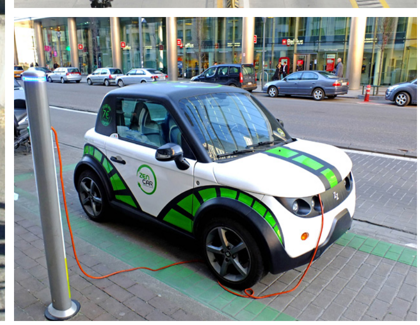
UNEP

A Toolkit for Preparation of Low Carbon Mobility Plan



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Acknowledgements

This toolkit refers to the Comprehensive Mobility Plan (CMP) Revised (2014) toolkit of the Ministry of Urban Development, India, which was developed by the Institute of Urban Transport (IUT) Delhi, and UNEP DTU Partnership, along with Indian project partners from the UN Environment Project *Promoting Low Carbon Transport in India*, as a starting point.

The toolkit for CMP was revised into a toolkit for Preparation of Low Carbon Mobility Plan (LCMP) for global application by a team of researchers comprising Dr. Subash Dhar, Dr. Talat Munshi and Dr. Minal Pathak. Our special thanks to Ms Kamala Ernest from UN Environment for her valuable support and inputs in the finalisation of this toolkit.

We would like to thank the authors of the CMP toolkit comprising of team from IUT : Mr M.L. Chotani, Ms Kanika Kalra and Ms Vijaya Rohini, our project partners in India: Prof Darshini Mahadevia (CEPT University), Prof Geetam Tiwari (the Indian Institute of Technology Delhi, IITD), and Prof P.R. Shukla (the Indian Institute of Management Ahmedabad, IIMA). We would like to extend our thanks to LCMP Consultants: Dr. Anvita Arora (Innovative Transport Solutions Pvt Ltd, iTrans) and, Mr Ranjan Jyoti Dutta (Urban Mass Transit Company Limited, UMTC).

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Foreword

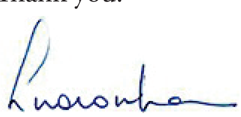
Following the successful completion of the Promoting Low Carbon Transport in India project (2010 to 2015), I am pleased to present a **Toolkit for Preparation of Low Carbon Mobility Plans (LCMP).** The toolkit supports the development of a long-term vision for sustainable urban transport. It is based on the experiences and the pilot cities of the project.

A sustainable low carbon transport sector is essential for building better and cleaner cities and, therefore plays a key role in implementing the Paris Agreement on Climate Change as well as the achievement of the 2030 Development Agenda of the Sustainable Development Goals.

The foundation for a low carbon transport pathway builds from a city development plan that integrates transport planning with safety, social inclusivity, reduced air pollution, and carbon dioxide emissions. Through a set of sustainability indicators and step-by-step approach, the toolkit provides guidance on how to strategize mobility planning as part of urban planning, prioritize accessibility for all socio-economic groups, prioritize shifts to sustainable transport modes and reduce environmental impacts.

I would like to thank the authors and all involved in the development of this toolkit. The toolkit caters for small, medium and large cities. It is my hope that it will be useful for cities around the world.

Thank you.



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Preface

The Low Carbon Mobility Plan (LCMP) provides a long-term vision for sustainable mobility for people, and the movement of goods in cities. The LCMPs advocate an integrated approach – e.g. looking at land-use and transport planning, together, and the integration of safety, environment and CO_2 mitigation. LCMPs have been developed for a number of Asian and European cities. This document draws inputs from these LCMPs, and mainly from the experience of preparing LCMPs in India where the authors of this publication were involved in developing an LCMP methodology and testing it in three Indian cities.

The authors were also involved in the preparation of the Toolkit for *Comprehensive Mobility Plan (CMP) Revised (2014)* for the Ministry of Urban Development, Government of India. The toolkit serves as a guide for Indian cities, and includes all elements of the LCMP.

The Toolkit for Comprehensive Mobility Plan (CMP) Revised (2014) is used as a starting point for the present toolkit. This toolkit for LCMP caters to a global audience, and provides a simplified approach for LCMP preparation for smaller cities, or cities in which no major investments are envisaged in the short-term. The toolkit has a specific focus on cities in less-developed and developing countries where significant infrastructure will be built to cater to a growing transportation demand and, therefore, land-use and transport policies can play an important role in shaping mobility demand and mode choice.

The LCMP toolkit may be useful for city planners, officials in the transport department, and consultants working with the cities for transport planning. The LCMP toolkit provides a methodology for assessing indicators for mobility, accessibility, safety, air pollutants and CO_2 emissions, both for the base year and for the future, and is, therefore, well suited for the preparation and implementation of Nationally Appropriate Mitigation Actions (NAMAs).

This publication is designed to become a living document and aims to reflect the latest developments and therefore please write to Subash Dhar (sudh@dtu.dk) and Talat Munshi (talat@cept.ac.in) in case of any questions, suggestions or clarifications.

Abbreviations

BAU	Business-as-Usual
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
DTU	Technical University of Denmark
E 2W	Electric Two Wheeler
E 3W	Electric Three Wheeler
E 4W	Electric Four Wheeler
EV	Electric Vehicles
GFEI	Global Fuel Economy Initiative
GHG	Greenhouse Gases
LCS	Low Carbon Society
LPG	Liquefied Petroleum Gas
LCMP	Low Carbon Mobility Plan
MT	Million Tonnes
NMT	Non-motorised transport
NO_x	Nitrogen Oxides
pkm	Passenger Kilometres
PM_{10}	Particulate Matter 10 microns
PM	Particulate Matter
PT	Public Transport
SO_x	Sulphur Oxides
TAZ	Traffic Analysis Zones
UNEP	United Nations Environment Programme

Introduction

Background

The form and pattern of urban growth in the future has vital implications on climate change and sustainable development. Urbanization rates in developing countries are lower than developed countries, however, in the future, the developing world will urbanize and grow rapidly (UNPD, 2014); cities are expected to propel growth and further agglomerate. This is expected to drive the demand for housing, transportation and services.

Travel demand arises from the individuals' need to participate in activities located at different geographical locations (land-uses). Travel can happen by non-motorised or motorised modes. When individuals travel by motorised transport, fuel is consumed. The consumed fuel, and its impact on the environment, is directly related to choice of transport mode, type of vehicle and fuel used. These choices depend on land-use configuration, availability and the provision of transport infrastructure. Therefore, since CO_2 emissions from urban transport depend largely on land-use and transport policies, their integration is essential.

Presently, urban transport projects in many developing countries are prepared without the understanding of individual mobility needs, and implemented in a piecemeal manner (Munshi, 2013). Some cities have included traffic and transport studies in preparing transport master plans, however, these have largely focused on vehicle movement and not on accessibility – which is defined as the extent to which land-use and transport systems enable individuals to reach activities by a (combination of) transport mode(s) (Guers, 2006). Thus, the major emphasis of these transport plans remains on extensive infrastructure development, such as expansion of road network, flyovers, improvement of road geometry, regulatory measures, etc. The aim of Low Carbon Mobility Plans (LCMP) is to develop a long-term vision for desirable accessibility and mobility pattern for people, and movement of goods in the cities.

LCMPs have been developed for a number of Asian cities, for example, Rajkot[1], Vishakhapatnam[2], and Udaipur[3] in India, and Medan, Menado and Batam in Indonesia[4]. In Europe, under the Transform project, Copenhagen, Genoa, Hamburg, Lyon and Vienna have also analysed options for low carbon mobility

1 http://www.unep.org/Transport/lowcarbon/Pdf's/Rajkot_lct_mobility.pdf

2 http://www.unep.org/transport/lowcarbon/Pdfs/PublicTransport_Vizag.pdf

3 http://www.unep.org/Transport/lowcarbon/Pdf's/udaipur_lct_mobility.pdf

4 https://unfccc.int/files/cooperation_support/nama/application/pdf/nama_implementation_indonesia_sustainable_urban_transport_initiative.pdf

(Jabber and Glocker, 2015). This document draws inputs from these plans, and mainly from the experience of preparing LCMPs in India, and has a specific focus on cities in less-developed and developing countries where significant infrastructure will be built and, therefore, land-use and transport policies can play an important role in shaping mobility demand and mode choice.

What is a Low Carbon Mobility Plan (LCMP)?

An LCMP provides vision for urban transport in the city. This vision encompasses an approach that addresses both climate change and development benefits through an integrated transport and land-use planning process. All elements of Urban Transport are covered under an integrated planning process recognising the two-way relationship between available mobility (means and choices available to move) and the individual's desire to move. The LCMP is based on the idea of a transformational change that follows a sustainable development pathway aligned to achieve the vision of limiting global temperature stabilization at 2^{o}C.

Scope of LCMP

The scope of the LCMP is to develop a mobility plan for a city[5] which is economically, socially, environmentally sustainable, and can be an integral part of urban development. It envisages the following:

- To gain an understanding of the key elements of the transport system, their characteristics, inter-relationships and past trends.
- Create a baseline by estimating: 1) the emission from urban transport based on the travel patterns, fuel and technology choices, and 2) individual wellbeing measured as accessibility to jobs and other essential activities.
- Develop future scenarios and identify possible interventions towards a sustainable development pathway, which will help to align GHG emissions with the globally agreed upon vision of stabilising global temperatures below 2^{0}C.

Main features

The main features are as follows:

- Integration: Integrate the mobility plan with urban growth, structure and urban form, and use this understanding in setting up the envelope of possibilities in travel decision-making.
- Equity: Provide accessibility and safety for different socio-economic groups and genders.
- Mode Shift: Prioritise sustainable modes of transport – i.e. public transport, and non-motorised transport.
- Environment: Reduce impacts of transport on local air quality and CO_2 emissions.

5 The city boundaries should be clearly defined.

How does it work?

The LCMP needs to be seen as an integral part of project/programme identification and implementation for transport at the city level. The outcomes of the LCMP should be included in decisions regarding projects/programmes in the city wherein their implementation would provide the basis for future LCMPs. The process of achieving mobility goals with lower CO_2 emissions consists of six main steps (Figure 1). The first five steps are related to the preparation of a Low Carbon Mobility Plan, and the last step is implementation and monitoring. LCMPs should be prepared every three to five years. Monitoring post-implementation is expected to provide an input to the subsequent exercise.

Each step of the process is detailed in this guideline document. This includes details on the need for this activity, issues to be addressed, and responses. The activities performed are also described in terms of the data required and the ensuing analysis. Stakeholder participation and consultations at each step are critical to ensure buy-in and to facilitate implementation.

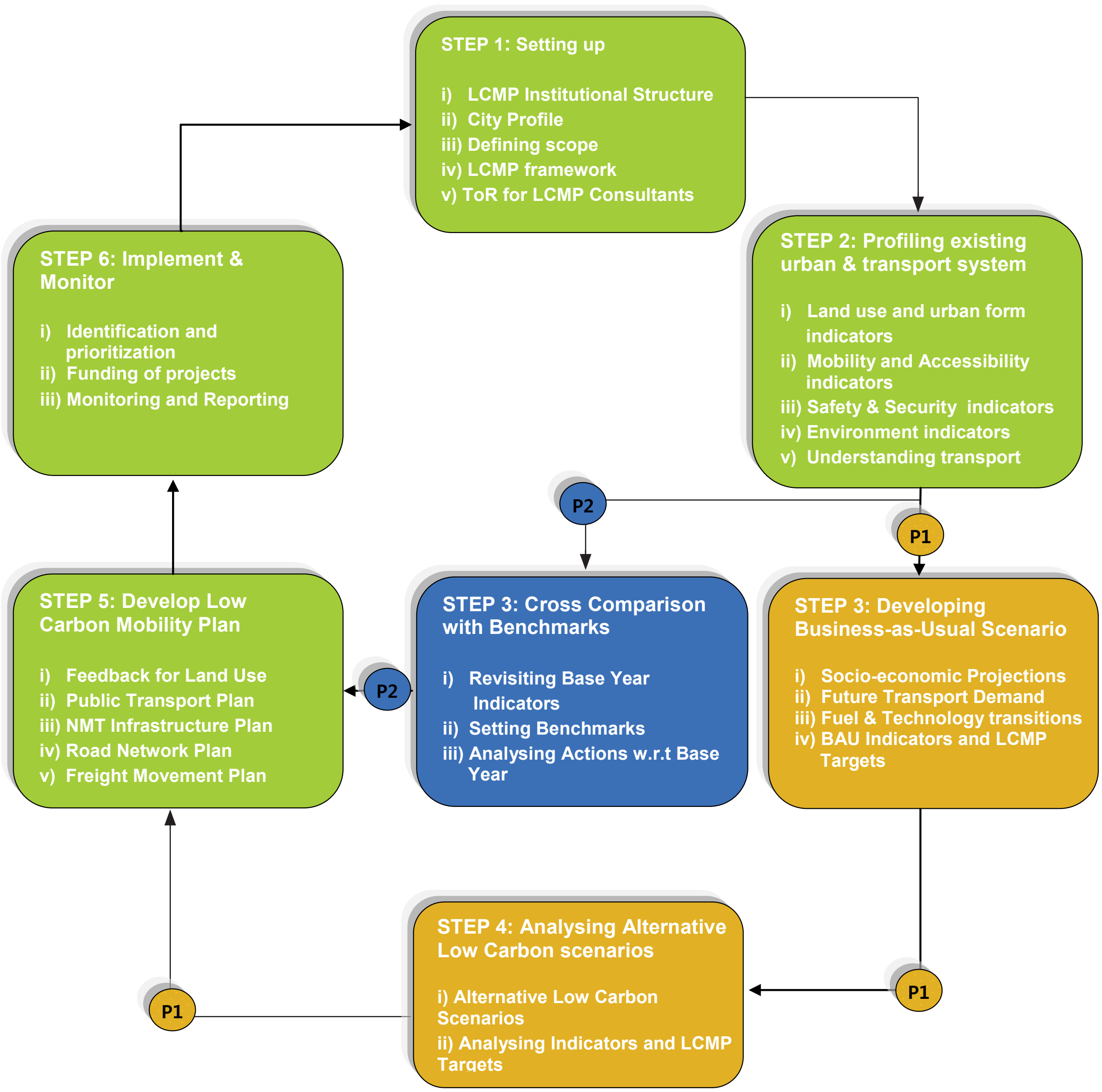
Figure 1 shows these steps. In total, there are five recommended steps; for small cities and cities with a small budget from LCMP an alternate path (P2) can be taken after step two, which requires less data collection and simplified analysis. Steps in Figure 1 are presented in a sequence, however, in practice, some of these activities would work simultaneously or in feedback loops as described later in the toolkit.

Key outcomes

The implementation of an LCMP should lead to the following outcomes:

- Improved mobility for all socio-economic groups and genders
- Improved access to opportunities and activities
- Improved safety and security for all, especially pedestrians and cyclists
- Reduced energy use, air pollutants and CO_2 emissions

Figure 1: The process of preparing low carbon mobility plans



Where, P1 = Path for large cities (population more than 1 million), P2 = Path for small cities (population less than 1 million)

Setting Up

This step involves creating the institutional setup and preparing the basic information that is required for formulating terms of reference (ToR) for the LCMP consultant.

Institutional structure LCMP

The LCMP preparation requires a multi-disciplinary team of experts/consultants who work in close coordination with city managers with input from stakeholders. The institutional arrangements for governance of cities will vary across countries. A suggested institutional structure for an LCMP is presented below, in Figure 2.

The key members needed for preparing the LCMP are:

a) LCMP Committee

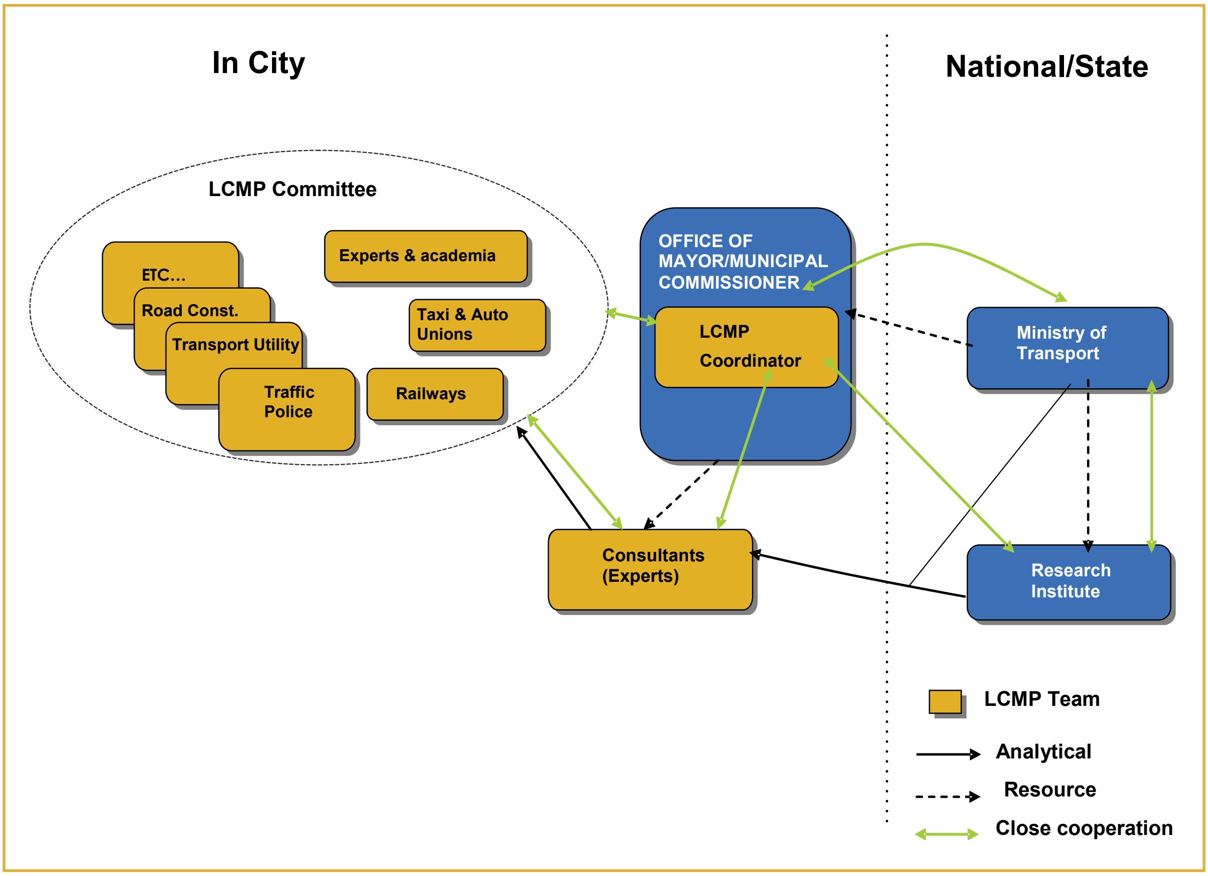
b) LCMP Coordinator

c) Consultants

d) National/State Level Actors

LCMP Committee is the key body responsible for approving the outputs and deciding on the priorities for the city. Depending on the institutional arrangements of the city, the LCMP Committee should be chaired by the Municipal Commissioner or the Mayor. The LCMP Committee includes members of government, social groups, politicians, etc. (refer to Annexure 2 on stakeholders). Female representation is required at every level to ensure that their views are heard and their needs are taken into account.

Figure 2: Roles of consultants and stakeholders (a generalized view based on UNEP LCMP work in India)



LCMP Coordinator is a person appointed from the office of Municipal Commissioner or Mayor, to act as point contact between consultants and various stakeholders within the city. He/she should have an overall vision of the plan, organise stakeholder meetings, and be responsible for coordination and implementation of the project.

Consultants are responsible for all the analysis and preparation of the LCMP report. They work in cooperation with the LCMP Committee and LCMP Coordinator. Preparing an LCMP requires expertise in multiple disciplines and, therefore, the LCMP consultant may bring together a team comprised of the following experts:

- Team Leader/Urban Transport Planner
- Public Transport Planner
- Land-use Planner
- Non-motorised Transport (NMT) Planning and Traffic Management Specialist
- Transport Engineer

- Traffic Survey and Modelling Specialist
- Energy and Environment Modelling Expert
- Safety Expert
- Social Expert

National/State Level Actors outside the city play an important part in many developing countries since the capacities for transport planning, project financing and implementation at the city level are limited. Therefore, LCMP implementation should integrate these institutions as necessary.

City profile

While the LCMP focuses on mobility within the city, the plan is, nevertheless, embedded in a wider regional and national planning framework for urban development and mobility. It is, therefore, imperative that along with the profiling of the urban area, a general understanding of the region is developed. Table 1 summarizes the data requirements for the city profile in an LCMP. Time-series data on GDP, population and vehicles, if available, is useful for understanding future growth.

