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Energy Efficiency in Urban Landuse and Transport Planning for Home-Based Daily trips,

A Case study of Kathmandu Valley

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Abstract

Escalating transport energy demand is one of the major issues for the Kathmandu Valley, with a rapid increase in mobilization and urban sprawl. The Kathmandu Valley is the center for economic activities and educational opportunities where the daily trips that constitute work trips and educational trips have a dominant share. In this context, this research is aimed to study travel behavior, urban landuse and transport system in relation to transport energy demand for home-based daily trips, in the context of the Kathmandu Valley.

Trip data of workers and students were collected from the household survey, carried out in different parts of the study area, using random sampling. Daily trips have a significant share in travel demand with about 2.1 million trips per day with modal share of private vehicles showing higher, as compared to other modes. Mode choice and trip length were studied in relation to the socio-economic and demographic background and it was found that the role of gender, age and income and household vehicle ownership were found to be influential to the travel behavior, more importantly for work trips.

Travel behavior was studied in relation to urban form for the travel energy assessment. Work trips are observed to vary more spatially, than educational trips. The correlation analyses of work trips show that population density and public transport accessibility, are having little impact on travel energy, whereas increasing distance from the central business district is found to have a significant rise in travel energy.

Four-Step Urban Transport Model, was developed to study the travel pattern in macro scale and for carrying out scenario analysis. The currently daily trips consume 3666 TJ annually. Cars and motorcycles contribute to most of consumption, accounting for over 80% of total transport energy.

Current willingness to shift to Public Transport like Bus Rapid Transit System, leads to the reduction in transport energy up to 44% for trips along the zones with access to the service. With the balance between Trip Production and Attraction, whereby Employment and Educational Services are provided in accordance to travel demand of work and education trips, respectively, the reduction is achieved by 6%. The reduction is further increased significantly by shift from motorized private more to non-motorized modes of transport. The research exemplifies the benefits of using travel behavior analysis and transport modelling for studying daily trips in macro scale, to promote energy efficiency in landuse and transport planning, in context of the Kathmandu Valley.

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Acronyms and Abbreviations

UTMS	Urban Transport Model System
GHG	Green House Gases
TAZ	Traffic Analysis Zones
KV	Kathmandu Valley
HH	Household
KL	Kiloliter
MJ	Mega joule
NMT	Non-Motorized modes of Transport
TJ	Terra Joule
TOD	Transit Oriented Development
PT	Public Transport
FSM	Four Step Model
GoN	Government of Nepal
EPI	Energy Performance Index

Chapter 1. Introduction

1.1 Background

Urban form and the urban transport system have significant impact on how the city functions and level of energy consumption, with rapidly growing economic activities and population, resulting in urban sprawl and auto-mobilization and as such, cities are the focal point of energy consumption. Although many nations of the developed world have given priority to this issue, most developing countries have paid little or no attention. Consequently, giving priority to issues related to energy, efficiency and sustainability become a vital issue when addressing urbanization (Khalil, 2015)

Sustainable development strategies are becoming a key concern for decision-makers, planners and the public, as a threat of climate change, global warming, rising energy demand and alarming levels of pollution, become apparent. Addressing land use and transport planning is one of the major elements within the sustainability endeavor, where positive action can take place (Banister, 1997)

A practical application of transport sustainability would seek to balance the negative effects of the transport system, such as energy use, pollution, delays in travel on congested roads and emissions, with the positive aspects, such as a high level of accessibility for individuals and organizations (Bertolini, 2005). It would also include the integration of transport and land use planning policy in order to reduce the need to travel by for example, creating a mixed-use development in close proximity to public transport and the enhancement of the urban environment to encourage walking and cycling (Banister, 1997). The layout of the city has an influence, on the way people travel. Reducing the frequency and distance of travel as well as allowing a shift from private automobiles to other, less carbon-intensive forms of transportation is one of the primary areas where urban form can play a role in bringing about reductions in energy consumption and GHG (Green House Gas) emissions (Salzberg, 2007) . The basic concept underlying a relationship between landuse and transportation is accessibility (Hanson, 1995). This requires an emphasis on accessibility rather than the hitherto traditional emphasis on increasing personal mobility (Whitelegg, 1997).

As the world economy grows with increasing population and rapid urbanization, there grows the tendency for urban sprawl and increase in travel demand. It is an increasing concern to the decision makers, planners, and the people, that the way our cities are functioning may not be sustainable in the long run (Jonsson, 2007). So, viewed from a sustainability perspective, urban transport planning cannot be treated in isolation from land use and the environment without compromising the goal of sustainability (Geerlings & Stead, 2003)

There is a growing consensus regarding the central place of integrated land use and transport strategy development in establishing more efficient and sustainable urban environments. However, empirical evidence shows that such integration is hard to achieve in daily planning practice, due to many institutional barriers and substantive differences (Brommelstroet & Bertolini, 2010). The integration of land-use and transport, even though it is evident about the clear linkage between them, the analysis is made complicated and problematic because of a number of limitations encountered in the approach. This creates a challenge for planners and policymakers. However, attempts should always be towards it, which is essential for sustainable, environmentally friendly, energy-efficient mobility.

A successful city must seek a balance in social, economic and environmental needs and it has to respond to pressure from all sides. It should also put the needs of its citizens at the forefront of all its planning activities. It recognizes its natural assets, its citizens and its environment and builds on these to ensure the best possible returns (Khalil, 2015).

Sustainable transport systems are those which aim to decrease emissions, fossil fuel consumption, and the utilization of natural land, while providing easy access to the people (Verma, 2018). More fundamentally, it has become very much essential to reduce the role of the private automobile as the main mode of transportation and moving towards other sustainable modes such as public transport, and use of bicycles and walking.

It is also essential to analyze trip purpose to study urban mobility, as there are considerable differences in travel pattern for different trip purposes (Feng, 2016). Different types of trip purposes are different by nature and generate various travel patterns that further affect mode choice and travel energy consumption (Maharjan et al., 2018). Daily trips are the trips that takes place daily. Home based daily trips, constitute trips with residence, as either origin or destination of a trip and these trips are mostly work and educational trips.

The study area for this research is the Kathmandu Valley, that is the center for economic activities and educational opportunities where the daily trips that constitute work trips and educational trips have a dominant share. This research aims to study how energy efficiency can be achieved by landuse and transport planning considerations, for home-based daily trips for the Kathmandu Valley.

1.2 Statement of the Problem

The study area for the research is the Kathmandu Valley that comprises of three districts, Kathmandu, the capital city, Lalitpur and Bhaktapur with population of over 2.5 million (CBS, 2011) and total area of about 700 sq.km.

In Kathmandu Valley, number of vehicles have increased drastically within the past few decades. In course of 10 years from 2001 to 2011, population has increased by 4.32 % per year from 1.6 million to 2.5 million (CBS, 2001, 2011). Over a period of about 17 years from 2000 to 2017, motorization has increased by about 20% per year, with the total number of vehicles registered, rising from 143,078 to about 1 million (DoTM, 2017). The modal share of public transport has remained fairly stagnant while the share of private vehicles has gone up rapidly (MoPIT/JICA, 2012).

