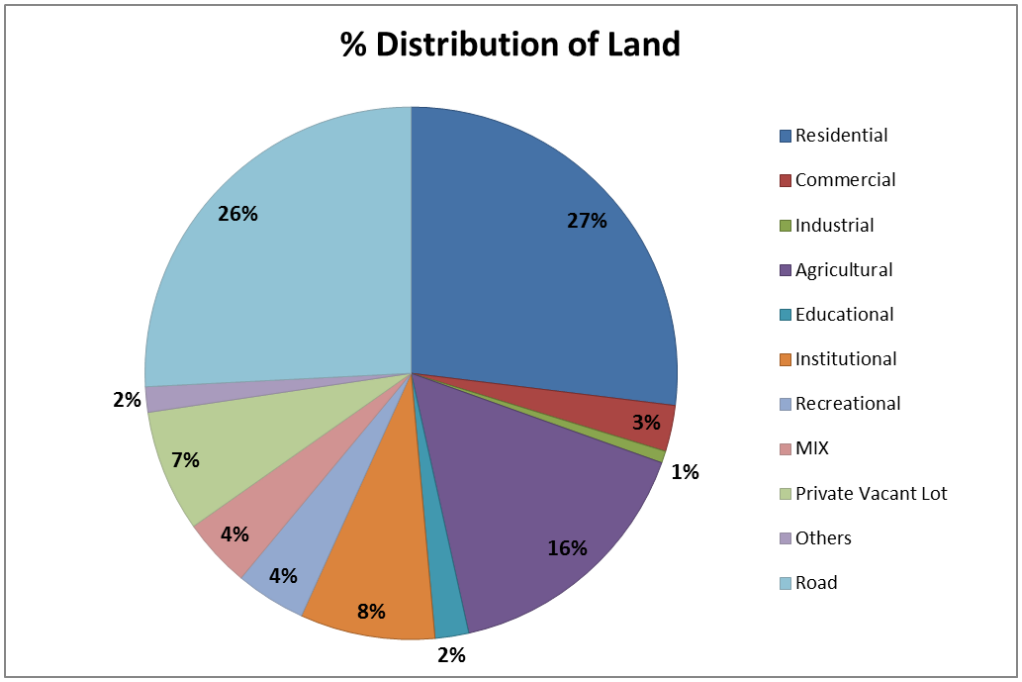


Figure 5.5 Land Use distribution map of PMC

Source: TERI's Analysis

Land use and transportation are closely linked and has a direct impact on the travel demand, number of trips made and trip distance; and therefore, it becomes imperative to understand the location of various land uses in the study area. Figure 5.5 illustrates the percentage distribution of land in the PMC area. Inter-zonal land distribution will help in understanding the allocation of a particular land use in a zone with respect to the total land use in the study area. On the other hand the intra-zonal land use distribution will help in understanding the allocation of different land uses in a particular zone with respect to total land available in a particular zone. The purposes of this type of inter and intra-zonal land use distribution will help in understanding the diversity of the land among and within the zones. This will further guide in understanding the relation between land use and transport with the help of origin-destination matrix.

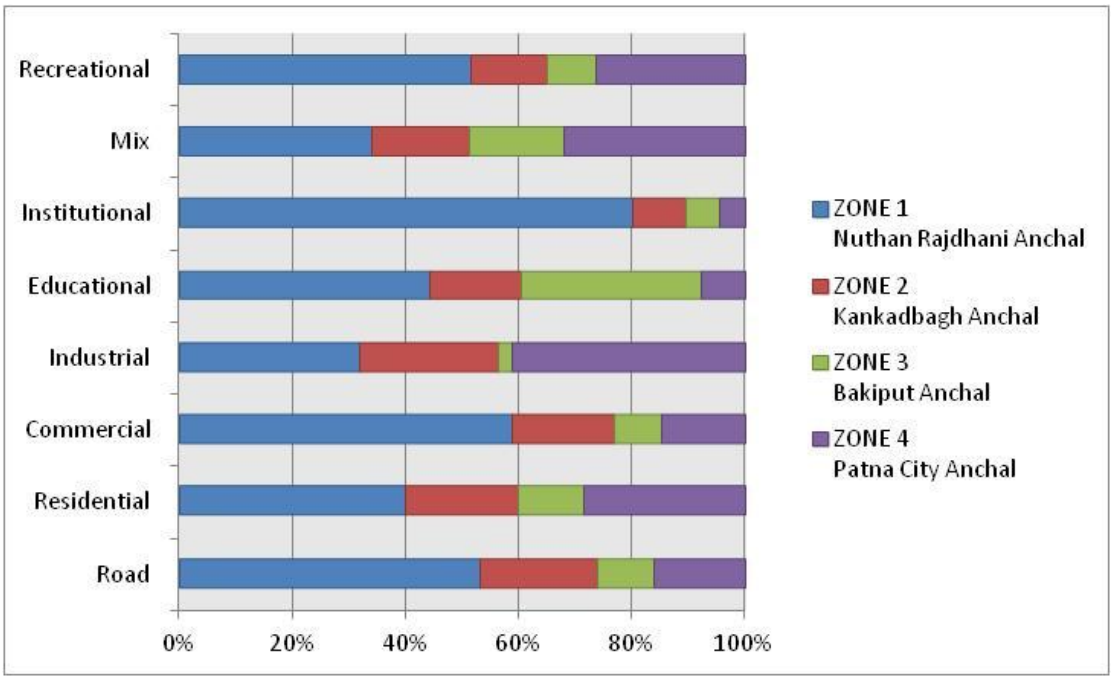


Figure 5.6 Inter-zonal Land Use Distribution

Source: TERI's Analysis

Figure 5.6 provides a clear picture of specific land use abundant and deficient zones, which will in turn reflect in inter-zonal travel demand of people for the activities associated with that particular land use. Zone-1 has high percentage of allocation of land for all types of land use when compared to other zones except industrial. This shows that manufacturing of goods is not a priority on the other hand institutional land allocation is higher, means service sector is more important. High allocation of institutional land which includes office spaces will ideally attract more work trips.

Zone-4 falls far short of educational and institutional land use as compared to the other three zones but has a decent amount of land allocated to recreational and mixed use land when compared with Zone-2 and Zone-3. It also has the highest land allocated to industrial purpose among all the zones. Zone-3 and Zone-1 has a high percentage of land allocated for educational purpose.

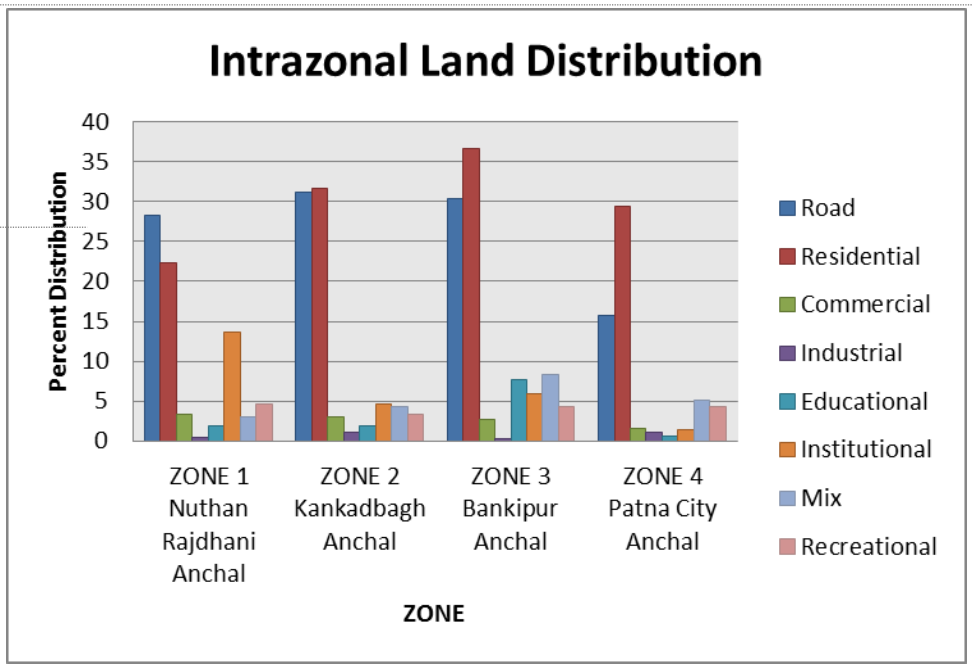


Figure 5.7 Intra zonal Land Use Distribution

Source: TERI's Analysis

The intra-zonal land use allocation as seen in Figure 5.7 provides the distribution of different land uses within the zone to recognize the diversity of the zone. This will correspond to the intra-zonal trips that are made in the zone for a particular purpose. Allocation of recreational land in each zone is almost same and that commercial land is similar in Zone-1, Zone-2 and Zone-3 but lower in Zone-4. Moreover, the industrial land allocated in each zone is the lowest with not more than 1% of the total land in a particular zone. This distribution of land identifies the nature of the city which is an institutional and commercial hub because of the capital city and not an industrial city and is moving towards urbanization.

Interesting observation can be made from the Figure 5.7, that is, the relation between residential land and land allocated for roads in different zones. It is clearly seen that the old Patna city (Zone-4) has higher percentage of residential land allocated per person as compared to that of road area which can also be seen in Zone-3 and Zone-2. On the contrary in the newly developed region (Zone-1) has lower share of residential land allocated per person as compared to transport infrastructure. This corresponds to the notion of providing more land for transportation than to any other land use including residential, implying the importance given to mobility of the people and goods and encouraging more vehicle on road than people.

Highlights of each zone are mentioned below to illustrate the land diversity in the study area.

Zone-1: The zone has a high percentage of land allocated for institutional and recreational purposes with 14% and 5% respectively and the rest are less than or up to 4%.

Zone-2: The zone has almost equal distribution of land for institutional and mixed land with 5% and 4% respectively and rest are less than 3%.

Zone-3: The zone has an equal distribution of mix and educational land allocation of 8% and around 6% of institutional land.

Zone-4: The zone is dominated by the recreational and mixed land use and falls behind enormously in educational and institutional.

5.8 Land Use Change

Land cover change in the two maps below (Figure 5.8 & 5.9) further emphasize on urbanization process in past two decades of Patna. Along with the urban population increase as mentioned above in the demographic section so did the settlement and supporting activities. This also corresponds to the change in vegetation of the city as seen in Figure 5.9.

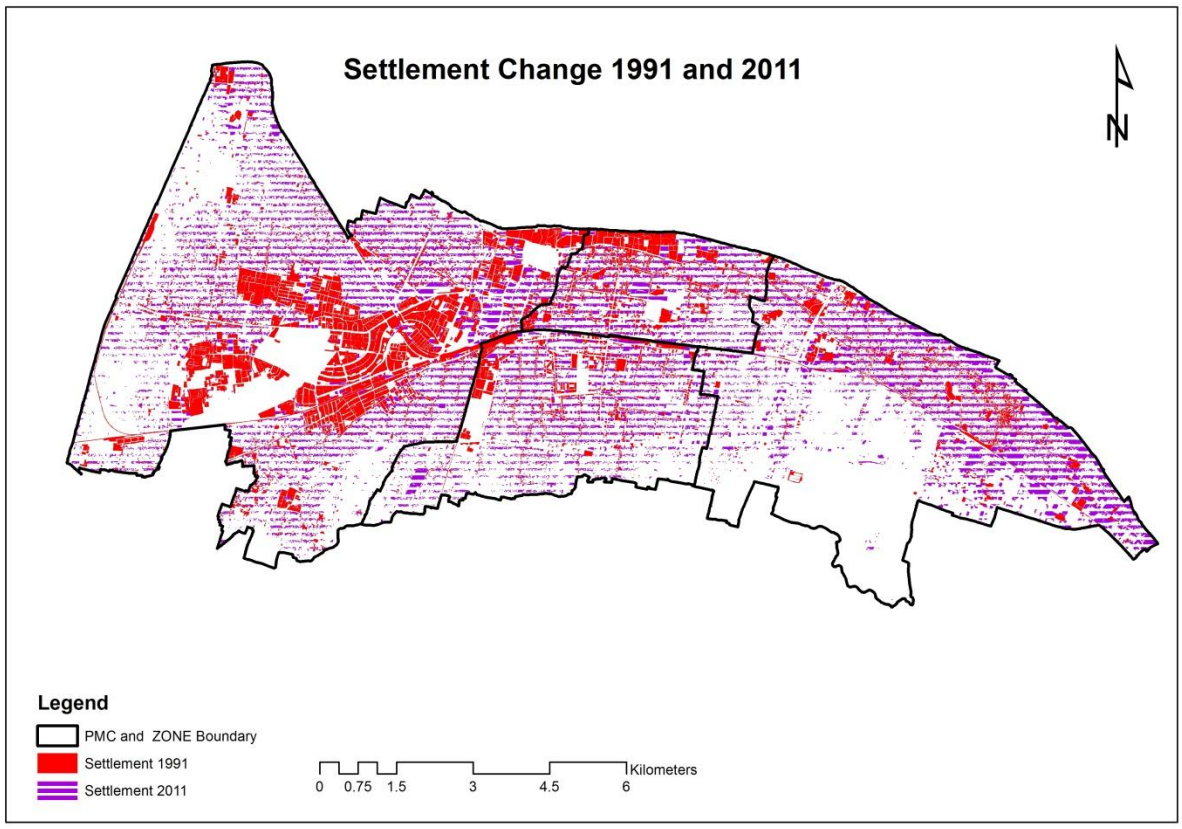


Figure 5.8 Change in Settlement from 1991 to 2011

Source: TERI's Analysis

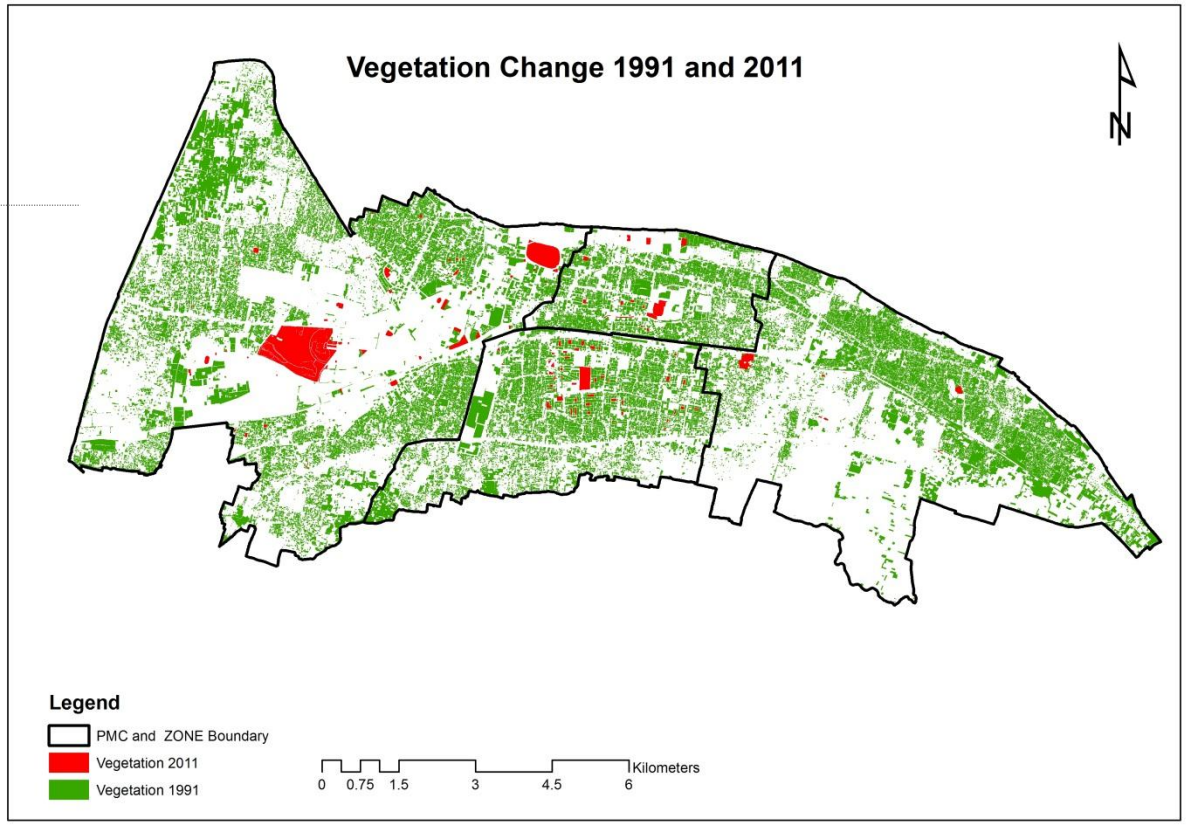


Figure 5.9 Change in Vegetation from 1991 to 2011

Source: TERI's Analysis

5.9 Transport

5.9.1 Road Infrastructure

Overall road density of the Patna Municipal Corporation area is 0.28 km per ha and among different wards it varies from 0.12 km per ha to 0.56 km per ha in ward 56 and 64 respectively. Whereas, among the four zones; Zone-4 and Zone-1 has the lowest road density of 0.24 km per ha and 0.27 km per ha respectively. Zones-3 and Zone-2 has the highest road density of 0.35 km per ha and 0.32 km per ha respectively. The road infrastructure of the city has 3 main categories with specific purpose and dimensions namely, arterial, major and collector as shown in Figure 5.10.

The total road length in the Patna Municipal Corporation area is 3040kms out of which arterial roads are 205kms, major are 183kms and collector are maximum of 2651kms.

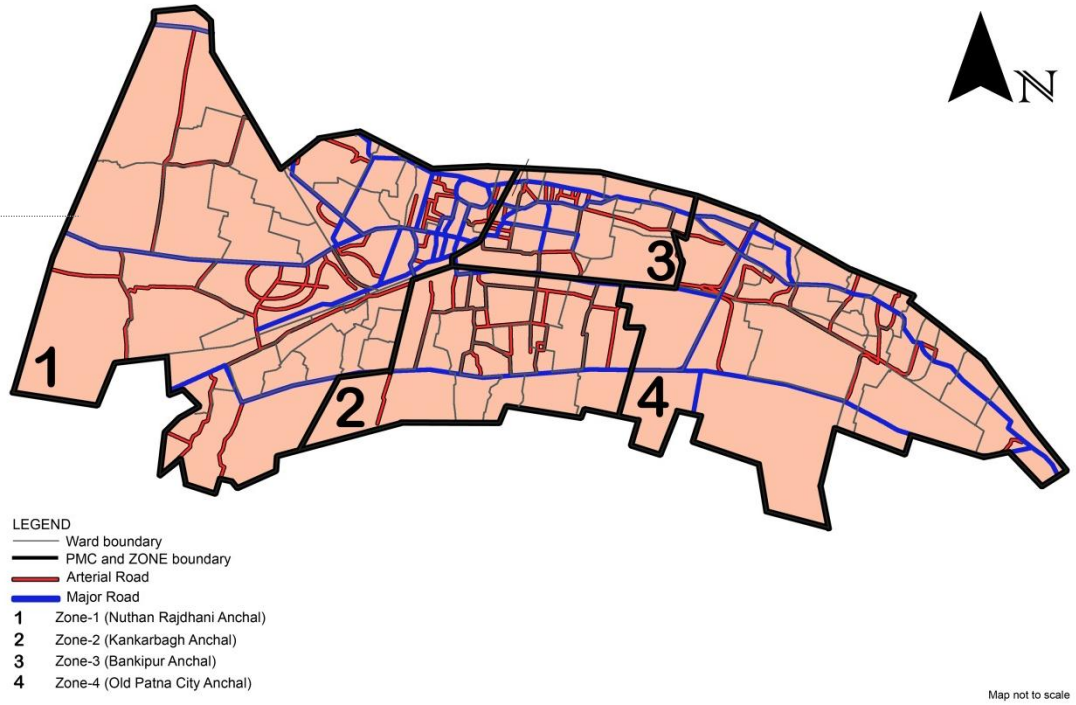


Figure 5.10 Road Network of the city

Source: CMP, 2009

5.9.2 Vehicular Growth

The total number of vehicles increased from nearly 2.2 Lakhs in 1996 to nearly 4.79 Lakhs in 2008, at a compounded growth rate of 6.7%. The share of buses in public transport modes decreased from nearly 13% in 1996 to nearly 4.8% in 2008. The decline in the share of buses is being supplemented in the city through private vehicles. This add-on could be seen in the compounded annual growth of cars and 2-wheelers at a rate of 9.8% and 7% respectively. The Figures 5.11 and 5.12 show a trend in vehicular growth of private vehicles, public transport and IPT.