Table 1: City profile data required and sources of data

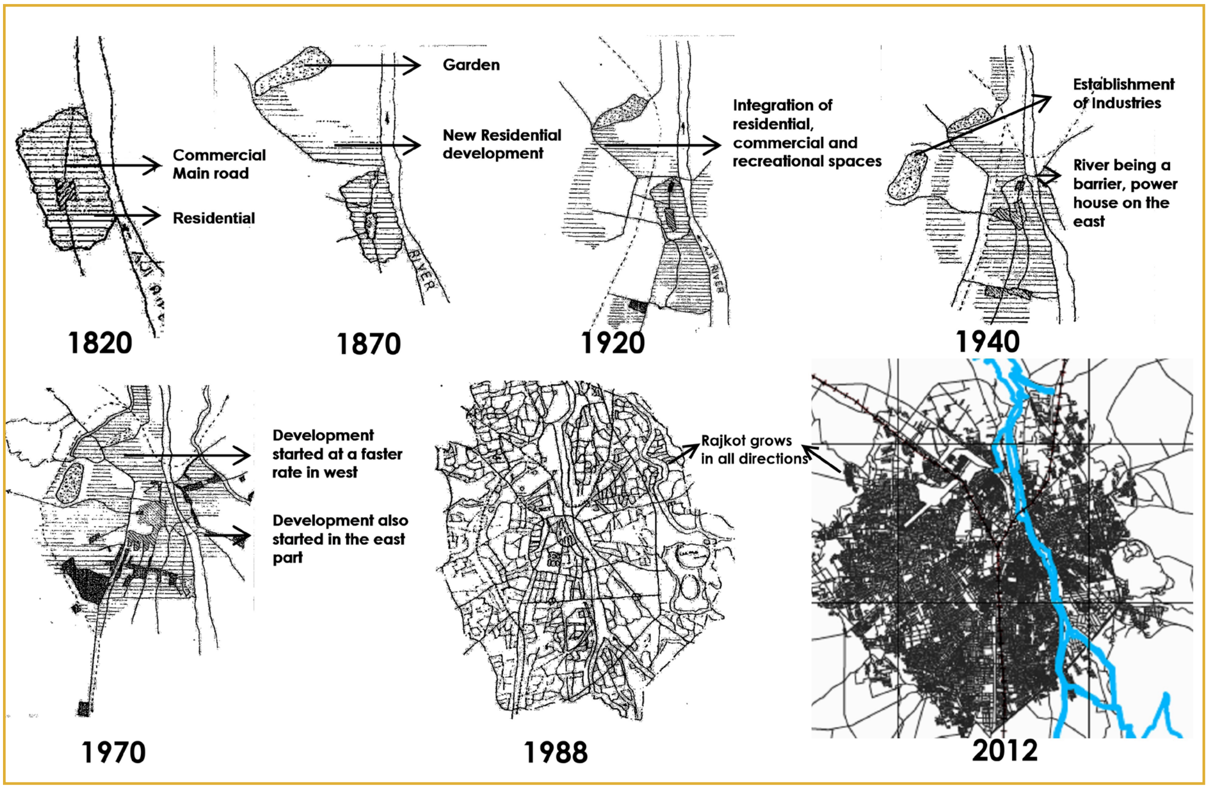
Data required	Description	Source for Primary Data	Data level
Location	Geographical location	Master plans of the city and region if available/ City or Municipal Development Plan	City*
Land area	Total area	Master plans of the city and region if available/ City or Municipal Development Plan	City*
	Growth pattern	Master plans of the city and region if available/ City or Municipal Development Plan	City*
	Identification of notified areas	Master plans of the city and region if available/ City or Municipal Development Plan	City*
Regional linkages	Road & Rail Network	Master plans of the city and region if available/ City or Municipal Development Plan	City*
Demography	Population growth trends by census wards or enumeration blocks	Census#	City*
	Number and size of households	Census	City*
	Age-sex pyramid	Census	City*
Environmental data	Air pollution emissions and control norms	Local Environment Agency	City*
Socio-economic data	Population by income	Census	City*
	Vehicle ownership	Motorised Vehicle Registration Agency	City*

* Data should be collected for the area covered under the Master Plan. If the city does not have a Master Plan then the considered area for data collection should be the urban agglomeration area.

Most countries barring five have a census (http://unstats.un.org/unsd/demographic/sources/census/wphc/QA.htm)

The form and direction of urban development gives an indication of probable future growth areas and directions. This can be assessed by marking out the urban growth boundary on a map, which can either be from a remote sensing-satellite image or any other available map. Figure 3 gives an example from the city of Rajkot. This visualisation is helpful in understanding how the urban area is likely to expand in the future, and in what direction, and the regional parameters that will affect urban development and mobility patterns in the city.

Figure 3: Urban Growth: An example from the city of Rajkot, India



Defining the scope

It is important to involve stakeholders in defining the scope, since they will play an important role during the implementation of the LCMP (refer to Annexure 2, which indicates the stages of consultation with various stakeholders). The scope of the LCMP would include identification of the planning area, planning horizons and work plan. They are, in turn, based on an understanding of how the city has grown in the past, and future trends. The availability of a mobility plan or master plan for a city also helps in defining the scope (Figure 4).

Figure 4: Scoping of LCMP

Understanding the city and region (Urbanization)

- How has the city grown in the past?
- What are likely future trends?
- What are the likely regional developments and how will it affect future growth and development?
- What are the likely future interactions and what will be the spatial extent of the intra-urban spatial interactions?

↓

Does the city already have a mobility plan/land-use plan?

- If prepared, have these been implemented?
- Do they follow the principles and objectives of LCMPs?
- If yes, to what extent?

↓

Finalise a proposal for LCMP

- Define a vision of LCMP for the city.
- Define the planning area, planning horizon and the work plan.
- Get endorsement of the stakeholders.

Planning area

The study area should be clearly identified and defined at the beginning of the LCMP. The area should be large enough to capture the most spatial interactions related to the urban area. For example, if trends show industrial growth just outside the city limits where a large number of urban residents are likely to travel, this should be included in the study area. Similarly, any residential or commercial growth present and forecasted for the planning horizon of the LCMP should be included. Therefore, while it is important to consider existing formal boundaries –like municipal limits, areas under development authorities– it is not necessary to limit the planning area to these boundaries.

Planning horizon

The LCMP should present results for short-, medium- and long-term horizons. Considering that the LCMP involves investments in transport infrastructure with long gestation periods and life, the long-term planning horizon should be at least 20 years. In addition, short-term and medium-term targets spanning five and ten years, respectively, should be included. The LCMP horizon should also be aligned with the timeline of the Master Plan.

Work plan

The average period for preparation of an LCMP will vary depending on the city's size, availability of data and time needed for collecting information (Table 4). Time frames should be revisited after finalizing the scope of the LCMP – as explained in the earlier section. Indicative time frames based on size of cities are provided in Table 2.

Table 2: Indicative time for preparation of LCMP

Population of the city (in millions)	Approximate time for LCMP preparation (in months)
< 1	12-15
> 1	12-24

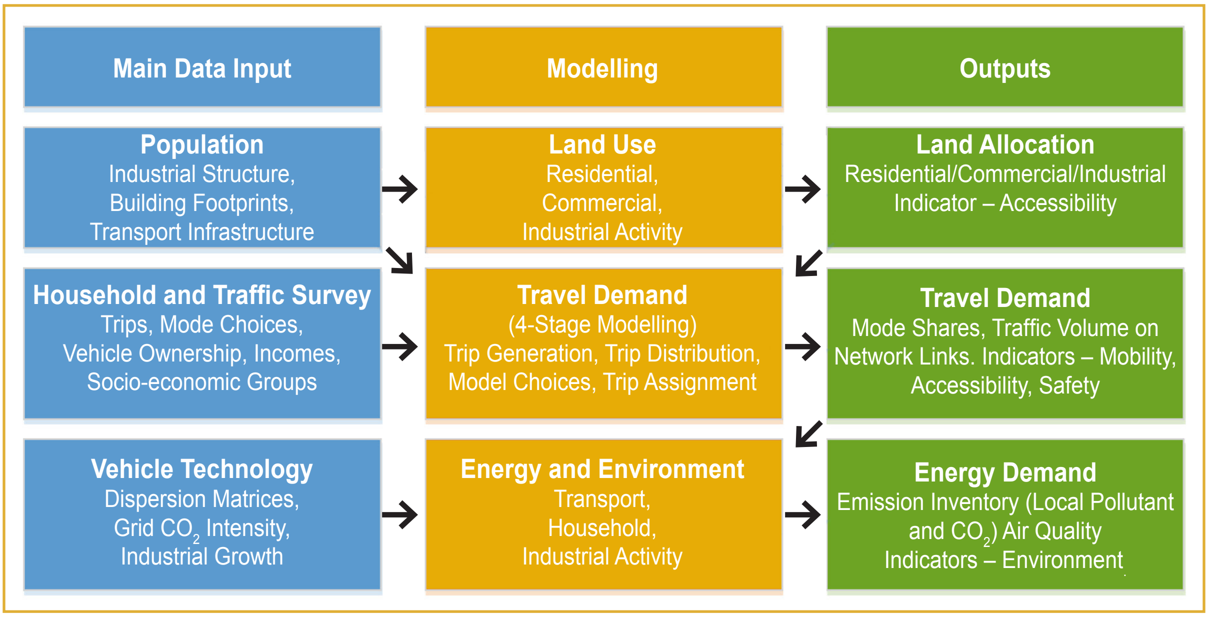
Smaller cities where no major infrastructure investments are envisaged in the next five years should undertake LCMPs, and can utilize the LCMP toolkit with suggested simplifications in each of the steps.

Framework for preparing the LCMP

The LCMP is based on strategies that: i. Avoid or substitute travel, ii. Facilitate shifts to more efficient modes, including public and non-motorised transports, and iii. Switch to improved and cleaner fuels and modes – electric/hybrid vehicles, biofuels, etc. The proposed strategies involve changes in land-use, and improvements in public transport, infrastructure for non-motorised transport, and vehicle and fuel technologies. Analysing these strategies requires a multi-disciplinary approach that interlinks them.

The traditional approach to urban transport planning considered land-use as a given, often taken as an input from the master plan. However, the modelling framework for the LCMP considers alternative land-use scenarios. Outputs of land-use modelling serve as an input for travel demand modelling (Figure 5, first row). Travel demand modelling answers questions related to trip generation, trip distribution, modal choice, and trip assignment (Figure 5, second row). The demand for motorised modes results in significant CO_2 emissions and air pollution within the cities. The methodology, therefore, integrates this as an integral part of the LCMP and is the third type of modelling for LCMPs (Figure 5).

Figure 5: The LCMP modelling framework



ToR for LCMP consultants

The LCMP Coordinator, together with transport department staff at the city level, can formulate the ToR for the LCMP consultants. In developing countries, sometimes the capacity within the cities may be limited, and in such cases the city can be provided with outside support. This support could be in the form of a small financial grant from National/State governments to engage experts or a research institution to develop the ToR for the work of consultants.

Profiling Existing Urban and Transport Systems

The LCMP needs to act as a communication tool between experts, stakeholders and policy makers. Thus, it is necessary to assess whether the LCMP helps achieve the desired outcomes. Indicators are a simple way of communicating the outcomes. The LCMP framework helps in the estimation of the following broad set of indicators:

- Land-use and urban form
- Mobility and accessibility
- Safety and security
- Environment

The indicators can be presented using maps or a table format. Indicative data that can be collected for small/ medium sized and large cities are marked in Table 3.

Table 3: Urban Transport Indicators

Indicator	Description	Small & Medium Cities	Large Cities
Land-use and Urban form Indicators			
Urban Expansion	% of population growth accommodated the present city administration boundary	✓	✓
Population Density	People per hectare	✓	✓
Job Density	Jobs per hectare	✓	✓
Population / Jobs Balance	Jobs/Household	✓	✓
Land-use mix	Land-use entropy index		✓
Mobility and Accessibility Indicators			
Mobility: Travel Behaviour			
Modal shares	Modal shares by trip purpose, i.e. work, education, health and others	✓	✓
	Modal shares by mode	✓	✓
	Modal shares by social groups, i.e. by income, women headed household		✓
Travel time and speed	Average travel time by trip purpose /mode	✓	✓
	Trip purpose wise average travel time disaggregated by social groups		✓
	Average speed on roads of different modes	✓	✓
Trip length	Average Trip Length (ATL) frequency distribution (for all modes including walk, cycle, bus, para-transit and private vehicle)	✓	✓
	Mode wise ATL disaggregated by social groups	✓	✓
	Trip purpose wise ATL disaggregated by social groups		✓
Mobility: Transport Infrastructure			
Density of roads, junctions	Road space per hectare	✓	✓
	Kernel density of roads	✓	✓
	Density of junctions	✓	✓
Pedestrian facilities	Area under footpath	✓	✓
	Area under footpath more than 2 m wide	✓	✓
	Area of footpath encroached upon (by type of encroachment)	✓	✓
Bicycle facilities	Road length with segregated bicycle lane	✓	✓
	Encroached area roads with segregated bicycle lanes		✓
	Area of segregated bicycle lanes with good lighting		✓
	Junction with priority to bicyclist		✓
	Number of bicycle parking available	✓	✓
Parking facilities	Number of total/on street/off street parking unit available for each mode	✓	✓
	Parking fee charged for each transport mode	✓	✓

Indicator	Description	Small & Medium Cities	Large Cities
Public transport and para-transit facilities	Kernel Density of PT stops/ routes	✓	✓
Accessibility			
Financial	% of population able to purchase PT ticket for their mandatory travel	✓	✓
	Average time spent on travel for mandatory and obligatory activities	✓	✓
Physical	% of junction incorporating barrier free design	✓	✓
	% of junction with traffic calming measures	✓	✓
	% of PT stops/modes with barrier free access	✓	✓
	Accessibility of disadvantaged groups by and to different modes		✓
	% of buildings in the neighbourhood with barrier free access		✓
Spatial Organization	% of population with grocery shops within 500 m	✓	✓
	% of population within 400 meters of primary transit network		✓
	Number of jobs locations within 30 minutes of travel by PT/Walk/Bicycle	✓	✓
	Number of schools/clinics/parks and gardens within 30 minutes of travel by PT/Walk/Bicycle	✓	✓
Goods and freight			
Modal Shares	Volume of freight moving in and out of the study area (intercity movement) by mode and type	✓	✓
	Volume of freight moving within the study area (intra-city movement) by mode and type	✓	✓
Trip Length	Average shipping distance within the city boundaries and from the city		✓
Safety and security			
Safety	Number of fatal accidents per 100,000 users of the mode	✓	✓
	Number of accidents by type (fatal/major injury/minor injury) and effected mode/person		✓
	Number of fatal accidents per 100,000 population	✓	✓
	% of roads having speed limit >= 50 kmph		✓
	% of road lit	✓	✓
Security	% of footpaths lit		✓
	% of people feeling safe to walk/cycle and use PT in city, by gender	✓	✓
Environment			
CO_2 Emissions	CO_2 emissions per passenger km by mode	✓	✓
Air Pollutant Emissions	PM2.5, NOx, SOx and CO emissions		✓

The following sections describe the details of processes including data collection and analysis for assessment of the above-mentioned indicators. The methods that can be used to collect data for the quantification of these indicators are described in Annexure 1. The statistical unit used to quantify and represent most of the indicators listed in Table 3 is Traffic Analysis Zone (TAZ). The size of traffic analysis zones also determines the resolution at which the data is collected. There are no standards to delineate the TAZ boundaries, but the criteria for delineation are discussed in Annexure 1.

Land-use and urban form indicators

How land-uses develop, the intensity of use and land-use mix affects travel behaviour. Thus, it is important to review and benchmark urban growth, population - employment densities (intensity of land-use) and land-use mix. Land-use and urban form indicators across TAZs and historical change can be visualized on a map – see Annexure 4 for the list of maps related to urban form. Analysing trends can help identify potential areas that might develop in the future, if the present development trend continues. These indicators can be quantified, as explained below.

Urban expansion

The growth of urban areas is studied with respect to present municipal/city administration boundaries. This gives a broad indication of controlled versus uncontrolled expansion. Uncontrolled expansion could be a low density urban sprawl with negative environmental externalities. Data collected using Survey Format 1 in Annexure 1 can be used to compute the percentage of the population residing within the administration boundary.

Population density

The spread of population is studied as density of population within the sub-regions of the urban area. Population data is collected from census. If the TAZ and the census units (zones/wards/enumeration block) are different, spatially, data can be disaggregated in proportion of floor space/area under residential use in each TAZ to floor space/area under residential use in the census unit. The survey format for collecting land-use data is illustrated in Survey Format 1. Population density is measured as number of residents/unit area. To estimate densities, the following equation should be used:

$$D_r = \frac{P_r}{A_r}$$

Where: D_r = Net Residential Density, P_r = Total persons residing in the TAZ, A_r = area under residential land-use within TAZ

The population density in TAZs should also be disaggregated by socio-economic groups; preferably two to three income categories can be created. If specific income data is not available, this disaggregation can be done by using proxy data on household assets and type of building – available from property tax data or collected during the household survey (Survey Format 2). If data on household assets is not available, the disaggregation of residential land-use into income groups can also be done by using per capita floor area as a proxy. This can be calculated using the formula below, and can be presented as a table.

$$per\ capita\ floor\ area = \frac{household\ area}{number\ of\ members\ in\ the\ household}$$

Job density

The spread and clustering of jobs in urban areas is studied as job density. Job density is measured as the number of jobs/unit area. Data on land/building use is collected using Survey Format 1 in Annexure 1, and the method to quantify jobs is also described in Annexure 1 – land-use and urban form data selection. To estimate job densities, the following equation should be used:

$$\text{Density} = D_e = \frac{J}{A_a}$$

Where: D_e = Net Employment Density (Jobs/square kilometre), J = Total jobs available in the area (No of Jobs), Area = area under economic activities in the grid cell (square kilometre)

Population/jobs balance

The ratio of residential land-use and employment-generating land-use has been found to have a significant influence on travel distance and choice of walking, cycling and public transport modes. Referred to as the job-housing ratio, this is measured as the ratio of the number of jobs to the number of households in each zone.

Land-use mix

Mixed land-use improves accessibility by providing more opportunities for an individual to participate in different activities. Data on the land-use mix can be collected through a detailed review of the existing statutory or non-statutory plans prepared for the city, such as the Master Plan. Several cities also record data on building and building-use, which can be used to extract the land-use. Data on land-use can also be collected, as mentioned earlier, using Survey Format 1 in Annexure 1. Land-use mix can be computed as an entropy index (land-use mix), which is computed as:

$$Entropy = E_i = \sum_j \frac{F_j \times lnF_j}{Ln(j)}$$

Where i is the spatial unit for which the entropy value is being calculated, j is the number of land-use classes (5 land-use classes or more can be considered, e.g. residential, commercial, institutional, industrial, recreational), Fj is the proportion of the total area under the j^{th} land-use type.

Mobility and accessibility indicators

Mobility is the level of ease of moving people and goods; accessibility in the context of this document goes beyond the movement itself – it is the ability to harness or reach an opportunity, the use of which has utility value (social, economic, health, etc.) for the individual. It is necessary to understand both these elements in order to develop a rational land-use and transport plan, and identify the mobility measures that result in improvement of individual accessibility to opportunities. The data for mobility and accessibility indicators is collected using a number of surveys. The sample survey forms to be used to quantify the mobility and accessibility indicators are shown in Annexure 1. The data collected must be visually represented on maps, to avoid any ambiguity. Description and quantification of indicators are described below.

Mobility: travel behaviour indicators

Access to different modes of transport, travel speed and time and distances people travel are considered indicators signalling how mobile a person is. Moreover, they reveal the present travel behaviour of the residents. The data for these indicators is mainly collected through the House Hold Survey (Survey Format 2).

Table 4: Mobility-Travel Behaviour Indicators

Indicator	What it tests/indicates	Description
Modal shares	Presents revealed mode choice. It indicates access to different modes and if these are in favour of low carbon transport or not.	Modal shares (also called mode split or modal split) is the percentage share of travellers using a particular type of transport mode. This is further quantified as: Mode share by modes used for different trip purpose, i.e. work, education, health and others Modal shares by modes used by social groups, i.e. by income, women headed households
Travel time and speed	Travel time and distance, when looked at together, provide a lot of information on the performance of the transport system (longer travel time and low speed indication congestion, *etc.*). Travel distances and time also indicate moving away from or towards non-motorised modes of transport, with longer travel distances favouring higher use of motorised modes of transport.	Average travel time and speed by traveller in date quantified by: Trip purpose Mode used Trip purpose wise disaggregated by social groups
Trip length		Average trip length (ATL) frequency distribution (for all modes including walk, cycle, bus, para-transit and private vehicle): For all trips made in the study area Mode wise ATL disaggregated by social groups Trip purpose wise ATL disaggregated by social groups

Mobility: transport infrastructure indicators

Transport infrastructure indicators represent transport supply indicating size and quality of transport infrastructure. Moreover, they give an indication of the options available to individuals to exercise their mobility choices. Provision of infrastructure also represents the locational advantage/disadvantage for each mobility option in the city and, therefore, helps in the transport decision-making process. The data for these indicators is mainly collected using the Survey Formats 3-7. The following indicators are used to represent the transport infrastructure supply.