Kathmandu valley is the main center for economic activities and employment opportunities. Work trip has 39% share in overall trip composition, which is the highest of all. Next to work trips, is school trips, having a share of 34%. Other trips that include personal, recreational and shopping trips are having 27

% share (CEN/CANN, 2012). The economic activities occur primarily in the CBD, located around the central region of the valley. Due to the pull factor of the CBD, urban development and population are concentrated around this region. However, with increasing urban sprawl, the settlements are expanding rapidly outwards and as a result, peripheral areas are also getting urbanized in quick succession, which has led to the increased trip distance for the people living in new settlements along the periphery. Therefore, attempts to cut down escalating travel energy and fossil fuel consumption is a major concern for the Kathmandu valley, that is undergoing rapid urbanization and motorization. In addition, Nepal does not have oil production and all commercial fossil fuels are imported from international markets.

1.3 Research Objectives

Main Objective

The main objective of this research is to investigate the influence of Urban Landuse and Urban Transport on the level of energy demand in the context of the Kathmandu Valley for home-based daily trips.

Specific Objectives

- To assess travel behavior of people in commuting their daily trips.
- To analyze how travel behavior and urban form are related to travel energy
- To identify the role of modal shift and mixed landuse on transport energy demand.

1.4 Research Gap

The population of the Kathmandu valley is increasing rapidly and with it, is a steep rise in energy demand. This initiates the need of effective strategies and awareness to promote energy efficiency in urban planning. There are numerous researches done for the valley, on urban form and transport planning, but they have not addressed the mechanism of how travel behavior and urban form affects transport energy consumption. This research attempts to fill this gap with the use of quantitative methods to study the relationship among travel behavior, urban form and travel pattern, and its impact on transport energy, in the context of the Kathmandu valley. Travel behavior studies are relatively new in the context of Nepal, and thus the research in this field is very important, to have a comprehensive knowledge of travel behavior and its impact on the travel pattern and travel energy.

1.5 Scope and Limitations

For this research, home-based daily trips, which includes work and education trips, is studied. These trips have the highest share in trip composition in the present context and accordingly, urban mobility is largely, contributed by these trips. For landuse assessment, residence, educational areas and employment areas were only focused, that are related to work and educational trips.

The role of other trip purposes such as recreational, shopping and other personal trips and also freight transport, are not included in the study. Thus, in landuse study, effect of other landuses on urban mobility and transport energy are not also assessed.

1.6 Significance of the Research

A vital issue for sustainable development is the relationship between transportation and land use. Urban land use and transport are closely inter-linked and is a common wisdom among planners that the spatial separation of human activities creates the need for travel and goods transport, that is the underlying principle of transport analysis and forecasting (Wegener, 2009). Improved integration of land use and transportation planning can reduce the need energy demand by better accessibility, modal shift to public and not-motorized modes and minimizing trip distances (SRPC, 2003).

Planning policies play a crucial role at the city level, that influence the extent of mixing of land use and the level to which development is clustered or concentrated, while at the local and neighbourhood level, the policies can affect the urban density and layout of the city development. While energy consumption is critical to economic and social development, it also is the leading source of pollution and a major contributor to natural resource depletion. As such, improvements in energy efficiency are one of the most important steps we can take towards sustainable development. Energy consumption takes place throughout all economic sectors, and throughout all aspects of our daily lives (Lion & Moavenzadeh, 2003).

This research will help to provide useful information to the people and planners and decision-makers, in taking appropriate steps for achieving our goal to promote energy efficiency in urban pattern and mobility. Urban form and urban transport play a crucial role in the pattern of energy consumption and it is very important to address urban planning from this perspective.

1.7 Structure of the Thesis

The thesis comprises of ten chapters in the following sequence.

Chapter 1. Introduction: This includes the general introduction, background, research problem, research objectives and questions and significance of the research.

Chapter 2. Literature Review: This chapter includes literature review for the study. It covers the topics related to energy demand in the transport sector and how urban landuse and urban transport system influence the transport energy.

Chapter 3. Research Methodology: This chapter describes the research paradigm and research methods used for this research.

Chapter 4. Study Area, The Kathmandu Valley: This chapter describes the current landuse and transport system of the Kathmandu valley and current energy scenario of the transport sector.

Chapter 5. Travel Characteristics of Home-based Daily Trips:

It describes the household characteristics and travel characteristics of the respondents, using descriptive statistics.

Chapter 6. Analysis of Travel Behavior with Socio-Economic Background

This chapter describes the relation between model choice and trip length with respect to their socio-economic and demographic characteristics for work and educational trips.

Chapter 7. Travel Behavior, Urban Form and Travel Energy

This chapter explores the role of urban form in travel energy of the daily trips, using Energy Performance Index as an indicator.

Chapter 8. Development of Urban Transport Model System

This chapter describes the development of the model for different scenarios. It explains the data acquisition, its preparation, the formulation of different stages of the model and its calibration and validation.

Chapter 9. Formulation of Scenarios and their Analysis

In this chapter, scenarios are formulated to study the transport energy in each scenario

Chapter 10. Conclusions and Recommendations

This chapter summarizes the findings of overall research and conclusions and recommendations from the research and areas of further research.

Chapter 2. Literature Review

This chapter covers the literature that includes topics, on general facts about the energy demand in the transport sector and the how urban landuse, urban transport system and neigbourhood planning is related to transport energy in different contexts.

2.1 Global Energy Demand

Improving energy efficiency is one of the quickest, greenest, and most cost-effective ways to address energy security and climate change while ensuring sustainable economic growth (IPEEC, 2019). All countries share common interests in improving their energy efficiency performance and there is abundant potential for local action and international cooperation among them. However, the challenge is great, both for developed and developing countries (SCP, 2016).

As per IEA (2018), global energy demand grew by 2.1% in 2017, more than twice the growth rate in 2016. Global energy demand in 2017 reached an estimated 14,050 million tonnes of oil equivalent (Mtoe), compared with 10 035 Mtoe in 2000. Fossil fuels met over 70% of the growth in energy demand around the world. Improvements in global energy efficiency slowed down drastically in 2017, because of weaker improvement in efficiency policy coverage as well as lower energy prices. Global energy intensity improved by only 1.7% in 2017, compared with an average of 2.3% over the last three years.

Transportation was responsible for 24% of direct CO_2 emissions in 2017. Road vehicles – cars, trucks, buses and two-wheelers – accounted for 77% of both global final energy demand and CO_2 emissions attributable to the transport sector as a whole (IEA, 2018).

2.2 What is Energy Efficiency?

The system is considered as energy-efficient if it provides more services for the same energy input, or the same services for less energy input (Conserve-energy-future, 2019). Energy efficiency in landuse and transport planning deals with the minimization of energy spent in urban mobility by effective distribution of urban activities and use of energy-efficient travel modes such as walking, cycling and public transport.

2.3 Urban Transportation

Urban transportation aims at supporting transport demands generated by the diversity of urban activities in a diversity of urban contexts. A key for understanding urban entities thus lies in the analysis of patterns and processes of the transport – land use system. This system is highly complex and involves several relationships between the transport system, spatial interactions and land use (Rodrigue et al., 2016):

Transport system. It includes the set of transport infrastructures and modes that support urban movements of passengers and freight. It generally expresses the level of accessibility.

Spatial interactions. It is the nature, extent, origins and destinations of the urban movements of passengers and freight. They take into consideration the attributes of the transport system as

well as the land use factors that are generating and attracting movements.

Land use. It is the level of spatial accumulation of activities and their associated levels of mobility requirements. Land use is commonly linked with demographic and economic attributes.

2.4 Urban Landuse

Urban land use comprises which activities are taking place where and their level of spatial accumulation, which indicates their intensity and concentration.