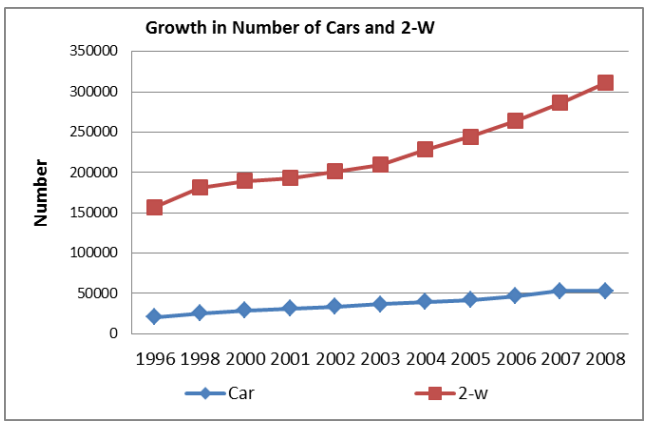


Figure 5.11 Share of various private modes

Source: CMP, 2009

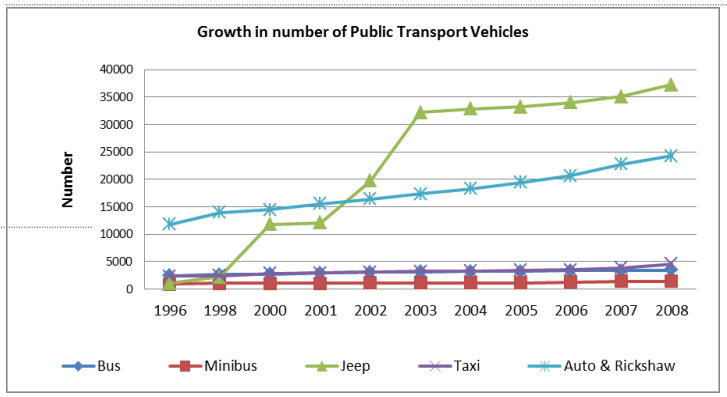


Figure 5.12 Growth in number of vehicles

Source: CMP, 2009

5.9.3 Existing Transport Issues

The study area faces problems like traffic congestion due to increased number of both private and public vehicles. Due to the increased number of vehicles the level of air and noise pollution has also risen along with this transport fatality rate. Parking is another issue that the city faces which is mostly disorganized and on-street thereby, further decreasing the carriage way in the city. The footpaths are largely discontinuous and are encroached by vendors and hawkers making it inaccessible for the users.

In reference with the transport problems that the city is experiencing it is imperative to understand the travel characteristics of the people in the city as well as the travel demand of the same. In the next section of the report will focus on the travel characteristics of the city, its residents and the share of mode. Further understanding of the effects of other factors like income and gender on the travel characteristics is also analyzed. The data for the analysis was collected through several surveys.

5.10 Travel Characteristics

Travel characteristics are the basic attributes of the transport system in a city defining the travel pattern of a city. These attributes are defined by several indicators and are disaggregated through sub-categorization under different income groups namely slum and non-slum and gender. Travel characteristics are also analysed on the basis of purpose of trips made which are categorized as mandatory (work, school and home) trips and non-mandatory (shopping and recreational) trips. These mandatory and non-mandatory trips for both slum and non-slum population are estimated to understand the mobility pattern of all category of residents. Furthermore, travel characteristics help in understanding the modal distribution of trips, mobility level, availability of public transport, accessibility to transport systems and more. The travel characteristics are also linked with the land use allocation for different activities in the city to know the interdependence of land use and transportation. The analysis of various indicators of urban transport, environment, economic and social will guide in defining the travel characteristics of Patna city. The trip production and attraction analysis disaggregated in different zones is also been carried out to further clear the relation between land use and transportation, with respect to the land use allocated in different zones.

In order to develop a better understanding of the travel pattern and modes used the analysis is being carried at an aggregate level by combining modes under four main categories namely private vehicle (PV) includes 2-wheeler and 4-wheeler, public transport (PT) includes the bus and minibus, intermediate public transport (IPT / Para-transit) includes auto rickshaws which are 4-seater and 6-seater and non-motorized transport (NMT) includes walk, bicycle and manual rickshaw.

5.11 Per Capita Trip Rate (PCTR)

The per capita trip rate (PCTR) indicates the mobility of the people through a particular mode of transport. It is the ratio of total number of trips made by a particular mode of transport to the total surveyed population. Higher the PCTR values of a mode of transport implies that large number of trips are being made by that particular mode of transport. PCTR for Patna are calculated at two levels a) motorized and non-motorized modes of transport which combines the aforementioned four categories of transport. The overall PCTR of residents in Patna are 1.98 which means that on an average approximately two trips are made by the residents of Patna, out of which 1.01 is made by motorized and 0.97 by non-motorized means of transport. Although the mobility through the two broad categories has not much of a difference, therefore it's important to understand the mobility of people by individual modes of transport system. The disaggregated PCTR for each mode of transport surveyed are mentioned in the Table 5.3.

Table 5.3 Per Capita Trip Rate of Mode

MODE	PCTR
2-Wheeler	0.314
4-Wheeler	0.208
Walk	0.623
Cycle	0.304
Manual Rickshaw	0.050
PT	0.279
IPT	0.211

Source: TERI's Analysis

5.12 Mode Share

Mode share helps in understanding the trip load shared by a particular mode in a study area. It is the ratio of trips made by a particular mode of transport to the total trips made in the study area. According to the primary survey, almost half of the total trips that are being made by the city are done by non-motorized means of transport with 49% and private vehicle and public transport has approx. equal share of 26% and 25% respectively. Although this doesn't provide a comprehensive share of trips by different modes of transport, therefore a detailed share of each mode is shown in the Figure 5.13.

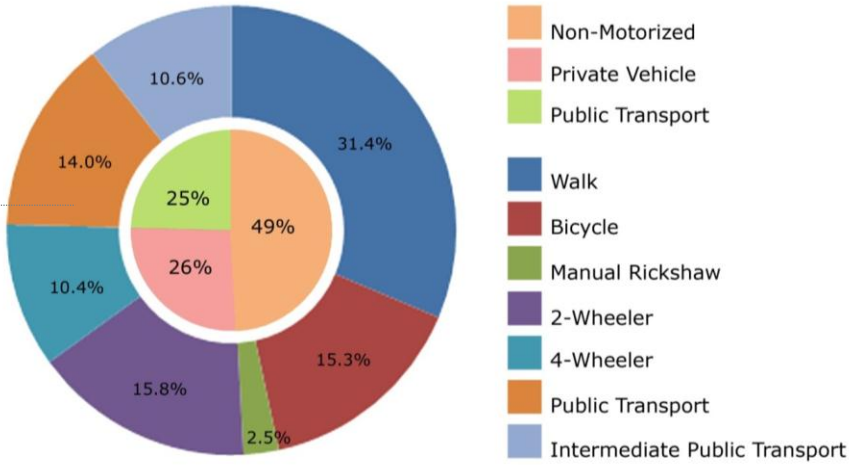


Figure 5.13 Mode Share of Patna Municipal Corporation as per Survey

Source: TERI's Analysis

It is visible from the figure above that walking constitutes for the maximum number of trips that are being made in Patna city of 31.4%. Then the 2-wheeler, cycle and public transport almost equally share the load of trips that are made in the city with 15.8%, 15.3% and 14% respectively. IPT and 4-wheeler has an equal popularity of 10.6% and 10.4% respectively among the residents for choosing them to commute. The least desirable mode of transport is the manual rickshaw with only 2.5% mode share in the study area.

5.13 Daily Trips of Patna

The actual number of trips made by the slum and non-slum residents for Patna city is being estimated through per capita trip rate of slum and non-slum dwellers with the help of the survey. According to the survey the PCTR of slum and non-slum population is 1.9 and 2.2 respectively. This PCTR is then used to estimate the daily total number of trips made by the slum and non-slum population in Patna. Further the mandatory trips are estimated through the working population and the total non-mandatory trips are estimated by taking the whole population into consideration. Tabulated below in Table 5.4 is the estimated total number of trips made in the city by different categories for different purposes.

Table 5.4 Total estimated trips made by different categories in Patna

CATEGORY	TOTAL TRIPS
Slum Trips	153858.9
Non-Slum Trips	3349809.3
SM Trips	121905.2
SNM Trips	42750.7
NSM Trips	2555407.3
NSNM Trips	995651.5

Source: TERI's Analysis

Once the PCTR for each category was estimated with the help of surveyed data it is then applied to the actual population of the city. According to which the total number of daily trips made in the city is estimated to be approximately 3504000 trips. Almost 71% and 24% of the trips are made by non-slum population for mandatory and non-mandatory purposes

respectively. On the other hand only 4% and 1% of the total trips are made by slum population for mandatory and non-mandatory purposes respectively.

The total trips estimated were then used to determine the actual mode share of the study area. Figure 5.14 shows the estimated mode share of the study area. It clearly shows the highest share of trips made by walking and 2-wheeler. Whereas the share of car, public transport and intermediate public transport is in decreasing order, showing that car is being preferred over PT and IPT but 2-wheeler is referred over car.

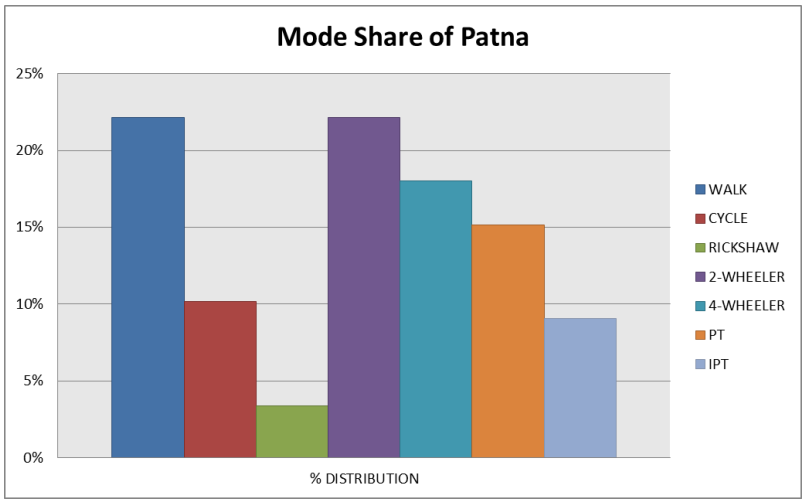


Figure 5.14 Estimated Mode Share of Patna Municipal Corporation

Source: TERI's Analysis

5.14 Trip Distribution

Trip distribution is the dissemination of total number of trips made by different categories of population. In this study the four categories are taken into account whose trips, mode used, distance travelled and time taken are analysed. The four categories for this analysis are slum mandatory, slum non-mandatory, non-slum mandatory and non-slum non-mandatory. In the Table 5.5 below total number of trips made in the city is divided among the above mentioned four categories. It is visible that equal amount of mandatory trips are being made by both slum and non-slum population in the city. Whereas, non-slum population makes more non-mandatory approximately 13% of the total trips made in the city as compared to the slum population who only make 9% of the total trips.

Table 5.5 Trip Distribution by user Category

Category	Trip Distribution
Slum Mandatory	38.0%
Slum Non-Mandatory	9.4%
Non-Slum Mandatory	39.3%
Non-Slum Non-Mandatory	13.3%

Source: TERI's Analysis

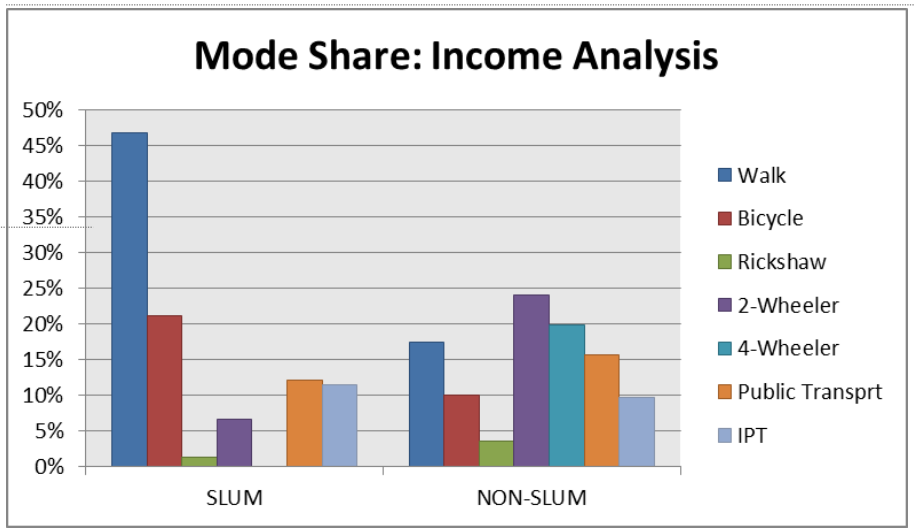


Figure 5.15 Mode Share by Different Income Groups

Source: TERI's Analysis

The mode share varies tremendously between the two categories of population as shown in Figure 5.15 within the study area. It is clear that approximately 50% of the trips made by slum population are through walking whereas only 17% walking trips are made by non-slum population. On the contrary the non-slum population commutes mainly through 2-wheelers (24% of the total trips) as compared to slum who use 2-wheeler for only 7% of their total trips.

Public transport and IPT has approximately share similar number of trips that are made3 by the slum population. Non-slum population shares lesser number of trips by PT and IPT as compared to 2-wheeler and 4-wheeler. The trip share of 4-wheelers by non-slum population is 20% whereas zero trips are made by slum population. Furthermore, the manual rickshaw seems to be least popular mode of transport among both slum and non-slum population in the city.

The total trips made by slum and non-slum population through different modes are in Patna are mentioned in Table 5.6 with respect to the distribution mentioned above. More than 8lakh and 6.6 lakh trips are made daily by non-slum population in a day by 2-wheelers and 4-wheelers respectively. Overall more than 6.5 lakh walk trips are made in the city. 5.4lakh and 3.4 lakh trips are made by PT and IPT in the city respectively.

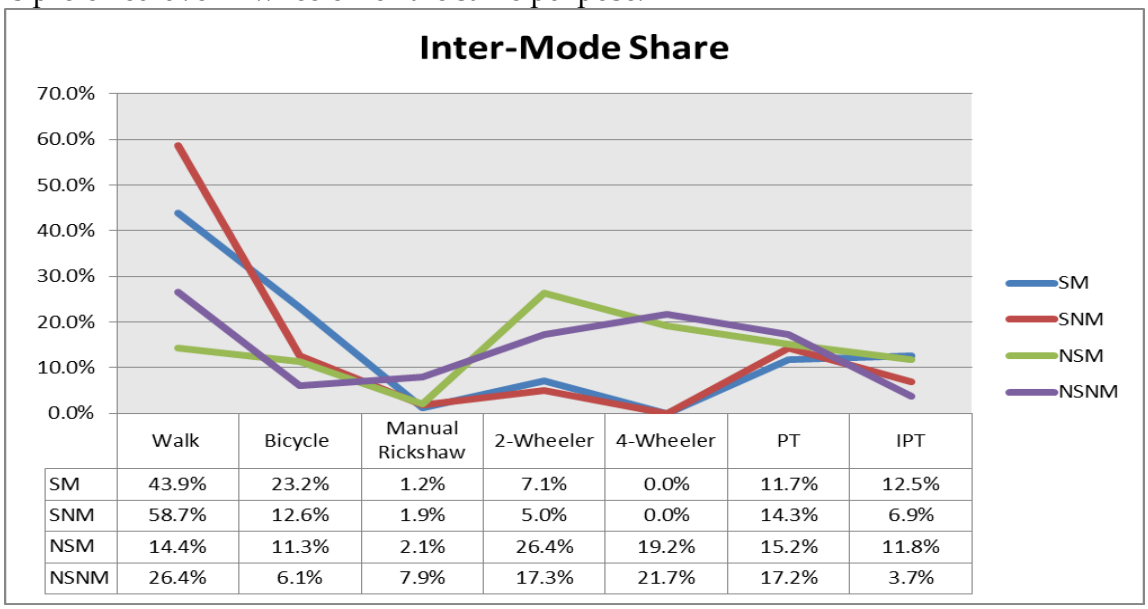
Table 5.6 Estimated number of Trips made by different modes each day

Modes	Slum	Non-Slum
Walk	72078	583819
Bicycle	32464	334837
Manual Rickshaw	2042	120198
2-Wheeler	10286	807045
4-Wheeler	-	663951
Public Transport	18749	525151
IPT	17581	327683

Source: TERI's Analysis

5.15 Mode Share (Purpose Wise)

This analysis in Figure 5.16 shows a clear picture of different modes used to commute for several purposes like work, school, recreation etc. by both slum and non-slum population. In case of slum population for both mandatory and non-mandatory purposes walk is the primary mode of making trips with approximately 44% and 59% respectively. Other modes that dominate the share in case of slum mandatory trips are bicycle, IPT and PT with 23%, 12% and 11% respectively. Private vehicles and manual rickshaw are least desirable modes of transport in case of slum population with an absence of the use of 4-wheelers. This shows that for the slum dwellers owning and using a 4-wheeler is not a priority also that the value of time of a slum dweller is way less than that of a non-slum dweller and can thus afford to spend more time in commuting. Furthermore use of manual rickshaw for small distance is an expensive mode for slum population. Public transport like bus and mini-bus and bicycle dominates the slum non-mandatory trips with a share of 14% and 12% respectively. The IPT is preferred over 2-wheeler for the same purpose.