Table 5: Mobility-Transport Infrastructure Indicators

Indicator	What it tests/indicates	Description
Density of roads, junctions	Higher density of roads improves the ease of movement, so it can also result in better access to opportunities. This can further result in higher use of motorised modes of transport that are not desired in low carbon mobility plan. Density of junction indicates urban block size. The higher the number of junctions, the lower the size of urban block, which favours use of non-motorised modes of transport.	Density of roads is quantified as: Road space per hectare in the study area and in TAZ Kernel density of roads The kernel density function is used, which is based on Tracy, Su, Sadek, & Wang (2011). The kernel density of road is computed as a raster (grid). The kernel density of roads around each grid cell is computed using a 750 m radius (equal to radius of a neighbourhood) where road width (right of way) is used in the population fields. For each TAZ the average (mean) value of kernel density can be presented. Density of junction is computed in a similar manner, the only difference being the population field in this case is kept vacant.
Pedestrian facilities	Facilities provided for pedestrians enable individuals to exercise the choice of walking as a mode of transport to access opportunities. It is desirable to have footpaths that are wider than 2 m after discounting for space lost due to encroachments. Proper treatment of junctions to facilitate pedestrian movement is also essential.	Facilities provided for pedestrian movement is quantified as: Area under footpath in the study area and in each TAZ Area under footpath more than 2 m wide in each TAZ Area of footpath encroached upon (by type of encroachment)
Bicycle facilities	Facilities provided for cycling enables individuals to exercise the choice of using bicycles as a mode of transport to access opportunities. It is desired that most roads have segregated bicycle lanes and junctions to provide priority to bicycle movement. Adequate bicycle parking facilities also promote the use of bicycles.	Facilities provided for bicycles and bicycle movement is quantified as: Road length with segregated bicycle lane Area of road encroachments on roads with segregated bicycle lanes in the study area and TAZ Area of segregated bicycle lanes with good lighting in study area and TAZ Junction with priority to bicyclist in the TAZ Number of bicycle parking available in the TAZ
Parking facilities	Higher availability of cheap off-street and on-street parking facilities for cars and two wheelers facilitates higher use of these modes.	Facilities provided for parking is quantified as: Number of total/on street/off street parking unit available for each mode in the study area and in each TAZ Parking fee charged for each transport mode in each TAZ
Public transport and para-transit facilities	Higher density of PT stops and routes indicates better access to PT services. The lower the interchanges the better the PT service.	The following group of indicators signify the level of public and para-transit service in the study area: Kernel Density of PT stops/ routes Distance to nearest PT stop Average number of interchanges per PT trip

Accessibility indicators

Accessibility, as described in Table 6, can be quantified using three indicators – financial, physical and spatial organisation of land use and transport. The first two indicators tell how equitable transport system provision is, whereas the third indicates the opportunities that land-uses and transport systems provide to individuals to participate in different activities. The data required for these indicators is mainly collected in Survey Format 8. Accessibility and equity can be tested by indicators presented in Table 6. For decisions based on finances, data should be collected separately for men and women if possible. There are existing inequalities between men and women in many societies in terms of access to and control of financial resources, hence less women might afford tickets which in turn affects their choice of transport.

Table 6: Accessibility Indicators

Indicator	What it tests	How to operationalize
Financial	Transport budgets (money and time) of different social groups and provision of transport service	% of population able to afford PT ticket for their mandatory travel Average time spent on travel for mandatory and obligatory activities
Physical	Physical access to transport and activities	% of junction incorporating barrier free design % of junction with traffic calming measures % of PT stops/modes with barrier free access Accessibility of disadvantaged groups by and to different modes
Spatial Organization	How transport and land-use are organized	% of population with grocery shop within 500 m % of population within 400 m of primary transit network Number of job locations within 30 minutes of travel by PT/ Walk/Bicycle Number of schools/clinics/parks and gardens with 30 minutes of travel by PT/Walk/Bicycle

Goods and freight

A review of goods and freight distribution includes, location and function of major freight terminals, and movement of goods within the city boundaries to markets. The data required for the goods and freight is provided in Survey Format 10. Table 7 presents a review of the indicators.

Table 7: Goods and Freight Indicators

Indicator	What it tests	How to operationalize
Modal Shares	Intercity freight movement and volume	Goods vehicles moving in and out of the city (Cordon surveys) Goods by type imported and exported from the city (Survey Format 10)
	Intra-city freight volumes	Volume of freight moving within the study area (intra-city movement) by mode and type
Trip Length	Transport distances	Average shipping distance within the city boundaries and from the city

Safety and security indicators

Traffic safety is one of the most important urban transport issues. The data related to safety and security indicators is described in Survey Format 11. A review of safety and security can be made by indicators presented in Table 8. Where possible, collection of sex-disaggregated data should be encouraged. For instance, safety issues should be looked at in terms of men and women. Sex-disaggregated data will help redirect focus on men and women's needs and capabilities separately, in order to find practical and lasting solutions accommodating their separate requirements.

Table 8: Safety and Security Indicators

Indicator	What it tests	How to operationalize
Safety	How safe the roads are for all users, especially cyclists and pedestrians	Number of fatal accidents per 100,000 users of the mode Number of accidents caused by the mode on other road users per 100,000 of all the road users Number of fatal accidents per 100,000 population % of roads having speed limit >= 50 kmph % of roads lit
Security	How safe individuals feel using and accessing transport facilities	% of footpaths lit % of people feeling safe to walk/cycle and use PT in city, by gender

Environmental indicators

Environment considerations are important dimensions of an LCMP. Quantifying energy consumption from transport is the first step in estimating the environmental indicators – CO_2 emissions and key air pollutants.

Energy consumption can be estimated in two ways: i) top-down, and ii) bottom-up. The top-down approach involves preparation of energy balances and relies on information available from energy suppliers, such as oil companies, electricity utilities, etc., and large consumers – e.g. railways, transport utilities, etc. The bottom-up approach estimates energy consumption from different vehicle categories based on information obtained through surveys of vehicle owners and data on vehicles from secondary sources.

Both top-down and bottom-up approaches for estimating energy consumptions should be obtained and combined to arrive at a more accurate estimate for total energy use within a city.

CO_2 emissions

The following steps may be followed to calculate CO_2 emissions.

Energy balance

Energy balances are a way of representing aggregate energy flows from energy suppliers to consumers, and are used as an accounting tool for estimating energy-related emissions. In general, energy balances cover all fuels; however, since the focus is on transport, diesel, petrol, LPG, CNG and electricity need to be covered. A simplified energy balance format for the energy consumption of the transport sector, at the city level, is provided in Annexure 1 (Survey Format 12). Table 9 lists the data required for compiling the energy balances.

Table 9: Energy Balance

Data required	Description	Data sources	Data level
Consumption of fossil fuels from transport	Diesel, petrol, CNG, LPG consumption in the city for transport	Retail outlets or fuel company supply/storage depots	City
Consumption of electricity for transport	Electricity consumed for metro/ trams/suburban trains/other rail/ electric vehicles	Railways and mass transit operators or electricity suppliers	City

Bottom-up estimation of energy use

The starting point of bottom-up estimation of energy use is the number of vehicles and the type of fuel used. Information on total number of vehicles, their mix by type, etc. (Survey Format 13) can be obtained from vehicle registration records that are generally available from local/regional transport authorities (Table 10). However, if the vehicle registrations do not record the vehicle retirements, suitable adjustments should be made.

These records generally do not include details regarding average kilometres travelled by a vehicle in a year, type of fuel consumed, or information on fuel economy. Therefore, these details need to be obtained by conducting a primary survey of vehicles at petrol pumps – refer to Annexure 1 (Survey Format 14).

Table 10: Vehicle Inventory

Data required	Description	Data sources	Data level
Registered vehicles (Survey Format 13)	Stock of vehicles by age (passenger and goods)	Survey from road transport authorities	City
Vehicle efficiency (Survey Format 14)	Efficiency characteristics of vehicle categories with vintage (mileage, average vehicle km travelled)	Surveys at petrol pumps	Sample

The information on vehicle population and average distance travelled by each vehicle category can then be used to compute the total vehicle kilometres (Table 11). Using the data of total vehicle kilometres travelled, fuel type, average fuel economy of each vehicle category, and energy use can be computed. This information can be compared with the top-down estimation available in the energy balance format to calibrate coefficients for fuel economy. The fuel economy of future years would depend on the introduction of new vehicles, the retirement of older ones (refer to Annexure 6 on methodology for deciding vehicle mix based on vintage), and expected fleet fuel economy for future years – refer to Annexure 7.

Table 11: A stylised table for vehicle kilometres travelled and fuel mix for base year

Vehicle Type	Total No. Of vehicles	Km travelled/ year	Million Vehicle km	% Fuel Type			Electricity
				Petrol	Diesel	Gas	
Cars	66,737	13,107	875	46%	47%	7%	0%
MUVs	13,813	9,788	135	0%	100%	0%	0%
2Ws	378,090	8,383	3,170	99%	0%	0%	1%
3Ws	25,862	18,656	482	0%	99%	0%	1%
Taxis	4,736	13,107	62	46%	47%	7%	0%
Buses	1,286	76,285	98	0%	100%	0%	0%
HDVs	11,384	20,775	237	0%	100%	0%	0%
LDVs	2,510	30,590	77	0%	100%	0%	0%

Calculation of CO_2 emissions

CO_2 emissions can be calculated from the total fuel consumption based on the CO_2 content of fuels. If available, local emission factors should be used. National emission factors are published in National Communications and Biennial Reports submitted to the UNFCCC[6]. If these are not available, default factors available from IPCC or other global databases should be used[7] (Table 12).

Table 12: CO_2 Emission Coefficients for Fossil Fuels

Fuel	Giga gram CO_2/Petajoule	Kg CO_2/tonne of fuel	Kg CO_2/lit of fuel
Petrol	69.30	3101	2.30
High speed diesel (diesel)	74.1	3214	2.71
Compressed Natural Gas (CNG)	56.1	1691	1.69*
Liquefied Petroleum Gas (LPG)	63.1	2912	2.91*

(*) Kg CO_2/ kg of fuel
Source: IPCC (2006)

Air pollutant emissions

Air quality is an important determinant of human health. Transport is a major contributing source to air pollution in cities. The long-term assessment of ambient air quality data is helpful for, i) understanding prevailing trends and, therefore, prioritizing policies such as emission norms, policies on public transport, etc., and ii) understanding the effectiveness of policies. Table 13 shows the data that needs to be collected for air quality.

6 http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php Accessed April 27, 2016.

7 http://www.ipcc-nggip.iges.or.jp/EFDB/main.php Accessed 25 April 25 2016.

Table 13: Air Quality Data

Data required	Description	Data source	Data level
Air quality	NO_x, CO, SO_x, Particulate Matter PM_{10}, $PM_{2.5}$ concentration by location and year	Pollution control boards	Sampling stations only

Air pollutant emissions from transport can be calculated by multiplying the VKTs (Table 10) with emission coefficients for different vehicles. Table 14 provides the annual emissions of PM 2.5 for VKTs given in Table 10, using emission coefficients for India[8].

Table 14: A stylised table for PM 2.5 Emissions for base year

Vehicle Type	Emissions PM 2.5 (Tonnes)				Total
	Petrol	Diesel	GAS	Electricity	
Cars	10	50	1	-	61
MUVs	-	29	-	-	29
2Ws	269	-	-	-	269
3Ws	-	108	-	-	108
Taxis	1	5	0	-	6
Buses	-	50	-	-	50
HDVs	-	144	-	-	144
LDVs	-	23	-	-	23
Metros/Trams					-
Total	280	409	1	-	690

The emission factors differ by vehicle type, age and fuel. In general, emission coefficients for different vehicle types can be estimated at the national level using the methodology described in Annexure 8. The same methodology can also be applied for developing city-specific emission factors.

Profiling of indicators for the current year

The indicators listed in Table 3, and further explained in the above sections, should be presented as maps and cross classification tables – see Annexure 5. This cross classification gives an indication of the relationship between travel behaviour and other indicators mentioned in Table 3, and, therefore, can be used as inputs for future business-as-usual and low carbon development scenarios. These scenarios are discussed in Steps 3 and 4.

8 The emission coefficients are based on the BAU scenario, provided in Annexure 6 (MoUD, 2014).

Developing the Business-as-Usual (BAU) Scenario

In Figure 1, two pathways are suggested for Step 3. The first pathway is suggested for large cities and cities where large investments in low carbon mobility are planned, and the second pathway is for small cities, and where investment is relatively low.

Large cities – developing the Business-as-Usual scenario

In the first pathway (Path P1, Figure 1), for identifying actions for low carbon mobility scenario, a methodology is used. First, the business-as-usual (BAU) scenario is developed. In the BAU scenario, future projections are based on the continuation of past trends. The BAU incorporates infrastructure development and land-use development according to the plans and projects that are in the pipeline. Future transport demand is based on the preferences of different socio-economic groups in the base year. The technology transformations, i.e. changes in the fuel economy of vehicles, fuel mix, adoption of alternative vehicle technologies, should be in line with current dynamics and implementation of current and proposed policies. These are discussed further in the following section.

Socio-economic projections

A city's future economic transition depends on current economic transitions taking place in the region. It is also necessary to understand the city's role in the state and country's economic development. For example, if a proposed large industrial development includes a certain city, it would lead to more economic development than the general trend for the country as a whole, or past trends for the city. Economic transition also leads to social transitions, in terms of population (local and migrant), household size, income levels and vehicle ownership.

Industrial growth projection

Industrial growth projection depends on the national and state level policies for the region, and the growth trend for each of the city's existing and planned industrial sectors. The growth rates for large industrial sectors (e.g. steel, cement, chemicals, and textiles) are linked to the overall economic growth projections for the country and region.

Employment projection

The total employment projections should be based on industrial growth and macro-economic projections for the region. To assess where these jobs will be located in the city, and the space required, the following procedures can be followed:

- Study past development and growth trends
- During the stakeholder consultation, determine possible locations where different non-residential sectors are most likely to develop
- Project the floor area that will be required for each non-residential activity in the future, using the following equation

  $FS_E = FA_E \times P_E$

Where,

FSE = floor space requirement for employment (for various sectors) FAE = existing per capita floor area for employment PE = projected employment (for various sectors)

In consultation with the stakeholders distribute the floor space (for various sectors) to TAZ. The land-use per TAZ can be computed from the computed floor space per activity.

Demographic projections

Demographic projection includes population projections for the city, along with other demographic variables like family - size, age group, gender proportion, etc. The population projections should also consider migration trends in the city and region, as a whole.

The estimated population that will reside in each zone in the future will be a function of the general development control regulation and attractiveness of this area. The attractiveness of a particular location for different groups can depend upon neighbourhood characteristics, location of employment and individual residential self-selection behaviour.

Future transport demand

The second important task, while profiling the existing urban and transport system, is to understand the transport demand. Given the present data availability and resources in developing countries, it is recommended that the modelling of the demand for passenger transport is estimated using a four-step model – see Annexure 3 for a detailed description of the four-step modelling.

The four-step model is based on inputs of existing travel behaviour obtained from the household survey (Survey Format 2), and of transport infrastructure and service quality. The first step involves calibrating the model for the base year. The traffic flows projected by the model on different road links are compared to the actual traffic volume counts observed at various locations across the city. The model is then recalibrated to match the actual volume counts.

The base-year model can then be used to identify and test various short-term measures that can be incorporated to improve the existing transport system. Once the transport demand model is calibrated for the base year, it can be used to estimate transport demand for future years. The inputs for this analysis will be the planned strategies, changes in socio-economic drivers – i.e. population and employment projections

– and changes in land-use. The BAU scenario assumes that people's travel behaviour (within the same age and socio-economic group) follow the base year pattern.

Fuel and technology transitions

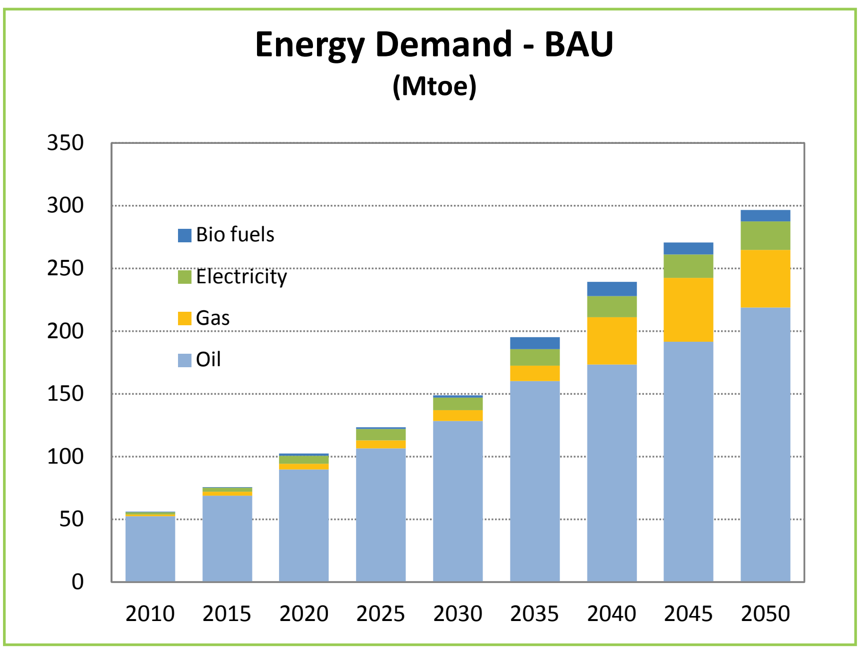
Fuel mix

Currently, the transport sector is largely dependent on fossil fuels. The future fuel mix is expected to diversify into cleaner fuels, including CNG, bio-fuels, and cleaner petrol and diesel. Cities play little role in formulating fuel mix policy, as those are significantly affected by national policies and regulations. Therefore, it should not be assumed that the future fuel mix will remain the same as for the base year. Future fuel mix should be decided based on scenario storyline, in consultation with experts, and analysis done at the national level – see Box 1. However, cities can also deviate from this national guidance if they have some specific plans, e.g. if a city is planning to have all public transport on CNG.

Box 1. Fuel Mix Transitions for India

The fuel mix transitions for the transport sector in India were analysed using scenario methodology and an energy system model for the country as a whole. Two scenarios were analysed: one that looked at the fuel mix transitions in the BAU scenario, and another where fuel mix transitions were analysed for a low carbon scenario. This national fuel mix was used within the city level analysis as default guidance. Figure 6 shows fuel mix transitions for transport sector of India at the national level.

Figure 6: Fuel Mix Projections for BAU in India



Source: Dhar, S., Pathak, M., & Shukla, P. R. 2013. Low Carbon City: A Guidebook for City Planners and Practitioners: UNEP Risoe Centre on Energy, Climate and Sustainable Development, Technical University of Denmark <http://www.unep.org/Transport/lowcarbon/Pdf's/LowCarbonCity_Guidebook.pdf>

Fuel efficiency

With increasing concerns over energy use and greenhouse gas emissions from passenger transportation, there is a greater focus on improving the fuel efficiency of vehicles. Global Fuel Economy Initiative (GFEI) has proposed targets for different vehicle categories. However, these targets would need to be adjusted for specific countries due to the differences in current fuel efficiencies and how stock of vehicles will evolve in the future – refer to Annexure 6.

Increasing share of electricity-based transport systems

Electricity is expected to play an increasing role in the future of transport in cites due to the introduction of metro rail, other rail transit systems, and a wider diffusion of electric vehicles – including two wheelers, cars and buses. Aside from national policies and programmes, cities can provide various incentives in parking, taxation, etc. to electric vehicles to improve the share of electricity. In many cases, electricity is supplied to cities from outside municipal boundaries, freeing the cities from local pollutants – SO_2, NOx, particulates, etc. Nevertheless, cites are obliged to account for CO_2 emissions based on scope of IPCC guidelines for emission inventories.

BAU indicators and LCMP targets

The indicators for horizon years of the BAU scenario are assessed using the LCMP framework. The indicators are compared against benchmarks to give decision makers an idea of what can and needs to be done. For example, the benchmark value for PM 2.5 is 10 micro gm/m3, and if the actual value is 40 then it means serious action is required. However, achieving the benchmark requires time. Therefore, through consensus, stakeholders decide the LCMP targets keeping in mind both what is needed and what is feasible for a given horizon year.

Small cities – cross comparison with benchmarks

In the second pathway (Path P2, Figure 1), the cities will not develop a transport model to assess future travel demands, but would broadly encompass the following steps.

Revisiting base year indicators

A cross-comparison of travel behaviour indicators with other indicators mentioned in Table 3 can be tabulated, as shown in Annexure 5. The stakeholders review these indicators to decide which ones are relevant for the city. They can either choose one set of indicators or a subset, for example mobility and accessibility indicators or improvements in the pedestrian network. Stakeholders can also choose a combination of indicators, for example mobility-accessibility and safety-security.

Setting benchmarks

After a comprehensive review of the cross-comparison table and low carbon mobility targets, the consultants can make a proposal for benchmarks, which are then discussed and approved by stakeholders. The cross-comparison in Annexure 5 will help stakeholders make decisions on which indicators need intervention for achieving their goals. These goals could be benchmarks, which are country-specific; for example, the Government of India has set up service level benchmarks for some of the indicators mentioned in Table 4.

Analysing actions with respect to base year

A comparison between indicators for base year and benchmarks must be done in order to identify actions/ interventions that can help achieve the goals set by the stakeholders. For example, they can decide that a set of indicators needs intervention to increase the public transport mode share for work purpose trips.

Analysing Alternative Low Carbon Scenarios

In this step, alternative low carbon scenarios are analysed using a back casting approach to identify alternative actions that can achieve the LCMP targets. Small cities, as suggested in Figure 1, skip Step 4 and move directly to Step 5.