The behavioral patterns of individuals, institutions and firms have an imprint on land use in terms of their locational choice. The representation of this imprint requires a typology of land use, which can be formal or functional. Formal land use representations are concerned with qualitative attributes of space such as its form, pattern and aspect and are descriptive in nature. Functional land use representations are concerned with the economic nature of activities such as production, consumption, residence, and transport, and are mainly a socioeconomic description of space (Rodrigue et al., 2016).

Theoretically, land use displays a number of geometric forms: concentric rings, sectors or wedges, multiple nuclei or small clusters, or a linear formation from a narrow strip to an arc or a corridor. The Burgess model (1925) posits that land uses fall into concentric zones extending outward from the CBD. Two alternative formulations complementing this schema are the sectoral model, arguing that wedges of similar activities radiate from the CBD along transportation corridors, and the multi-nuclei model asserting that secondary CBDs and suburban economic centers emerge to accommodate second-order activities. It appears that these three forms of land-use arrangements can coexist in a single urban area. For example, concentric rings and corridor-type of uses are evident in a polycentric Los Angeles (Wong, 2001).

The rise of subcenters and polycentric urban form is a direct result of continuous urban expansion and shifts in population and employment distribution. As population and employment disperse, they gravitate to suburban centers and transform the old monocentric urban structures into polycentric ones. These centers have a propensity to cluster or distribute loosely in a sectoral form (Wong, 2001).

Land use is often studied in isolation. While land use is of clear interest on its own, it should also be studied in relation to other issues, the most obvious connection is with transport (Duranton & Puga, 2015).

2.5 Energy Efficiency in Urban Landuse and Urban Transport

Energy-efficient transportation needs to be promoted on three different levels as per Baedeker and Huging (2012). According to them, there is potential to achieve greater energy efficiency for individual vehicles (vehicle efficiency) and trips (travel efficiency), as well as the whole transport system (system efficiency). Corresponding to these three levels of energy efficiency in transport, three basic strategies exist to improve energy efficiency:

- Avoiding increased transport activity and reducing the current demand for transport;
- Shifting demand to more efficient modes of transport;
- Improving the vehicles and fuels used.

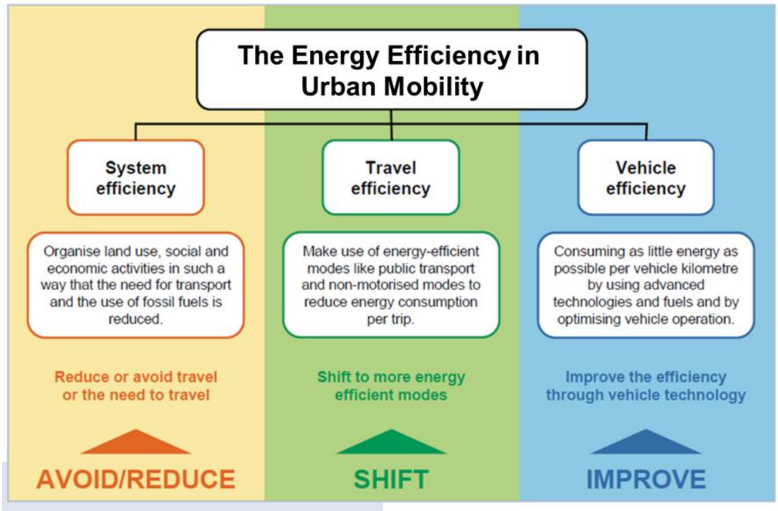


Figure 2.1: The Energy Efficiency System

Source: Baedeker and Huging (2012)

2.5.1 System Efficiency

System efficiency is related to the generation of demand for transport and the different modes of transport. Land use has a substantial effect on travel demand and travel patterns. Land use planning is necessary to assure sustainable urban and regional development. Urban space serves a variety of human needs: housing, working, social interaction, leisure, and mobility of persons and goods. Human beings also need nature within their living areas, together with greeneries for recreation and relaxation. The distribution pattern of housing, working, shopping, leisure, and other activities in a city, determine average trip distances, that is linked with urban transport.

2.5.2 Travel Efficiency

Travel efficiency relates to the energy consumption of different modes of transport. The main parameters of travel efficiency are the relative preponderance of the different transport modes (modal split) and the load factor of the vehicles. An effective way of enhancing energy efficiency is to encourage travelers or shippers to use more efficient forms of transport, such as public transport and non-motorized vehicles. In general, private motorized modes of transport are much less energy-efficient than public transport. Other important alternatives include non-motorized forms of transport that do not need any fuel at all. Per capita energy consumption depends to a great extent on the occupancy rate of the vehicles used.

2.5.3 Vehicle Efficiency

Reducing the per-kilometer fuel consumption of vehicles increases their efficiency. This can be done with technology and design improvements, but also through efficient driving techniques. Measures can be clustered into three categories:

- Improvement of existing vehicles;
- New fuel concepts;
- Development of new car concepts

The strategy of improvement is not only relevant for private cars, but also for freight and public transport. Specific measures for passenger cars include the use of lightweight materials, downsizing (reducing the volume of the engine and size of the car) and/or using hybrid engines. A combination of such measures significantly reduces energy

2.6 Urban Form and Urban Transport Energy

Stead and Marshall (2001) have identified nine aspects of urban form, ranging from regional strategic planning level down to specific local planning issues at the neighbourhood scale. These are

a. Distance of residence from the urban center
b. Settlement size
c. Mixing of land uses
d. Provision of local facilities
e. Density of development
f. Proximity to transport networks
g. Availability of residential parking
h. Road network type
i. Neighbourhood type

Lefèvre (2009), pointed out urban population density and urban structure as the main determinants of urban transport energy consumption and these two factors have an influencing role in determining the pattern of urban mobility. These are further discussed below:

2.6.1 Average Urban Density

Newman and Kenworthy's famous hyperbola "Urban population density and transport-related energy consumption" shows a high correlation (R^2 = 0.86) between average urban density and intra-urban transport-related energy consumption per capita. These results are due to density being highly correlated with modal distribution and the intensity of automobile use.

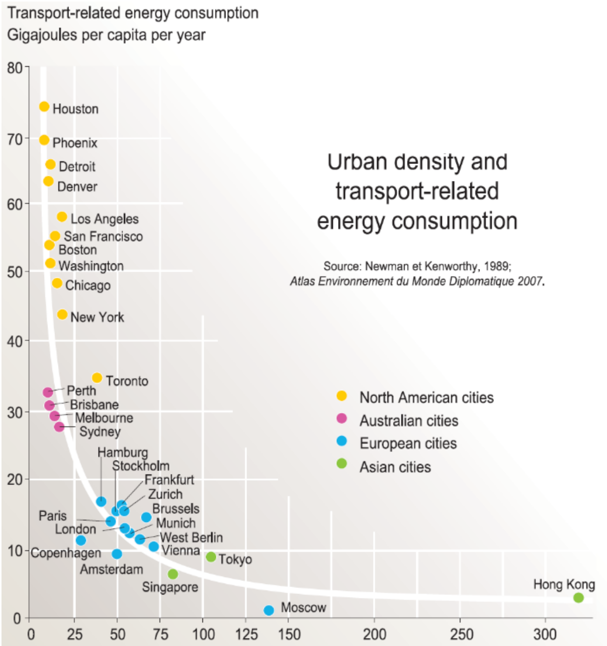


Figure 2.2: Urban density and transport-related energy consumption

Source: Newman and Kenworthy (1989)

These results show that the density is highly correlated with modal distribution and the intensity of automobile use, as shown in Table 2.1.