	Walk	Bicycle	Manual Rickshaw	2-Wheeler	4-Wheeler	PT	IPT
SM	43.9%	23.2%	1.2%	7.1%	0.0%	11.7%	12.5%
SNM	58.7%	12.6%	1.9%	5.0%	0.0%	14.3%	6.9%
NSM	14.4%	11.3%	2.1%	26.4%	19.2%	15.2%	11.8%
NSNM	26.4%	6.1%	7.9%	17.3%	21.7%	17.2%	3.7%

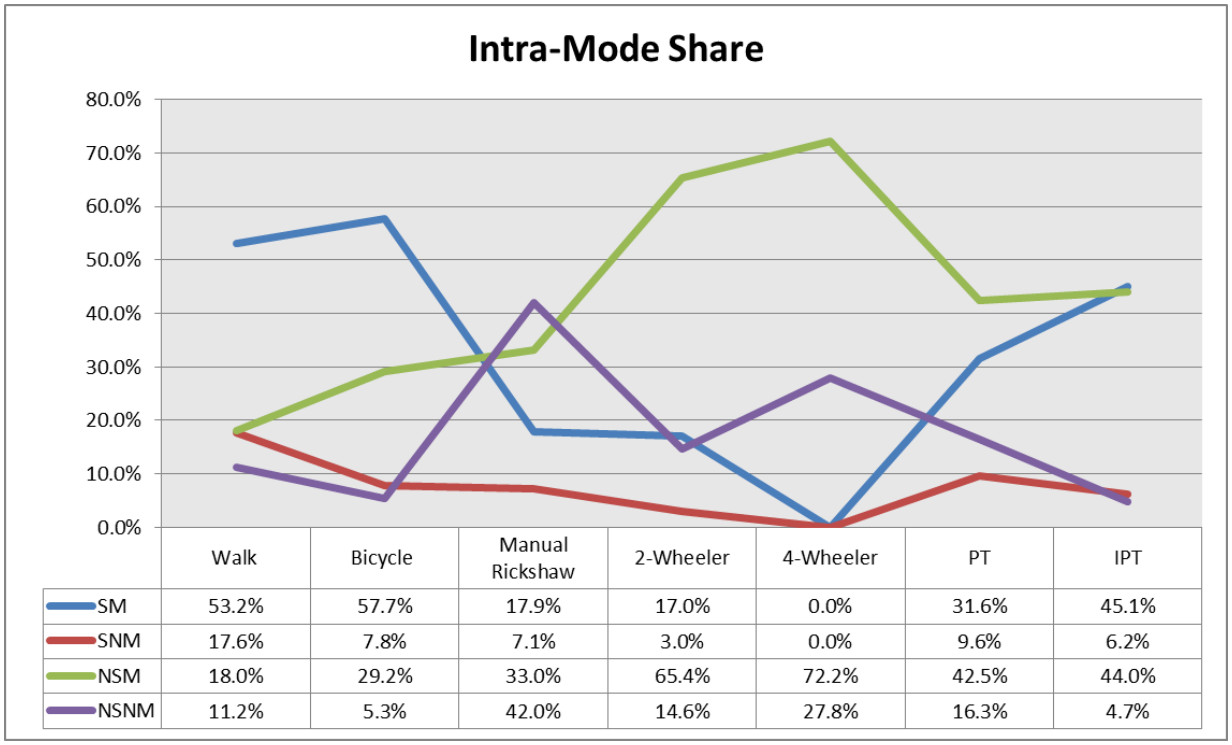
Figure 5.16 Percentage of Inter-mode share by Different Categories

Source: TERI's Analysis

In case of non-slum population in the city most of the mandatory trips are being made through 2-wheelers and 4-wheelers which constitute around 26% and 19% of the total non-slum mandatory trips respectively. Other prevalent modes of commuting for mandatory trips by non-slum population are PT, Walk, IPT and bicycle with 15%, 14%, 12% and 11% respective mode share. Manual rickshaw still has a back seat in sharing the load of mandatory tips within the non-slum population. In making the non-mandatory trips by the same category of population walking and 4-wheeler dominates the mode share with 26% and 22% respectively. 2-wheeler and PT approximately have an equal share on the trip load and so does the bicycle and manual rickshaw, whereas, IPT is least desirable for non-slum non-mandatory trips.

The Figure 5.17 below demonstrates the distribution of total number of trips made by a particular mode among different categories of population i.e. slum mandatory (SM), slum non-mandatory (SNM), non-slum mandatory (NSM), and non-slum non-mandatory trips

(NSNM). It is clearly seen in the figure below that amongst the total walk and bicycle trips that are being made in the city more than 50% of the trips are done by slum population for mandatory trips and least by non-slum population for non-mandatory trips. Manual rickshaw is used by the non-slum population more for both mandatory and non-mandatory purpose as compared to the slum. In case of private vehicle both 2 and 4-wheeler are popular among the non-slum population because of the affordability of it. Whereas, both buses and auto rickshaws (big and small) are prevalent in slum and non-slum commuters for mandatory trips but not so much for the non-mandatory purpose.



	Walk	Bicycle	Manual Rickshaw	2-Wheeler	4-Wheeler	PT	IPT
SM	53.2%	57.7%	17.9%	17.0%	0.0%	31.6%	45.1%
SNM	17.6%	7.8%	7.1%	3.0%	0.0%	9.6%	6.2%
NSM	18.0%	29.2%	33.0%	65.4%	72.2%	42.5%	44.0%
NSNM	11.2%	5.3%	42.0%	14.6%	27.8%	16.3%	4.7%

Figure 5.17 Percentage of Intra-mode share by Different Categories
Source: TERI's Analysis

5.16 Mode Share: Gender Analysis

The purpose of the trip varies in the trip distribution matrix of the study area, where male makes more mandatory trips than the females which is 83% and 68% respectively and female make more non-mandatory trips than males which mainly consists of short trips to market are very common.

The trip distribution among the male and female in the study area is also very close to equity in the city. Male population in the city makes 57% of the total trips while female make the rest 43% of the trips. To further understand gender aspect in the travel pattern it is essential to know the mode share of the trips made by both male and female in the city. The graph below clearly shows the dominance of walk trips by females in the city. Other than walk, public transport like buses and mini-buses are used. When compared the mode share between male and female, males make higher number of trips by bicycle, 2-wheeler and 4-wheeler as compared to females. Moreover, males and females approximately make an

equal number of trips by IPT and females make more trips by manual rickshaw as compared to males.

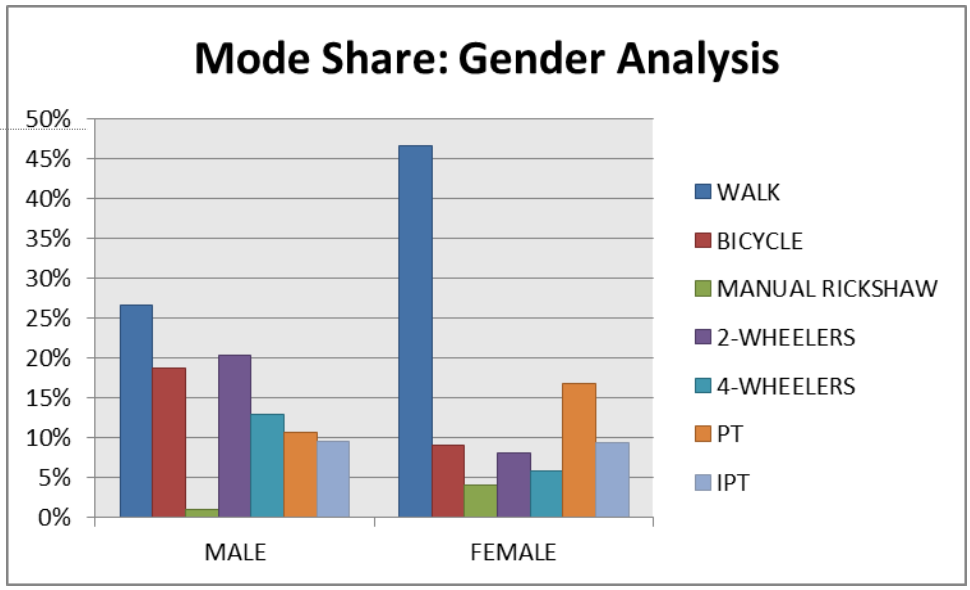


Figure 5.18 Mode share of trips made by male and female in the city

Source: TERI's Analysis

The Figure 5.18 implies that better lit and safer infrastructure for NMT is essential to ensure the safety and security of the commuters which in case of Patna are mainly females. Also, improvement in the quality of PT and IPT is also necessary in terms of comfort, safety and frequency.

5.17 Mode Preference

During the survey process, respondents were referred to know what changes they would want in the public transport services to increase its popularity and usage.

The replies evidently highlighted the priorities between Slum and non-Slum residents. Firstly, the Slum respondents prefer the same cost of travel, but ask for higher frequency and reduction in the travel time by ½ or ¼. Surprisingly, comfort was not valued much during the travel, which is concluded based on their preference of still opting for the non-AC buses.

Secondly, the non-Slum respondents provided an important insight about the kind of services required. Majorly, the two opted preferences were, first, higher fare for the AC buses with higher frequency and reduced travel time; and second, to keep the same fare for the low frequency buses i.e. only during the peak hours with reduction up to ¼ of the total travel time and need of AC buses. Hence, preference given to AC buses by the non-slum respondents' shows importance of comfort during their travel.

While analysing the average travel time by individual mode and mode preferences, it is clear that higher time taken by the public transport is a perceived notion by the residents who prefer private vehicle. This because both private and public modes of transport take similar amount of time to travel the same distance.

5.18 Transit Accessibility

Transit accessibility delineates the ease to access bus stop and IPT stop from residence. A stop within 0.5 kms radius of a residence is the benchmark for transit accessibility. On the basis of this, the slum and non-slum surveyed households are checked for accessibility to transit. The transit accessibility for each category of household is examined for each zone. The two Figures 5.19 and 5.20 below show the accessibility to bus and IPT stop in different zones by the non-slum and slum category of the residents in the city respectively.

The purpose of this analysis is to understand the availability of transit in proximity with the residence and thus establishing a relation between the level of usage and travel expenditure incurred by the slum and non-slum household. Furthermore, the comparison between bus and IPT stop is made to understand the popularity of a particular mode of transit.

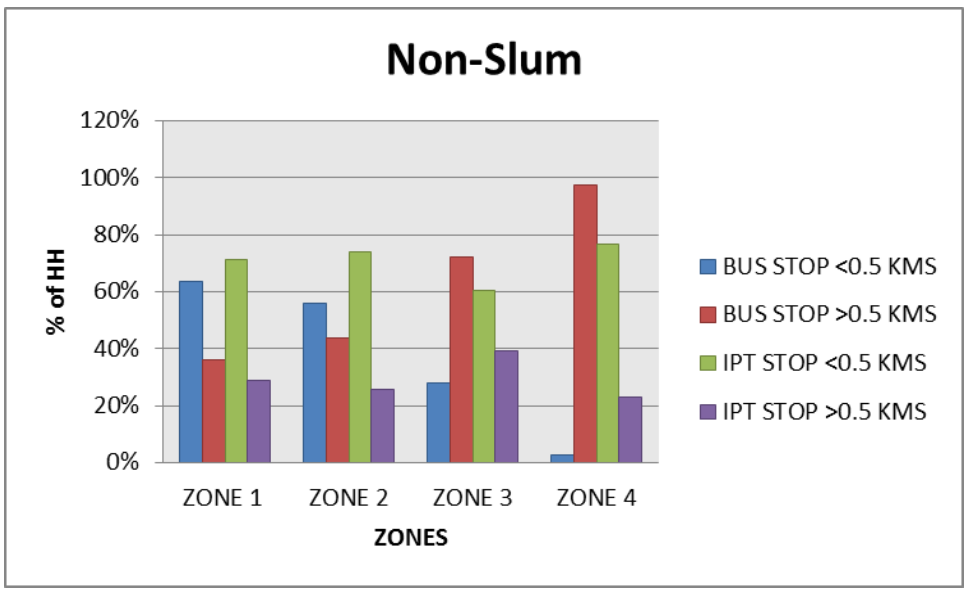


Figure 5.19 Transit Accessibility of Non-Slum population
Source: TERI's Analysis

Figure 5.17 above Zone-1 and Zone-2 have higher number of non-slum HH have an easy accessibility to bus of 64% and 56% but for the same zones IPT is accessible to more than 70% of the HH. Furthermore, in these zones the gap between the accessibility of bus stop and IPT stop is not too high. In case of Zone-3 and Zone-4 more than 70% and 90% of the non-slum HH respectively have poor accessibility to bus stop, whereas, 60% and 77% of the non-slum HH respectively have IPT stops within 0.5kms. Therefore in all the zones IPT is much easily accessible and available mode of transit than bus, which would affect the use and popularity of bus as a mode of transport to commute.

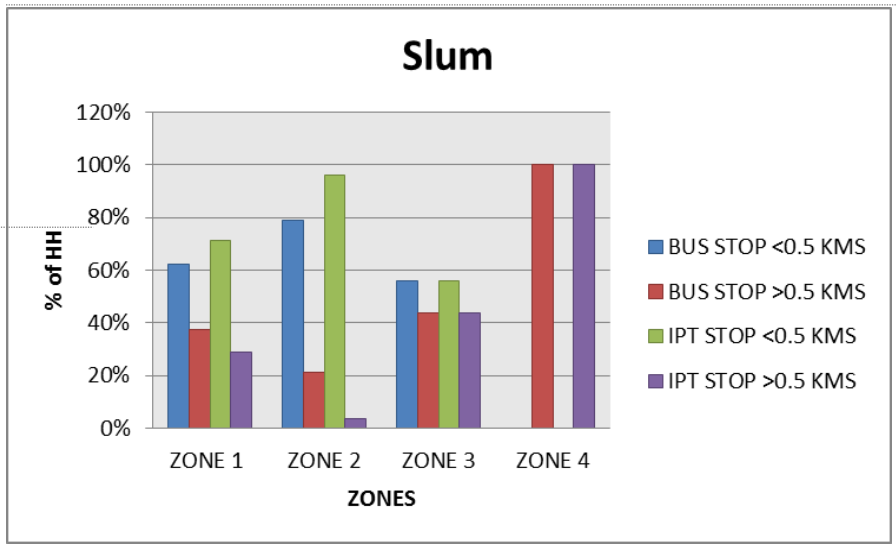


Figure 5.20 Transit Accessibility of Slum population
Source: TERI's Analysis

Figure 5.20 shows percentage of slum HH in proximity to bus stop and IPT stop in all the four zones. In Zone-1, Zone-2 and Zone-3 almost 60%, 80% and 55% of HH respectively are within 0.5kms of a bus stop, whereas, more than 70%, 90% and 55% of HH respectively are within 0.5 kms of an IPT stop. Amongst the three zones above Zone-1 and Zone-2 display a higher percentage of slum HH with high accessibility to IPT stop as compared to bus stop. For slum HH of Zone-4 experiences least accessibility to both bus and IPT, this has been inferred according to survey analysed that none of the HH lies within 0.5kms of a bus or IPT stop.

The following Figure 5.21 provides information on the percentage of HH located within exact distance to a bus and IPT stop. This would further delineate the percentage of slum and non-slum HH that have low accessibility to transit system.

In case of bus stop, more than 30% non-slum dwellers live up to 1 km whereas only 15% of slum dweller live within 1km. Furthermore, a higher number of non-slum HH are residing up to 2kms of bus stop as compared to slum HH. In case of IPT stop less than 5% of non-slum HH live beyond 1.5kms and 2kms, whereas a little more than 20% live up to 1 km of an IPT stop in both slum and non-slum category of HH.

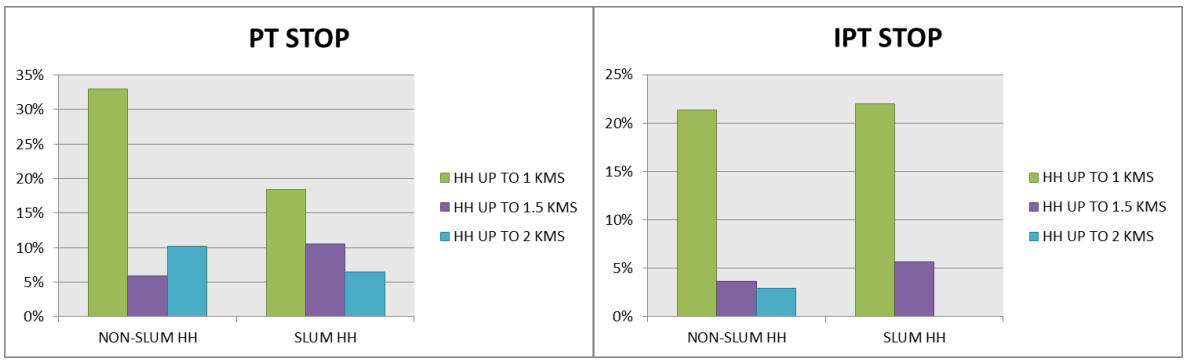


Figure 5.21 Percentage of HHs at a distance more than 1km of PT and IPT stop

Source: TERI's Analysis

Moreover, when compared the percentage of non-slum HH situated more than 2kms away from an IPT and bus stop, it is visible that higher number of HH are situated away from bus stop as compared to IPT stop. Furthermore, there is less number of non-slum HHs that live at a distance of 1.5kms from IPT stop as compared to PT stop. So, after comparing the accessibility of bus and IPT stop for slum and non-slum HH it is clear that non-slum HH have a lower accessibility to transit as compared to the slum HH. This lack of accessibility corresponds to the popularity of IPT over PT and also the expenditure when compared with the private vehicle.

5.19 Average Trip Length and Average Travel Time

Average travel length is the average distance travelled by a particular mode in a day and average travel time is the time taken to travel that distance. Table 5.7 provides the average daily distance travelled by different modes in the study area and the time taken to travel that distance. With the help of primary survey it has been deduced that private vehicles are preferred for travelling distances that are more than 5 kms whereas, shorter distance that is less than 5kms are covered by public transport, IPT and NMT. Although the time taken by public and private transport system is similar suggesting that the use of private vehicle depends on the perception of the people that they are faster or due to other qualitative aspects like comfort and reliability. The time taken by public and private vehicle also suggests that there is lack of ordinance in allocating space for different modes within the city. Although the choice and perception of mode depends on the purpose of the trip and affordability of the commuter which would be more clear in the next two tables.

Table 5.7 Average Trip Length and Average Travel Time for PMC

Modes	Average Travel Length (kms)	Average Travel Time (Mins)
Walk	1.23	12.30
Cycle	3.44	19.00
Manual Rickshaw	2.11	15.67
2-Wheeler	6.33	27.15
4-Wheeler	7.02	33.89
Public Transport	5.46	24.62
IPT	5.71	30.90

Source: TERI's Analysis

5.20 Average Trip Length and Average Travel Time (Purpose and Income Wise)

5.20.1 Slum Population

The travel distance by slum for mandatory and non-mandatory purpose and the time taken will throw light on the travel pattern of the slum population in the study area. For mandatory purposes slum population travels more than 6 kms by public transport and almost 4kms by bicycle and cycle rickshaw.

Table 5.8 Average travel Length and Average Travel Time of Slum dwellers for mandatory and non-mandatory trips

Purpose	Slum Mandatory		Slum Non-Mandatory	
Modes	Avg. Travel Length (kms)	Avg. Travel Time (mins)	Avg. Travel Length (kms)	Avg. Travel Time (mins)
Walk	1.33	13.61	1.10	12.09
Bicycle	3.89	21.06	2.98	15.38
Rickshaw	3.90	21.90	2.25	12.50
2-Wheeler	6.30	27.37	3.90	15.52
4-Wheeler	-	-	-	-
Public Transport	6.73	25.25	4.88	20.77
IPT	6.89	39.41	3.90	19.97

Source: TERI's Analysis

5.20.2 Non-Slum Population

The travel expenditure on public and private vehicle depends on the income group that the resident belongs to. In case of non-slum population it is clearly seen that as the income rises the expenditure on private vehicle both 2 and 4 wheeler. A similar spike in the expenditure is seen while using private vehicle by the high income slum dweller. Hence, it is evident from the data that as the income raises the travel expenditure increases also the private vehicle use. Also the expenditure has increased more in case of a slum dweller than that of a non-slum dweller which implies that with the rise in income the comfort and status factor plays an important role in meeting deciding the mode of transport used.