Alternate low carbon scenarios

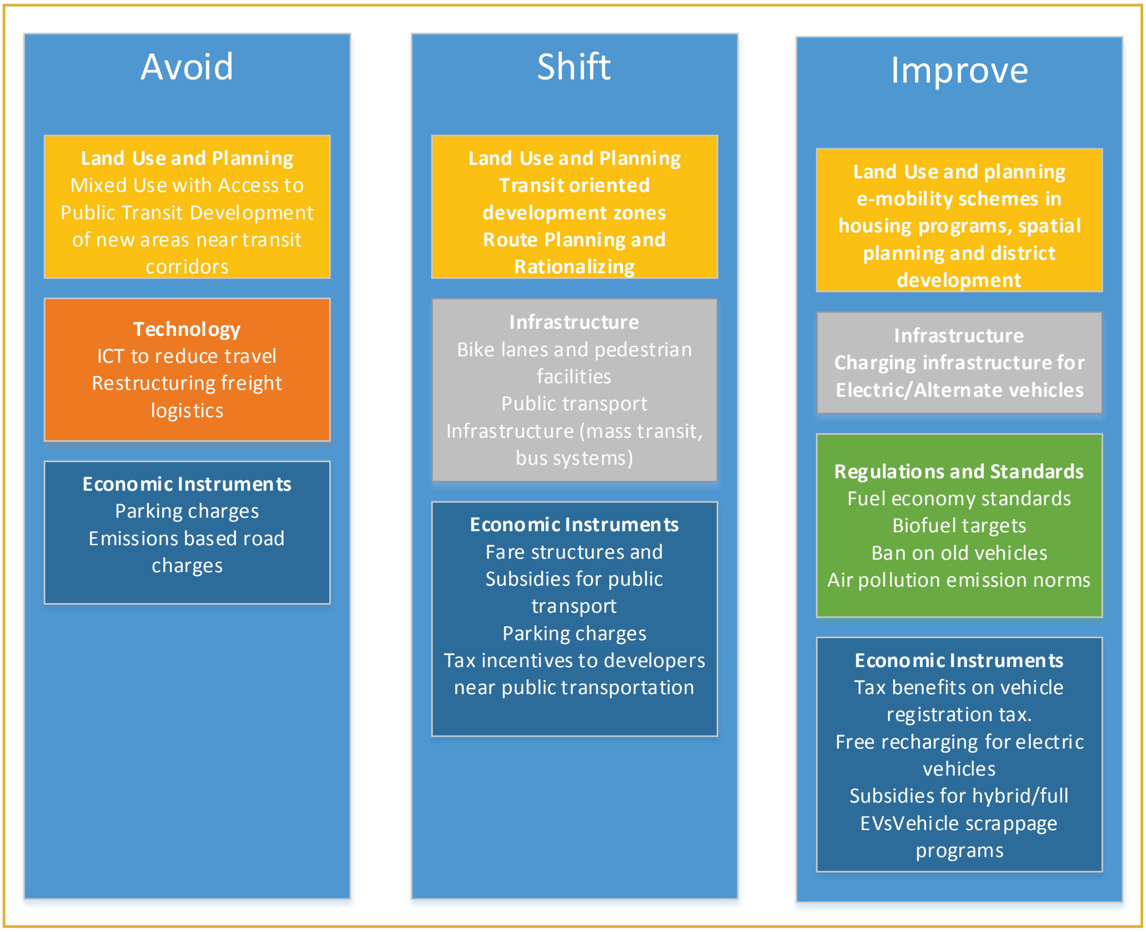
Low carbon strategies can be based on actions that: i. Avoid travel, which may include measures to reduce trip lengths or number of trips, ii. Facilitate shift to more efficient low carbon modes including public and non-motorised transport, and iii. Switch to improved and cleaner fuels and modes (Figure 7).

The ASI framework is helpful in elaborating the different options, however, for simplicity and better link to institutional structures in cities, the scenarios can be developed in terms of changes in the following broad areas:

1. Land-use and planning
2. Non-motorised transport (NMT)
3. Public transport
4. Vehicles
5. Regulations

The low carbon scenarios analyse strategies in each of these broad areas, individually and also in combination. The low carbon scenario preparation follows a back-casting approach where the aim is to achieve the targets for the LCMP indicators related to mobility, accessibility, safety, inclusiveness and environment including those for CO_2 emissions. The analysis framework (Figure 5) is the same as that for the BAU scenario. The subsequent sections discuss different scenarios for: i. Land-use and planning, ii. NMT, iii. Public transport, iv. Vehicles, and v. Regulatory and financial measures.

Figure 7: Exploring Options for Low Carbon Mobility



Adopted from UNEP (2012); MoUD (2014); Sims et al. (2015); Hoornweg et al. (2011)

Land-use and planning

The scenario has interventions that influence land-use to encourage compact, mixed-use land-use patterns with an aim to reduce motorised travel demand, and involve the following:

1. Restricting the development area of the city
2. Increasing density of jobs (poly centric development) and population
3. Improving access to activities by appropriating land-use mix
4. Decreasing the size of development block

From the available evidence, the above stated measures will help shorten trip lengths and encourage higher use of public transport and non-motorised modes and, therefore, contribute to both avoid and shift. The changes in zoning regulations and floor area ratio (FAR) include some of the planning and regulatory measures, which can help achieve higher density and compact development.

In the LCMP prepared for Rajkot city, node development along transit lines was proposed in combination with densification and land-use mix strategies.

Non-motorised transport

In this scenario, various improvements in NMT infrastructure are considered – e.g. enhancing footpaths and bicycle lanes. These improvements can better accessibility and safety, and user experience of pedestrians and bicycles. The scenario also considers campaigns to improve awareness of citizens w.r.t beneficial impacts of cycling on the environment, health and CO_2 emissions. Reducing barriers and impediments on roads to improve bicycle safety is another aspect considered. Reduced conflicts (possibilities of accidents) between non-motorised and motorised modes on roads can result in a moderate increase in bus speed.

Public transport

The public transport scenario includes NMT, as any public transit trip includes a component of NMT for access and egress. Since many cities in developing countries lack a reliable bus service, two kinds of scenarios for public transport may be considered:

1. Improved bus service with compatible pedestrian and bicycle infrastructure

The assumption here is that bus infrastructure and operations are improved so that reliable bus service is available, at least along all arterial roads. In addition, initial ideas on operational interventions like better routing and scheduling, improved frequency, better bus stop design, improve bus speed, overall safety and bus user comfort should be incorporated. The option of providing para-transit modes on the sub arterial and connecting roads should also be considered. This will help limit the access/egress trip length to less than 1 km. The provision of access and egress support infrastructures should also be stressed for walking and cycling. The above-mentioned changes should be used to check the preferred mode choice of respondents, stated in the household survey. This will help to compute the increased demand for public transport in a scenario where public and non-motorised transport infrastructure is sufficiently improved.

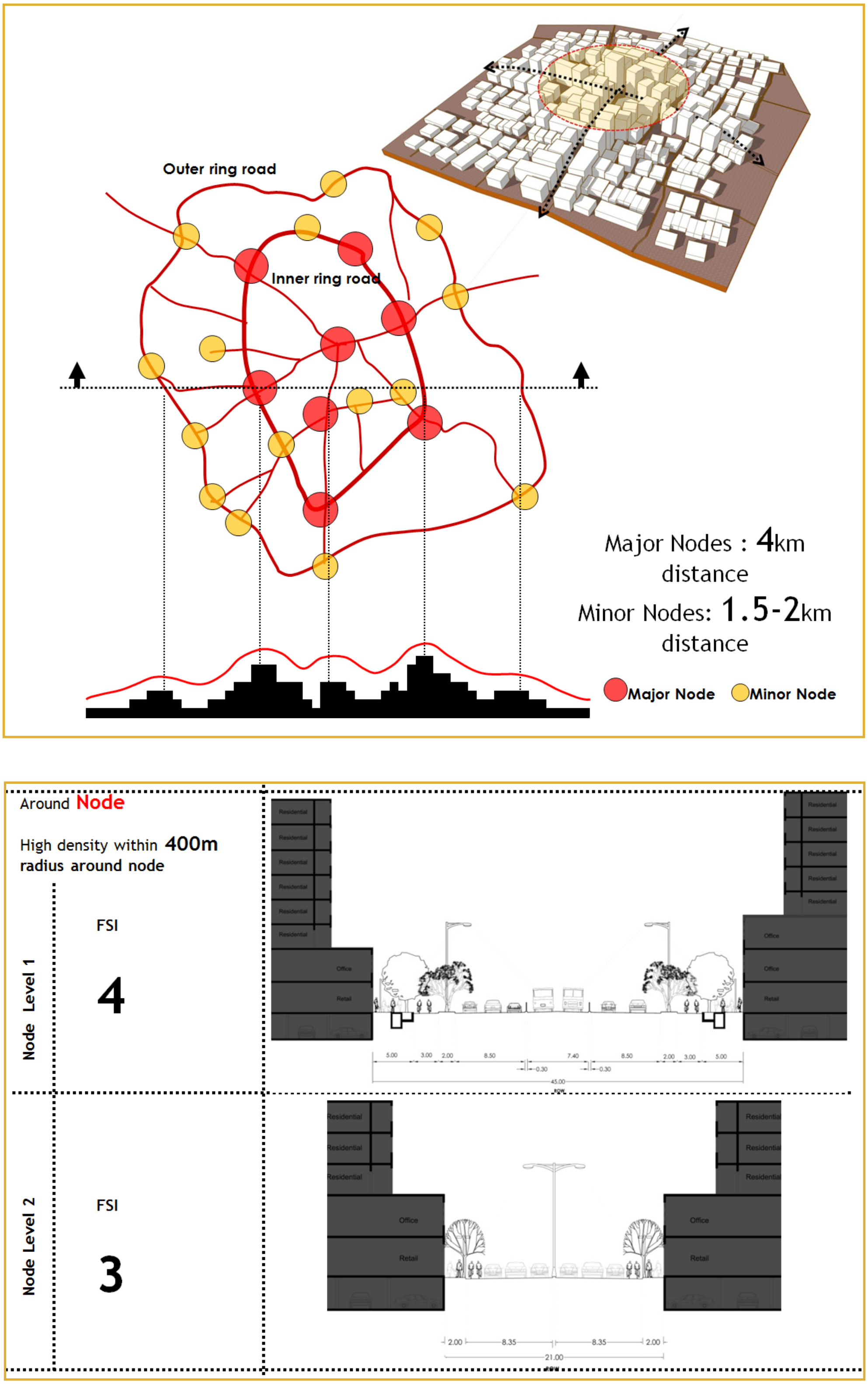
2. Improved bus service and mass rapid transit with compatible pedestrian and bicycle infrastructure

This scenario includes all improvements detailed above in the improved bus service scenario, as well as a mass rapid transit system on selected traffic corridors. Mass rapid transit options could include BRT (exclusive lanes on all arterial roads), light rail, a metro rail system or mono rail system.

Vehicles

Technology changes encompass vehicle technology, including change in efficiency or alternate vehicle technologies – including hybrid or electric vehicles. Often, changes in vehicle technologies are influenced by national policies, for example National Electric Vehicle policies, Fuel Economy standards, etc. Cities can facilitate adoption of low carbon and cleaner technologies by providing supporting infrastructure (e.g. EV charging stations), through incentives (free charging, subsidies) and incorporate these in existing

Figure 8: Land-use strategy in LCMP Rajkot



land-use plans and guidelines – e.g. charging infrastructure and regulations. Cities can restrict the use of old polluting vehicles through financial assistance, and set up effective emissions monitoring systems. Technology transitions such as ICT may reduce the number of trips in the future and may result in overall lower travel demand in the low carbon scenario.

Regulatory and financial measures

A range of regulatory and fiscal measures can be implemented to facilitate the shift from private transport modes to sustainable urban transport. These interventions internalize the cost of externalities imposed by private vehicles. Examples of such measures include parking policies, congestion pricing, registration tax and carbon tax. These are incorporated in the model in the form of increased generalized cost of travel by private modes. Below is an example of the approach for modelling parking policies.

Parking policies (economic instruments + regulations)

Parking is generally low cost, not free, in most developing cities. As a result, there is no disincentive for owners of private transport modes like cars and motorised two wheelers to stop using them.

In this scenario, in addition to infrastructure improvements for pedestrians, bicycles and public transport, parking cost is increased. To implement a robust on-street parking management and enforcement system, on-street parking spaces must be regulated by the cities. The existing parking management system, including current earnings and expenditures, operational systems, and public perception, must be documented, assessed and improved. An expanded and improved parking management system can help facilitate the efficient allocation of road space, generate revenue for sustainable transport projects, and encourage a shift to more sustainable modes. **In the four-step model, these measures should increase the generalized cost of travel of motorised modes as compared to NMT and PT mode, which will favour use of NMT and PT modes.**

Analysing indicators and LCMP targets

Cities can prioritise interventions depending on context, feasibility of implementation and stakeholder inputs. The next step is to test these measures within the four-step model to estimate its impact on travel demand for different modes under alternative scenarios. The low carbon transport scenarios, mentioned in the earlier section, need to be operationalized in an integrated manner. The four-step model, in conjunction with land-use projection models, can be used to analyse the above stated measure, how they affect the indicators mentioned in Table 3, and ultimately help in achieving LCMP targets.

Develop Low Carbon Mobility Plan

The LCMP should be developed on the basis of the analysis carried out under Steps 2-4, and in consultation with the stakeholders. Since the plan would need to take into account the implementation aspects, it is suggested that the LCMP be split into the following plans, although they must be developed in an integrated manner. Furthermore, all these plans should envisage the different actions/activities that would be needed for implementation, and the responsible entities.

Feedback for land-use plans

The feedback for the land-use plans should include specific inputs to the zoning plan and development control regulations. The feedback should also include how land-use density and clustering is envisaged, based on analysis done in Step 4, what types of land-uses would develop together, and how land-use mixing is encouraged. Land-use plans must orient towards public transport development, therefore, these inputs will also include public transit-oriented development zones and related regulations.

Public transport improvement plans

These plans would specifically include plans and projects that are proposed to improve public transport in the city, based on analysis done in Step 4. Depending on that analysis, this will include plans for:

A. Metro/Bus Rapid Transit corridors

1. Bus network plans for improvement in mobility/accessibility/financial performance
2. Para-transit network improvement plans for improvement in mobility/accessibility/financial performance

B. Intermodal integration plans

C. Ticketing and Traffic Plans

D. Vehicle efficiency improvement plans

E. Technology plans for bus fleet monitoring, fare collection, passenger information, traffic monitoring

F. Development around transit stops (in conjunction with land-use plans) for revenue enhancement

NMT infrastructure improvement plans

NMT infrastructures, e.g. bicycle tracks, footpaths, etc., are deficient in most developing countries. Therefore, these plans would specifically include plans and projects that are proposed to improve the NMT infrastructures in the city, based on analysis done in Step 4.

A. Bicycle master plan

1. Bicycle lane network
2. Bicycle sharing schemes
3. Plans for clear zones
4. Plans for parking facilities for bicycles in the city

B. Pedestrian master plan

1. Lane network
2. Pedestrian areas and access management plan

Road network improvement plans

The road network improvement plans relate closely to the public transport and NMT infrastructure plans, and should include plans for improvements of road network and road junction.

Freight movement plans

Freight movement includes both goods destined for the city and those that are simply passing through. The plans assess the expected freight growth trajectory, keeping in mind past trends, growth in industrial and commercial activity, overall growth of city, etc., and accordingly include:

1. Goods distribution plan for intercity goods movement
2. Goods distribution plan for intra-city goods movement
3. Plans for fleet management and policy for the logistic providers
4. Location of wholesale markets and freight terminals
5. Plan for non-motorised or electric vehicles for last mile delivery

Mobility management measures plan

Urban transport in developing countries cannot be transformed solely on the basis of improving the supply of infrastructures; it also requires policies that change consumer behaviour. These policies should be designed with a view to enhance the use of public and non-motorised modes that are inherently more sustainable and low carbon. Some of the policies can also help in revenue generation of cities that can in turn be directed at improving public transportation and NMT infrastructures. A wide variety of policies can be adapted based on local circumstances, however, a general list of fiscal and non-fiscal policies is provided below:

A. Fiscal policies

1. Parking management and pricing
2. Access management and road pricing
    i. Priority measures for buses and NMT
    ii. Flexible access to cleaner freight and passenger traffic
    iii. Staggering rush hours
    iv. Congestion pricing, especially for the central business districts
1. Vehicle taxation (e.g. green tax)
2. Fuel taxation
3. Incentives for car-pooling, electric vehicles, etc.

B. Non-fiscal policies

1. Closure of city centre for car traffic (on certain days)
2. Decreasing speed limits or dynamic speed limits
3. Allowing tele-working
4. Walking and cycling enhancement/services (linked with NMT plan)

Implement, Monitor and Report

The various plans within the LCMP would be implemented as policies, programmes and projects. During the development of the LCMP, the responsible entities for implementation are also identified. The next step is to identify required resources for the implementation of the programmes/projects. Since resources for implementation, particularly in developing country cities, are limited, there is a need for prioritisation. The LCMP should, therefore, guide cites to prioritise various programmes/projects into:

Short-term	0-5 years
Medium-term	5-10 years
Long-term	More than 10 years

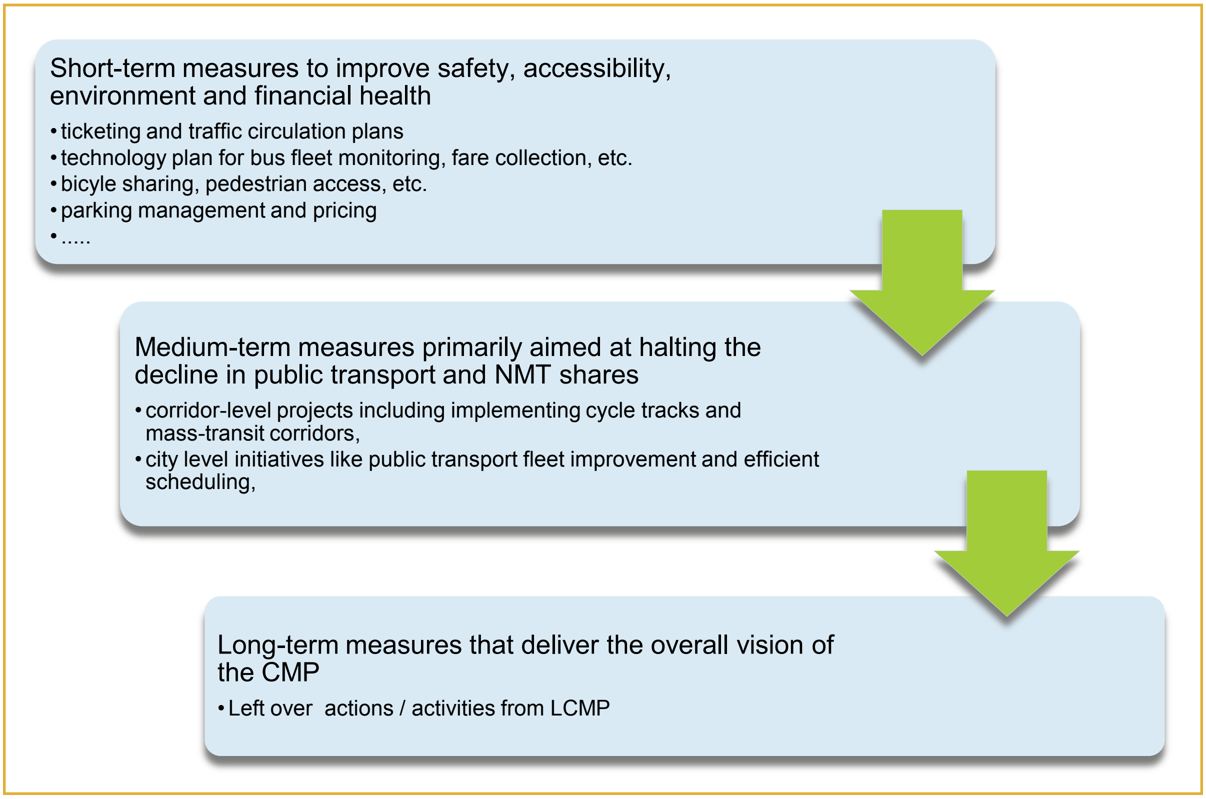
Identification and prioritisation of projects

All the programmes/projects and policies should be presented to the city stakeholders and the implementing agencies to prioritise them for implementation. The roadmap of the LCMP implementation can be charted out by prioritising projects for the short-, medium- and long-term. A broad suggestive roadmap is shown in Figure 9.

An additional set of criteria for prioritising programmes/projects can be as follows:

- Balance between improving existing infrastructure and creating new infrastructure in upcoming areas of development. Preference can be given to projects that improve existing infrastructure by giving them higher scores.
- Benefits measured in terms of mobility and accessibility, safety, energy, environment and CO_{22} mitigation.

Figure 9: Approach for prioritising programmes/projects



Multi Criteria Assessment (MCA) techniques[37] can be used to facilitate stakeholder discussions. The projects identified as short-term measures should then undergo detailed studies on implementation, cost estimates, and likely funding agencies.