Table 2.1: City typology based on average urban density and transport

Global urban density	**Low**	**Medium**	**High**
	< 25 hab/ ha	**50 - 100 hab/ha**	**> 250 hab + /ha**
Modal distribution	MPT:80%	MPT: 50%	MPT:25%
	PT: 10%	PT:25%	PT: 50%
	NMT: 10%	NMT: 25%	NMT:25%
Automobile use (km/ pers/ yr)	> 10,000		< 5,000
Public transport use (trips/ pers/ an)	< 50		> 250
Petrol consumption for transport (MJ/ pers/ an)	> 55,000	35,000 - 20,000	< 15,000
Representative Positions	North American and Australian Cities	European Cities	Asian Cities

MPT: Motorized Public Transport. PT: Public Transport. NMT: Non-Motorized Transport. Density: number of inhabitants and jobs per hectare of net urban surface (omitting green and water surfaces)

Source: Newman and Kenworthy (1999)

Low-density metropolitan areas reveal an almost total dependence in automobile use and total transport-related energy consumption is considerable (frequently more than 55,000 MJ/person/yr.). High-density metropolitan areas have a balanced tri-modal distribution with a considerable emphasis on the use of public transport (from 40 to 60% of travel). The total transport-related energy consumption is four to seven times less than in low-density cities. European cities occupy an intermediate position in terms of urban density: between 40 and 120 (inhabitants+jobs) net per hectare. Modal distribution is somewhat balanced, but cars are still very dominant, particularly in peripheral low-density sub-urban areas. Total transport-related energy consumption is two to four times lower than in low-density cities. While the general conclusions put forward by Newman and Kenworthy (1999) are not disputed, they have been criticized, particularly, because the spatial distribution of activities and households are not investigated. An analysis of average density may not be sufficient to explain the relationship between the structure of a city and transport energy consumption. In particular, factors such as the relative location of residents, workplaces, services and amenities, transport options and network connectivity have a significant impact on the number and length of trips (Lefèvre, 2009). Bertaud (2001) has argued that the density gradient – i.e., the rate of density change from the center to the periphery – is a more important determinant of transport energy and the urban spatial structure. Public transport is incompatible with low-density and dominantly polycentric urban structures (Figure 2.3). Investment in public transport infrastructure is sustainable if housing and employment density are sufficient within the catchment area of transit stops (800 meters or a 10-minute walk). Other research supports the finding that dense and moderately polycentric cities are compatible with an effective public transport system (Bertaud & Malpezzi, 2003).

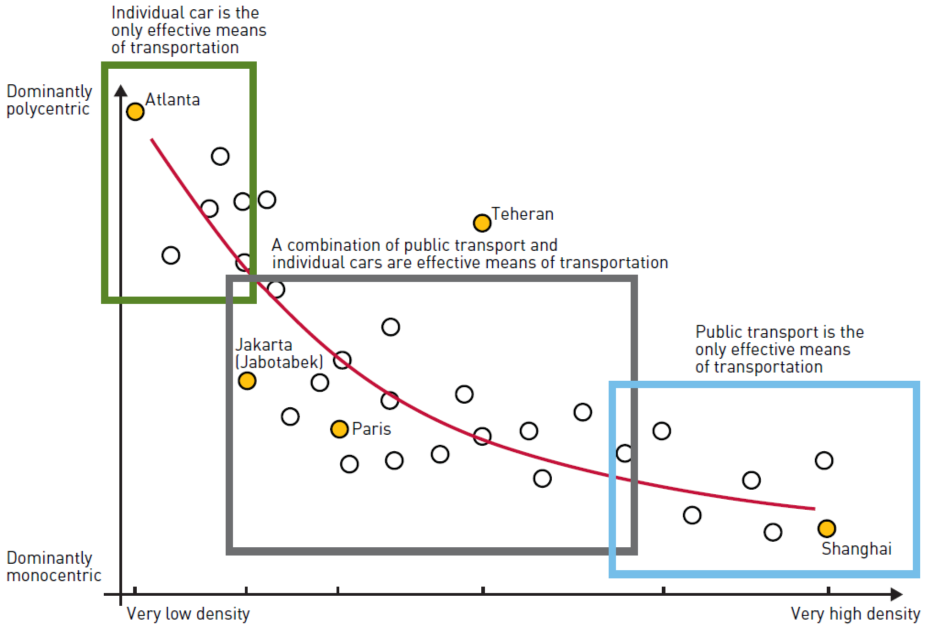


Figure 2.3: Relationship between spatial structure and the effectiveness of public transport

Source: Bertaud and Malpezzi (2003)

2.6.2 Urban Structure

2.6.2.1 The spatial distribution of travel

The most inspired economic model of urban dynamics in urban form is the monocentric city with a "Central Business District" (Lefèvre, 2009). Findings of Alonso (1964), Mills (1967) and Muth (1969) on density gradients in urban areas are based on a monocentric city assumption. However, with time, it became evident that many city structures do not follow the monocentric model and that trip generating activities are distributed in "clusters" throughout the urban area and outside the CBD. Bertaud (2001) identifies four cases in point to describe the spatial distribution of trips, in a city, which are

a. The monocentric model
b. The polycentric model: The urban village version
c. The polycentric model: The random movement version
d. The mono-polycentric model: Simultaneous radial and random movements

Figure 2.4 shows, the schematic representation of trip patterns within a metropolitan area for each model.

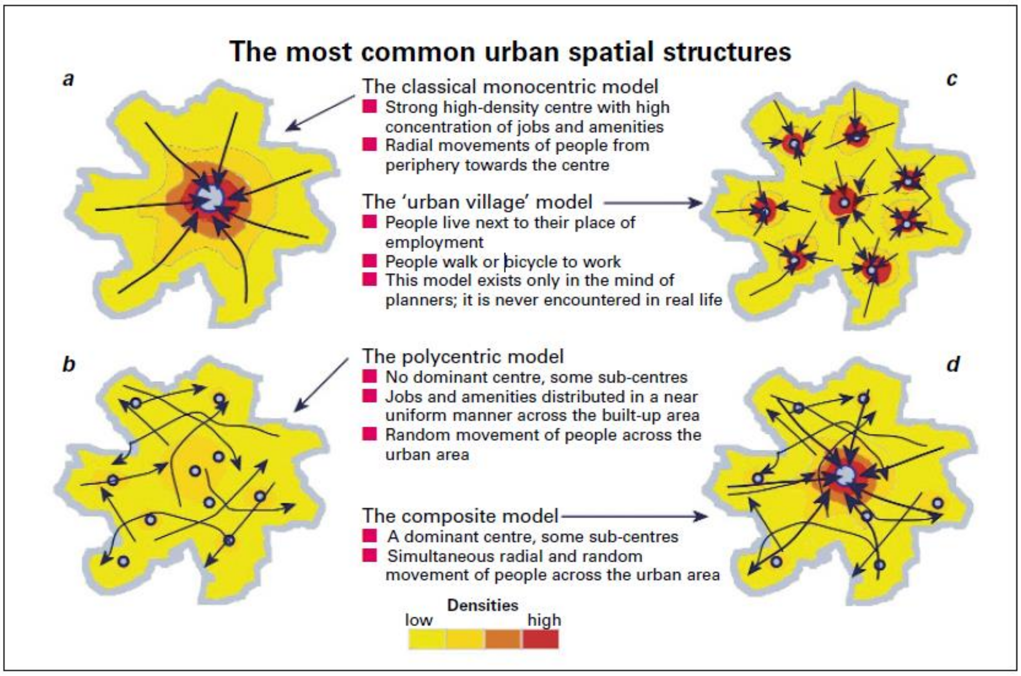


Figure 2.4: Typology of urban movement

2.6.2.2 Eco density - Vancouver, Canada

In 2008, the city council of Vancouver adopted an Eco-Density Charter, which commits the city to strive for environmental sustainability in all planning decisions. Greater density will be created especially in low-density areas and along transit routes. Areas of mixed usage are to be developed, where shopping, employment and public amenities are within walking distance of each other. The aim is to create high-density areas that are attractive, more energy-efficient and have a low ecological footprint (CCPA, 2008).