Table 5.9 Average Travel Length and Average Travel Time of Non-Slum dwellers for mandatory and non-mandatory trips

Purpose	Non-Slum Mandatory		Non-Slum Non-Mandatory	
Modes	Avg. Travel Length (kms)	Avg. Travel Time (mins)	Avg. Travel Length (kms)	Avg. Travel Time (mins)
Walk	1.08	8.25	1.17	12.92
Bicycle	2.86	16.83	2.36	13.92
Manual Rickshaw	1.73	16.08	1.62	13.23
2-Wheeler	6.77	29.56	4.85	18.51
4-Wheeler	7.74	37.13	5.13	25.73
Public Transport	4.92	25.78	4.75	22.67
IPT	4.89	24.61	4.55	22.50

Source: TERI's Analysis

While comparing the Average Travel Length and corresponding travel time taken by different modes of transport by slum and non-slum dwellers from Tables 5.8 and 5.9, it is clearly visible that for mandatory trips slum population travels longer distances in public transport and IPT as compared to non-slum residents. Although the time taken by both the categories of residents takes similar amount of time to travel the same distance but prefer separate modes. This further confirms the perception of public transport taking more time than the private vehicle and the comfort level. Also in case of walking, biking or taking manual rickshaw for mandatory trips non-slum dweller travels shorter distance as compared to the slum dweller.

Looking into non-mandatory trips, non-slum population travels longer distances with private vehicles as compared to the slum population. Also the time taken to travel similar distance through public transport by slum dweller takes lesser time in a public transport as compared to a non-slum dweller. This also corresponds to the difference in accessibility to transit through a slum and non-slum household

5.21 Travel Expenditure

When looking at the travel expenditure per person (Figure 5.22) it is observed that a non-slum individual spends more on public transport as compared to the slum person. The reason being accessibility to a bus stop by a non-slum individual as seen in the above section, the inaccessibility is met by using an IPT (auto rickshaw or a manual rickshaw) which increases the cost of travel through public transport by a non-slum resident. Whereas, a slum dweller would rather walk (as seen from the average walking distance travelled by slum individual) to the public transport stop than use another mode of transport to reach the stop so as to reduce the expenses. Furthermore, the expenditure on travel by an IPT for short distances is higher as compared to the longer distance due to minimum charges applicable. On the other hand, the difference in the expenditure by a slum dweller on public and private vehicle is very high this corresponds to the choice of transport by the slum dwellers. An interesting observation and relation could be made with respect to expenditure on private vehicle and income. Which is that as the income rises the expenditure on private vehicle increases exponentially as compared to that of public transport.

It corresponds with the accessibility of public transport stop. In case of non-slum dwellers the accessibility of an IPT stop is much better than that of buses thus encouraging the non-slum dwellers to use IPT and not the public transport. Although the IPT is much more accessible to both the categories of the population but the affordability and comfort factors comes into play thus by increasing the expenditure on public transport.

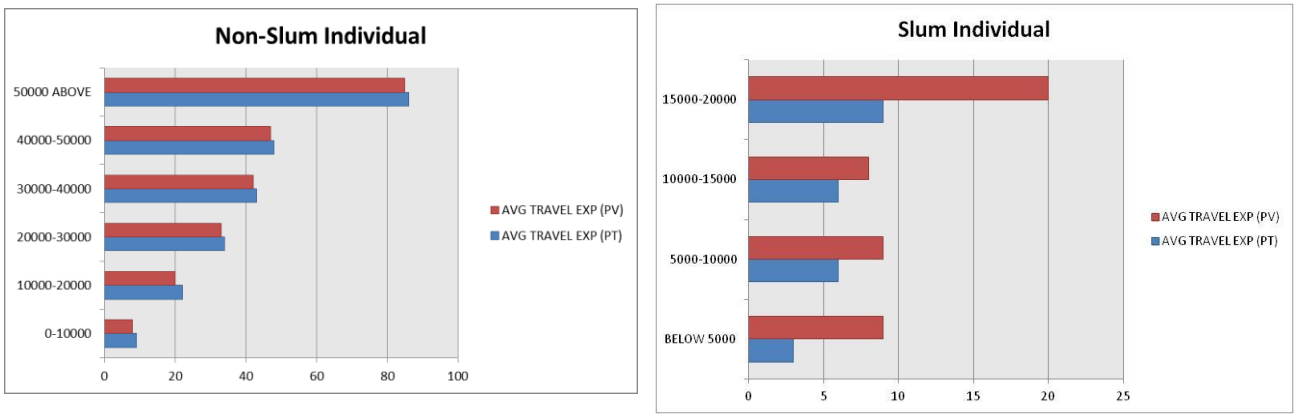


Figure 5.22 Daily Travel Expenditure of an Individual in Non-slum and Slum category on PV and PT

Source: TERI's Analysis

The Figure 5.23 below shows the growth in expenditure on public and private transport with respect to HH income in slum and non-slum category. It is visible from the Figure 5.20 that as the income increases the difference in the expenditure on public and private transport also expands. In case of non-slum HH the expenditure on private vehicle doubles

as the income rises. Furthermore, if looked closely at the slum HH expenditure at a similar income has the same trend like that of non-slum HH.

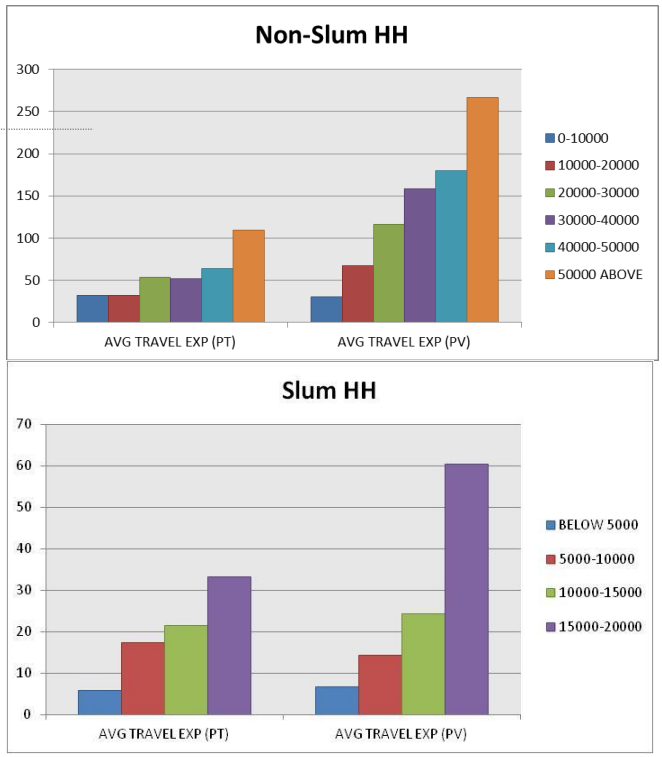


Figure 5.23 Daily Travel Expenditure of a Non-slum and Slum Household on PV and PT

Source: TERI's Analysis

This display of similarity corresponds to the fact that as a HH income increases importance to transport and shift from public transport to private transport occurs, thereby, declining the usage of public transport use.

5.22 Infrastructure Availability

5.22.1 Footpath

The organized survey reported that availability of footpaths were as low as 7% of the total road length. It was also found that only 6% of the total population actually uses the footpath and remaining 94% avoids it. This resulted due to two main reasons, as:

1) Poorly maintained footpaths, and

2) The lack of continuity.

Hence, absence of infrastructure restricts users from walking even the shorter distances of up to 1 to 2 kms. Moreover, it is ironic to find that when it comes to modes, walking is widely opted. But, the infrastructure available is not even half the total road length.

Therefore, to promote walking among all the categories of occupants it becomes imperative to first provide the adequate infrastructure facilities in the city.

5.22.2 Patna Metro

The final corridors of Patna metro has been approved which will be covered and executed in two phases. Figure 5.24 provides information about the corridors and the phases that will undertake the construction process. All the corridors run along the major road and rail corridors in the city and connect the major bus stops and extreme ends of the city. This will not only improve the connectivity between the extreme regions of the city but will also improve the mobility of the people.

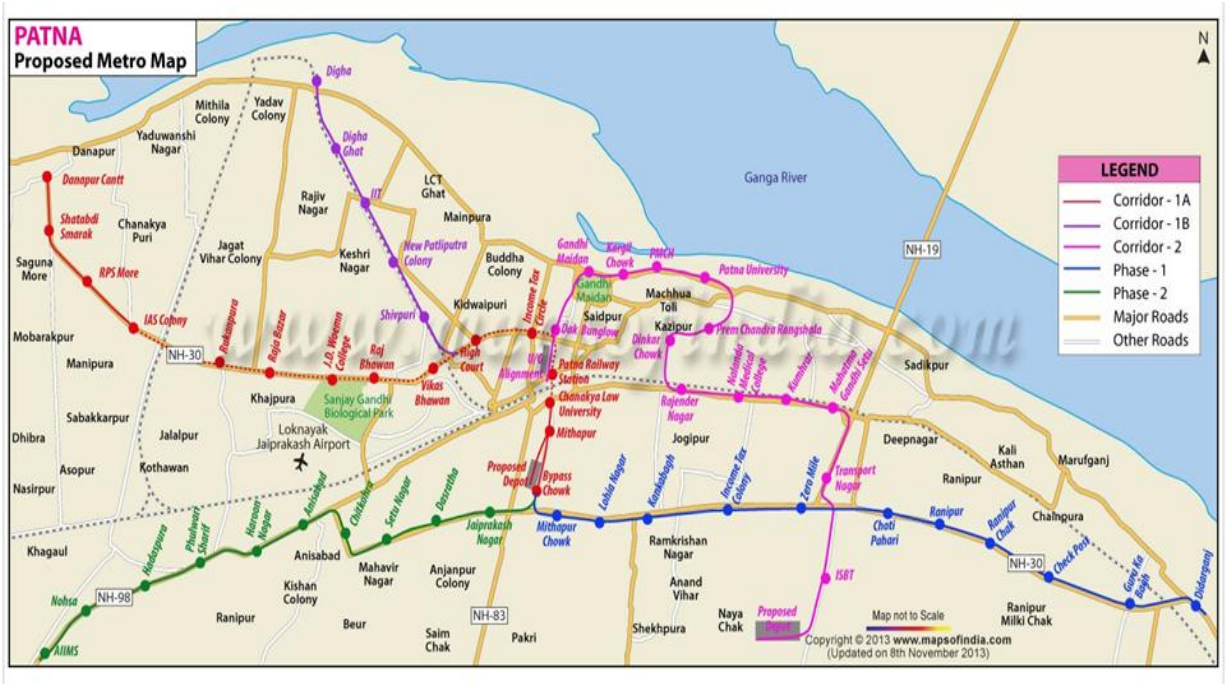


Figure 5.24 Proposed Patna Metro Corridors

Source: RITES

5.22.3 Parking

Among the surveyed areas, a total of 24 Parking sites were located, which can briefly be categorized as – 04 Private sites, 04 Informal sites, and 16 allotted as Public sites. As informed by sources, some of the informal parking sites are supposed to get transferred to the public jurisdiction. Firstly, at a city level, Zone-4 has only 01 informal existing parking site that accommodates maximum number of Heavy Utility Vehicles, whereas, the public parking sites are evenly located in Zone-1, Zone-2 and Zone-3.

Secondly, it is well read from the map (Figure 5.25) that 2-wheelers and 4-wheelers have taken up a vast parking space. The parking lots, namely – 3, 6, 7, 9, and 11 are traced to be close to the government offices and colleges that in turn hold high percentage of 3-wheelers and manual Rickshaws as well. On the other hand, a very few parking sites, as - 12, 13, 18 and 20 accommodate high percentage of Bicycle users.

Therefore, location and occupancy pattern of the Parking sites help to understand the importance of providing parking facility and its distribution among the different areas within PMC. Likewise, it can also help in policy interventions, as to, how the price hike at

the parking areas can reduce; or how to restrict the usage of parking lots. As a result, awareness can divert users to opt for the public mode of transportation.

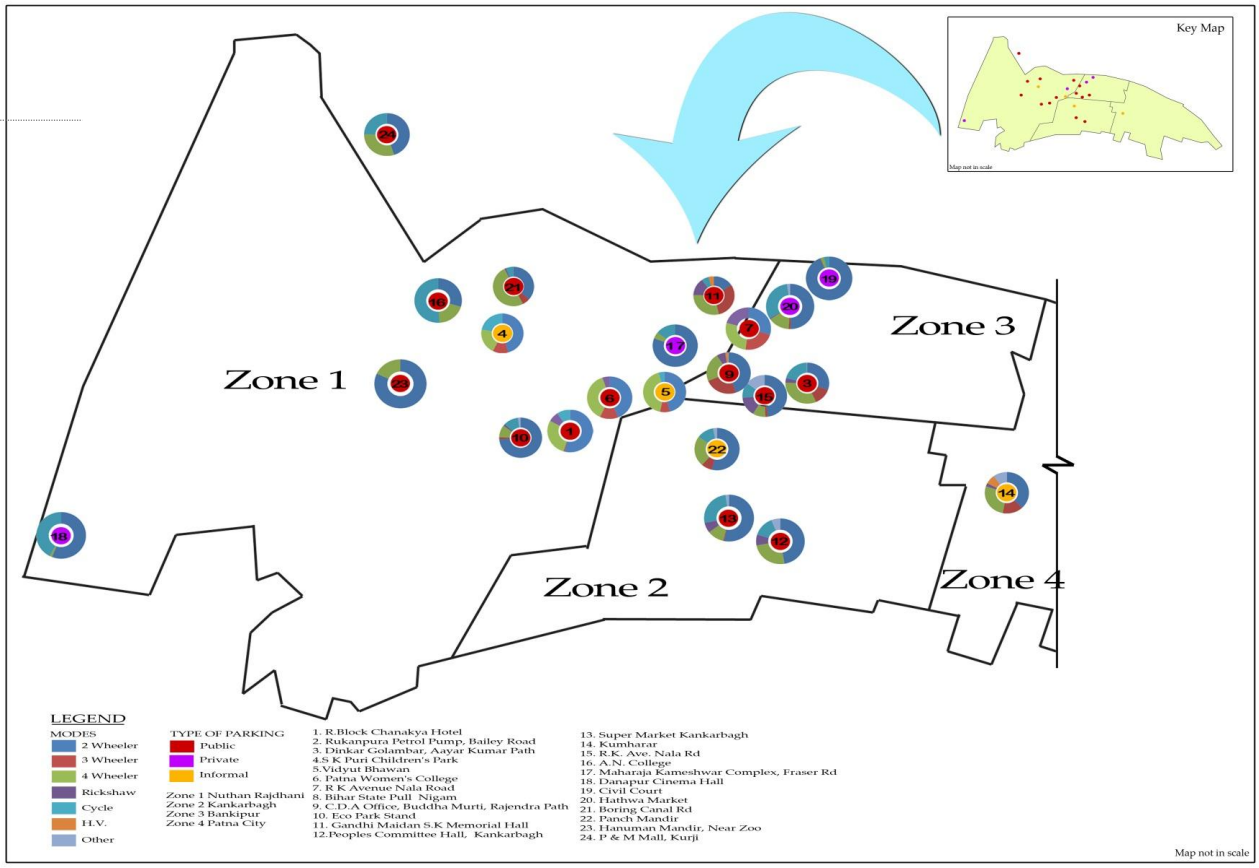


Figure 5.25 Location of off-street parking facility in Patna with distribution of vehicles parked
Source: TERI's Analysis

5.23 Trip Assignment

The Origin-Destination Matrix is a tool used to analyse the number of trips produced by a particular zone and number of trips attracted by the same or another zone. It statically provides information on the distance people prefer to travel for particular activities and the time taken to do the same. The matrix also aids in comprehending the relation between land use and transport demand by different zones depending on the availability of activity in a particular zone.

Considering the Land-use pattern, the gathered information about such trips can further be examined to recognize the inter-relationship between the land-use allocation and travel demand, travel distance and travel time. The Tables 5.10 to 5.18 for educational, work and recreational trips below provide the percentage trips produced and attracted by different zones along with the average distance travelled and average time taken for the trip made respectively.

Table 5.10 Origin-Destination matrix of Educational Trips

	Zone 1	Zone 2	Zone 3	Zone 4	Residential (Ha)	Educational (Ha)
Zone 1	79%	18%	3%	1%	40%	44%
Zone 2	14%	66%	17%	4%	20%	16%
Zone 3	29%	37%	33%	1%	11%	32%
Zone 4	29%	32%	25%	14%	28%	8%

Source: TERI's Analysis

Table 5.11 Daily Average Trip Length for Educational Trips (in kms)

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	3	3	5	4
Zone 2	2	2	3	2
Zone 3	6	3	4	7
Zone 4	3	6	2	4

Source: TERI's Analysis

Table 5.12 Daily Average Travel Time for Educational Trips (in mins)

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	19	16	24	20
Zone 2	13	12	17	15
Zone 3	25	15	23	30
Zone 4	16	21	15	15

Source: TERI's Analysis

The educational trips: It includes to - and - fro trips for educational purpose at schools, colleges and universities. According to the table, it is implied that Intra-zone school trips has hit the maximum in Zone-1 and Zone-2 with 79% and 66%, respectively. Whereas, more than 60% of the school trips from Zone-3 and Zone-4 are evenly distributed between the two central zones. In particular, Zone-3 alone produces 33% trips within for the purpose. Furthermore, least number of trips are destined to Zone-4 due to lack of infrastructure.

"This also corresponds to the lowest allocation of educational land in the whole PMC". However, even though the land allocation is low in Zone-2 there are more trips made from Zone-3 to Zone-2 because the average trip length is lower than the Intra-zone. In Zone-4, users travel long distances due to lack of resource availability.

Table 5.13 Origin-Destination matrix of Work Trips

	Zone 1	Zone 2	Zone 3	Zone 4	Work + Business(Ha)	Residential (Ha)
Zone 1	71%	22%	3%	4%	75%	40%
Zone 2	34%	43%	14%	9%	12%	20%
Zone 3	30%	41%	19%	10%	7%	11%
Zone 4	32%	24%	34%	11%	7%	28%

Source: TERI's Analysis

Table 5.14 Daily Average Trip Length for Work Trips (in kms)

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	5	6	8	8
Zone 2	6	5	5	6

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 3	7	5	4	8
Zone 4	4	10	4	5

Source: TERI's Analysis

Table 5.15 Daily Average Travel Time for Work Trips (in mins)

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	27	28	37	39
Zone 2	32	22	29	30
Zone 3	25	21	21	32
Zone 4	19	34	16	22

Source: TERI's Analysis

The work trips: It includes commuting for work and business purposes. As observed, maximum Intra-zone trips were made in Zone-1 with 71%; and approximately 30% Inter-zone trips from each end. This corresponds to 75% land-use allocation with respect to total land for business allocated in Zone-1.Whereas, Zone-2 with 12% land allocation attracts 40% trips from within and Zone-3. It is noticeable that trips from Zone-4 to Zone-2 are lower as the average trip length is 10 KMs, whereas, trip distribution from Zone-4 to Zone-1- and -3 are similar, due to similar travel length.

Table 5.16 Origin-Destination matrix of Recreational Trips

	Zone 1	Zone 2	Zone 3	Zone 4	Residential (Ha)	Recreational
Zone 1	74%	17%	6%	3%	40%	52%
Zone 2	15%	67%	11%	7%	20%	13%
Zone 3	29%	39%	26%	6%	11%	8%
Zone 4	33%	24%	10%	33%	28%	26%

Source: TERI's Analysis

Table 5.17 Daily Average Trip Length for Recreational Trips (in kms)

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	3	6	2	6
Zone 2	5	2	2	3
Zone 3	6	2	2	5
Zone 4	7	6	3	3

Source: TERI's Analysis

Table 5.18 Daily Average Travel Time for Work Trips (in mins)

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	18	24	16	22
Zone 2	28	14	17	16
Zone 3	24	12	15	8
Zone 4	22	30	10	17

Source: TERI's Analysis

Recreational trips: Maximum Intra-zone trips for recreational purposes are made in Zone-1- and Zone-2 with 74% and 67%, respectively. And, most of recreational trips from Zone-3 are destined to Zone-1- and Zone-2, which corresponds to low land allocation of just 8% in Zone-3. Although, Zone-3 attracts less trips from Zone-1-and Zone-4 as the land allocation in these zones are higher than the other two zones.