Funding of projects

The long-term goal should be to have a financially sustainable transport system. However, cost of transport projects vary greatly – some require high initial investments and many also require subsidies. The following sources can be leveraged for financing urban transport infrastructure:

1. Municipal Budgets: Projects requiring small budgets (e.g. junction design improvement) can be financed entirely through local resources. Some local contribution would always be required, even for larger projects, to show buy in and to give comfort to lenders. Therefore, it is important to improve municipal revenue through user charges, better targeting of subsidies, property development, land value capture, etc.
2. Public Private Partnerships: Projects can be implemented through PPPs to reduce pressure on public funds. PPP projects involve a partnership between a public entity and a private company, and the main idea is to pass financial, technical and operational risks on to the private sector. The private

sector can gain from revenue that the project generates. There are various models for PPP agreements, and more details can be obtained from the World Bank website.[9]

3. National Programmes: National governments can support urban transport projects such as expanding electric bus fleets, fuel quality improvements, etc.
4. Alternative Finance: Projects that enhance sustainable development and CO_2 mitigation can be eligible for leveraging green funds, carbon funds, and corporate social responsibility funds. Many transport projects address problems related to safety, air pollution and CO_2 emissions and, therefore, can be eligible for these alternative sources of financing.

Monitoring and reporting

A robust Monitoring and Reporting system is required to provide feedback to cities and make comparisons with the ex-ante assessments done in Steps 3 and 4. The Monitoring and Reporting system should be institutionalised at the national and city levels. They should also be made a part of the implementation of various programmes and projects. Monitoring and Reporting would also need investment into Information Technology Systems & Data Processing. Moreover, the Monitoring and Reporting should be related to indicators & benchmarks developed in Steps 2-4. Finally, in order to ensure that cities have an interest in Monitoring and Reporting there should be incentives for achieving benchmarks, which can be provided by creating national programmes – e.g. a national programme for reducing accidental road deaths

9 https://ppp.worldbank.org/public-private-partnership/agreements

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Glossary

Accessibility

Accessibility is defined as the extent to which land-use and transport systems enable individuals to reach activities. In general, people who are in places that are more accessible can reach many other activities or destinations quickly, whereas those in inaccessible areas can reach fewer places in the same amount of time.

Alternate vehicle technologies

Road transport vehicles have traditionally been based on petrol and diesel engines, however, vehicles that employ or combine new engines, drivetrain systems or fuels do not solely rely on petrol and diesel. These vehicles can also lead to significant improvements in fuel economy and better environmental performance – e.g. reduced NOx, SO_2, particulate emissions, CO_2 emissions. The most common alternative vehicles include Electric Vehicles (EV), Plug in Hybrid Electric Vehicles (PHEV), Hybrids, Natural Gas Vehicles, etc.

Avoid Shift Improve (ASI) concept

Avoid Shift Improve (ASI) is a concept promoted for reducing greenhouse gas emissions from transport. The ASI concept comprises interventions that: i. Avoid or substitute travel demand, e.g. through integrated transport and land-use planning, ii. Shift demand to low carbon modes, e.g. from motorised private vehicles to walking, cycling and public transport, and iii. Improve vehicle efficiency or deploy alternative vehicle technologies to reduce emissions.

Census

Census is a procedure to systematically acquire information about the entire population in a defined geographical region. It is different from sampling, where information is drawn from a small subset about the entire population. In general, the geographical units are the national boundaries, and due to the extensive amount of data collection they are conducted at a minimum of 10-year intervals. This exercise is undertaken by the government.

Business-as-Usual scenario

A scenario defined by the assumption that future development would follow the trends of the past, and is often used as a counter factual reference or baseline for assessing the policy interventions. When framing this scenario for developing countries, the future development in this scenario is often expected to follow the resource intensive path followed by developed countries. The scenario, however, does have improvements in energy efficiency, labour productivity, etc. and is, therefore, not a frozen technology scenario. (Also read Scenario and Baseline.)

Baseline
The baseline (or reference) is the state against which change is measured. (Also read BAU Scenario.)

Base year
Base Year is the reference year against which the change for future years is assessed.

Biofuel
A liquid fuel produced from biomass or waste vegetable oils. There are two types of biofuels - ethanol and biodiesel. While ethanol can be blended in petrol for use in petrol engines, biodiesel can be blended in diesel for use in diesel engines.

Co-benefit
Co-benefits, within climate change discussions, refer to the positive effect that an intervention aimed at reducing GHG emissions might have on other objectives – e.g. economic development, environment, etc. The co-benefits approach places more focus on the positive aspect of mitigation efforts, although there can also be co-costs – e.g. diverting large amounts of land for growing biofuels can lead to food security issues.

Decarbonisation
The carbon intensity of economies is generally measured in terms of tCO_2 per unit of GDP. Decarbonisation is the process by which countries can decouple their economic growth from CO_2 emission and, therefore, reduce their carbon consumption.

GDP
Gross Domestic Product (GDP) is a measure of the market value all final goods and services produced in a period. GDP values are generally computed at the national level; however, they can also be calculated at sub-national levels.

Electric Vehicle (EV)
Electric Vehicles use an electric motor instead of an internal combustion engine (ICE) for propulsion. An on-board battery provides energy to the electric motor. (Also read Alternate Vehicle Technologies.)

Hybrids
Hybrids are vehicles that use different forms of energy to drive. For example, a hybrid car uses an electric motor in addition to an internal combustion engine (ICE) for propulsion. An on-board battery provides energy to the electric motor, whereas petrol and diesel engines provide energy for ICE. (Also read Alternate Vehicle Technologies.)

Emission inventory
Emissions of certain gases (e.g. SO_2, NOx, CO_2, CO, CH_4, etc.) from human activities are considered harmful. Emission inventories are a way to track their emissions in terms of different sources, different geographical areas, and within a specified time span. For example, the greenhouse gas emission inventories at the national level, in terms of originating sources, is a mandatory requirement for countries under the United Nations Framework Convention on Climate Change.

Energy balance
Energy balances are a way of representing aggregate energy flows from energy suppliers to consumers. The energy balances cover all fuels and renewable energy on the supply side.

Fuel efficiency
Fuel efficiency, with regard to vehicles, is the amount of fuel consumed per unit transport activity, and can be measured in terms of distance covered with a given volume of fuel or, conversely, as amount of fuel consumed for a given distance. It is generally measured in kilometres per litre or as litres of fuel per 100 km.

Fuel mix
This is the mix of fuels that characterises a transport system. These may include a combination of gasoline, diesel, CNG, etc.

Kernel density
The kernel method consists of placing a kernel (a probability density) over each observation point in the sample. A regular rectangular grid is superimposed on the data, and an estimate of the density is obtained at each grid intersection, using information from the entire sample. The estimated density at each intersection is essentially the average of the densities of all the kernels that overlap that point. If used for junctions, it indicates average density for junction within the kernel area.

Land-use mix
A measure that denotes how different uses of land – residential, commercial, cultural, institutional, industrial or recreational – blend with each other.

Low Carbon Scenario (LCS)
A Low Carbon Scenario is relative to a Business-as-Usual Scenario, targeting a much lower level of CO_2 emissions. The level of CO_2 emissions in LCS is generally linked to a global stabilisation target for CO_2 emissions or a global temperature rise – e.g. 2^0C temperature rise until 2100.

Master/development plan
A long-term statutory plan for guiding the planned development of the city.

Mobility
The ease of movement for people or goods.

Mode
For transport, modes include the way in which people or goods are transported. For passengers, these could include cars, two-wheelers, buses, bicycles, trains, etc. For freight, these could include rail, ships, heavy-duty trucks, light commercial vehicles, etc.

Modal split of passenger transport
This is the share of each mode of transport in total inland transport, expressed in passenger-kilometres (pkm).

Para-transit
Para-transit is normally a mode of transport that fulfils a need that neither public transportation nor personal vehicles are able to fulfil, and are typically operated by private operators. Para-transit modes in

India include a wide variety of vehicles – three-wheeled shared autos (e.g. Vikram), minibuses, auto-rickshaw taxis, vans, etc.

Passenger kilometre (pkm)
A passenger-kilometre represents the measurement of transport of one passenger by a defined mode of transport (road, rail, air, sea, inland waterways, etc.) over one kilometre.

Planning horizon
The time period (in years) for which a plan is prepared.

Scenario
A scenario is a possible description of how the future may evolve, based on a set of assumptions about key driving forces (economic, social, technological change) and relationships. The assumptions must be coherent and internally consistent. Scenarios are neither predictions nor forecasts, but are useful in providing a view of the implications of developments and actions.

2°C Scenario
A scenario consistent with the goal of stabilising global temperatures to 2^0C by the end of the century. (Also read Scenario.)

Stakeholders
Stakeholders are individuals or groups that would be affected by a particular action or policy.

Traffic Analysis Zone (TAZ)
These are geographic units used in transport studies to inventorise demographic, land-use and transport data.

Urban agglomeration area
An urban agglomeration area is a continuous urban spread consisting of the city and its suburbs, linked in a continuous area.

Annexures

Annexure 1: Data Collection Approach, Methodology and Sources

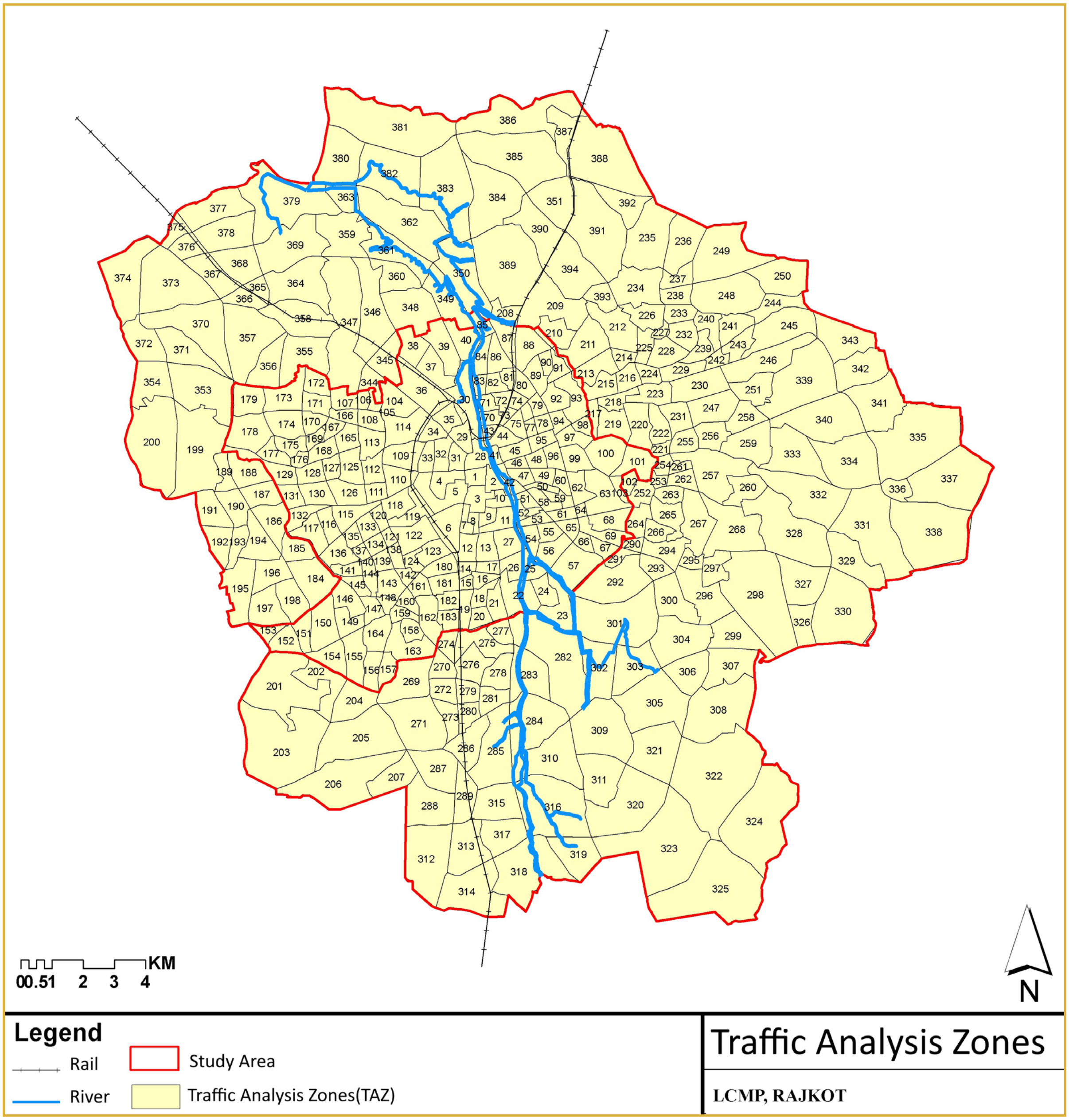
Delineation of Traffic Analysis Zones (TAZ)

As part of the data collection exercise, the consultant should start with the delineation of Traffic Analysis Zones (TAZ) (Figure 5 shows TAZ for Rajkot). The size of traffic analysis zones also determines the resolution at which the data is collected and mobility interactions represented in the study area (for more information, see Annexure 3). There are no standards to delineate the TAZ boundaries, but the following criteria can help in guiding the delineation of TAZ boundaries (de Dios Ortúzar and Willumsen, 2001[10]):

- Zoning size must be as small as possible so as to capture spatial interaction that are short in distance. This are important for modelling walking and bicycle trips.
- To avoid Multiple Areal Unit Problem the zoning system must be compatible with **administrative divisions**, e.g., census zones;
- Zones should be as **homogeneous as possible in their land-use and/or population composition**
- Zone boundaries must be **compatible** and with the zoning systems used in earlier studies (if available) and reference lines that can be used to screen intercity and intra-city passenger and goods movements.
- The **shape of the zones** should allow an easy determination of their centroid connectors (connecting centre of TAZ with the road network)
- Zones do not have to be of equal size; if anything, they could be of **similar dimensions in travel time units**, therefore generating smaller zones in congested than in uncongested areas.
- **Similarly, zones in the city centre can be smaller and those in the periphery can be** larger in size to avoid inter-zonal trips.
- **Specific traffic generators at regional**/city level like railway station, sports complexes / major freight centres etc. might be considered as separate zones.

10 DE DIOS ORTÚZAR, J. & WILLUMSEN, L. G. 2001. Modelling transport, Wiley.

Figure i : TAZ for Rajkot City



Land Use and Urban Form Data

Data required		Data level	Source
Population		Plot, TAZ	Census
Jobs		Plot, TAZ	Land use survey
Land use		Plot, TAZ	Land use survey

Land use data, need to be collected at two levels one at plot level, and second at the building level. For cities where enough resources are not available building level details can be collected only for selected corridors. For example transit corridors. In case land use data is available from secondary sources they should be represented as shown in the survey format 1.

Data on jobs can be estimated at a disaggregated level using data on building use/land use and a ratio to total jobs in the city. Likewise population data available from census sources can be disaggregated to plot level using data on building/land use with residential use.

Survey Format 1: Building and land use

Predominant Land Use (Plot Level)

Predominant Land Use (Plot Level)						
TAZ No	Area Code	Survey No	Plot UID (Auto Generated)	Predominant Land Use (Predominant)	Land Use Sub Code (Secondary)	Building No

Land use codes: RESIDENTIAL (R),COMMERCIAL (C), INDUSTRIAL (I), HEALTH (H), EDUCATION (E), PUBLIC SERVICES (P), VACANT LAND (V), AGRICULTURAL LAND (A), WASTE LAND (WL), TRANSPORT (T), PUBLIC FACILITIES (PF), MIXED USED LAND (M), RECREATIONAL (RC), WATER BODIES (W), RELIGIOUS (RE), QUARRY (Q), FOREST (F), OTHERS (O)

Building and Floor space use

Building Use																						
TAZ No	Area Code	Survey No	Plot UID (Auto Generated)	Building Code	Building use Main Code	Building Use Sub Code	No. of floors	G - 1	G - 2	G	G + 1	G + 2	G + 3	G + 4	G + 5	G + 6	G + 7	G + 8	G + 9	G + 10	Building Cond-ition	Heritage Building	Under Construction	Remarks

Building use codes

COMMERCIAL	C	HEALTH	H	TRANSPORT	T	RECREATIONAL	RC
CAFÉ/RESTAURANT /EATERY	CR	GOVT HOSPITAL	HG	RAILWAY STATION	TR	SPORT COMPLEX/STADIUM	RCS
SHOPS/RETAIL	CS	PRIVATE HOSPITAL	HP	BUS TERMINAL	TB	STUD FARM	RCSH
MALLS/MULTIPLEX	CM	PRIMARY HEALTH CENTRE (GOVT)	HHC	BUS STOPS	TS	RELIGIOUS	RE
HOTELS	CH	DISPENSARY/CLINIC GOVT	HDG	AUTO/ JEEP STAND	TA	TEMPLE	RET
COMMUNITY HALL	CC	DISPENSARY/CLINIC PVT	HDP	PARKING(Off STREET)	TP	MOSQUES/DARGAH	REM
BANKS	CB	EDUCATION	E	LOGISTICS HUB/TRUCK PARKING	TLH	CHURCH	REC
WARE HOUSE/ GODOWN	CW	UNIVERSITY/COLLEGE	EU	PUBLIC FACILITIES	PF		
OFFICE/FIRM	CO	PROFESSIONAL EDUCATION (ITI/ POLYTECHNIC)	EP	PUBLIC TOILET	PFT		
PETROL PUMPS	CPP	HIGHER SECONDARY SCHOOLS	EHS	PUBLIC LIBRARY	PFL		
INFORMAL STALLS	CI	PRIMARY SCHOOL	EPS	SEWAGE TREATMENT PLANT/ OXIDATION	PFSTP		
INDUSTRIAL	I	SECONDARY SCHOOL	ESS	WATER TREATMENT PLANT/ FILTRATION	PFWTP		
MANUFACTURING	IM	DAY CARE / PRE SCHOOL	ED	WATER PUMPING STATION	PFWPS		
COTTAGE INDUSTRIES	ICO	RESIDENTIAL HOSTEL	EH	SEWAGE PUMPING STATION	PFSPS		
AGRO BASED	IA	PUBLIC SERVICES	P	ESR/WATER SUMPS	PFESR		
CERAMIC	IC	POLICE STATION	PS	ELECTRIC SUB STATION	PFESS		
DAIRY	ID	POWER STATION	PP	COMMUNICATION TOWERS	PFCT		
MINERALS	IM	FIRE STATION	PF	PETROL PUMP	PMP		
TEXTILE	IT	POST OFFICE	PO				
OTHERS	IO						

**Adapted from CEPT, Urban Development Studio work.*

Mobility and Accessibility

Travel Behaviour

Data required		Data level	Source
Mode share	Modal shares by trip purpose i.e. work, education, health and others. (Survey format 11)	Sample	Household survey
	Modal Shares by mode (Survey format 11)		
	Modal shares by social groups i.e. by income, women headed household (Survey format 11)		
Jobs	Average travel time by trip purpose /mode(Survey format 11)	Sample	Household survey
	Trip purpose wise average travel time disaggregated by social groups(Survey format 11)		
	Average speed on roads of different modes(Survey format 11)		
Land use	Average Trip Length (ATL) frequency distribution(for all modes including walk, cycle, bus, para-transit and private vehicle) (Survey format 11)	Sample	Household survey
	Mode wise ATL disaggregated by social groups(Survey format 11)		
	Trip purpose wise ATL disaggregated by social groups(Survey format 11)		

Household Survey

General or Household interview

Socio-demographic characteristics, activity patterns and travel behaviour are inter-related. In order to effectively understand transport demand and supply, personal as well as socio-demographic characteristics such as age, gender, employment status, family size, income levels, etc. must be taken into consideration. The study of travel behaviour based on these characteristics will also help ensure that transport proposals are inclusive (that is, the benefits and costs are distributed proportionally across socio-demographic sectors). Therefore, it is essential to collect the above information while conducting the household survey for the comprehensive and inclusive mobility plan. It is possible that the income data gathered will not be representative. Therefore, for determining the income status, it is important that details on household assets are also collected during the household survey.

Individual survey

For conducting the household survey, a travel diary method is to be used, wherein the respondent is asked to recount his or her travel behaviour on the previous day, and all trips, including the trip-chains, short distance and casual trips are noted. An analysis of travel behaviour should only draw on data collected from individuals who have been interviewed for the survey. For this sample to be truly representative, it is important to collect and include data on the travel behaviour of women, children and old people.

The household survey questionnaire can be broadly divided into two sections: a revealed preference survey[11] and a stated preference choice[12]. The revealed preference survey must include questions related to information on the household and its members as well as their choices under existing conditions, whereas the stated preference choice includes their alternative choices which may be non-existent.

Based on the identified indicators for LCMP, it is necessary to collect information regarding the existing use and availability of modes, and criteria related to safety, security and cost. Also, the trip chain data should be able to capture details for multi-modal use and include information like access and egress mode, distance, travel time and cost.

Sampling for household survey

LCMPs need to account for different cross sections of society, and thus a representative sample survey from all levels of society is necessary. It is also important to distribute the sample geographically. If data on building footprint/households and its/their attribute (as in the case of LCMP Rajkot (Munshi et al, 2015)) is available the same can be used for the sampling exercise.