Metro Vancouver is a federation of 21 municipalities, one Electoral Area and one Treaty First Nation that collaboratively plans for and offers regional-scale services. Metro Vancouver has a close link with municipalities, TransLink, senior governments, and other stakeholders to coordinate complex land use and transportation decisions. The region's goals and actions are formulated in regional plans and strategies that include Metro 2040, Metro Vancouver's Integrated Air Quality and Greenhouse Gas Management Plan, TransLink's Regional Transportation Strategy, and the Regional Transportation Investment Vision by the Mayors' Council on Regional Transportation (Metrovancouver, 2017).

Metro 2040 improvises coordinated land use and transportation planning by encouraging action at many levels of government (Metrovancouver, 2017).These are

- Reduction in parking requirements by municipalities in new developments within Urban Centers and Frequent Transit Development Areas
- Improvement of municipal infrastructure to support transit, carpooling, cycling, and walking
- Assessment of how new communities, infrastructure and transportation affect public health, including air quality and noise impacts
- Preparation of TransLink and implement a regional goods movement strategy
- Provision of support safe and efficient goods movement by Provincial and federal governments by protecting rail rights-of-way and access points to navigable waterways.

2.7 Link between urban structure and efficiency of various travel modes

2.7.1 Mass Transit Oriented City Development

Transit Oriented Development (TOD) is a significant way of improving the effectiveness of transit as well as supporting community goals and improving accessibility (Cervero et al., 2004). TOD is a compact, mixed-use development within an easy walk of a transit station. Its pedestrian-oriented design encourages residents and workers to drive their cars less and ride mass transit more (DVPRC, 2016). It has been widely recognized as an important planning paradigm to create attractive, livable and sustainable urban environments. The purpose of TOD is to place residential and commercial development near to existing (or occasionally, extended) transit infrastructure, that provides an alternative to automobile trips. Most TOD development has coverage of roughly a half mile – or less than 10 minutes walking distance – from its nearest rail or bus station (CMAP, 2016).

BRTS is a subset of TOD implementation and it plays a vital role in promoting the use of mass transit. BRTS systems, which are less costly than other forms of mass transit, such as metros, can meet these cities' traffic demand Transit and land-use integration is one of the effective means of reversing the trend of automobile-dependent sprawl and placing cities in developing countries on a sustainable pathway (Suzuki et al., 2013).

2.7.1.1 TOD: Curitiba, Brazil

Curitiba is the seventh largest city in Brazil, with a population of approximately 1.8 million, and ranks fourth in terms of GDP. Curitiba presents a striking example of how a coherent set of policies can transform a city by encouraging the development of an impressive and economically successful low-carbon, energy-efficient transport system. Since the 1960s, the city has been pursuing transit-oriented development. By developing the city linearly along its arteries, the downtown area ceased to be the primary focus of everyday transport activity. This helped to avoid peak hour commuter congestion. Employers offer transport subsidies for their low-skilled and low-paid workers.

Car-oriented development has not occurred, and there is only limited parking in the city centre, which discourages drivers from clogging the area. The last, and perhaps most eye-catching element of Curitiba's development is a highly efficient bus rapid transit system along the arterial roads, which has ushered in a modal shift from car travel to bus travel. Compared to the people of other Brazilian cities of comparable size, Curitibans consume 30 % less transport fuel. Overall, the policy package for energy-efficient transport has proved very successful in Curitiba (Bongardt, 2010).

Figure 2.5: Public Transport System in Curitiba

Photo Courtesy: Inhabitat (2007)

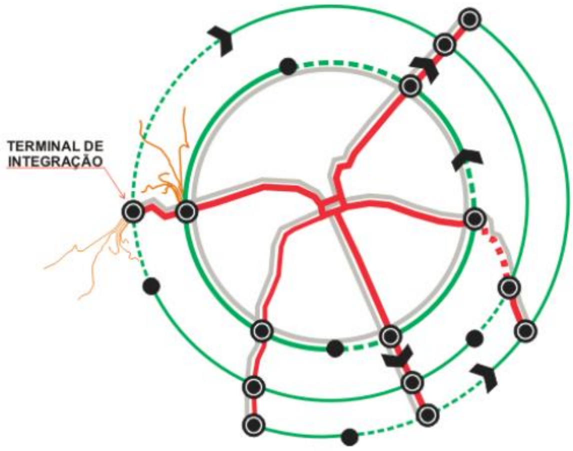


Figure 2.6: Radial and Circular Bus Routes in Curitiba

Source: Pienaar et al. (2005)

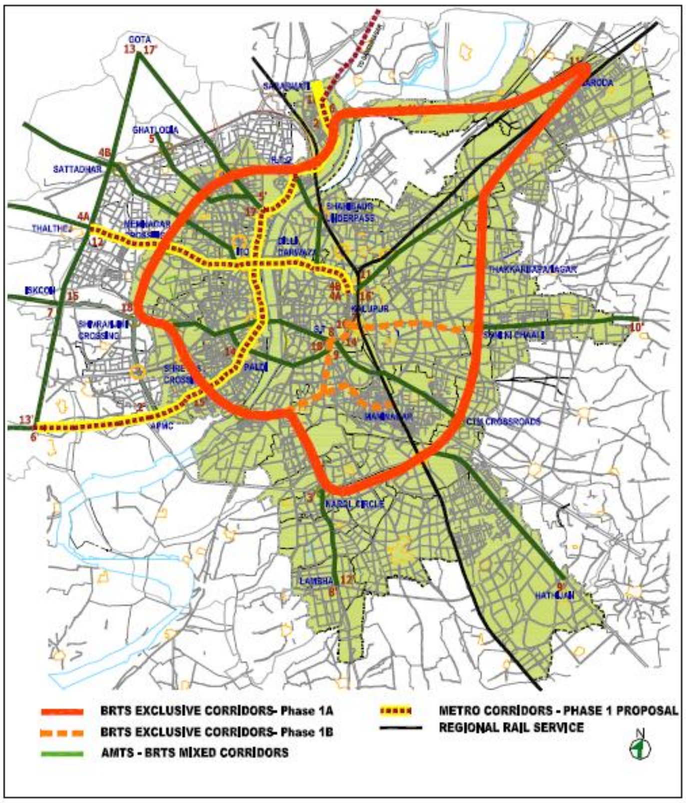
2.7.1.2 TOD: Bus Rapid Transit System, Ahmedabad, India

(UNFCCC, 2019).

Ahmedabad is a city with a population of more than 5.5 million where commuting options were limited. Commuters have options, either to drive, take the municipal bus (which was overcrowded) or auto rickshaws. An affordable public transport network that would allow people to reach their destinations in the quickest possible time, in the possible comfortable manner, was required. The Ahmedabad bus rapid transport system (BRTS) served to be that system.