Therefore, understanding the Origin-Destination Matrix with respect to Land-use allocation can guide the authority to deduce the travel pattern within and among each zone. This also provides insights on the relation between travel distance and travel time from one zone to another to help understand congestion within the zone and between the zones.

5.24 Safety Indicator

The safety indicators rely mainly on the road accident and fatality data for a city or a district. To understand the level of road safety that is present in Patna district is evaluated by looking at the trend. The calculation of the indicators involve population, which in this case has been used as the projected population for 2008,2009, 2010 and 2012 and for 2011 is according to the recoded census data.

Overall the road safety of the city has decreased in the past years, it is been measured by various parameters and the trend is seen for the past 5 years. The first parameter is the number of road fatalities which is measured as persons killed in road accidents per lakh of population. This road fatality has increased from 6.66 in 2008 to 8.50 in 2012. Whereas, the number of persons injured in road accidents have decreased over the years as the accident severity has increased. This is measures as number of deaths per 100 accidents which has risen from 34.2 in 2008 to 43.0 in 2012 which an increase of 25.7% in 5 years. Aforementioned indicators point out that on road safety has decreased in Patna. The safety index of Patna has decreased from 0.15 in 2008 to 0.12 in 2012. Safety Index = 1/Accident Fatality Index where Accident Fatality Index=Persons killed in road accidents per 100,000 population.

5.25 Security Indicator

The security on road is measured by the amount of road length lit by street lighting, calculated as the ratio of road length with street light to the total road length. In the study area the street lighting indicator provides alarming and disturbing percentage of roads that have street lighting. The indicator is being calculated with the help of survey data in which the in availability of street light provision is taken as length

The collector roads which are mainly the roads that connect the main residence of the people to the major or arterial roads are the least securing as only 13.5% of the collector roads are lit. Whereas the street lighting is maxim1um in the arterial roads of around 56% and 21% on the major roads, which clearly shows enhanced security as compared to collector road.

The absence of provision for street light can be a demotivating factor for most of the commuters especially female to use NMT (walk, bicycle or cycle rickshaw) where they make more than 50% of their trips through NMT.

5.26 Congestion Indicator

The congestion on the roads is calculated through the congestion index, it is defined as the inverse of mobility index by MoUD (2008). Where, mobility index is the calculated as 1-(A/M), where A is average journey speed observed on major corridors of the city during peak hrs. M=Desirable average speed on major road networks during peak hours preferably

30km/hr. In case of the index if the congestion index is low which will mean that the mobility index is high and thereby, defining the level of congestion which in quantitative manner should be 0.25. In case of Patna city the overall congestion index of the city has been calculated which came out to be 2.33 the average speed of around 17kms/hr in the city was drawn from the speed delay survey data.

5.27 Environmental Indicators

To calculate the environmental indicators like fuel and energy consumption, emission and concentration of emission in specific regions of the city, vehicular activity in the city was monitored with the help of three surveys. These surveys are traffic count, parking lot and GPS based surveys, where, each survey had specific task to meet in order to estimate the energy consumption and emissions.

The traffic count survey is to assess travel demand in the city based on actual on-road vehicles; the survey includes vehicles which are not registered with in the city. There by, providing the actual vehicular population occupying the streets of a city. Parking lot survey is to assess the distribution of vehicles (based on types, vintage, models and fuel), their usage, occupancy and maintenance practices in the city so as to understand the fuel consumption and mileage of different vehicles. Finally, to assess the driving patterns of different vehicles, GPS based survey was carried out at different location within the city.

In the following sections the estimation of emissions and energy consumption is elaborated on the basis of above mentioned surveys.

Traffic volume count survey

Traffic volume count surveys are conducted to measure the volume of traffic on the city roads for a given interval of time. Key aspects should be taken into account while conducting a traffic count survey; these include the identification of main intersections in the study area, peak and off-peak hours, purpose of the study, and financial and human resources.

The traffic count are usually done manually as prescribed in the 'Manual methods use field personnel to count and classify traffic flowing past a fixed point' (Kadiyali, 1997) and the data is collected for both the direction of traffic flow.

The purpose of the survey is to assess the number of different modes plying on several categories of roads in a city. The data is collected at different times of day that is peak and off-peak hours which acted as representative sample for the rest of days which could be categorized as weekdays and weekends. Based on traffic count, vehicle kilo meter travelled (VKT) for different categories of roads are estimated using road length of the respective road categories (CPCB, 2010). VKT is also being calculated on the basis of the registered vehicles in the city so as to compare the two values and understand the following facets of emission and energy consumption listed below.

1. Outside registered vehicles plying in the city
2. Older vehicles registered in the city not plying anymore
3. Registered vehicles moving out of the city.

VKT = Traffic count (Major or minor roads) x Road length → EQ1 (Major or minor road)

VKT = Registered vehicles x daily km travelled → EQ2 (parking lot survey)

Survey locations

Survey locations play an important role in the traffic count survey as the survey acts as a representative of the traffic in the whole city. So, being a representative survey, traffic count survey is done on each category of road such as arterial (primary arterial and secondary arterials), connector (larger urban roads linking local roads to the arterial network), and local roads (roads providing direct access for residential and other areas of development in urban areas). While choosing the representative sample for the survey following aspects are taken into account including characteristics like road network, population density, land use patterns and other factors impacting traffic flow. The information gathered for the locations that should be surveyed involved the process of consultations with city –level authorities and local transport experts and secondary literature review (City Development Plans, Comprehensive Mobility Plans, and Master Plans etc.)

Frequency of sampling

The frequency of sampling refers to the number of times that the count has been done on a particular road and is done to acquire accurate data. Initially a preliminary traffic count survey is done at 2 locations for 7days. Then standard deviations within the days are calculated for different locations. Based on the results of observed standard deviation, frequency of sampling for the rest of the samples are decided. Representative traffic count is done for each hour of the day to estimate the traffic count on a certain type of road in a city.

Parking lot and fuel pump Survey

Parking lot and fuel pump surveys are carried out to understand the existing fleet of vehicles and there vintage which includes the make year of the vehicle, fuel used and other technological specifications. This data base is important to estimate on road emissions by the transport sector. While number of vehicles utilizing a city's transport infrastructure is acquired from the regional and district Transport office where the data for registered vehicles in all category. Through the survey average daily distance travelled by different modes of transport is being calculated depending upon the land use distribution income and availability of public transport.

The methodology used to decide the sample size for the parking lot survey depends upon the following factors:

1. Minimum acceptable level of precision (95%)
2. Confidence lnterval (5%)
3. Time and resources available

The formula (Cochran, 1977) in being used to calculate the sample size mentioned below

$ss = [t^2 * (p) * (1-p)] / c^2$

Where,

ss : Sample size

t : t value (1.96 for 95% confidence level or 0.05 alpha value)

p : percentage picking a choice, expressed as a decimal (0.5 used for sample size needed),

c : confidence interval, expressed as decimal or acceptable margin of error

p* (1-p) is measure to estimate variance and will produce the maximum possible sample size when both are equal i.e. p = 1-p = 0.5. So, sample size obtained by assuming p = 0.5 is big enough to ensure precision.

Alpha value (t) represents the level of risk the researcher is willing to take that true margin of error may exceed the acceptable margin of error. In most of the research studies alpha level of 0.05 or 0.01 is used (Bartlett et.al. 2001) and in Cochran formula, alpha level is incorporated by using t value based on selected alpha level.

If sample size exceeds 5% of population, following correction factor is applied

Correction factor

New ss = ss / {(1+ ss) / pop}

Where,

POP: Population

Currently, 95% precision with ±5% confidence interval (for categorical data , 5% confidence interval or margin of error is acceptable (Bretlett et,al., 2001) is used to estimate minimum sample size for parking lot surveys in different cities. Based on recent registered vehicles, data sample size calculations has been done and results are presented below:

Road selection using spatial analysis

Selection of road is an important aspect of the estimating environmental indicators which is done with the help of spatial data on road network, land use pattern and administrative boundary of an urban agglomeration under consideration. This data base is then digitalized with the help of GIS tool. As a pilot study the municipal boundary of a selected city is identified, which is then divided into 2x2km grids. The ward boundary is then overlaid on the municipal and road map, thereby, recognizing the land use patterns, road lengths, population and other important attributes in the different grids of 2x2 km^2.

The overlay of land use map over the study domain helped in identifying the pre-dominant land use of different grids. Based on this, all the grids in the study domain were categorized in to different land-use land cover (LULC) classes. With the help of the above created map eight representative grids are identified with pre-dominant land use which acts as a representative grid and is then redistributed to other grids with similar specifications.

According to the above mentioned methodology the basic data gathering was achieved to calculate the fuel and energy consumption as well as the emissions of the pilot city. These two indicators are being estimated in the upcoming sections for the city of Patna.

5.27.1 Fuel Consumption

The fuel consumption in the city depends on the type of vehicle, its make year, and engine type. All these parameters help in determining the amount of fuel used by a particular vehicle type for travelling one unit of distance. The fuel consumption has been calculated on

the basis of traffic count survey done for the exemplified city. The registered vehicle count does not take into account the vehicles travelling from adjacent rural or semi-urban spaces.

Table 5.19 shows in detail the consumption of each fuel type by different modes of transport each day which is then converted into energy consumed by the city each day and annually. It is clear from the Table 5.19 that most of the heavy vehicles that cover the road transport of the city are diesel based along with 3-wheelers who consume 1.6 times more than petrol. 2-wheelers are the major consumers of petrol along with cars and 3-wheelers which are petrol based. Annually the city consumes 113.24Mtoe and 78.62Mtoe of energy through the consumption of diesel and petrol respectively. This energy consumed by diesel and petrol shows their impact on the emission in the city. The emissions and concentration of specific hazardous emissions are discussed later in this section.

Table 5.19 Fuel and Energy Consumed in Patna Daily and Annually

Modes	Fuel consumed (Litre/Day)		Energy Consumption (Mtoe/day)		Energy Consumption (Mtoe/Year)	
	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol
LCV Diesel	35281.27	0.00	0.06	0.00	20.10	0.00
HCV truck	24919.89	0.00	0.04	0.00	14.19	0.00
Tractor	10137.08	0.00	0.02	0.00	5.77	0.00
Bus	21216.41	0.00	0.03	0.00	12.09	0.00
Car	34064.87	50029.16	0.05	0.07	19.40	27.05
MUV	7566.65	0.00	0.01	0.00	4.31	0.00
2-Wheeler	0.00	55611.66	0.00	0.08	0.00	30.06
3-Wheeler	65622.99	39792.66	0.10	0.06	37.38	21.51
TOTAL	198809.16	145433.49	0.31	0.22	113.24	78.62

Source: TERI's Analysis

5.27.2 Emission Inventory

Two approaches are used to calculate the emissions, first by using the registered vehicles and second by using actual traffic count to assess on-road vehicular movement. The type of on-road vehicle distribution acquired from parking lot survey is used in both the methods.

Emission factors

Emission factor is a necessary component in the estimation of emission of a vehicle category like 2-wheeler, car, bus, auto etc. Emission factors used in the study are developed by ARAI, 2011, where ARAI, 2011 is the collection of extensive work done on developing emission factors for different categories of on-road vehicles by following different vehicular emission norms (Pre-BS, BS-I, BS-II, BS-III) in different time frames. However, to assess the emission factors for BS-IV norms the reductions assumed in CPCB, 2011 has been used.

Emission estimation

The steps involved in the estimation of emission for the two approaches mentioned above are tabulated below Table 5.20 which is the standard 5-step method the only distinction between the two methods are the difference in the method of collecting data i.e. primary and secondary survey for traffic count and vehicle registration approach respectively

Table 5.20 Approaches to Estimate Emissions

S.No	Step	Approach-I	Approach-II
1	Assessing the number of vehicles	Vehicle registrations	Traffic counts
2	Analysing the distribution of vehicles based on vintages, technologies, and fuel types	Parking lot surveys	Parking lot surveys
3	Computation of vehicle kilometre travelled (VKT) for all sub-categories of vehicles	Registered vehicles and parking lot surveys	Traffic counts and road length
4	Selection of emission factors for each sub-category	ARAI, 2011, CPCB, 2011	ARAI,2011, CPCB, 2011
5	Computation of emissions	VKT x Emission factor	VKT x Emission factor

Source: TERI Analysis

Where, data collected in approach-I is on the basis of daily kilometer travelled by different categories of vehicles and life of vehicle is assumed to be 15yrs and in approach-II traffic counts on the eight representative grids are taken for different road category. The traffic count is extrapolated for the city based on land use categories and population densities. The extrapolation method of data from 8 representative grids to the whole city is described below.

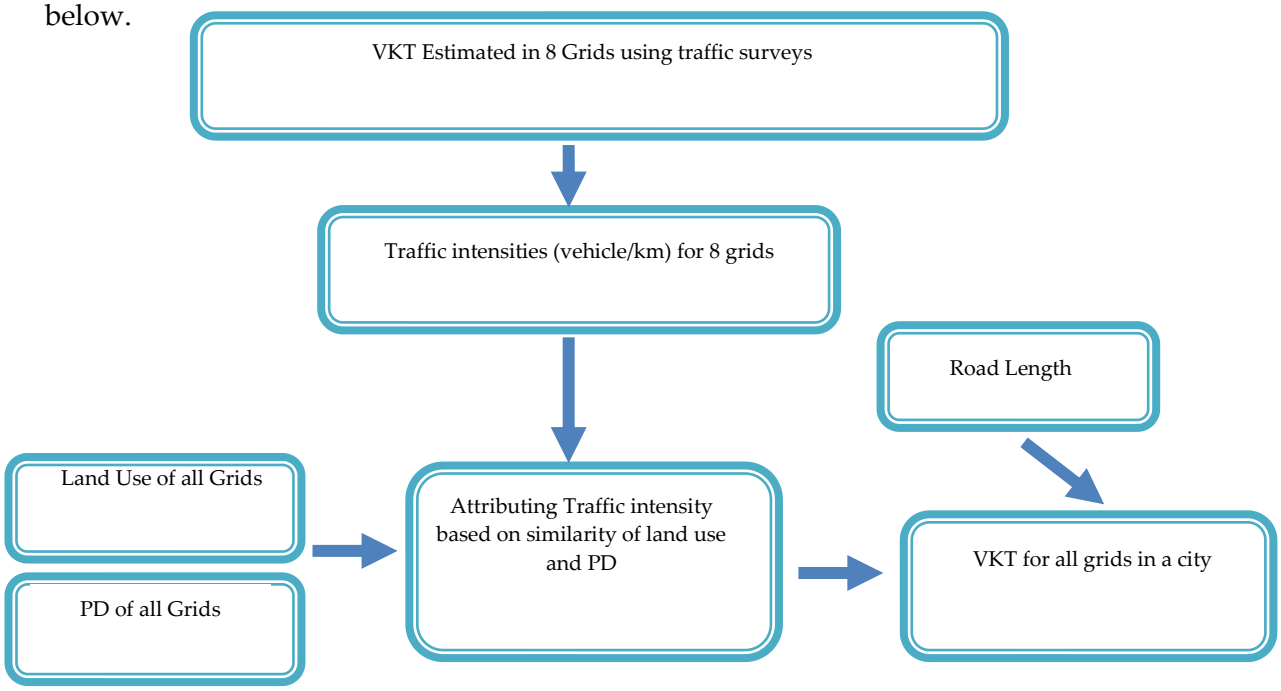


Figure 5.26 Extrapolation method used for VKT assessment of the city based on 8 survey grids
Source: TERI's Analysis

Figure 5.26 illustrates the methodology that has been standardized during the source apportionment studies carried out in 6 cities (CPCB, 2011).

Emission for Patna

In 2013, Patna city was still at BS-III standard of fuel quality and vehicles. The VKT estimated through two different approaches for several vehicle categories are mentioned in the Figure 5.27 below. The estimated VKT differences in the approaches are due to inflow of vehicles registered outside the city as attracts external trips being the capital city.

A marginal difference of 13% is being observed in the two approaches and therefore indicates the reliability of the estimates. Additionally, the VKT estimates are also compared with the fuel consumption data for the city collected from the oil companies.

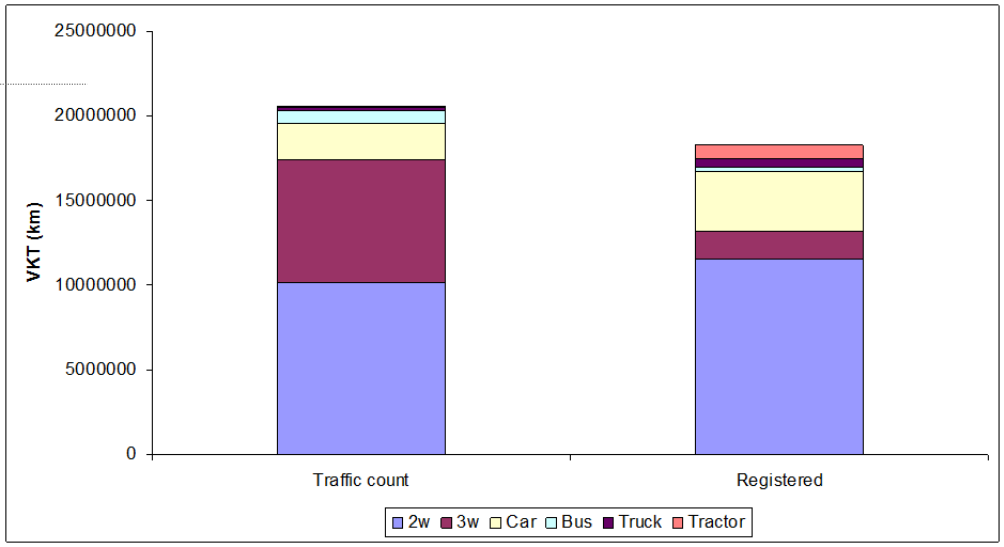


Figure 5.27 Comparison of VKT estimates using the two approaches based on registered vehicles and traffic counts

Source: TERI's Analysis

In order to calculate emission estimate of the city, VKT is estimated for each vehicle category by using the above mentioned approaches is multiplied by emission factor. The final emissions estimated using the approach based on actual traffic count surveys are presented in Table 5.21.

Table 5.21 Emission inventory of Road Transport Sector of Patna

Pollutants	Emissions
CO (tonnes / day)	47.4
HC (tonnes / day)	17.7
NOx (tonnes / day)	18.3
CO2 (tonnes / day)	2369.0
PM (tonnes / day)	2.9
SO2 (tonnes / day)	0.4
Benzene (g/day)	1374.0
1-3 Butadiene (g/day)	640.3
Acetaldehyde (g/day)	141.4
Total Aldehyde (g/day)	577.1
Total PAH (g/day)	23918.9

Source: TERI's Analysis

Road transport sector contributes to almost 2.9 tonnes or PM each day. The emissions of gaseous pollutants such as NOx, CO, HC, and SO2 are 18.3, 47.4, 17.7, and 0.4 Tonnes per day respectively. Lower level of SO2 emissions is attributed to lower levels of sulphur content in the fuel.