Broad categories of zones

Distance from CBD	Residential	Slums	Commercial/Industrial
0 -1 km			
1 - 3 km			
3 - 5 km			
more than 5 km			

If building level/household level data is not available then from the broad zone categories defined in the Table above, sample TAZs are selected for surveying and collecting data. A stratified sample is done based on the socio-economic profile of the city so that it is significant at the level of 95% confidence interval.

Urban areas are large and highly diverse, therefore, the more diversified the sample, the more the strata identified and the better the identification of strata more representative the sample is. As the first layer of stratification the urban areas in a city can be selected representing following criteria to represent unbiased spatial distribution:

I. Spatial distribution determined by administrative units (based on demographics) such as municipal wards to get spatial units representing different economic and social groups.

II. Land-use structure or city's morphology

III. Distance from the city centre (Core city, intermediate, peripheral and outer periphery)

IV. Spatial distribution determined by traffic-analysis zones

11 Revealed Preference survey is based on actual market behaviour which cannot directly predict response to new alternative. It requires large sample.

12 Stated Preference survey is based on hypothetical scenarios which can elicit preferences for new alternatives. It requires smaller sample as compared to revealed preference survey.

While ensuring unbiased spatial distribution, it is important to ensure that various socio-economic groups are also well-represented as part of these samples. Within each spatially representative area/zone/cluster of zones, the low-income group housing or slum households should be included in the sample. The sample of slum households in each selected zone/area should be at least as much as the percentage of population residing in slums at the city level (or at the zone level if data at zonal level is available). It should be ensured that all socio-economic groups are well-represented. While surveying in low-income housing or slums, it should be ensured that housing typologies (i.e. kutcha houses) and socially vulnerable groups (i.e. female-headed households). In slums, care must be taken to pick up samples of households living in kutcha housing to be able to get a sample of the poorest of the poor.

Logistics

- The h/h surveys should be conducted in the household settings answered by one adult member of the family.
- There should be a team of two senior people to monitor the survey teams.
- Ideally, data-entry of the surveys should be simultaneously done so that in case of missing information or errors, the surveyor can be sent back again for the survey.
- This is a generic sampling guide for the purpose of transport related household survey in cites. Cites have diverse set of data and situation, the researchers can use this note as a guide while taking cognizance of the diverse situation in different cites based on their own perceptions and intuition.

Instruction to Surveyors

A workshop should be conducted with surveyors to explain the purpose of the surveys and the data that needs to be collected. Specific instructions include the following:

- The trips taken and travel needs for the last day are to be recorded. This will include all multiple or single trips made during the last day by every member of the household.
- The access and egress part of the trips needs to be recorded if public transport or para-transit modes of transport are used. This means there will be a minimum of three segments for each trip: the access trip, the line-haul trip and the egress trip. Boarding and alighting time, boarding and alighting stations, access and egress distance and access and egress modes will all be included. If transfers are made to change the bus or other route it should be defined as a separate segment.
- Surveyors need to record parking charges if respondent or person making trip is using private modes of transport (including bicycle).

Cross-Checks and Continuous Monitoring

Survey forms should be randomly checked at regular intervals to keep track of the quality of information being collected. Also, cross checks are required regarding the type of information collected. It is advised that for survey personnel, a suitable number of supervisors are provided by the consultant. A second way of cross checking is triangulation for data so that some data are collected using different approaches to see the differences.

Travel behaviour - Household information	
Data required	**Description**
Personal information	Age
	Gender
	Education
	Occupation (to get idea about current and future travel demand/ need)
	Monthly income (in range, may be by proxy variables like household assets)
	Vehicle ownership and age of vehicle and fuel type (needed for emission factor)
	Monthly expenditure on transport
Trip making information	Trip purpose
	Trip origin
	Trip destination
	Travel distance
	Mode used
	Access mode & cost
	Egress mode & cost
	Access to Public Transport (PT) stop
	Egress from PT stop
	Distance to access PT stop
	Distance of egress PT stop
	Travel time to access
	Travel time to egress
	Average waiting time for PT (or shared auto)
	Total travel time
	Total travel cost
	Expenditure on fuel
	Mileage
	Alternative mode used
Transport infrastructure	Perception about Safety
	Perception about security
Rating for different modes	Perception about comfort
	Perception about cost

Survey format 2

Part I (Revealed Preference Survey)

1. Reference

Date:	Surveyor name:		
Area:	TAZ no:	Address/ Door No.:	
Contact number of respondent (Landline and mobile):	Email id:		

2. Household Information

S. No.	Name	Relation with head	Sex (M/F)	Age	Education	Main Activity (Occupation)
	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						
7						

Household Assets owned	Y/N	Number
Car		
Scooter (M2W)		
Cycle		
Phone / mobile phone		
Fridge		
LPG Stove / Cylinder/Connection		
Cooler		
A.C.		
T.V.		
Desktop / Laptop Computer		
Desktop / Laptop Computer		

Average Monthly Income*	
Monthly Expenditure on Transport*	

*varies from city to city

Code (Relation with Head of the Household) (2)	Education (5)	Activities (6-7)
1. Self	1. No school education	1. Salaried employment (regular waged)
2. Wife / Husband	2. Primary education (Up to 8th)	2. Daily Wages employment (casual labour)
3. Son / Daughter	3. Matriculation/up to 12th	3. Self Employed (work in h/h enterprise)
4. Mother / Father	4. Graduate	4. Student
5. Others	5. Others (Specify)	5. Unemployed
		6. Others - specify

3. Vehicle Ownership in the household

	Present				Before 2 year			
	Type	Make (Year)	Fuel	Mileage	Type	Make (Year)	Fuel	Mileage
1								
2								
3								
4								
5								

Type: Car, Motorized two Wheeler

4. Choice and Opinions

How far is the nearest public transport / shared transport station from your house?															
No.		Mode	Nearest stop (distance)	Time taken to reach	Avg. Waiting time	How often do you use it in a week? (No. of times per week)	service reliability			Safety of the mode			Cost of travel (fare)		
1	Public Bus						Good	Ok	Bad	Good	Ok	Bad	Good	Ok	Bad
2	BRTS (if any)						Good	Ok	Bad	Good	Ok	Bad	Good	Ok	Bad
3	Shared Auto						Good	Ok	Bad	Good	Ok	Bad	Good	Ok	Bad
4	Do you think it is safe and convenient to walk on roads of _______________ city?						Good	Ok	Bad	Good	Ok	Bad	Good	Ok	Bad
5	Are you satisfied with the way you travel in the city?					Yes				No					
6	If No, What do you think needs to be improved?														

Instruction for travel diary: In the survey one trip is the round trip made by the respondent. Here a trip is divided into 6 segments, where each segment of the trip presents the additional activity taken within a trip that can be either changing mode of transport, doing interchange or additional trip purpose like buying vegetables or dropping kids. Primary trip purpose is the main trip being made by the respondent. For example, main trip is going to work while dropping child or buying vegetables on the way is the secondary trip. If number of segments in the round trip is more for a respondent then he/she can use the other table for filling up the details.

5. *Travel Diary (Similar format will be filled for each member of the household travelling on the previous day)*

HH Member no:						Day of Trip	Monday/Tuesday/Wednesday/ Thursday/Friday			
Seg.	Purpose*	Mode#	Start Location	Start time	Waiting Time	End Location	Travel time (min)	Distance (km)	Fare / parking cost	Trip Frequency
1										
2										
3										
4										

* Trip purpose: 1-Home; 2-Work; 3-Education; 4-Access to Public transport; 5-Access to Auto Rickshaw/ Tempo; 6-Recreation;7-Others

Mode: 1-Car; 2-2 Wheeler; 3-Bus; 4-Auto; 5-Shared Auto; 6-Walk; 7-Bicycle; 8-Cycle Rickshaw; 9-Taxi; 10-Any others (Please Specify)

6. *Surveyor's remarks*

____

____

Household Survey - Part II (Stated Preference Choice survey)

This survey format is designed to capture people's behaviour in making choices when alternative mode is available and improved. This requires providing choices to the respondents including the improved and existing alternatives. The respondents can then either choose among the given alternatives or choose an alternative within a scenario.

However, there are certain points of concern while formulating the choice set within each scenario:

- People may be biased for a certain alternative either on negative or on positive side.
- Time and cost attributes are comparatively easy to introduce and understand; however the change in safety and security parameters needs to be strongly addressed.
- It is likely that inferior modes are not considered as an available alternative for middle income and high income group.

- It is extremely important to ensure that an alternative within a choice set does not dominate as it is difficult to determine the trade-offs between different alternatives.

Stated preference choice surveys can help an analyst to identify the probability of a respondent shifting from one mode to another under varying conditions and thus estimate shifts in alternative scenarios for LCMP. This requires analysing the effect of factors on the mode choice of people. Thus, in the survey various scenarios are presented to respondent that shows variations in the attributes of different modes/options and the respondent is asked to choose one preferred mode of travel in each scenario. With the help of variations in attributes of modes and respondent choice, the effect of parameters can be determined in making mode choice that can be extrapolated based on the socio-economic profile of the respondent. The survey methodology enables the analyst to understand the impact of improving infrastructure, taxation and pricing regime or introducing new choice mode in alternative scenarios.

7. Stated preference survey and perception study

Description of scenarios: Choice sets (examples shown below) : sample																
	Scenario 1						Scenario 2					Scenario 3				
	Walk	**Bicycle**	**Bus**	**MTW**	**Car**	**Auto Walk**	**Bicycle**	**Bus**	**MTW**	**Car**	**Auto Walk**	**Bicycle**	**Bus**	**MTW**	**Car**	**Auto**
Fare																
Comfort																
Safety																
Travel time																
Parking cost																

Which mode will you use for each of the following scenarios?

Member No.	Trip Purpose	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	work trip				
	shopping for daily needs				
	Going to School				
2	work trip				
	shopping for daily needs				
	Going to School				
3	work trip				
	shopping for daily needs				
	Going to School				
4	work trip				
	shopping for daily needs				
	Going to School				

Example: (Vishakhapatnam Low-Carbon Mobility Plan)

SCENARIO 1

Attribute	Car	Two Wheeler	Transit	Auto/Taxi	Bicycle	Walk
Travel time	More due to congestion	More due to congestion	15% Less (Independent lane)	More due to congestion	Comparable to car(Independent lane)	15% less (Footpath)
Travel Cost	More due to increased travel time	More due to increased travel time.	Same	More due to increased travel time	-	-
Frequency (Transit)						
Comfort	Same as today	Same as today	Same as today	Same as today	No gradient, better surface, access control, more width	No gradient, Independent footpath, better surface, more width
Safety	Same as today	Same as today	Same as today	Same as today	Better (Independent lane, Traffic speed control)	Better (Independent lane,Traffic speed control

SCENARIO 2

Attribute	Car	Two Wheeler		Transit	Auto/Taxi	Bicycle	Walk
Travel time	More due to congestion	More due to congestion	15% Less (Independent lane)		More due to congestion	25 % less (Independent lane)	15% less (Footpath)
Travel Cost	More due to increased travel time.	More due to increased travel time.	25 % Higher fare		More due to increased travel time, increased fare.	-	-
Frequency (Transit)	-	-	20 % More		-	-	-
Comfort	Same as today for vehicle.	Same as today	More due to level boarding, leg room, Standing space, Air Conditioning		Same as today	No gradient, better surface, access control, more width.	No gradient, independent footpath, better surface, more width.
Safety	Same as today	Same as today	Lesser Risk, lighting of stops		Same as today	Better (Independent lane, Traffic speed control)	Better (Independent lane, Traffic speed control)

SCENARIO 3

Attribute	Car	Two Wheeler	Transit	Auto/Taxi	Bicycle	Walk
Travel time	More due to congestion	More due to congestion	15% Less (Independent lane)	More due to congestion	25 % less (Independent lane)	15% less (Footpath)
Travel Cost	More due to increased travel time, increased fuel cost, parking cost.	More due to increased travel time.	25 % Higher fare	More due to increased travel time, increased fare.	-	-
Frequency (Transit)	-	-	20 % More	-	-	-
Comfort	Same as today for vehicle, farther parking places.	Same as today	More due to level boarding leg room, Standing space, Air Conditioning	Same as today	No gradient, better surface, access control, more width.	No gradient, Independent footpath, better surface, more width.
Safety	Same as today	Same as today	Lesser Risk, lighting of stops.	Same as today	Better (Independent lane, Traffic speed control)	Better (Independent lane, Traffic speed control)

Transport Infrastructure

Sampling technique for collecting data related to infrastructure

In order to prepare an infrastructure inventory, information about the existing level of service and infrastructure type is to be collected for non-motorized transport, para transit, public transport and personal motor transport. Data on roads and infrastructure type is collected for three categories of roads, based on the ROW and the purpose served: arterial or sub-arterial; collector roads; and local roads. The road inventory for the entire city is developed on GIS platform and data is collected using a sample of road amenities and facilities. From each of the broad category of zones defined earlier, sample TAZs are selected based on their spatial distribution. From each of the selected TAZs, a detailed survey is conducted on minimum 50% of the randomly selected roads covering arterial, collector and local roads. Based on the land-use characteristic and spatial distribution of TAZs, a relationship can be drawn to extrapolate the infrastructure type.

Data required		Data level	Source
Road Network Inventory	Road infrastructure (Survey format 3a)	Sample	Primary Survey
	Intersections (Survey format 4)	Sample	Primary Survey
	Parking (Survey format 6)	Sample	Primary Survey
Infrastructure for pedestrians	Footpath (Survey format 3b)	Sample	Primary Survey
	Intersections (Survey format 4)	Sample	Primary Survey
	Access (Survey format 3b)	Sample	Primary Survey
	Lanes (Survey format 3c)	Sample	Primary Survey
Infrastructure for bicycle and cycle rickshaws	Intersection treatment (Survey format 4)	Sample	Primary Survey
Public transport (bus)/ Shared rickshaw services.	Infrastructure (Survey format 9 a &b)	Sample	Primary Survey
	Bus stop (Survey format 8 c)	Sample	Primary Survey
Traffic count	Screen line by modes (Survey format 5)	Sample	Primary Survey
	At intersection by modes (Survey format 5)	Sample	Primary Survey
	Delay by mode (Survey format 5)	Sample	Primary Survey
Delay and queue length	Travel speed by mode (Survey format 7)	Sample	Primary Survey

Survey Format 3: Road Inventory

3a. Road Inventory for Motorised Vehicles

3b. Footpath Inventory

3c. NMV Lane Inventory

3d. Infrastructural Facilities along road, Encroachment and Vehicle restrictions

Road Inventory for Motorised Vehicles (Survey Format 3a)

Road Name	Node Number		Length (kms)	No. of lanes	Divided/ Un-divided	Carriage Way (Kerb to Kerb)			Service Lane Width (m)		Street Lighting	Right of way width
	From	To				LHS width (m)	Median width (m)	RHS width (m)	LHS	RHS	(Y/N)	(m)

Footpath Inventory (Survey Format 3b)

Left hand side						Right hand side					
Type (P / UP)	Length (m)	Width (m)	Encroachment*	Lighting (Y/N)	Barrier free design**	Type (P / UP)	Length (m)	Width (m)	Encroachment*	Lighting (Y/N)	Barrier free design

Note: P: Paved
UP: Unpaved

*parking/Vendors/Trees/Electric Poles/ Other obstacles

**access at entry/guiding tiles/ audible/none

NMV lane Inventory (Survey Format 3C)

LHS						RHS					
Length (m)	Width (m)	Pavement condition	Segregation tools to separate NMV lane from other mode **	Encroach-ment	Lighting (Y/N)	Length (m)	Width (m)	Pavement condition *	Segregation tools to separate NMV lane from other mode **	Encroach-ment	Lighting (Y/N)

Note:

*Good/Poor/Bad **painted marking/kerbed/none ***Parking/Vendors

Infrastructural Facilities and Enforcement along road (Survey Format 3d)

Any Auto Stand		Any Taxi Stand		Is it a bus route? (Y/N)	No. of on-street parking		Encroachment on Road						Vehicle restriction		
							LHS			RHS					
LHS	RHS	LHS	RHS		LHS	RHS	(Y/N)	Road width encroached (m)	Type of Encroach-ment	(Y/N)	Road width encroached (m)	Type of Encroach-ment	PMV	NMV	IPT

Note: Survey Formats 3a, to 3d is a single format

Survey Format 4: Junction Inventory

Intersection Name	Type of intersection*	Type of traffic operation**	Traffic calming tools	Barrier free access	Other NMV facilities (NMV box etc.)	Intersection Design (No. of arms)

*1 - Un-Signalized 2 - Signalized 3 - Roundabout 4 - Signalized Roundabout 5 - Others
**M - Manual A - Automated

Survey Format 5: Traffic volume count at screen line, cordon and intersection

<table>
<tr><td></td><td colspan="5">Location</td><td colspan="6">Direction from</td><td colspan="9">Date/Month Year</td></tr>
<tr><td rowspan="4"></td><td colspan="5">Count station no</td><td colspan="2">Direction</td><td colspan="2">Right</td><td colspan="2">Straight</td><td colspan="2">Left turn</td><td colspan="7">Day</td></tr>
<tr><td colspan="14">Passenger vehicle</td><td colspan="6">Goods Vehicle</td></tr>
<tr><td colspan="2">Heavy fast</td><td colspan="7">Light fast</td><td colspan="3">Slow</td><td></td><td rowspan="2">Other</td><td colspan="2">Heavy fast</td><td colspan="2">Light fast</td><td colspan="2">Slow</td></tr>
<tr><td>City bus</td><td>Intercity bus</td><td>Mini bus</td><td>Car</td><td>MTC</td><td>Auto</td><td>Van</td><td>Jeep</td><td>Taxi</td><td>Shared auto</td><td>Cycle rickshaw</td><td>Pedestrian</td><td>Other</td><td>Truck</td><td>MAV/Trailers</td><td>LCV</td><td>Others</td><td>Cycle rickshaw trolley/carts</td><td>Others</td></tr>
<tr><td>6 - 7 am</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>.......</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5 - 6 pm</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>....</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Survey Format 6: Parking Survey

On-Street Parking (Survey Format 6a)																					
Node/ name	Node/ name			Count of vehicles								Parking fee									
Road Name	Start	End	Length of parking	Car	2W	Auto	Cycle	Rickshaw	Tempo	Truck	Others	Car	2W	Auto	Cycle	Rickshaw	Tempo	Truck	Others	Nearest PT stop	Distance to PT stop

On-Street Parking (Survey Format 6b)

Name of Parking lot	Area of Parking lot	Count of vehicles								Parking fee								Nearest PT stop	Distance to PT stop
		Car	2W	Auto	Cycle	Rickshaw	Tempo	Truck	Others	Car	2W	Auto	Cycle	Rickshaw	Tempo	Truck	Others		

Survey Format 7: Speed and Delay Survey

Speed & Delay - Car (Survey Format 7a)

Sl. No.	Road name	From Node	To Node	Distance (km)	Start Time (min)	End Time (min)	Time	Delay (sec)	Purpose of delay

Speed & Delay - PT (Survey Format 7b)

Sl. No.	Route name	Road Name	From Node	To Node	Distance (km)	Start Time (min)	End Time (min)	Time	Delay (sec)	Purpose of delay

Public Transport, Cycle Rickshaws and Autos

Public Transport System - City Bus, and also for other mass transit systems if any (Metro, LRT, etc.)