Figure 2.7: BRTS System in Ahmedabad

BRTS system is given the name “Janmarg” or “the people’s way”, that began operation in October 2009. It has grown from 12 km of route to 45 km and is still growing. Number of passenger have also grown, from 18,000 at the time of launching, to nearly 130,000 in the present context.



Map 2.1: BRTS Network in Ahmedabad

Source: AMC et al. (2007)

Janmarg is developed as a strategic intervention, to increase the share of transit, improve air quality and help the city remain compact. Its main features are: a closed BRT system with median bus stations; specially designed buses with right-hand side doors and bus floor and bus station platform heights matching; a complete renovation of the right of way for inclusion of cycle tracks and pedestrian facilities; a commercial operating speed of 25 km/hr enabling faster commuting; and off-board fare collection. Janmarg has made several innovations in the planning and designing of the system including a fully ‘pedestrian and transit’ only street section at one location and a one-way bus lane to manage narrow right of way. Overall, Janmarg has demonstrated that BRT system to be effective in India. The activity has well promoted public transportation in Ahmedabad and in the country as a whole.

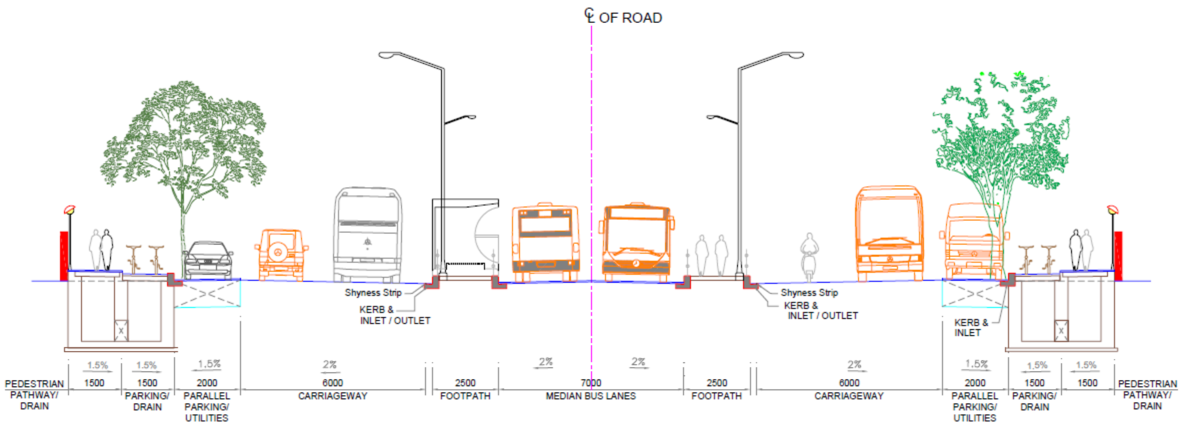


Figure 2.8: Typical Road Cross Section – ROW: 35m

Source: AMC et al. (2007)

2.7.2 Non-Motorized Transport (NMT)

A broad definition of NMT would be any kind of a transport system that would not run on a motor. Some such examples are walking, cycling, rickshaws etc. Including these modes is very important should a city aim to be sustainable in terms of transport (GTZ, 2010). Most of the developing cities are striving hard to improve their transport situation. In this course, several new transport investments are being made such as implementing rail-based mass transit systems, bus-based systems and also improving the road conditions and even expansion of the existing road space. In this urgency of improving the urban transport system one particular yet a very important part of the whole urban transport fabric is often overseen or neglected feeling it is not important. This sector is the ―Non-Motorized Transport (GTZ, 2010).

Some of the benefits of using NMT are as per GTZ (2003) are:-

- Pedestrians, bicyclists, and cycle rickshaw passengers generate no air pollution, no greenhouse gases, and little noise pollution
- Bicyclists and pedestrians are more efficient users of scarce road space than private motor vehicles, helping to combat congestion
- Bicycling and walking are the most efficient and environmentally sustainable means of making short trips
- Promoting safe bicycling and walking are crucial to improving the accessibility of the poor, and social cohesion
- Bicycling and walking provides important aerobic exercise which is important to combating high cholesterol, obesity, diabetes, and depression

2.7.3 NMT: Cycling in Netherlands

Cycling is a ubiquitous mode of transport in the Netherlands, with 31.2% of the people listing the bike as their main mode of transport for daily activities (as opposed to the car by 48.5% and public transport by 11% (EC, 2014). Cycling has a modal share of 27% of all trips (urban and rural) nationwide (MoTPW, 2009). In cities this is even higher, such as Amsterdam which has 38%, though the smaller Dutch cities well exceed that: for instance, Zwolle (pop. ~123,000) has 46% and the university town of Groningen (pop. ~198,000) has 31% (Walljasper, 2013). This high modal share for bicycle travel is enabled by excellent cycling infrastructure such as cycle paths, cycle tracks, protected intersections, ubiquitous bicycle parking and by making cycling routes shorter, quicker and more direct than car routes.

In the countryside, a growing number of inter-city bicycle paths connect the Netherlands' villages, towns and cities: some of these paths are part of the Dutch National Cycle Network, a network of routes for bicycle tourism which reaches all corners of the nation.

Figure 2.9: Cycling in Netherlands

2.7.4 Automobile City

In automobile-dependent cities, the majority of public investment goes to automobile-related facilities, such as roads and parking, taking money away from the upgrading of public transit or nonmotorized transport facilities, such as footpaths, bike lanes, and bike parking.

Activities are hardly mixed at all in the available space. Jobs are concentrated in the CBD and citizens live on the outskirts (Lefèvre, 2009). Cars are the dominant means of transport and the intense segregation of activities in the available space does not allow for the use of slower conveyances. Public transport is marginalized and ends up being provided solely for the use of people who cannot drive or cannot afford to. The heart of the city is often entirely given over to a high density of commercial activities. Shops, services and industry are separate and scattered throughout the metropolitan area. Journeys cover long distances and are highly scattered (Newman, 1996).

Low-income residents benefit disproportionately from investments in public transit and bikeways, because they are much more reliant on these relatively low-cost modes than other income groups.

Directing scarce national, regional, and municipal revenues to roads and highways does little to improve the livelihoods of people who do not own cars (Suzuki et al., 2013).

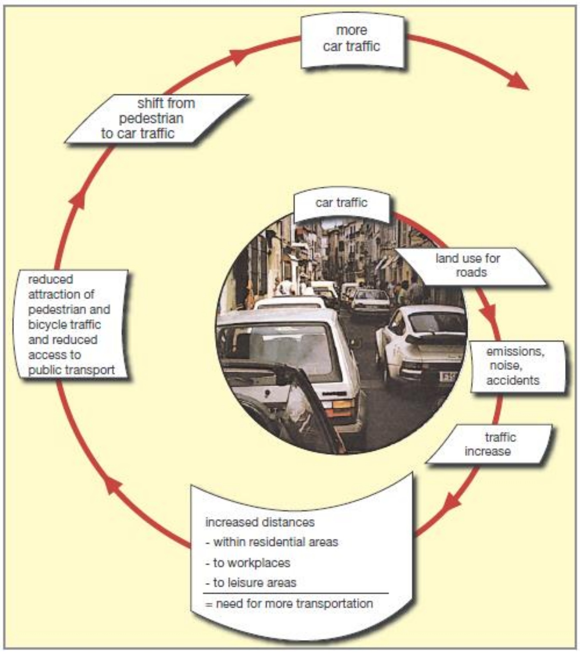


Figure 2.10: Traffic and land use interaction (traffic spiral)

Source: Petersen and Schafer (2004)

Figure 2.10 illustrates the "vicious cycle" of car traffic leading to deteriorated living conditions, heading to sub-urbanization and transforming the rural areas into settlements, in which households are dependent on the private car for daily mobility. Increasing car use again follows the traffic spiral, when more roads are built to satisfy car commuters, transforming precious urban land into wasteland as shown in the Seattle photo (Figure 2.11). North American urban development models in particular do not provide good guidance for densely populated Asian and Latin American regions.