The emission contribution of different vehicle type shows that three wheelers have the highest percentage of contribution in PM, CO, SO2, HC and CO2 with a share of 43%, 40%, 37%, 35% and 33% respectively. Buses contribute maximum to the NOx emission of 47% which is due to the diesel based engines. They also contribute 35%, 37% and 43% of CO2, SO2 and PM emissions respectively in the city. Finally 2-wheelers contribute more than 50% of HC content and 30% of CO in the city. CO and HC are main by-products of petrol based vehicles whose share in the city is 22% of 2-wheelers and 9% of three and six seaters. Share of cars is comparatively smaller as compared to buses, 2-wheelers and 3-wheelers in the overall energy used and hence lower estimates of pollutants are estimated from 4-wheeler in the city. Table 5.22 presents the vehicle categories which contribute maximum towards the emissions of different pollutants.

Table 5.22 Vehicle categories contributing maximum towards emissions of different pollutants

Pollutants	Vehicle category contributing the most	Percentage share in total emissions
CO	2 and 3 wheelers	38% and 40%
HC	2 and 3 wheelers	53% and 35%
NOx	Bus	47%
CO2	Buses and 3 wheelers	35% and 33%
PM	3 wheelers and buses	43% and 33%
SO2	3 wheelers and buses	37% and 34%

Source: TERI's Analysis

Zonal analysis of emission

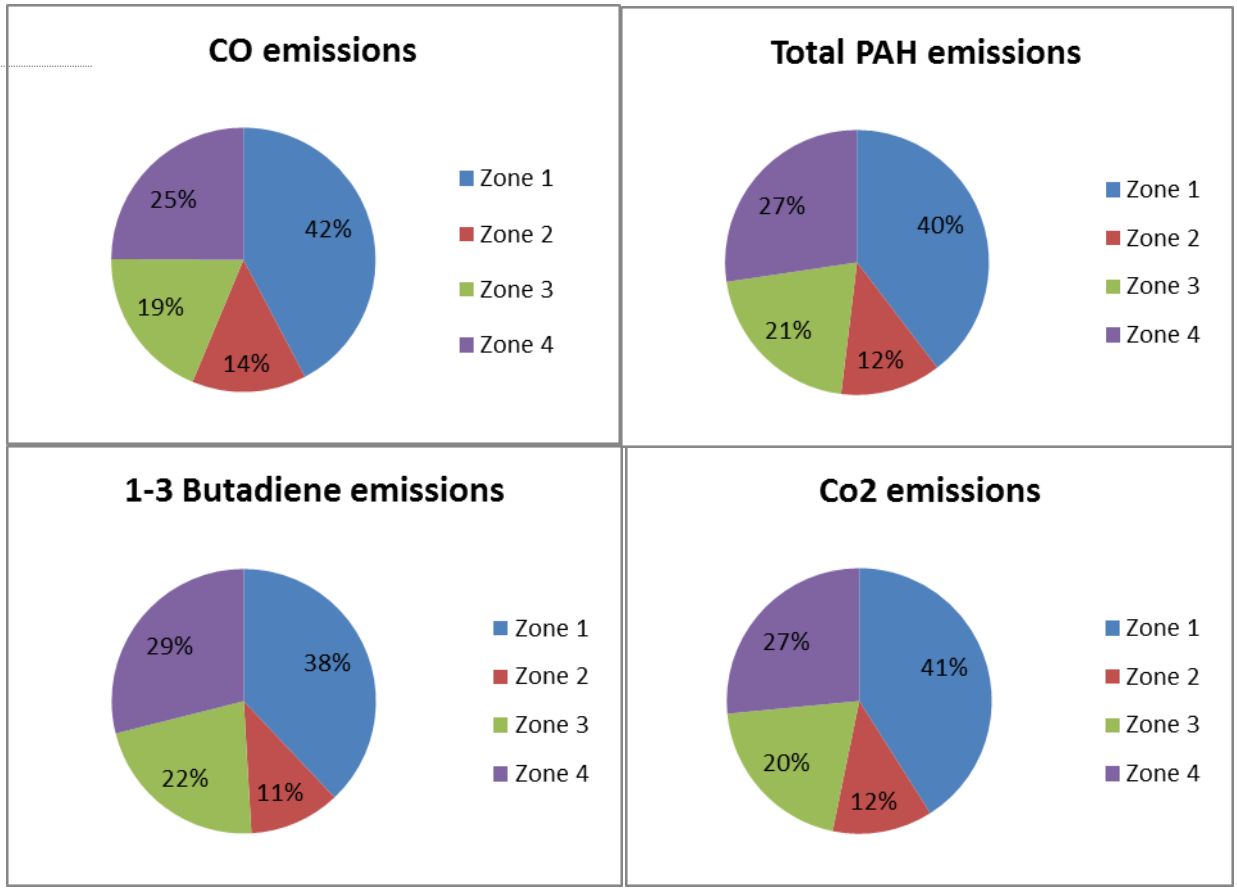
The methodology for zonal analysis of emission has been done using grid wise emission data. Number of grid lying in specific zone has been identified using Arc GIS 10.2.1 after overlaying the Zone boundary over Grid boundary. Zone-1 contains largest number of grid near about 15 followed by Zone 4 which contains 14 grids. Zone-2 and Zone-3 contains 4 and 5 grids respectively. Emission of respective grids was sum up for respective zone for further analysis.

Table 5.23 Zone wise emissions of different pollutants

Pollutants	Zone 1	Zone 2	Zone 3	Zone 4
CO (kg/day)	21.9	7.3	9.7	12.9
HC (kg/day)	7. 9	2.7	3.4	4.5
Nox (kg/day)	7. 8	2.2	4.2	5.4
Co2 (kg/day)	1196.2	357.2	590.5	773.9
PM (kg/day)	1.2	0.4	0.6	0.8
Benzene (gm/day)	632.9	221.3	265.5	351.0
1-3 Butadiene (gm/day)	267.6	78.4	155.1	203.8
Acetaldehyde (gm/day)	62.8	20.5	28.35	37.7
Total Aldehyde (gm/day)	291.7	93.6	129.6	171.9
Total PAH (gm/day)	9756.8	3040.7	5104.8	6740.2
SO2 (gm/day)	0.2	0.1	0.1	0.1

Source: TERI's Analysis

Analysis trend shows that Zone-1 is contributing maximum pollutants followed by Zone-4. Figure 5.28 shows that pollutant emissions of Zone 1 are almost three times more than Zone-4.



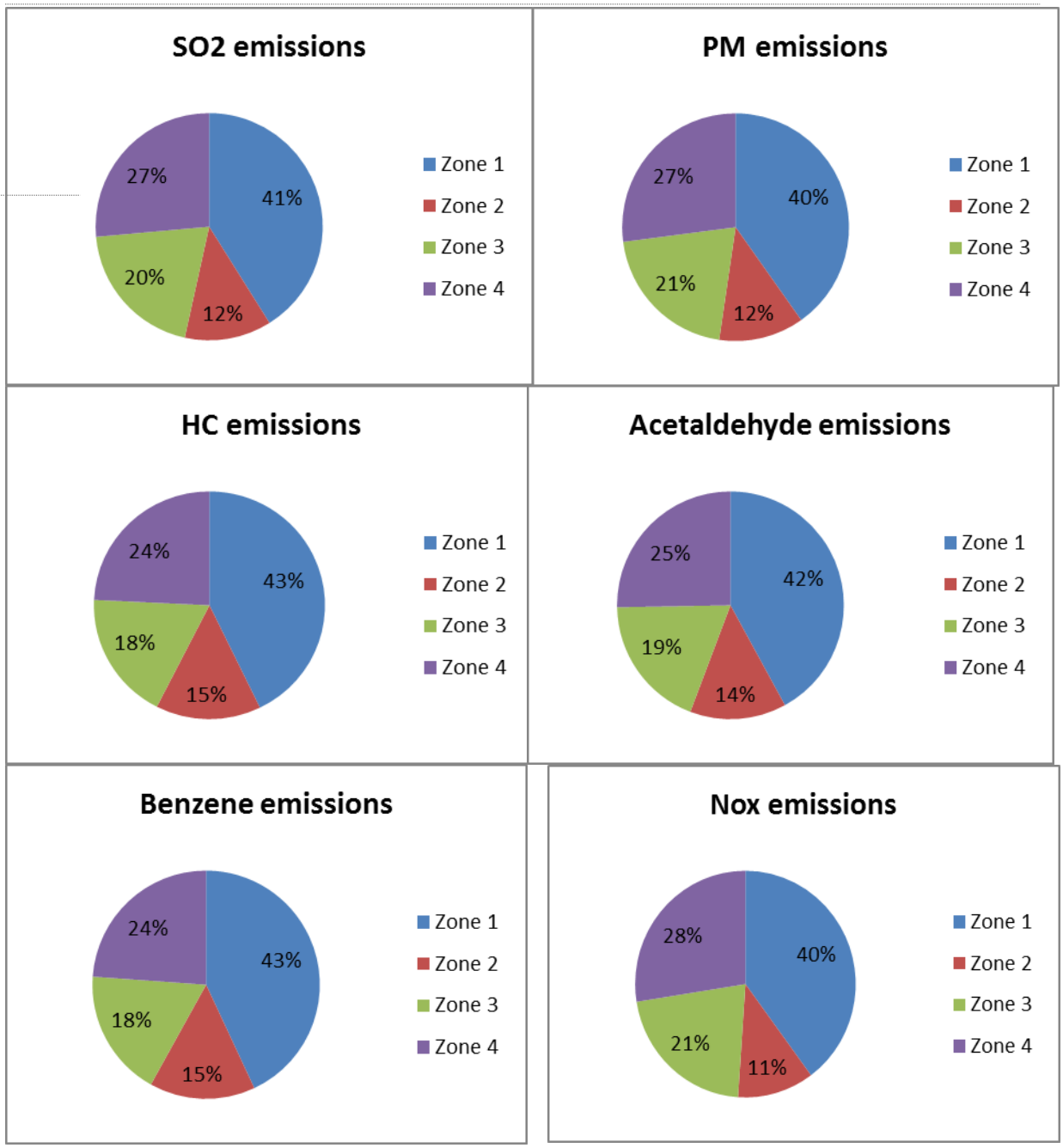


Figure 5.28 Zone wise Emission
Source: TERI's Analysis

5.27.3 Air Quality Analysis

Air quality simulations for the year 2013 have been performed using the Weather Research and Forecasting (WRF) (version 3.1.1) model and Community Multi-scale Air Quality (CMAQ)(version 4.7) model. Models-3/CMAQ modeling system (version 4.4) (Byun and Ching, 1999) is used in the current study to assess chemical transport of different pollutant species under prevail meteorological conditions. CMAQ system is based on multi-pollutant and one atmosphere approach and is a leading air quality model used for assessment of ozone (O_3) and aerosols (Byun and Schere, 2006). Meteorological inputs for CMAQ could be prepared using different meteorological models like MM5, WRF etc. The WRF-CMAQ

combination has also been successfully used in different studies (Im et al, 2010, Theresa, 2013, Shimadera, 2011) for simulation of meteorology and air quality at a regional and urban scale. Based on the widespread applicability and requirements of multi-pollutant prediction, WRF (ver 3.1.1)-CMAQ (ver 4.7) combination has been chosen for carrying out the assessment. The models require input data related to emissions, meteorological and terrain for the selected domains where meteorological data is collected from National Centre for Environmental Prediction (NCEP). Basic flow of various processes in an air quality modeling simulation is shown in Figure 5.29.

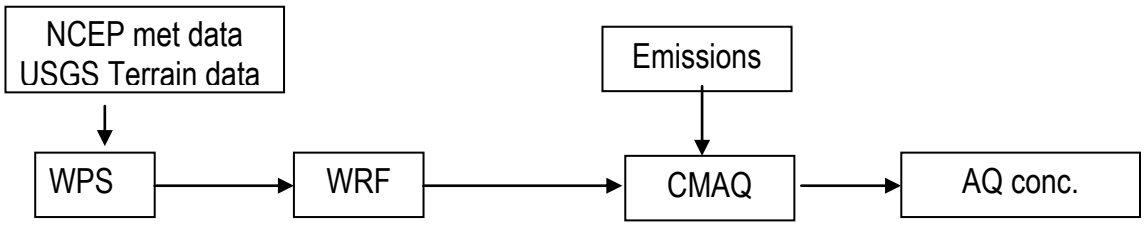


Figure 5.29 Basic flow of various processes in the air quality modelling simulation

Source: TERI Analysis

The air quality analysis has been done from the data available for the year 2010. For this purpose data from 6-hourly files for different months of the year are inputted in ungrid and metgrid programs of WPS. The output file from WPS is then fed to WRF model for the generation of meteorological fields, which then acts as an input to the CMAQ model.

Apart from this, grid-wise emission inventory (PM, CO, SO2, NOX, and NMVOC) prepared as mentioned before which acted as an input to the CMAQ model. In this particular study the grid-wise emissions from the transport sector is taken into account for the above mentioned pollutants.

Once the WRF and CMAQ models are run for the year 2010 it was bifurcated among two seasons with representative months as May and December. The results of the model are presented below.

While monitoring is carried out for PM10, NOx, SO2 regularly at all monitoring stations, wide spread violation of prescribed standards have been noted for ambient PM concentration. Several studies have concluded that PM has known to have maximum health impact along with impacting visibility and ecology.

The concentration of Particulate matter is dependent on emission sources and local meteorological conditions. While emission sources remain same across the year, PM concentration shows a wide variation due to change in meteorological conditions. Higher wind speeds and longer day time during summers lead to unstable conditions which are known to cause more dispersion of the pollutants. On the other hand lower wind speeds and inversion conditions in winters lead to accumulation of PM concentration in a region. Therefore, to study PM concentration in both the seasons, a month each in summers and winters are being selected.

CMAQ and WRF model runs were initiated for the base year 2010. Simulations were carried out for two seasons (May and December months) of the base year 2010, for the study domain covering Patna city. Season-wise results are presented below.

Figure 5.30 and 5.31 shows PM10 concentrations across the study domain for the two months of the base year 2010. It could be observed that PM10 concentrations are high during winters in December and goes down with increased height of PBL and wind speeds in the summer month of May. Figure 5.28 and 5.29 shows in detail the PM10 concentrations at various grids of the study domain and shows that the higher intensity of PM10 concentrations can be observed at the heart of the city which comes under zone 3. The North east region which comes under zone 4 also shows higher concentrations mainly due to transport of PM due to prevailing wind direction.

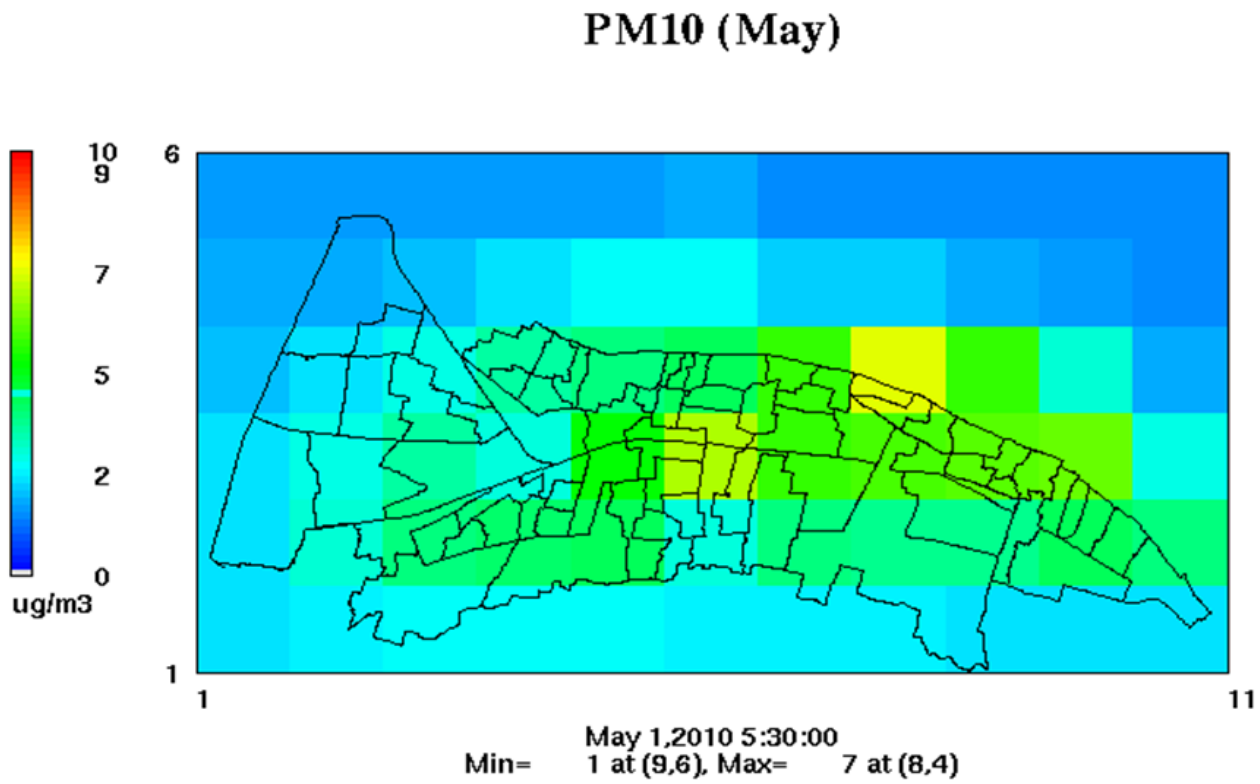


Figure 5.30 PM10 concentrations in May 2010

Source: TERI's Analysis

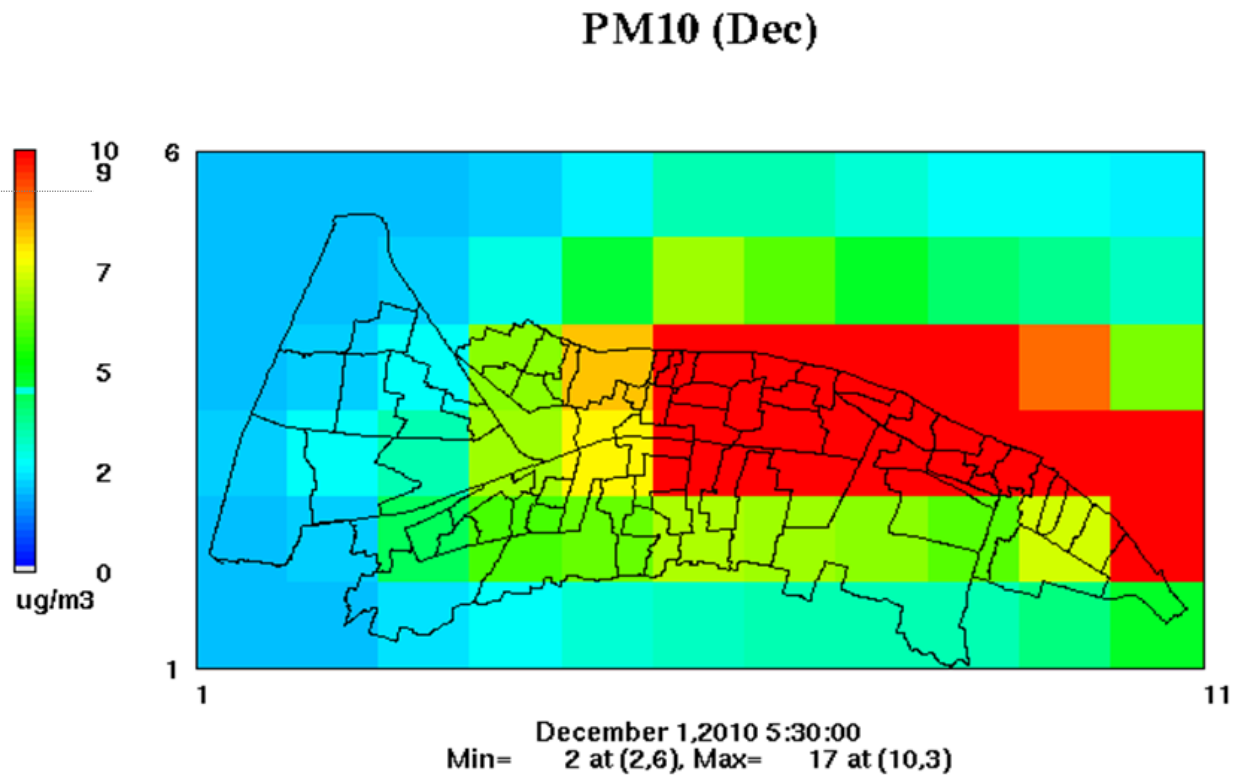


Figure 5.31 PM10 concentrations in December 2010

Source: TERI's Analysis

6 Moving Forward

6.1 Conclusions

The analysis of the primary survey and secondary survey reveals that transport and land use allocation of activities play an important role in deciding the travel demand, trip length and trip distance. The analysis also assisted in understanding the extent of fuel used annually and also the cause of pollution in a city. Several issues and inferences that became apparent during the analysis of the data were as follows:

1. The mode share of the city was dominated by two modes walking and 2-wheelers. Therefore, it becomes necessary to at least maintain the walking in the city and reduce the 2-wheeler use as they are also one of the reasons for increased emission.
2. Again from the mode share database it is comprehensible that private modes of transport are preferred more than public transport which further increases the on-road vehicular population.
3. The preference of the residents to use public transport depends on the level of comfort and time taken to reach the destination. This preference also differs from the category of household that is in the study are slum and non-slum.
4. Further, when looked into the mode share among different genders it was clear that females use walking as a mode of transport for majority of their trips as compared to males.
5. Lack of footpath availability, its discontinuous nature and encroached by local vendors are discouraging for the people to walk as almost 22% of the trips made in the city are done by walking and the availability of footpath is just 7% which is either discontinuous or are encroached by vendors.
6. Furthermore the collectors in the city are least lit i.e. the provision of street lighting is missing in almost 87% of the collector roads in the city. Where collectors play a major role in the connectivity of the people from home to a public transport or IPT.
7. Accessibility to a public transport stop is an important factor to use the transport system that lacks in case of non-slum households. Higher percentage of slum households has easy accessibility to a public transport as compared to non-slum HH.
8. The average travel length of a slum dweller is higher for mandatory purposes as compared to a non-slum resident. This shows that the slum population resides in areas that have cheaper land or no land value and commute longer distances for work.
9. Travelling longer distances for work by slum HH through public transport also means that their travel disutility because of time is lower as compared to non-slum dweller.
10. Private vehicle and public transport take similar time to travel the same distance. This means that its people's perception to believe that public transport takes more

time as compared to private vehicle which is due to the last point connectivity or the accessibility to a bus stop or residence is poor.

11. Dominance of a particular type of land use in a specific zone is a common feature in the city which is a cause of increased in travel demand and number of trips in a particular zone for that purpose.
12. Apart from the existing transport system in the city, metro is being proposed which is to be run along the major road corridor in the city. Therefore, it is essential that the city should be using this opportunity to plan better along the corridors and at the stations.

6.2 Recommendation

Policy amendments associated with safety of pedestrians and bicycle riders, traffic management through Intelligent Transport System (ITS), improvement in the speed, safety, capacity, priority to public transport, route planning and coordination while incorporating privatization of bus services and integration among different government agencies to integrate policies and better funding opportunities to reduce motorization is crucial for a developing country.

Therefore, after considering the aforementioned results and conclusions of the analytical framework developed in the study for a city, to improve the mobility pattern and move towards sustainable urban mobility, it is recommended that:

1. Implementation of certain policies like providing high frequency, air-conditioned buses with lesser travel time in transport services should be provided so as to shift the private vehicle user to public transit or mass transit.
2. Improving the road design which includes continuous and uninterrupted footpaths, proper road crossings and adequate street lighting should be implemented in the city. This should be taken as priority to involve more residents in walking and also to maintain the existing mode share of walking in the city.
3. Another necessary issue to be tackled is the city is streetlighting of the collectors as they are the least lit roads and are most important in the connectivity to main and arterial roads. Furthermore, the street lights intalled could be solar based so that it is independent of the grid and provides uninteruppted light.
4. Since the IPT has a better accessibility for both slum and non-slum dwellers there for it become imperative to improve the efficiency of the IPT and also convert them to CNG based vehicles so as to decrease the air pollutant levels in the city.
5. Increment in parking fare should be implemented on on-street parking facilities and more stringent rules should be incorporated so as to move people from on-street parking to off street parking facilities or to decrease the use of private vehicles thereby, reducing congestion on the roads.
6. E-rickshawshould be put into practice within the city to improve the small distance connectivity and accessibility of the residents which are energy efficient and environmental friendly. This should include safety measures and regulation related to vehicle registration.

7. Mixed use development and transit oriented development should be incorporated in the city and areas that being newly developed so as to decrease the number of trips, travel distance and travel time. with the decreased travel distance and improved road design would encourage people to walk rather than using a 2-wheeler or an intermediate public transport. For example provision for new schools in the new development area along with institutional and commercial spaces. Furthermore, the existing schools should be improved and a few schools should be provided on borders of zone 2, 3 and 4 so as to reduce the commuting time and distance.
8. City Development Plan of Patna city emphasized on the multi-modal transport system for the city and has approved three metro corridors. With the metro corridors implemented the provision for better feeder buses to improve the accessibility to metro station must be met.
9. Since the metro line is being initiated, the allocation of land along the stations should be done before so as to develop it as a mixed land use under transit oriented development. Prior allocation of land might help in dealing with the problem of land pricing once the metro route is working.

6.3 Lessons learnt

The development of the framework to analyse the existing issues of transport in a city was a part of the study which has been reflected through several survey data. The framework further facilitated in recommending policy measures to retain the existing mode share and work towards reducing or shifting of mode from private to public or non-motorized transport.

The framework analysed the mobility pattern, travel demand, mode share, and travel expenses of a city, the same framework could be used to understand the same parameters for a similar sized city going through urbanization process. It not only created a picture of travel characteristics but also helped in understanding the relation between land use and transportation. An understanding of how location of activities plays an important role in determining the travel distance, time and mode.

Moreover, any pilot study is a step forward in improving and creating the existing framework more feasible so as to provide accurate recommendations to a city. In order to do so certain points should be considered.

1. Increase the sample size of the survey which should be in proportion to the population.
2. Income is a much refined way to categorize population of a city so as to understand travel demand and mode preference.
3. While using an analytical freeware tool it is essential to gain understanding about the requirements of the tool so as to gather quality data through survey.
4. Traffic count, road inventory surveys should be done meticulously to develop an understanding about the existing conditions of the city's transport infrastructure.

5. Information on the travel pattern of the individuals should be collected meticulously with information on link trips and mode used along with distance and time taken. Further the waiting time involved in several modes should be documented properly.

References

Agarwal, O. P. (2006). *India Infrastructure Report.* Kanpur: IIT Kanpur.

Ahmed M. El-Geneidy, David M. Levinson (2006), Access to Destinations: Development of Accessibility Measures

Ambient Air Quality Monitoring and Emission Source Apportionment Studies, Automotive Research Association of India

ARAI,2011, Report on "Emission Factor development for Indian Vehicles "as a part of

Banister, D. (2008). The Sustainable Mobility Paradigm. *Transport Policy*, 73-80.

Beimborn, E., Horowitz, A., Vijayan, S., & Bordewin, M. (1999). Land Use – Transportation Interaction. In *An Overview: Land Use and Economic Development in Statewide Transportation Planning* (pp. 10 - 24). Milwaukee: FEDERAL HIGHWAY ADMINISTRATION.

Ben-Elia, E., Shefer, D., & Shiftan, Y. (2003). Transportation Impact Statement (TIS) - a new tool for transportation and land-use planning. *Environment and Planning*, 2177-2190.

Camagni, R., Gibelli, M. C., & Rigamonti, P. (2002). Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion. *Ecological Economics*, 199-216.

Center for Sustainability (2004) www.c4s.info, Transportation Research Laboratory, www.trl.co.uk.

Cervero, R. (2009) *The World Bank.* Retrieved October 4, 2013, from www.worldbank.org: http://info.worldbank.org/etools/docs/library/115504/toronto99/assets/t-cervero-mod09.pdf

Cervero, R. (2013). Linking Urban Transport and Land Use in Developing Countries. *Journal of Transport and Land Use*, 7-24.

Cervero, R. E. (2010). Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association*, 265-294.

Chawla, S. (2012). Land Use Changes in India and its Impacts on Environment. *Journal of Environment*, 14 -20.

CIP, (. I. (2000). About Planning: What Planners Do.

Cochran, W. G. (1997). Sampling techniques (3rd edition). New York: John Wiley & Sons

Commission, P. (2012). Report of the Steering Committee on Urban Development for Eleventh Five Year Plan (2007-2012). New Delhi: Government of India.

CPCB, 2010A, Status of the vehicular pollution control programme in India , Central Pollution Control Board, New Delhi

CPCB, 2011, Source apportionment studies for 6 cities, Central Pollution Control Board, New Delhi

D.T. Ory, P.L. Mokhtarian (2005). When is getting there half the fun? Modelling the liking for travel, Transport Research A, issue 39, pages 97-123.

Daniels, R., & Mulley, C. (2013). Explaining Walking Distance to Public Transport: The Dominance of Public Transport Supply. *The Journal of Transport and Land Use*, 5-20.

Dr. Santosh A.Jalihal, D. R. (2005). TRAFFIC CHARACTERISTICS OF INDIA. *Eastern Asia Society for Transportation Studies* (pp. 1009-1024). J-Stage.

EMBARQ. (n.d.). Sustainable Urban Transport in Asia - Making the Vision a Reality. CAI-Asia.

Environmental Planning Collaborative (2012), Sustainable Urban transport in India – Principles, Standards, Implementation and Best practices

Environmental Planning Collaborative (2012), Sustainable Urban transport in India – Principles, Standards, Implementation and Best practices

Ewing, R., & Cervero, R. (2010). Travel and Built Environment: A Meta-Analysis. *Journal of the American Planning Association*.

Frank E. Horton and David R. Reynolds (Jan., 1971). Effects of Urban Spatial Structure on Individual Behavior. *Economic Geography* , Vol. 47, No. 1, Perspectives on Urban Spatial Systems pp. 36-48, Clark University

G. Tiwari (2011), Key mobility challenges in Indian cities

Geurs, K. T., & Wee, B. v. (2004). Accessibility evaluation of land use and transport stategies: review and research directions. *Journal of Transport Geography*, 127-140.

Ghate and Sundar (2010), Putting Urban Transport Sector on a Low Energy and Low Carbon Path - A Focus on the Passenger Transport Sector in Million-Plus Cities

Ghate, A. T., & Sundar, S. (2013, June 8). Can We Reduce the Rate of Growth of Car Ownership. *Economic & Poliutical Weekly*, pp. 32-40.

Giorgi, L. (2003). Sustainable mobility: challenges, opportunities and conflicts; a social science perspective. *International Social Science Journal*, 179-183.

GIZ , Sustainable urban Transport: Avoid Shift Improve Available at www.transport2020.org/file/sutporg-asi-factsheet.pdf

GIZ, Measuring public transport performance – lessons from developing cities, 2011

International Energy Agency, A Tale of renewed cities - A policy guide on how to transform cities by improving energy efficiency in urban transport systems, 2013

Jalihal, Dr. Santosh A., D. R. (2005). TRAFFIC CHARACTERISTICS OF INDIA. *Eastern Asia Society for Transportation Studies* (pp. 1009-1024). J-Stage.

James E. Bartlett, II, Joe W. Kotrlik and Chadwick C. Higgins. "Organizational research: determining appropriate sample size in survey research". Information technology, learning and performance journal vol. 19, No. 1, spring 2001.

Kadiyali, L.R., (1997) 'Traffic Engineering and Transportation Planning'. Khanna Publishers, Delhi

Kyte, R. (2012). A good public transport system must be easy and convenient to use, fast, safe, clean and affordable. *Global: The international Briefing*, pp. 14-15.

Lothlorien Redmond (2000), Identifying and analysing travel- Related attitudinal, personality and lifestyle clusters in San Francisco Bay Area, Institute of Transportation Studies, University of California, and Davis.

Marshall, D. S. (2001). The Relationships between Urban Form and travel Patterns. An Internatiional Review and Evaluation. *European Journal of Transport and Infrastructure Research*, 113 - 141.

Ministry of Urban Development (2006), Government of India, National Urban Transport Policy (NUTP)

Ministry of Urban Development, Government of India, "Study on traffic and transportation policies and strategies in urban areas in India", 2008

Ministry of Urban Development, Government of India, Service Level Benchmarks for Urban Transport at a Glance", available at http://urbanindia.nic.in/programme/ut/Service_level.pdf

Ministry of Urban Development, Government of India, Toolkit on Transport Demand Management (2013) Available at http://iutindia.org/CapacityBuilding/Toolkits.aspx

MoUD, M. o. (2012, October 2012). *Home: Urban Growth*. Retrieved October 10, 2013, from Government of India: Ministry of Urban Development: http://moud.gov.in/urban_growth

Murray, A. T., R. Davis, et al. (September 1998). "Public Transportation Access" Transportation Research Part D: Transport and Environment 3(5): Pages 319-328

OECD, & IEA. (2013). *Topics: Energy Security*. Retrieved December 10, 2013, from International Energy Agency: http://www.iea.org/topics/energysecurity/

Patricia L. Mokhtarian, Ilan Salomon (2001). How derived is the demand for travel? Some conceptual and measurement considerations, Transport Research A, issue 35, pages 695-719.

Pucher John, Renne John L. (Summer 2003). Socioeconomics of urban travel: Evidence from 2001 NHTS, Transportation Quarterly.

Pucher, J., Korattyswaropam, N., Mittal, N., & Ittyerah, N. (2005). Urban transport crisis in India. *Transport Policy*, 185-198.

Pucher, J., Peng, Z.-r., MIttal, N., Zhu, Y., & Korattyswaroopam, N. (2007). Urban Transport Treands and Policies in China and India: Impacts of Rapid Growth. *Transport Reviews*, 379-410.

Replogle, M. (1987). Sustainable Transportation Strategies for Third World Developments. *Human Powered Transportation and Transportation Planning for Developing Countries, 67th Annual Meeting (1988).* Washington DC: Tranport Research Board.

Rodrigue, D. J.-P. (2006). Transportation and the Urban Form. In J.-P. Rodrigue, C. Comtois, & B. Slack, *The Geography of Transport Systems* (pp. 170-203). New York: Taylor & Francis e-Library,.

Shaheen, Susan; Guzman, S., and H. Zhang. (2010). "Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future". Transportation Research Record: Journal of the Transportation Research.

Suzuki, H., Cervero, R., & Kanako, I. (2013). Transforming Cities with Transit:Transit and Land-Use Integration for Sustainable Urban Development. Washington DC: The World Bank.

TERI (2009), Arghyam, Sustainable Urbanism International, An exploration of sustainability in the provision of basic urban services in Indian cities

TERI (2011), Review of Comprehensive Mobility Plans

TERI (2013), GRIHA for Large Developments (GRIHA-LD)

TERI and World Business Council for Sustainable Development, Mobility for development, Bangalore, India, 2010

TERI and World Business Council for Sustainable Development, Mobility for development, Bangalore, India, (2010)

The Brundtland Commission, T. W. (1987). *Our Common Future.* Oxford University Press.

Tiwari, G. (2011). Key Mobility Challenges in Indian Cities. *Discussion Paper NO. 2011-18, International Transport Forum*. Leipiz.

Toth-Szabo, Zsuzsanna; Várhelyi, András; Koglin,Till; Angjelevska,Beti (2011,March). Measuring sustainability of transport in the city – development of an indicator-set. Lund, Sweden.

TransAfrica, Report on statistical indicators of public transport performance in Africa, 2010

Transit Oriented Development (TOD) - Study of Existing Metro Corridor between Chattarpur and Arjangarh of Delhi Metro Project of Phase II. A study conducted by Delhi Metro Rail Corporation (DMRC) and Capita Symonds`

U.S. Energy Information Administration, E. (2013). *International Energy Outlook 2013.* Washington, DC: U.S. Energy Information Administration, Office of Energy Analysis, U.S. Department of Energy.

UN – ESCAP (2012), Low carbon Green Growth Roadmap for Asia and the Pacific: Urban Transport Available at http://www.unescap.org/esd/publications/environment/lcggroadmap/Roadmap-FINAL-rev.pdf

UNEP (2010), Share the road: Investment in walking and cycling road infrastructure 31

UNEP, 2011, Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication Available at www.unep.org/greeneconomy

UNEP, Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World" Available at http://www.unep.org/PDF/UNEPGreenjobs_report08.pdf

UNEP, Promoting low carbon transport in Indian cities, available at http://www.unep.org/transport/lowcarbon/

UNEP, Promoting low carbon transport in Indian cities, available at http://www.unep.org/transport/lowcarbon/

UNEP, Share the road: Investment in walking and cycling road infrastructure, 2010

UNFPA, U. N. (2007). *UNFPA Annual Report.* New York: United Nations Population Fund.

United Nations Environment Programme, 2011 Green economy - Transport investing in resource and energy efficiency

Veneri, A. C. (2009). Spatial structure and mobility patterns: towards a taxonomy of the Italian urban systems. Rivista di Economia e Statistica Del Territorio, 25-62.

Wegener, M. (2004): Overview of land-use transport models. In: Hensher, D.A., Button, K.J. (Eds.): Transport Geography and Spatial Systems. Handbook 5 of Handbook in Transport. Kidlington, UK: Pergamon/Elsevier Science, 127-146

Working Group on Road Transport for the Eleventh Five Year Plan, Planning Commission, Government of India

Zegras, P. C. (2005, September). Sustainable Urban Mobility: Exploring the Role of the Built Environment. Boston, Massachusetts, USA.

Annexure

Annexure A: Survey Questionnaire

Household Survey

General Information

Date of Interview			
Interviewer		Supervisor	
Address		Area/ Locality	
Street Name		Ward	
Apartment/ Floor			
Independent House			
Part of the House			
Signature of interviewer		Signature of supervisor	

2.2 Distance to nearest Stops and Stations (Public transport or transit service)

	Distance (in KM)
Bus Stop	
Taxi Stand	
Auto Stand/ Tempo stand	

2: Residence

2.1. Location

Respondent's Name		**Contact no.**	
Type	Owned	Rented	Employer Provided

2.2 Personal Detail

	Person 1*	**Person 2**	**Person 3**	**Person 4**	**Person 5**	**Person 6**
Relationship with the Respondent	Self					
Gender						
Age						
Education						
Occupation*						
Monthly Income						

*Occupation Government – 1. Private - 2. Industry/ Manufacturing – 3. Health – 4. Education – 5. Finance – 6. Transportation/ Communication – 7. Students – 8. Senior Citizen – 9. Housewife – 10. Unemployed – 11. Any Other – 12.