Data required		Data level	Source
Fleet usage detail	Number of buses by type of bus (standard, mini, low floor), fuel used and age	Citywide	Urban local body/Transport Authority
	Fleet utilization rate	Citywide	City's bus company/Corporation
	Vehicular kilometres	Citywide	City's bus company/Corporation
	Average kilometres per bus per day	Citywide	City's bus company/Corporation
	Percentage occupancy- peak hour and average	Citywide	City's bus company/Corporation
	Total passengers per day	Citywide	City's bus company/Corporation
Route detail	Route inventory along with bus stops	Citywide	City's bus company/Corporation
	Headway on different routes		
	Boarding and Alighting surveys (on board) (Survey format 9d)	Sample	Primary Survey
	Transit passenger survey (multimodal trips, last mile etc.) (Survey format 9e)		
	Average route speed		
	Service reliability		
	Operation cost per km		
	Tax levied		
Cost and fare	Fare structure & Mobility card (Pass)	Citywide	City's bus company/Corporation
	Revenue per km		
	Profit/loss		

Para-Transit System

Data required		Data level	Source
Fleet usage detail	Type of ownership	Citywide	Transport Authority, para-transit workers' union &survey
	Number of para-transit by type (shared and personal autos), fuel used and age		
	Vehicular kilometres		
Route detail	Boarding and Alighting surveys (on board if possible) (Survey format 10e)	Sample	Primary Survey
	Transit passenger survey (multimodal trips, last mile etc.) (Survey format 10f)		
	Route inventory	Citywide	Transport Authority
	Average waiting time for auto, cycle rickshaw and shared auto	Sample	para-transit workers' union
	Operation cost per km		
Cost and fare	Tax levied	Sample	para-transit workers'
	Fare structure	Citywide	union
	Revenue per km		
	Profit/loss		

Survey Format 8: Inventory for Public Transport

8a. Inventory for BRT
8b. Inventory for City Bus
8c. Bus Terminal
8d. Fleet Inventory
8e. Cost & Fare
8f. Route Inventory
8g. Boarding & Alighting
8h. Interchange Survey

Inventory for BRT Corridor (Survey Format 8a)

Name of road	Node (bus stop)		Width of Bus lane (m)		Length (km)	Bus lane location wrt road section (Median/left side)	Type of bus infra-structure (open/ close)	Bus lane Segregation tools (Kerbs/ lane/ marking/ fences)	Type of bus stop (Staggered/ island)	Average speed (kmph)
	From	To	L	R						

Inventory for City Bus (Survey format 8b)

Route Name & Number	Length (km)	Name of Bus stop	Location (coordinates)		Bus stop capacity	Average Speed (kmph)	Near / far junction
			X	Y			

Bus Terminal Survey (Survey Format 8c)

Time	Bus Route Number	Route Name	Type of Bus	AC/Non AC	Remarks

Fleet inventory (Survey format 8d) - Secondary Data

Owner	Fleet size	Type of fleet (As per Urban Bus Specifications, 2013)	Fleet utilization rate	Vehicular km	Average vehicle age	Occupancy		Average Passenger per day
						Peak hour	Average	

Cost and Fare (Survey format 8e) - Secondary Data

Operator	Operation cost per km ($)	Tax levied ($)	Type of Fare structure & Fare Structure	Revenue per km ($)	Profit/ loss ($)	Fuel efficiency

Route Inventory (Survey format 8) - Secondary Data

Route number	Route length	Location covered	Headway (minutes)	Average passenger $/day	Average routing time (hour)		Average Delays (minute)
					Peak hr.	Average	

Boarding Alighting (Survey Format 8g)

Time	Bus Stop Name	Route Name	Boarding	Alighting	On Board	Remark

Interchange survey (Survey Format 8h)

Type of Interchange	Name	CCTV		Passenger Information System (PIS)		Parking Available for cycle / Cycle Rickshaw within 250 m	
		Y/N	Count	Y/N	Count	Y/N	Count

Survey Format 9: Inventory for Cycle Rickshaws and Autos

9a. Fleet Inventory for Auto Rickshaws

9b. Route Inventory for Shared Autos

9c. Cost & Fare of Shared Autos

Fleet inventory - auto rickshaw (Survey Format 9a) - Secondary Data

Owner (owned/rented)	Type of fleet (capacity)	Use (shared or not)	Average vehicular km/day	Average vehicle age	Average earning per day	Occupancy		Average passenger per day
						Peak hour	Average	

Route inventory for shared auto rickshaws (Survey Format 9b) - Secondary Data

Route number	Route length	Location covered	Headway (minutes)	Average passengers/day	Average routing time		Average delay
					Peak hour	Average	

Cost and Fare of Shared Autos (Survey format 9c) - Secondary Data

Operator	Operation cost per km	Tax levied	Fare structure	Revenue per km (Rs)	Profit/ loss (Rs)	Fuel efficiency

Freight

Sampling technique for freight

Freight Transport

Data required		Data level	Source
Freight vehicle Survey (Survey Format 9)	Origin and destination points		
	Parking areas for freight vehicles and cost	Sample	Primary Surveys
	Vehicle typology		

Both motorized and non-motorized vehicles carrying goods coming into the city and moving within city needs to be surveyed. This can be done at sampled outer cordons and cordon points where these vehicles enter the core city area. For example, in case of Visakhapatnam, five out of twenty sampled intersections were selected for collecting data related to freight movement in the city. Of these three were outer cordons while other two were entry points to the core-city area. 16 hour turning movement counts have been carried out at each of these intersections on a typical working day. Along with origin and destination of the trips; the survey also needs to capture type of vehicle used and commodity carried (Survey format 10)

Survey Format 10: Freight Survey

Freight survey (Survey format 10)							
Date of survey:					Survey corridor:		From:
Day of survey:		Type of transport service provided	Goods Transported		Direction of survey:		To:
Time	Vehicle type		Type	Weight	Origin	Destination	Trip frequency

Vehicle	Code
LCV	1
2-Axle truck	2
3 - Axle truck	3
Multi-axle vehicle	4
Tractor	5
Tempo	6
NMT	7

Transport service	Code
Intercity	1
Intra-city	2

Trip Frequency	Code
Daily once (one-way)	1
Daily twice (up & down)	2
Daily thrice or more	3
Others	4

Traffic safety

Survey Items	Description	Sample Form
Inventory of Traffic Accidents	Collect statistics on traffic accidents and outline trends.	Survey form 11
Enforcement	Enforcement is a key aspect in realizing an efficient urban transport system	Annexure 1, Survey Form 3D

Data required		Data level	Source
Traffic Safety		Sample	Primary Survey
Number of victim involved in	By victim mode		
traffic fatalities and location	By impacting vehicle	City level	Traffic police FIR

Survey Format 11: Traffic Safety- Secondary Data

Traffic survey – secondary data (survey format 11)

Accident Location	Type of Accident (Fatal / Non-Fatal)	Type of vehicle Involved in the Accident	Along Road / Junction / Flyover

Format 12: Energy Consumption in Transport: City Level

Survey format 12 (Energy consumption in transport: City level)				Unit: MTOE
Sr. No.	**Item**	**Year1**	**Year2**	**Year3**
	Transport			
1	Road			
	Petrol (MS)			
	Diesel			
	Compressed Natural Gas(CNG)			
	LPG			
	Electricity			
2	Rail based			
	Diesel			
	Electricity			
3	Water based			
	Diesel			
	LNG			
	Other (Specify)			

Instructions for filling:

- Priority should be on collecting data for latest year or the year for which the information is collected for other activities
- The information should be collected at an aggregate level from the respective Oil Companies, Electricity Utility, Public Transport Utilities, Railways or Mass Transit Operators
- If the information is not available at city level then district wise figures should be recorded. In order to achieve consistency with the LCMP, planning area population should be used as a proxy.

Survey Format 13: Vehicle inventory

Survey format 13 (Vehicle inventory – Registered vehicles at city level)

Vehicle Type	Fuel	Year 1	Year 2	Year 3	Year 4	Latest Year
Two Wheelers	Petrol					
	Electric					
	Others					
Three Wheelers	Petrol					
	Diesel					
	CNG					
	Electric					
	Others					
Four Wheelers	Petrol					
	Diesel					
	CNG					
	Electric					
	Others					
Taxis	Petrol					
	Diesel					
	CNG					
	Electric					
	Others					
Buses	Diesel					
	CNG					
	Others					
Trucks (LCV) (Up to 7.5 tons)	Diesel					
	Others					
Trucks (HCV)	Diesel					
	Others					

Survey Format 14: Vehicle Survey at Petrol Pump

Survey format 14 (Vehicle survey at petrol pump)

Type of vehicle (Tick one)	**Car**	**SUV**	**3 wheeler**	**2 wheeler**	**Bus**	**Truck**	**Other (Specify)**
Type of fuel (Tick one)	Petrol	Diesel	CNG	LPG	Electricity		Other (Specify)
Make			Model			Year of Mfg.	
Mileage		Km/Litre	Odometer Reading				Kilometres

Sampling Methodology for the Petrol Pump Survey

The choice of petrol pumps should be based on convenience sampling but preferably in different areas of the city. Random vehicles are surveyed in proportion of their share. For instance, in Rajkot the following proportions were considered for survey: 33% cars, 33% two wheelers, 10% three wheelers, 12% buses and 12% trucks to develop a confidence level at 95% significance. Simultaneously, a crosscheck on the composition of vehicles (age and type) needs to be done as per the number of registered vehicles. A sample of at least 3,000 vehicles (two-wheelers, cars, buses, autos and trucks) should be collected to cover the sufficient number of vehicles of different vintage.

Instructions for filling questionnaire:

To be carried out at petrol pumps or CNG stations and preferably at stations with emissions testing so that vehicle pollution parameters can also be measured. Vehicles sampled should be in proportion to their population as per Survey format 13.

Annexure 2: Stakeholder Consultation

[Adapted from Groenendijk and Dopheide (2003)[13]]

Successful implementation of LCMP proposals depends significantly on the involvement of key stakeholders in conceptualising, designing and planning these proposals. It is important to identify the various conflicts of interests among stakeholders, and to avoid the resistance to policies and projects proposed as part of the LCMP. The direct involvement of the key parties in Problem Analysis and further project planning creates ownership of, and commitment to, the planning process, and, thus, contributes to the success of the LCMP.

Stakeholder consultation is an important exercise for various reasons, including:

a) Understanding the city: It is necessary to engage with stakeholders who work in the city. The ground experience of the stakeholders with the city is valuable and must be captured. This exercise will help to understand not just the characteristics of the city but also its main bottlenecks and strengths. By understanding the limitations within which the stakeholders work, it is possible to develop more relevant scenarios for the city and make better recommendations.

b) Stakeholder consultations: It has been widely recognised as an important exercise in recent times. The top-down approach, where recommendations are made to a city without involving stakeholders in the deliberation process and using its know-how, has been widely criticised. It is now recognised that each city has its unique characteristics. The recommendations made, have to suit the unique circumstances under which the city functions.

c) The scope of work of each organization: There are a number of agencies that operate in a city. Sometimes, multiple agencies will be involved in the same area. For example, construction and maintenance of roads in a city would not fall under the jurisdiction of a single agency – a number of agencies are involved in that process. There is usually a clear demarcation of each agency's scope of work and, therefore, understanding the exact jurisdiction of each agency is important. This will help in understanding the exact tasks that each organization is responsible for and also identifying areas where there is an overlap of tasks and responsibilities.

13 GROENENDIJK, L. & DOPHEIDE, E. 2003. Planning and management tools. *A reference book. The International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands.*

d) Developing alternative scenarios: The LCMP will involve developing alternative scenarios of urban transport. The difference between the alternatives will be differences in policy, institutional framework, transport plans of the city, technological innovations, and other such details. Stakeholder consultation will help in building these alternative scenarios.

e) Building a rapport with the city: By engaging with the stakeholders, a rapport will be built with the city. This is vital because recommendations made in the LCMP will need to be implemented. Having a rapport with the city will ensure that the recommendations are smoothly implemented, and problems and bottlenecks are minimised in the implementation stage.

f) It is to be noted that certain stakeholders may not contribute to the creation of LCMP but could be powerful enough to hinder the implementation. Engaging these stakeholders, keeping them regularly in the loop of the project, and taking some of their recommendations into consideration will help to ensure maximum support from the city.

The following can be distinguished as the key objectives of Stakeholder Analysis:

- To improve the effectiveness of low carbon mobility plan (policies or projects) by explicitly considering the stakeholder's interests and the challenges they represent.
- To better address the distributional impacts of urban development and transport projects by breaking down the analysis, in order to assess separately the interests and impacts of intervention on different stakeholders, with a special consideration towards equity.
- To ensure the involvement of all sections of society, especially the disadvantaged (transport-wise), in participatory methods while developing the urban development and transport models and inputs to models.
- To strengthen communication and collaboration mechanisms among stakeholders.
- To strengthen the implementation of transport projects and accelerate the operations involved.
- To better understand complex multi-stakeholder situations.

Classifying and Identifying Stakeholders

Stakeholders include all actors or groups who affect and/or are affected by the policies, decisions and actions of a project (Groenendijk and Dopheide, 2003). Stakeholders represent systems with their own objectives, resources and sensitivities. Special groups of stakeholders are those with 'no voice', such as the urban poor. The interests of these groups are promoted by others, such as NGOs, scientists or the international community.

Stakeholders can be listed and classified by looking at the fundamental division between them – stakeholders who frame and implement the urban development and transport policies and projects (that is, make decisions or take action), and those *affected* by these decisions or actions. Stakeholders are also categorised according to their relative influence and importance: *key* stakeholders are those that can significantly influence, or are important to, the success of the project (Groenendijk and Dopheide, 2003).

Therefore, it is important to study the different stakeholder attributes and their interest in the stated transport projects. Some stakeholders might benefit from the project and may be sympathetic to the objectives, while others might be negative, as the project might be against their interests. Based on Groenendijk and Dopheide (2003), it is suggested that the consultant should list down for each stakeholder:

- What are the stakeholders' expectations of the project?
- What benefits are there likely to be for the stakeholder?
- What resources might the stakeholder be able and willing (or unwilling) to mobilise?
- What other interests does the stakeholder have which may conflict with the project?
- What is your level of control over key stakeholders? (Can you influence his/her participation?)
- How does the stakeholder regard others on the list?

The other important consideration in stakeholder analysis is the influence or power that the stakeholder has over the LCMP project in terms of decision making and exerting pressure that can be positive or negative for the success of the project. Identification of influence, which people, groups or organizations (i.e. stakeholders) are able to persuade or coerce others into making decisions and following a certain course of action, is also important.

While identifying the stakeholder it is also important to prioritise the stakes, in the project as in the importance each group of stakeholders should be assigned during the consultation process. This is, of course, influenced by the interests and influential aspects of the stakeholder selection process. There will often be stakeholders, particularly the vulnerable section of the population (elderly, women, children, urban poor, physically challenged, etc.) to whom the project accords great priority. Their capacity to participate in the project may be weak, and their power to influence key decisions limited, thus, it is important that during the consultation process importance and priority is given to their views and that their voices are heard.

Classifying stakeholders on the basis of their role in transport

- Organizations or individuals responsible for making decisions regarding transport. These organizations could be involved either at the city-level planning of transport or framing policies, or in transport operations. That is, government organizations for which transport is one of the primary focus and, thus, they are directly involved.
- Organizations or individuals who are not part of the government but are directly involved in the transport operations in the city. This could include auto rickshaw unions, taxi drivers' association, etc. This group could also include private players who are involved with the government in various transport-based PPP operations, like operation of buses, toll roads, etc.
- Organizations or individuals (government or non-government) whose activities tend to shape the transport needs and demands of the city. This will include large industrial units, urban development authorities, ports, railways, etc.

- Organizations and individuals (government or non-government) who hold prominent positions are important opinion makers in the city. This will include the press; universities, colleges and other educational institutes; popular NGOs and other popular representative organizations like Confederation of Indian Industry.

The following table lists the key stakeholders that should be part of any LCMP consultation process.

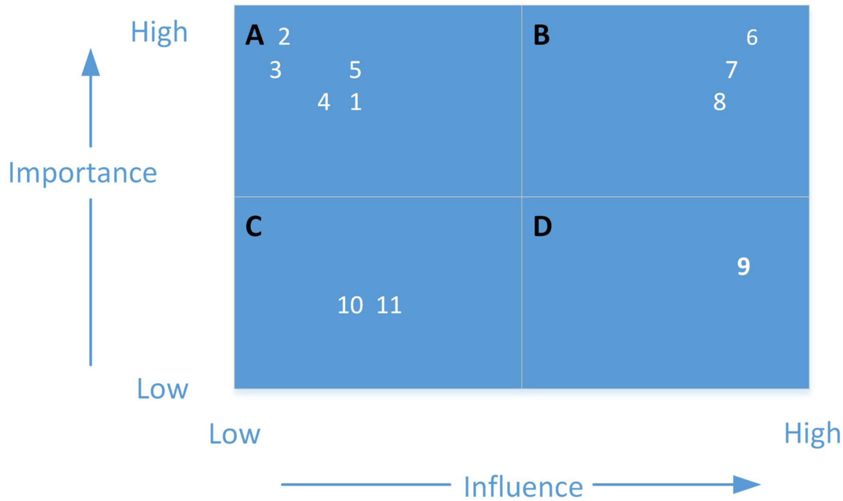
Government	Communities/ Social groups	Businesses	Politicians	Others
Local and Regional Planning Authorities Transport authorities Traffic police Other transport bodies Utility managers Emergency services Other organizations governing land-use and transport	Non-government organisations Community based organisations Citizens Bicycle/Walking groups IPT/PT associations Physically challenged Older people Children Women	Transport operators/ providers Oil Companies Other transport energy providers Chamber of commerce Association of Builders Association of Architects Retailers Informal sector representatives Small businesses Industries	Local councillors Members of ruling party Member of the opposition party	Research institutes Universities Land-use and transport experts

The stakeholder interest table, below, includes only select stakeholders for demonstration purposes.

	Interests	Potential project impact	Relative priorities of interests
Primary stakeholders			
1. Citizens	Travel choices Lower Transport Cost	+ -?	=1
2. Physically challenged 3. Older people 4. Children 5. Women	Accessibility Equity	+ + -/+	=1
Secondary stakeholders			
6. Local and Regional Planning authorities 7. Transport Authorities 8. Other Transport bodies	Achievement of targets Control over funds and activities Avoid liability for any negative reactions	+ - -	3
9. Transport providers	Sales volume Profits Public image	+ +/- +/-	=2
External stakeholders			
10. Research groups 11. Land-use transport experts	Institutional learning Methodological inputs	+/-	4

* *This is a list for demonstration purposes adapted from Groenendijk and Dopheide (2003)*

The above table shows how each stakeholder has several interests. The proposed project will have a positive impact on some of these interests, but not all. The table also identified the relative priorities to be given to each stakeholder, according to the objective of the LCMP. By combining the influence and importance of each stakeholder in a matrix diagram, assumptions and risks regarding the stakeholders can be identified.



** This is for demonstration purposes adapted from Groenendijk and Dopheide (2003)*

In the above figure, boxes A, B, C are key stakeholders in the project. During the consultation process stakeholders in box A will require special initiative to protect their interest, as they are important but have very little influence. The consultants need to build a good working relationship with stakeholders in box B, as these are necessary for the success of the LCMP. Stakeholders who are in box C can pose a lot of risk to the project, and they have great influence but are not very important for the LCMP project – these stakeholders will need careful monitoring and management. Stakeholders in box D are unlikely to cause any risk to the project. The following are important to know.

- What are the roles or responses of the key stakeholders that must be assumed if the project is to be successful?
- Are these roles plausible and realistic?
- Are there negative responses that can be expected, given the interests of the stakeholders?
- If such responses occur, what impact would they have on the project? How probable are these negative responses, and are they major risks?
- In summary, which plausible assumptions about stakeholders support or threaten the project?

Listed below are stakeholders who would fall under boxes B and C for the case of Vishakapatnam.

Mode	Hierarchy	Planning & Policy	Infrastructure	Operations	Monitoring &Evaluation
IPT	State	VUDA		IPT Operators, Traffic Police	RTA, APPCB
	City		GVMC		
	Centre	HPCL	NHAI		
City Bus	State	VUDA, APSRTC	APSRTC	APSRTC, Traffic Police	RTA, APPCB
	City		GVMC		
	Centre	HPCL			
BRT	State	VUDA		APSRTC, Traffic Police	VUTCL
	City	GVMC	GVMC		
	Centre	HPCL	NHAI		
Intercity Bus	State		APSRTC, AP R&B (PWD) Dept.	APSRTC	
	City				
	Centre	East Coast Railway	East Coast Railway	East Coast Railway	
Railways	State				
	City				
	Centre	AAI	AAI	Airlines	DGCA
Airport	State				
	City				
	Centre	Ministry of Shipping	Ministry of Shipping, VPT	VPT	
Port	State				
	City				
	Centre		NHAI		
Goods	State	VUDA			
	City		GVMC	Private Operators	

HPCL - Hindustan Petroleum Corporation Ltd., VUDA - Vishakhapatnam Urban Development Authority, NHAI - National Highway Authority of India, GVMC - Greater Vishakhapatnam Municipal Corporation, APSRTC- Andhra Pradesh State Road Transport Corporation, APR&B (PWD) - Andhra Pradesh Road & Buildings Public Works Department, RTA - Regional Transport Authority, APPCB - Andhra - Andhra Pradesh Pollution Control Board, VUTL - Vishakhapatnam Urban Transport Company Ltd., VPT - Vishakhapatnam Port Trust

Once the list of stakeholders is decided, the consultant should start preparing for the meeting. The following steps are suggested by Groenendijk and Dopheide (2003):

- Prepare
  - Meet with participants before the meeting (if possible)
  - Distribute relevant information ahead of time
  - Decide on who will facilitate the meeting
  - Send the draft agenda to the participants
  - Make sure all groups are able to participate in the meeting
- Facilitate
- Use of methods
  - Focused conversation
  - Brainstorming
  - Mapping
- Prepare meeting report and incorporate the suggestions into the LCMP

Annexure 3: Four-Step Modelling

Model Framework (Four-step Modelling)

The four-step modelling approach for CMP needs to account for different social groups and gender (see the Figure below), as well as all modes of transport, including non-motorised transport (NMT), para-transit and public transport. This is slightly different from the conventional four-step modelling where there is no differentiation in terms of socio-economic groups and gender, and where the focus is mainly on motorised transport. Modelling software like QuantumGIS, ArcGIS, TransCAD, CUBE, VISUM, EMME, OmniTrans, etc. can be used to create the travel demand model of the city.

The base year travel demand model is required to replicate the road network and travel patterns of the city in modelling software, and to test for various short-term measures that can be taken to improve the existing transport systems. The following table gives the input parameters and the data sources used for developing the base year model.

Trip Generation

Trip generation involves estimating the total number of trips produced and attracted to each TAZ. Trip production is dependent on socio-economic characteristics of households within the TAZ, while trip attraction depends on the land-use type of the TAZ, as explained below.