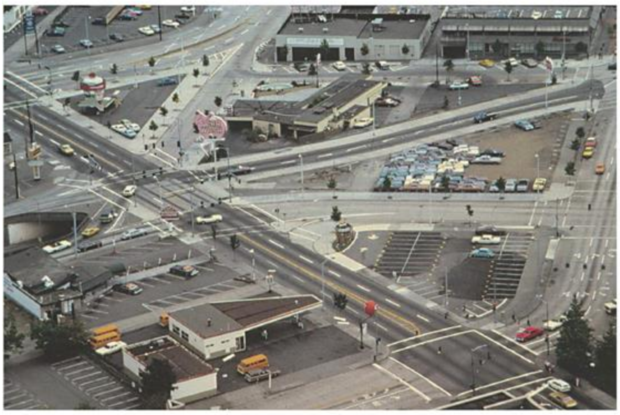


Figure 2.11: Seattle, an example of US-style of urban land use.

Photo Courtesy: Petersen and Schafer (2004)

2.7.5 The Motorcycle City

Motorcycles play a growing role in mobility in cities of the South, particularly in South-East Asia, where its usage is quite high, with an increasing ownership rate of the motorcycles per household (Lefèvre, 2009). When traveling by motorcycle, the speed of travel is often higher, as compared to other modes of transport and time saving is especially important in a situation of traffic jam, which is common in megacities. In urban areas, it has also the advantage in parking as it takes up less space to park which makes it further convenient in its use. Motorcycles are therefore an obvious choice when street space is limited and thus the name "the motorcycle city" is suggested by Barter (1999).

2.8 Landuse and Transport Integration for Energy Efficiency

Urban transport, especially passenger transport, forms a significant proportion of global energy consumption and is also a major contributor to greenhouse gas emissions (Zhou et al., 2013). As per United Nation (2018), the transport sector accounted for 25% of the world total's total energy consumption demand in 2015. Currently, most of the developing countries have progressed to rapid urbanization. Urban built-up areas are undergoing dramatic land use conversion due to urban population growth, along with the rapid expansion of the transportation system (Sekar & Gangopadhyay, 2017). Growing urbanization and increase in urban sprawl also lead to a rise in urban transport energy consumption level with an increase in commuting distance.

Cities, where economic activities are booming, have an urgent need to promote sustainable transport in order to create pathways towards sustainability. Along with rapid city growth, more and more people, especially the younger generation, pursue modern lifestyles that are high in energy consumption and CO_2 emissions (Dimitriou, 2006).

Urban mobility patterns and related energy consumptions are affected by the dimension, density, design and transport level of service of the city, as well as by socio-economic features (Inturri et al., 2016). Urban form has a crucial role in determining travel behavior, characterized by mainly trip purpose, trip distance, trip frequency, modal choice, which are the main determinants of transport energy consumption (Banister et al., 1997). Studies from several authors have shown that there is an association between urban form and travel behavior (Cao et al., 2009; Ewing & Cervero, 2010; Lefèvre, 2009; Stead & Marshall, 2001).

Interaction between land use and transport is linked with the distribution of land use, mainly residential, commercial and industrial areas, that influence living, working, shopping, and leisure activities (Alqhatania et al., 2012). Intermixing housing, offices, retail shops, and other urban amenities in close proximity to public transit stations integrates long-distance travel by transit and short-distance, within-neighborhood travel by foot (Suzuki et al., 2013). Mixed land use is particularly an important element of Transit Oriented Development (TOD). When planning new urban areas, planners should pay close attention to the spatial relationships between different transport route types and urban land uses (Ma et al., 2018).

However, there are many issues concerning landuse, causing controversies among many of the researchers. Some of them advocate and promote the mixed landuse idea, while others prompt to use segregation due to many drawbacks, that resulted from the mixed use (Nabil & Eldayem, 2013).

Newman and Kenworthy (1999) have attempted to explore the connection between urban density and travel energy. In their research, they found a strong inverse relationship between urban density and transport consumption, which was based on data from 32 cities located in different parts of the world. According to them, low-density metropolitan areas exhibit an almost total predominance of automobile use and the total transport-related energy consumption is considerable. High-density metropolitan areas are more favourable to public transport.

Similarly, research by Banister et al. (1997) applied population density as the urban form variable and their result revealed that there were significant relations between urban form and energy consumption. Likewise, the study by Susilo and Stead (2008) showed that commuters who live in denser urban areas have less energy consumption compared to commuters who reside in less urbanized areas.

Many other scholars have also pointed to the fact that people in high-density areas have short trip length and less car use, preferring public transport (PT) and non-motorized modes of transport (NMT), such as walking and bike riding, with positive implications to the environment (Alford & Whiteman, 2008; Bertaud & Malpezzi, 2003; Cervero & Kockelman, 1997; Steiner, 1994). However, mode choice is also affected by the level of service and accessibility provided by public transport, by car ownership rate and by the transport demand measures adopted to limit the use of cars (Inturri et al., 2016).

On the contrary, Kitamura et al. (1997) and Van de Coevering and Schwanen (2006) had a different conclusion. According to them, urban density is not the main factor for travel energy consumption and their findings revealed that the impact of density on travel pattern is negligible. Fang (2008) also revealed in his study that the miles driven by cars remain virtually unaffected by density.

Distance of residence from the urban center is one of the important aspects of urban form that influence travel pattern (Stead & Marshall, 2001). Increasing distance from home to the urban center is associated with the increase in travel distance and increasing proportion of car journeys, together with the rise in transport energy consumption (Næss et al., 1995).

Low-density population leads to increased travel distances to and from the city center, where employment density is high (Steiner, 1994). According to Naess (2012), a central location of employment opportunities could also be expected to contribute to lower energy consumption for transport, for areas close to it. The reason for this is the accessibility of public transport, that is usually the highest in the central parts of the city. In addition, congestion and less availability of parking space in downtown areas may cause a number of potential car commuters to leave their car in the garage at home. Distinct from this, suburban jobs are often poorly accessible by transit, while access by car is easy with less congested roads and usually ample parking. However, Bento et al. (2005) found that the effect of urban sprawl and transit availability have only modest effects on the mode choices and annual vehicle miles traveled, in urban areas of the United States.

It is also required to look at the travel purpose along with the urban form. Different types of travel purposes differ by nature and generate various travel patterns that further affect mode choice and travel energy consumption (Maharjan et al., 2018). So, it is important to study different trip purposes, as there are considerable differences in travel pattern for each trip purpose (Feng, 2016).

Even though a number of studies have looked at the relationship between urban form and travel behaviors, yet the relationship is hard to quantify (Buchanan et al., 2006). Despite mixed findings, there has been a growing recognition that changes in urban form characteristics have a significant impact on people's travel behavior (Maharjan et al., 2018). Energy efficient transport systems constitute a broader scope and more context-based and as such efficiency solutions in one city may not be the best solutions in another (IEA, 2013).