Note: Detail of all family members need to be entered

3. Household

3.1.Vehicle Ownership Details

Vehicle Type	Number of Vehicles Owned	Owned by Household (H)/ Govt. Company owned (G)	Year of purchase	Make and Model	Where do you park your vehicle?	Average Distance travelled per day (in KM)	Fuel used (diesel/ petrol/ CNG/LPG)	Average Expenditure on Fuel (per Month)	Average frequency of servicing of vehicle	Average cost incurred for per servicing	Average Number of persons travel per Trip
Car											
Scooter											
Bike											
Bi-cycle											
Any Other											

4. Trip Information(Collect information on daily travel person wise)

SI No.	Person No.	Trip No.	Link Trips#	Origin	Destination	Purpose*	Mode#	Alternative mode	Waiting Time(PT/IPT)	Dist. travelled (KM)	Time taken (Min.)	Cost (Rs.)	Vehicle parking location at destination	Parking charges per trip in Rs.	Days of travel (Mon – Sun)

*Purpose of Travel Work –WR Education – ED Business – BS Shopping – SH Recreational/Social – RC Others (Medical etc) – Return Home – Ret.
#Mode and Link Trip Walk – WA Cycle –CY Cycle Rickshaw – CR 2 wheeler – TW Car – C Bus – BS Auto/Tempo – AT, Taxi – TX

5. Preferred Mode

	Mode used*	Reasons for using existing mode#	Preferred* mode	Reason #
Travel to work				
Travel to school				
Travel to entertainment				
Travel to shopping				
Travel to grocery				

*Mode: Walk – WA, Cycle –CY, Cycle Rickshaw – CR, 2 wheeler – TW , Car – C, Bus – BS, Auto/Tempo – AT, Taxi - TX

#Reasons Affordability – 1. Reliability – 2, Reachability – 3, Comfort – 4, Security – 5, Safety – 6, No other mode available – 7. Any other, specify – 8

6. Rating of Various Modes

6.1. How do you rate this transport system on a scale of 1-5 (1 being very poor to 5 being very good)

	Affordability	Reliability	Reachability	Comfort	Security	Safety
Walk *						
Bicycle						
Car						
Auto-rickshaw/Tempo						
Cycle Rickshaw						
Two-wheeler						
Bus						
Taxi						
Any Other						

Please rate pedestrian facility

6.2. What are the major problems that you face when you are traveling on road? (Check whether options are relevant)

Traffic signal	Stop	Pedestrian Crossing	Congestion	Accident	Road Repair	Breakdown	Ticket issue / toll	Encroachment	Any other

Note: This information is required to have general opinion of people on their travel issues.

7. Will you be willing to change your house location?
8. Will you prefer to move to Southern part of Patna to a location (like Ramakrishna Nagar) that is still in developing stage?

9. Your preference of location of house would be near

Work place	School	Market place	Hospital	Shopping Mall	Outskirt	Any other, mention

10. Footpath:

Is there a footpath in the near locality?	Yes				No	
Do you use it?	Yes				No	
If not tick from the following option	Poorly maintained	Insufficient width	Encroachment	No lighting	No continuity	Other(specify)

Truck/ LCV operator survey

Operator Details:

1. Name of the operator:
2. Address:
3. Date:
4. Day:
5. Time:
6. What are the problems faced regarding terminal and facilities?
7. Vehicle detail:

Vehicle No.			
Year of purchase			
Vehicle Type(LCV/HCV)			
Number of Vehicles Owned			
Make and Model			
Average Service Life (in Years)			
Origin			
Destination			
Fuel used (diesel/petrol/CNG/LPG)			
Fuel consumed (in litres)			
Average Expenditure on Fuel (per Month)			
Annual Maintenance Cost (Rs./Year)			
Distance (KM)			
Purpose (Loading/unloading)			
Total No. of trips per day			
Frequency Daily/alternative/weekly/monthly			
Commodity (food grains, vegetables, cereals/wood/Industrial materials/Consumer items/empty/others)			
Load capacity in tonnes			
Vehicle parking space (on Street/ off street)			
No. of workers per vehicle			
Revenue earned per vehicle per month			
Expenses made per vehicle per month			

Traffic Count and Pedestrian Count Survey

Date/ Day	Time	Location	Origin	Destination	Width	Width of Footpath (Left)	Width of Footpath (Right)

Time	Passenger Vehicles									Goods Vehicle		
	Car	2 Wheelers	Bikes	3 Wheelers	Bus	Mini-Bus	Cycle	Others	Pedestrians	LCV	HCV	Others
8:00-9:00												
9:00-10:00												
10:00-11:00												
11:00-12:00												
12:00-13:00												
13:00-14:00												
14:00-15:00												
15:00-16:00												
16:00-17:00												
17:00-18:00												
18:00-19:00												
19:00-20:00												

Transport Authority

1. What are the emission standards for various vehicle types?

Vehicle Type	Emission standards

2. What budget allocation is sanctioned for transport infrastructure development for Patna Urban Agglomeration Area?

Year	2008-09	2009-10	2010-11	2011-12	2012-13
Heads					
Sanctioned amount for PUAA					

3. How is the revenue utilized, generated from the parking fees?
4. What guidelines are there for passenger information system?
5. Is there norms issued for public transport and the bus stops to be equipped with passenger information system?
6. Is security personnel deployed in public transport?
7. No. of vehicles

Mode	No. of vehicles
Bus	
Low Floor buses	
Buses with GPS services	
No. of buses installed with route map	
No. of buses installed with CCTV	
No. of AC buses	
Auto Rickshaw	
Manual Rickshaw	

Speed and Delay Survey (GPS)

- Turns
- Delay at turns
- % Speed Reduction at V/C=1
- % Maximum Speed Reduction
- V/C at Maximum Reduction
- Two way (Yes/ No)

No.	Date/ Day	Origin Node	Destination Node	Time at Origin Node	Time at Destination Node	Speed at Origin Node	Speed at Destination Node	Delay	Delay Cause

Delay Causes

A. Traffic Signal

B. Stop

C. Pedestrian Crossing

D. Congestion

E. Accident

F. Road Repair

G. Breakdown

H. Ticket issue/ toll

On-Boarding Survey

1. Name of Bus stop:
2. Road Name:
3. Date:
4. Direction/route:

Time	Type of bus (Low floor/AC/Regular)	Route	Boarding	Alighting	Total

5. What kind of settlements are there within 500 meters radius of bus stop:

Land use type	
Commercial	
Residential#	
Institutional/Education	
Recreational	
Tourism	
Mixed	
#Residential	High Income Group – 1. MIG – 2. LIG – 3.

6. Services available at the bus stop (Tick if the service is available):

Seating	
Shade	
Lighting	
Passenger Information System	
Any other (specify)	

Other Operator Survey

1. Name of the operator:
2. Address:

3. No. of permanent employees:
4. No. of employees on daily wage:
5. Vehicles detail:

No. of Vehicles					
Vehicle Type					
Year of purchase					
Number of Vehicles Owned					
Make and Model					
Capacity(passenger carrying capacity)					
Distance covered per day (in KM)					
Fuel used (diesel/petrol/CNG/LPG)					
Fuel consumed (in litres)					
Average Expenditure on Fuel (per Month)					
Annual Maintenance Cost (Rs./Year)					
Average Service Life (in Years)					
Average Number of Passengers Carried per Trip					
Vehicle Type					
Number of employee per vehicle					
Expenses on employee per vehicle (in month)					
Do you have permit to park the vehicle					
Location where vehicle is parked					
Parking Cost					
Rate charged per KM from passenger					
Revenue earned per vehicle per month					
No. of vehicle on move in a day					
Reasons for other vehicles lying idle					
Average stoppage time at the bus stop (in minutes)					
No. of seats reserved for women					
Average speed of vehicle					

Inventory of Parking Space

Location	Ownership of facility Public/Private/ Informal	Types of vehicles parked	Parking Tariff (vehicle wise)	Parking Tariff(Hour wise)	Occupancy rate during peak hrs.	Condition of street markings	Type of restriction (e.g. for on street)

6. How much you are willing to pay for better parking facilities?

Inventory of Road Network

Major Roads

Road Name	Stretch		Length (KM)	Width of ROW (meter)	Width of Carriageway(m)	No. of Lanes	Width of footpath in meter		Width of divider in meter	Stretch	Cycle Track	Encroachment	Median	Pedestrian Facilities	No. of street lights	Parking Facilities	Adjoining land use
	From	To					Left	Right									

Arterial roads

Road Name	Section		Length (KM)	Width of ROW(meter)	Width of Carriage way(m)	No. of Lanes	Width of footpath in meter		Width of divider in meter	Stretch	Cycle Track	Encroachment	Median	No. of street lights	Pedestrian Facilities	Adjoining land use
	From	To					Left	Right								

Collector

Road Name	Section		Length (KM)	Width of ROW(meter)	Width of Carriage way(m)	No. of Lanes	Width of footpath in meter		Width of divider in meter	Stretch	Cycle Track	Encroachment	Median	No. of street lights	Pedestrian Facilities	Adjoining land use
	From	To					Left	Right								

Socio-Economic, Land use and Other Ward Wise Data

	Total in Municipality Area	Total in Urban Agglomeration	Ward 1	Ward 2
Population				
No. of Households				
Average Size of Household				
Population Growth Rate				
Area				
Area under circulation-Land use wise				
Residential				
Commercial				
Industrial				
Mixed				
Agriculture				
Transportation				
Water Bodies				
Vacant Land				
Others				
Population Density				
Area of low income settlements within 500 mts of any Public Transport stop				
Distance to nearest Railway Station				
Distance to nearest Bus Stop for Inter-city buses				
No. of workers by category:				
Government				
Industry				
Agriculture				
Service				
Non-Workers				
Average Wage Rate				
Average Household Income				
No. of Registered Vehicles – Category Wise				
Parking Area and Location				

Note: Information required for all wards

Annexure B: Survey Location

Table B.1: List of surveyed roads in PUAA

Sl. No.	Major Road	Arterial	Collector
1.	Danapur – Khagual Road	DPS Road	Abhinav Bindra stadium road
2	Bakipur – Danapur road	Vijay Nagar road	Pathri ghat road near homeopathy college
3	Khagual – Naubatpur	Gola road	Rajeev Nagar road
4	Bailey Road	Gandhi Maidan road	Sri Krishna nagar road
5	Bihta – Vikram – Pali road	Pun Pun bazaar path	Gardanibag kali Mandir road
6	Danapur – Usrai – Shiwali road	Fraser road	Mainpura / LCT Ghat road
7	Masurahi – Pitmash – Naubatpur	SP Verma Road	SK puri road
8	Pali – Ullhar – Mausahi road	Dak Bungalow road	Punai chowk road
9	Chandos – Simori – jamui road	Exhibition road	Pani tanki Patliputra road
10	Bihta – Jamui road	Bhattacharya Path	Moin ul Haq stadium road
11	Raghoprur – Patoot road	Bari path - Ashok Raj path	
12	Bihta – Lai road	Station road	
13	Raja Ghat NH 78 via Newa gram	Nala Road	
14	Shiwala – Bihta Road	Bazar samiti road	
15	Mithapur – Anishabad – Khagaul road	Rajendra Nagar main bridge road	
16	Aashiyana Dikha road	Kankarbag Main road	
17	Agam Kaun marufgunj	Mithpur bus stand road	
18	Ashok Raj path	Boring road	
19	Saidpur Rampur Nala	Boring canal road	
20	Fatua Link road	Chhajubag link road	

TableB.2: List of locations surveyed for Traffic count Survey

Sl. No.	Major Cordons		Inner Cordon / Outer cordon
1	Gandhi Setu hajipur toll	Patna to Muzafarpur Pull	Outer Cordons
2	Jehanabad cut NH 30	Patna to jehanabad	Outer Cordons
3	Danapur Cantt	Maner - Danapur	Outer Cordons
4	NH 98 Khagaul	Fatua to Neora	Outer Cordons
5	Bihta – Danapur via Khagaul, Military Canteen	Maner to Danapur	Outer Cordons
6	Patna Phulwari Sharif		Inner Cordons
7	Anishabad Moore		Inner Cordons
8	Exhibiton road chauraha		Inner Cordons
9	Saguna Moore		Inner Cordons
10	Danapur Bazaar		Inner Cordons
11	R block charaha		Inner Cordons
12	Patna city chowk		Inner Cordons

TableB.3: List of surveyed bus routes

Sl. No.	Name of the Operator	Operational route	Fare per person
1	Jai mata Di	Patna Railway station – Danapur	Re1/Km
2	Tirupati	Mithapur – Agamkuan	Re1/Km
3	Jai maa ambe	Patna Junction – Kurji	Re1/Km
4	Amar jyoti	Patna Junction – Hanuman Nagar	Re1/Km
5		Naubatpur – Gandhi Maidan	Re1/Km
6		Gandhi Maidan – Patna city	Re1/Km

Table B.4: List of surveyed bus stops

S.No.	Bus Terminal	Bus stops	Bus stoppage	Destination
1.	Patna Junction.	Kankarbag, hanuman nagar	Gandhi Maidan	Engineering College
2.	Patna Jun.	R block	Kahgual	
3.	Patna Jun.	Rajvanshi Nagar	Patel Nagar	
4.	Patna Jun.	Boring Road	Kurji Moore	
5.	Kankarbag	Patna Jun.	Exhibition Rd.	Gandhi Maidan
6.	Gandhi Maidan	Rajapur Pul	Kurji	Danapur

Table B.5: List of surveyed Inventory of parking facilities

S.No.	Parking Area for survey	Location / Road/ landmark
1	**Munna Chawk to Kumbhrar Toli**	**Kankarbagh Path** Sankhya 2, Kankarbag purana bypass road, Chiraiyatar aur Rajendra Nagar ke beech mein)
2	Peoples Community hall towards Viklang Bhawan (North)	
3	Near Super Market	
4	SK Puri Children's Park and nearby	Sahdev Mahto Marg
5	Vaishali Golambar to Dinkar Golambar	Arya Kumar Path
6	Vidyut Bhawan ke samne	Bailey Road
7	Rajvanshi Nagar Hanuman Mandir se dakshin ke taraf	
8	Rukkanpura near Shiv mandir	
9	R Block, Near Channakya Hotel	Vir Chandra Patel Marg
10	Near Eco park	Strand Road
11	CDA building to Bhattacharya path (near Plastic house)	Rajendra Path
12	Nigam Pump House near Dinkar golambar	RK Avenue Nala Road
13	2. Near Asha Traders shop	
14	Station Road, Frazer Rd	Near Maharaja Kameshwar complex
15	Around Gandhi Maidan	Complete
16	Mangles Path	KB Sahay ke Murti se east ke taraf Pull nirman off tak
17	Boring Road	Near AN Coll
18	Boring Canal Road	Rajapul auto stand to hartali moore
19	Daroga Rai path	Panch mandir to Shahjanand Bhawan (east)
20	Hathua Market	Ashok Rajpath

S.No.	Parking Area for survey	Location / Road/ landmark
21	Near St. Joseph's Convent School	
22	Danapur Police station	Danapur
23	Women's College	Bailey Road

Table B.6: List of surveyed off street parking demand survey

S.No.	Parking Location	Nearest landmark
1	Fraser Road	Vishal Mega Mart
2	Hathua Market	Near Mona Cinema
3	Notre Dam Academy	Near P & N Mall
4	PMCH Hospital	Ashok Rajpath
5	Ashok Rajpath	Mahendru
6	Buddha Marg	Ashok Cinema Hall
7	Mt. Carmel School	Bailey Road
8	Aashiyana Colony and the complete road	Bailey Road
9	Mahavir Cancer Hospital	Kankarbagh
10	Commerce Coll	Rajendra Nagar Terminal

Table B.7: List of surveyed locations for parking demand

S.No.	Parking Area	Nearest landmark
1	Mauraya Hotel	Frazer Road
2	Exhibition Road	Exhibition Rd Golambar
3	R BLOCK	Hotel Chanakya
4	Boring Canal Rd	On the verge
5	Gandhi Maidan	Khuda Baksht Library
6	Mona Cinema Hall	-
7	Danapur	Danapur Terminal
8	Buddha Jayanti park	Station Rd
9	Kankarbag Golambar	Near Auto Stand
10	Kuji P & M Mall	outside the mall
11	Ashok Cinema Hall	Buddha Jayanti Park
12	Regent Cinema Hall	-

Table B.8: List of surveyed Transport Operators

S.No.	Major Operators	Nearest landmark
1	Bus operator Sai Rath	Mithapur bus stand
2	Bus operator, Krishna	Urmila Rita Apartment, Rajbanshi Nagar
3	Manual Rickshaw Union	Rajendra Nagar Vaishali Cinema
4	Taxi Union	Station road
5	Taxi Union	Station road
6	Auto Union	Bangali tola devisthan
7	Manual Rickshaw Union	Mushale pur Kela mandi

Table B.9: List of surveyed Truck/LCV operators

S.No.	Landmark for truck/LCV operators
1	Bhutnath road patna
2	Bhagvat nagar patna
3	Gulzarbag road no 13
4	Bypass road krishna near sudharsan school
5	Bhagvat nagar road no.2
6	Bypass near petrol pump

Table B.10: List of surveyed households in non-slum

S.No.	Residential Colonies (Non-slum areas)	HHs surveyed in each colony
1	Patliputra colony (old & new)	15 HH
2	Rajeev Nagar	10 HH
3	SK Puri	10 HH
4	Nageshwar colony and Vivekanand colony	15 HH
5	Indrapuri	10 HH
6	Patel Nagar	10 HH
7	Shastri Nagar/ Kidwai puri	10 HH
8	Magistrate Colony / Shiv Puri	10 HH
9	Aashiyana Nagar and Khajpura	15 HH
10	Jagdev Path, Bailey Road	10 HH
11	Rajabazaar / Sarai	10 HH
12	Ara Garden / Ram jaipal singh colony	15 HH
13	Kurji Muhallah / SK Puri	10 HH
14	Rajendra Nagar Colony	20 HH
15	Kankarbagh (Doctors colony, Hanuman Nagar, AG Colony)	50 HH
16	Kadam Kua and Agamkua	20 HH
17	Ashok Nagar, Patna City	20 HH
18	Saidpur Mullah, Bahadurpur	05 HH
19	Danapur	20 HH
20	Anidhabad	20 HH
21	Sultan Gunj	5 HH

Table B.11: List of surveyed households in slum

S.No.	Slums	HHs surveyed in each colony
1	Nehru Nagar	10 HH
2	Buddha Colony Police station	10 HH
3	Shivpuri, Chitkohra - Ambedkar Nagar	10 HH
4	Budh Ghat/ Bass Ghat, Golghar choraha	10 HH
5	Punai Chak (Lalita bhawan to Sabji Mandi) and Indrapuri Near Durga Mandir	10 HH
6	Rajiv Nagar Rd no. 23 near Garden	10 HH

S.No.	Slums	HHs surveyed in each colony
7	Digha Moore, Alpana cinema hall, Harijan Tola	10 HH
8	Sipahi Ghat/ Tar Ghat (New Collectorate)	10 HH
9	Shastri Nagar PWD Maidan	10 HH
10	Rukkanpura Musheri	10 HH
11	Rajapur dujra pahelwan Ghat	10 HH
12	Sachiwalya Gumti No. 1	10 HH
13	Gardanibag road No. 15 and Kankarbag Doctor's colony ke opposite	20 HH
14	Babu bazaar Gardanibag	10 HH
15	Amalgunj Machua Tola	10 HH
16	Chakbinda Gardanibag	10 HH
17	New yarpur Gardanibag	10 HH
18	Anta Ghat	10 HH
19	West Lohanipur, New Budh Murti Kadam Kua	20 HH
20	Old Pani Tanki near malai pakhri	10 HH
21	Kumrar park harijan tola	10 HH
22	Shivaji Park Kankarbag	10 HH
23	behind Kankarbag police station, lohia nagar	20 HH
24	Chitkohra pull ke neeche (jagjeevan nagar)	20 HH
25	Hanuman Nagar	20HH