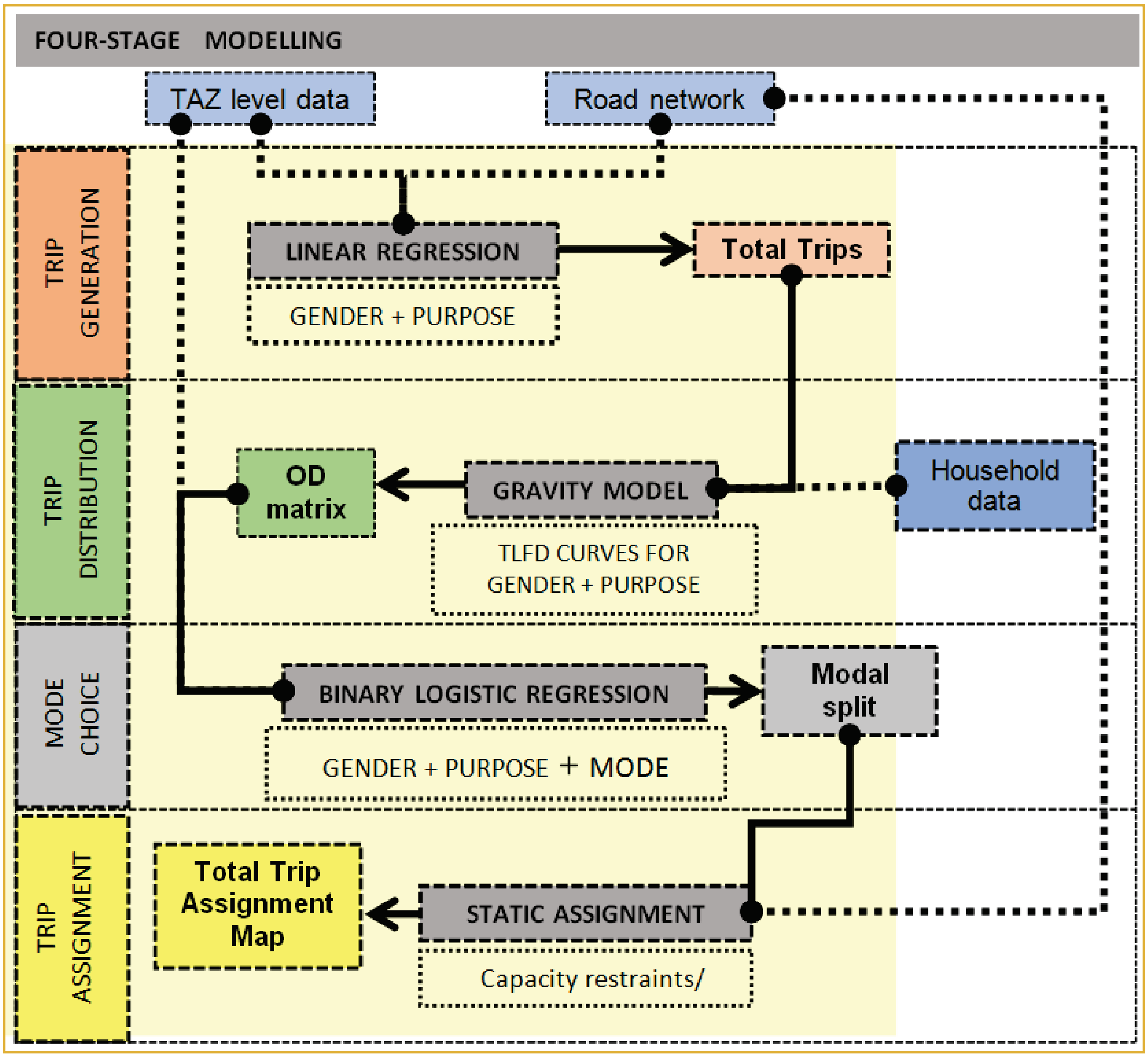
Trip Production

Household interview data is typically used to estimate the trip production trends for various types of households using the following steps:

- Purpose-wise trips (e.g. work, school/college, social, recreation, etc.) produced in each household are derived as a function of the socio-economic attributes of the household – like household size, income and vehicle ownership.

- Total number of households in each TAZ is derived from the census data or the property tax database, and its total number of households and number of trips produced are estimated.
- The socio-economic characteristics of each TAZ are derived from the HH Interview data.
- If detailed household level data is unavailable, TAZ level data and parameters, like TAZ population, employment opportunities, etc., are used to derive the productions for each TAZ.

Four-Step Modelling Framework



Trip Attraction

The number of trips attracted to each TAZ is estimated in this step. The attractiveness of a zone is a function of the type of land-use of that zone. For example, residential land-uses produce trips while commercial, institutional and industrial areas typically attract trips. Hence, the existing land-use mix is considered as the critical variable in determining the trips attracted to each TAZ. Land-use data at the city level is provided by the Master Plan of the city, but they are only indicative as the land-use allocation in the Master Plan, and the actual usage of land-use is observed to be varying widely in practice.

The Property tax data from the municipal corporations maintain building-wise land-use type and its plinth area. Types of land-use in the buildings include: Residential, Commercial, Educational, Industrial, Public Use, Shops, Hospitals, Cinema/Pub Entertainment, Others. Except for residential, all other land-use types attract trips. **Therefore, the total plinth area of each type of attracting land-uses can be calculated and used as a measure of attractiveness of the TAZ.**

Purpose-wise trips attracted to each zone from the household interviews are correlated with land-use types in each TAZ, using multiple linear regression technique to derive the relationship between the trips attracted and the land-uses of the TAZ. Based on these equations, the number of trips attracted to each zone is recalculated. However, this only gives the number of trips at the scale of the sample size of data, since the sample trips are used for deriving the equation. Therefore, these attractions are used as the relative attractiveness of each zone. **The attractions of each zone are then up scaled proportionally to the total attractions based on the total trips produced for each purpose.**

Trip Distribution

Trip distribution is used to derive the Origin-Destination (OD) matrix from the Production Attraction (PA) table prepared in trip generation. Gravity Method is generally adopted for trip distribution. In this method, trips between zone i and zone j (T_{ij}) are distributed in proportion to the number of trips produced in i, number of trips attracted in j, and in the inverse proportion of the impedance between these zones – i.e. travel time, travel cost, relative safety, etc.

$$T_{ij} = P[(Ai\ Fij) / (\sum Ai\ Fij\ )$$

Where,
T_{ij} = trips produced at I and attracted at j, P_i = total trip production at i,
A_j = total trip production at j,
F_{ij} = (friction factor) or computed using the TLFD curves i = origin zone, j = destination zone

Trip Distribution can be carried out purpose-wise or mode-wise based on city specific characteristics. Trip length distribution should be observed both purpose-wise and mode-wise, and whichever parameter has more clearly defined trip length distributions should be selected. If the type of mode is affecting trip length more, mode share split can be carried out before the trip distribution. The following is the step-wise procedure.

The purpose-wise peak hour trips are added up to get the total trips produced and attracted to each TAZ. The TAZ-wise mode-share values can be derived from the HH Interview data and applied to the PA table to get the mode-wise PA table for all zones.

Current users: The mode share of public transport and cycles in each TAZ is obtained from the household interview data, and is used to derive the PA table for current public transport and cycling trips. The PA table can be for the peak hour or for the entire day, based on the study requirements.

Potential users: All the trips in the city form the potential public transport and cycle users in the city, and it is important to model these trips in parallel to estimate their potential shift to public transport and cycles, respectively.

One of the features of the four-stage demand modelling process is that only the inter-zonal trips are considered for assignment. Hence, the proportion of intra-zonal trips in each TAZ is calculated from the HH Interview data, and these trips are excluded from the demand modelling process.

The PA table containing inter-zonal public transport trips is used as the input for trip distribution.

For public transport trips, the generalised cost is considered as impedance, which is worked out based on time taken for access, waiting, line haul, transfer, line haul and egress, and disutility of each of these in monetary terms.

Mode Choice

Mode choice models should be developed for all modes of transport, including public transport and para-transit modes. As discussed in Task 2-2, TAZ size for modelling needs to be small enough to cater to walk, bicycle trips, and account for impact of access/egress trips on public transport.

Mode Choice Equations

These are computed based on revealed and stated preference of individuals surveyed in the HH survey. A Multinomial logit, Nested logit models or any other logit function were run to achieve the mode choice equations. As stated, mode choice is the dependent variable and socio-demographics of the individual, built form indicators at the trip's origin and end, and travel costs are the independent variables in the equation.

Mode Choice for Walk and Bicycle

One of the major differences in modelling NMT modes, compared to motorised modes, is the impact of speed on mode choice. Speed of NMT (walk and bicycle) is constant, and there is negligible impact of congestion. Other parameters like distance to be travelled, infrastructure quality, safety and security concerns have wider impact over mode choice of walk and bicycle. Along with the mode-related parameters, individual socio-economic information needs to be accounted for modelling mode choice for NMT modes of transport.

Mode Choice for Public Transport

Utility of public transport has a minimum of three inter-related segments – i.e. access trip, haul trip and egress trip. Studies have shown that access/egress trip has a significant impact over public transport as a mode choice. The impact is not only in terms of public transport in vicinity to origin/destination, but also in terms of the discomfort and disutility associated with the modes used for access/egress trips and mode interchanges. The utility function for public transport, thus, involves waiting time and discomfort of changing modes, other than mode-related parameters for access/egress trip and haul trip.

Trip Assignment

This step is performed to determine the number of trips made by different modes on each of the existing transport network links during peak and off-peak hour periods. Trip assignment for NMT should account for land-use and density parameters in the vicinity of the infrastructure/facility. Trip assignment for bicycles also includes parameters related to pavement quality, slope, traffic volume and speed. This involves using a bicycle compatibility index (BCI) and other such measures.

The person trip OD matrices for current and potential users are converted to vehicle trips, based on the average occupancy observed in each mode from the occupancy survey carried out in the city. The floating populations coming into the city through the numerous entry points are captured from OD surveys at these locations. These sample surveys are up scaled to total volume based on the traffic volume counts at those locations. **The OD matrices from these surveys are added to the OD from trip distribution to develop the overall OD matrix of the city.**

The mode-wise calibrated OD matrices derived from the above step are assigned to the road network using User-Equilibrium or Capacity Restraint methods based on Wardrops equilibrium[49] for motorised modes. **For cyclists, the All or Nothing (AON) method is used, in general, by considering the minimum BCI or travel distance between ODs of the cyclists as the determining factor for route choice.** Since most links are assumed to have enough capacity for cyclists, and since cyclists are more sensitive to safety and security issues than to speed, the AON method is adopted.

Network Validation

The link flows observed from trip assignment are compared to the actual traffic flows observed from traffic volume counts conducted at various locations across the city. If it is observed that the link flows from traffic assignment vary from the traffic volume counts, the network needs to be rechecked for its accuracy. Some missing links in the road network are identified through this procedure. However, the larger contributing factor to this error can be the OD matrix derived from trip distribution, as it has to be recalibrated for it to match the traffic volume counts. For this, an iterative process is available in modelling software called the OD matrix estimation (TransCAD, CUBE)/ t-flow fuzzy (VISUM). Using this procedure, the network is calibrated to match the actual volume counts observed on the ground.

For details, refer to Demand Assessment Module available at: https://www.dropbox.com/sh/99ngmessm2cgb76/IRv2lC9AwZ

Annexure 4: List of Maps to be Prepared

1. Urban form maps
    a) Population density (TAZ wise)
    b) Decadal change in population density (TAZ wise)
    c) Average per capita use of residential space/social classes (TAZ wise)
    d) Land-use entropy index
    e) Land/floor area under land-use
    f) Job/Housing ratio
    g) Accessibility to jobs

2. Environmental Emissions
    a) CO_2 emission
    b) Per capita CO_2 emission

3. Maps of Road Network Inventory including:
    a) Location of existing footpaths
    b) Major intersection locations
    c) Existing cycle tracks and widths
    d) Location of existing dedicated bus lanes
    e) Existing bus stops – with and without shelters

f) Existing bus terminals and depots

g) Existing para-transit stops

h) ROW of all major streets

i) Location of on-street/off-street parking

j) Location of regulated parking

4. Maps of Public Transport Systems:

    a) Key bus routes

    b) Key para-transit routes

    c) Frequency counts during peak hours along transit routes (including bus and para-transit)

    d) Occupancy counts during peak hours along transit routes (including bus and para-transit)

5. Road safety maps:

    a) Key crash locations/black spots

Annexure 5: Travel Indicators and Travel Behaviour

Survey Items	Measure		Mean trip length	% Trips by walking	% Trip by Bicycle	% Trips by PT	% Trips by Private Automobile
Density	Jobs Population	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Land-use	Entropy Index Job Housing ratio Concentration of land-use	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Outline of Road Network	Density of roads	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Inventory of Arterial Road Network	Density of arterial roads	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					

Survey Items	Measure		Mean trip length	% Trips by walking	% Trip by Bicycle	% Trips by PT	% Trips by Private Automobile
Inventory of Flyovers and Underpasses	Density of flyovers	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Inventory of Major Intersections	Density of junction	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Parking Facilities	On street parking area	$\bar{X} + 2\sigma$					
	Off street parking area	$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Pedestrian Facilities	Density of area under footpath Density of area under footpath more than 2m wide	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
NMV Facilities	Length of bicycle tracks	$\bar{X} + 2\sigma$					
Public Transport and Para-transit Facilities	Density of PT routes Distance to nearest PT stop	$\bar{X} + 2\sigma$					
	Percentage of population within 400 metres of primary transit network	$\bar{X} + \sigma$					
		$\bar{X}$					
	Percentage of job within 400 m of primary transit network	$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					

Survey Items	Measure		Mean trip length	% Trips by walking	% Trip by Bicycle	% Trips by PT	% Trips by Private Automobile
Goods access	Percentage of intermodal and within 1600 m of primary goods movement network	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Land-use and transport organisation accessibility	% of population with nearest grocery shop within 500 m No of jobs reached with 30 minutes of travel by PT/Walking/ Bicycle	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Financial accessibility	% of population who cannot afford public transport fares	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					
Physical accessibility	% of PT stops/ buses/etc. with barrier free access. % of building with barrier free access	$\bar{X} + 2\sigma$					
		$\bar{X} + \sigma$					
		$\bar{X}$					
		$\bar{X} - \sigma$					
		$\bar{X} - 2\sigma$					

**Just A demonstration, actual indicator use can be different*

Example of cross-classification method

Population Density (Persons/hectare)	Distance from Centre of Town	HH Members/Earner	Mean Trip Length	PT choice	Bicycle Choice	Two Wheel Choice	Walk Choice
< 150	< 2.5	< 1					
		1 - 1.5		Option 2			
		1.5- 3					
		> 3					
	2.5 - 5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	5 - 7.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	> 7.5	< 1					
		1 - 1.5			Option 1		
		1.5- 3					
		> 3					
150 - 250	< 2.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	2.5 - 5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	5 - 7.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	> 7.5	< 1					
		1 - 1.5					
		1.5- 3	Travel Behavior A				
		> 3					
250 - 500	< 2.5	< 1					
		1 - 1.5	Travel Behavior C				
		1.5- 3					
		> 3					
	2.5 - 5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	5 - 7.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	> 7.5	< 1					
		1 - 1.5	Travel Behavior B				
		1.5- 3					
		> 3					
> 500	< 2.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	2.5 - 5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	5 - 7.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					
	> 7.5	< 1					
		1 - 1.5					
		1.5- 3					
		> 3					

Option 1: The socio-demographic forecast indicates that in the future year, the number of household members per earner will reduce, and that is there are more earners in each family. The decision maker can then take the decision to increase the density in one of the peripheral areas of the city. This will mean that the forecast of the travel behaviour A (as shown in figure above) for the same area will be reflected as travel behaviour B (as shown in figure above) for the future year.

Option 2: The decision maker in this case adopts all strategies of option 1, but also plans to convert a mono-centric town to a poly-centric town ensuring the distance from anywhere in the town to a sub-centre in the town is not more than 2.5 kilometre. In this case the forecasted travel behaviour will be C.

Likewise the decision makers can look at several options that will help them achieve their sustainable transport objective, and implement the best-suited objective. In the above example only three indicators are used (Population density, distance from city centre, HH members per earner in the household. However, a different set of indicators or more can be used to generate a similar cross-classification table for decision making. For example for a PT-related decision, the indicator distance from /to PT stop can be included as the fourth indicator in this cross-classification table. For walk and bicycle choice, road safety related indicator could have been included in this cross-classification table.

Annexure 6: Methodology for Establishing Vintage for Vehicles

Vehicle performance deteriorates with age, which is also related to the vehicle standards that were prevalent at that time. In order to find the number of vehicles of a type (e.g. car petrol) and vintage Yt in current Yn ($Car_{Yt,Yn}$), two things must be known.

$$Car_{Yt,Yn} = Car\ Sold_{Yt} - Car\ Retired_{Yt,Yn} \qquad [1]$$

First is the number of vehicles sold in Yt ($Car\ Sold_{Yt}$), and second is the vehicles retired until Yn ($Car\ Retired_{Yt,Yn}$). The number of vehicles sold should be estimated from the vehicle registration data. To estimate the number of vehicles retired, different techniques can be used. A simple way is to consider an average life for a vehicle, which can be based on a survey, discussions with transport experts, scrappage dealers or a published report. A more advanced methodology for estimating the vehicle mix by age is described in Goel and Guttikunda (2014).

The year-wise data for simplification can be aggregated, put as % share and put into 5 years buckets – all vehicles over 15 years can be put in one bucket (e.g. per 2005, in table below). The vintage that will come in the future can be included under the category advanced.

This information on vehicles is further used to calculate emission coefficients (see Annexure 7).

Age profile of vehicles

Vehicle Type	Fuel	Age	% share in current year (Yn)	% share in 2025	% share in 2035
Car	Petrol	Advanced*			
		(2010-15)			
		(2005-10)			
		(pre 2005)			
	Diesel	Advanced			
		(2010-15)			
		(2005-10)			
		(pre 2005)			
	Electric	-			
Two-wheeler	Petrol	Advanced			
		(2010-15)			
		(2005-10)			
		(pre 2005)			
	Electric	–			
	–	–			
	–	–			
Bus	Diesel	–			
		–			
		–			
		–			
		–			
		–			
	–	–			
–-					

**Advanced refers to future technology advancement. This depends on the scenario assumptions.*

Annexure 7: Future Fuel Efficiency

Fuel efficiency is the amount of fuel consumed per unit transport activity, and can be measured in terms of kilometres per litre or as litres of fuel per 100 km. Average fuel efficiency of new vehicles would depend on the technology changes within drive train technologies of vehicles, and consumer preferences for size of vehicles – e.g. if people have a preference for larger cars in the future, the improvements in drive train can be nullified.

Fuel efficiency should improve over time, even in the reference scenario, and these improvements can be linked to those that happened in the past. Since the alternative scenarios are for a low carbon world, it is useful to link to global targets that are indicated in the table below.

Average Fuel Efficiency of vehicle mix and Fuel Economy Targets for 2 Degree Scenario (Litres gasoline equivalent/100 km)*

	2010	2020	2030	2040	2050
Passenger car	7.6	5.4	4.1		3.5
Light/medium trucks	13.4	10.7	9.5		
Heavy trucks and buses	35.9	31.8	27.1		
Two wheelers	2.9	2.6	2.3		

Source: IEA (2012); UNEP

Annexure 8: Estimating Air Pollutant Emission Factors

Emission Factor (EF) is the fleet average emission factor (gm/km) for different pollutants for a vehicle type. These will differ by age (a) and fuel (f) for each pollutant. EF is estimated for each vehicle type for the base year, as well as horizon years. As a first step, the emission standard prevailing during the bucket period (e.g. 2005-2010) for a particular vehicle type is put into the table below, and remains the same through the entire row. These values of emission standard are further multiplied by % share of that vintage (see Table in Annexure 6), and summed together to provide the weighted average coefficient for the particular vehicle category. Therefore, it is important to have the same bucket sizes in Annexures 6 and 8.

Projections on emission coefficients for the future should be put in the advanced row, which would depend on policies related to emission norms – e.g. the timing of emission norms introduction. Consequently, the emission coefficient would vary with year – e.g. the 2035 value would be more stringent than 2025. In general, countries would have to plan for the introduction of more advanced emission standards, which would help in putting the values.

Template for estimating emission coefficients for air pollutants (overleaf)

Template for estimating emission coefficients for air pollutants

			Emission Factor (Gm/km)														
Vehicle Type	Fuel	Age	Base Year					2025					2035				
			PM2.5	NO_x	CO	SO_2	VOCs	PM2.5	NO_x	CO	SO_2	VOCs	PM2.5	NO_x	CO	SO_2	VOCs
Car	Petrol	Advanced															
		(2010-15)															
		(2005-10)															
		(pre 2005)															
		Average															
	Diesel	Advanced															
		(2010-15)															
		(2005-10)															
		(pre 2005)															
		Average															
	E4w		-	-	-	-											
Two wheeler	Petrol	Advanced															
		(2010-15)															
		(2005-10)															
		(pre 2005)															
		Average															
	E2w		-	-	-	-											
		Advanced															
Bus	Diesel	Advanced															
		(2010-15)															
		(2005-10)															
		(pre 2005)															
		Average															
	Gas	–															
		–															
		–															
	Biofuel	Advanced															
	EV	Advanced															

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