2.8.1 Job – Housing Balance

The concept of Job/Housing (J/H) balance was initially floated by Cervero (1989). Since then it has been much into debate and most researchers, policy analysts and environmentalists support the idea as an efficient tool to reduce commute time and distance. The aim of the Jobs/housing balance is to provide an adequate provision of employment in a defined area that generates enough local workers to fill the housing supply. Many studies have observed the link among commute to work, J/H balance, land use mixes and residential preferences (Buliung & Kanaroglou, 2002; Layman & Horner, 2010; Small & Song, 1992). However there are contrasting view as well whereby, some research suggests that there is little evidence on the direct or linear relationship between Job-housing balance and Vehicles Miles travelled and the link between where people decide to live and where they choose to work is complex, and may be a weak determinant of job access considerations (Crane, 1999; Giuliano, 1991).

2.8.2 Urban form and Educational Trips

A wide range of factors has been found to be associated with active school commuting. Stewart (2011) review of 42 studies found 480 correlates including: distance to school, family income (access to private transport), concern about traffic and crime en route, parental views on walking, cycle use and family timetables. Urban form has both a direct effect on mode of travel choice and, by influencing parental opinion, an indirect effect.

The rise in the volume of road traffic associated with increased private car use has also led to rising concerns about road safety, which has, in turn, contributed to decreasing child independence and increased parental surveillance. Parental strategies to cope with this dual challenge often most conveniently involve driving children to school en route to work. All of these factors have combined to produce a highly complex pattern of travel from home to school characterized by, and enabled by, growth in the use of motorized forms of transport (Easton & Ferrari, 2015).

Notwithstanding the effect of distance, the choices that children (and their parents) make with regards to school commuting may depend crucially on the interaction of several factors operating at a number of levels. Neighbourhood-level factors, which include characteristics of the urban form and structure, may have a range of direct and indirect effects on travel behavior (Easton & Ferrari, 2015).

2.9 Travel Behavior

Travel behavior can generally be referred to as the study of what people do over space and how people use transportation (Hayes, 1993). Travel behavior is mainly characterized by trip purpose, trip distance, trip frequency and modal choice, and the urban form has a crucial role in determining travel behavior (Banister et al., 1997). There are also several studies that have emphasized the fact that socio-demographic variables have a significant impact on travel behavior (Hsieh et al., 1992; Taylor et al., 1993; Teaff & Turpin, 1996).

Urban transport system is constituted by the accumulation of travel behavior of all commuters. Travel behavior is more context specific and it needs to be explicitly studied as travel behavior of one area cannot be generalized to another area.

2.9.1 Relation of Socio-economic and Demographic characteristics with Travel Behavior

Many research done in studying travel behavior emphasizes gender, household composition, income, occupation and vehicle ownership as significant factors in influencing travel behavior (Best & Lanzendorf, 2005; Curtis & Perkins, 2006). Many studies have investigated the relationships between work patterns, time-use and travel behavior (Aguiléra, 2008; Vilhelmson & Thulin, 1991).

Gender is one of the significant factors in accounting for differences in mobility and travel behaviour. The existence of the links that exist between gender, mobility and sustainable development has only recently begun to emerge in the literature on gender and mobility. This is partly because the unavailability of gender-differentiated statistics makes it difficult to understand gender differences relating to the reasons for making journeys, journey frequencies, distance traveled, or mobility-related problems in accessing services and employment (CIVITAS, 2014).

The reason behind the gender differences in travel behavior have been the subject of a variety of interpretations (Hanson & Johnson, 1985). Hanson and Johnson (1985) argued that women’s shorter trip distance is mainly due to spatial and economic factors that include lower average incomes, the location of female-dominated occupations in metropolitan areas, and women’s greater dependence on public transit. While economic and spatial factors play a major role in women’s home and work location choices, commuting patterns, and involvement in employment, a number of researchers have argued that a difference in division of power and labour in the household is a crucial determinant of gender variation in travel behavior (Hanson & Pratt, 1990; Madden, 1981; Preston et al., 1993). Many research on gender travel characteristics revealed that the difference exists between men and women mobility patterns in both developed and developing countries, more specifically, with respect to modal choice, distance travel and frequency of trips to different locations (Oyesiku, 2002; Peter, 2000).

While gender differences in travel behavior are relatively well known in developed countries; this phenomenon has got far less attention in the developing world, where it is believed that the differences might be wider and even unique in some aspects (Babinard & Scott, 2009; Duchene, 2011; Nobis & Lenz, 2004; Peter, 1998). A study of the gender and travel behaviour in towns and cities in developing countries will allow the planners, policy formulators and city managers to sort out appropriate and sustainable solutions to problems on urban mobility of women and the possible direction of future development (Adetunji, 2012).

The difference is seen to differ as per place and context. Differences in travel behaviour by gender was recognized in many papers with women identified as being more likely to assume sustainable travel behaviours, as compared to men (Curtis & Perkins, 2006). Polk (2004) found a significant relationship between sustainable travel patterns and gender in studies of travel behaviour in Sweden. Women were more willing to cut down their use of the car than men, more positive towards minimizing the environmental impact of travel modes and more optimistic towards ecological issues. Polk (2004) concludes by stating that gender must be considered as a factor in attitudinal research on car use.

Moriarty and Honnery (2005) investigated urban travel in all Australian State capital cities. Although the main emphasis was on studying the relationship between the distance from place of residence to the Central Business District (CBD) of each city and the impact on travel behaviour, their study revealed that women on average travel less often and for shorter distances than men.

In one of the study of travel behaviour and constraints of low-income households and females in Pune, India, Astrop et al. (1996), found that there are variations by gender in household trip frequencies, distance traveled and modal choice. According to them, women are mostly dependent on foot for short trips and rely on public transport, particularly bus when commuting longer, while men depend on motorcycle and scooter to supplement family-owned vehicles to meet their travel demands.

Extent of mobility also varies with gender. According to research carried out by Adeel et al. (2014) in Pakistan, women made only half the trips as men do and women spend more time in travel using public transport, which makes their leisure time short. He accounted that socioeconomic variables like age, marital status and main role of respondents seem to affect the trip characteristics of women more than men. However, in the study carried out by Conger (2001) in Knowville, USA, it was observed that women made more trips than men do, at the ratio of 3.61 to 3.29. So, it is quite evident that the gender difference in travel behavior is subjected to vary with place and social environment. This initiates the need to study the difference, specific to the area, to have detailed understanding of the role of gender in the way of travel.

When it comes to mode choice, workers are using more motorized modes on average, than the rest of the adult population. Indeed, the private mode is often the most relevant mode to reach the workplace mainly when it is located in remote subcenters (Aguiléra, 2005). The share of kilometers traveled daily, particularly by private modes by workers is quite important and hence policies promoting a balance between employment and residence location are to be given the prime importance to reduce travel demand and particularly in the use of car within metropolitan areas (Korsu & Massot, 2005).

Age is also one of the factors, influencing travel behavior, but it is often difficult to separate the age factor alone as other factors also play a role simultaneously (Newbold et al., 2005).

Vehicle ownership has a significant effect on the level of private vehicle use. There are numerous factors associated with the ownership of vehicles in a household like income group, spatial dimension, household structure and household size. Income group is one of the main factors in vehicle ownership. Vehicle ownership is generally high among high-income groups (Boarnet & Sarmiento, 1998; Dieleman et al., 2002; Schwanen et al., 2002). Thus, use of private vehicle is also often high among high-income groups. In addition, the average distance to the workplace is generally greater for high-income workers (Aguiléra et al., 2007).

2.10 Indicators for Urban Transport Energy Consumption

It is essential to monitor the impacts of policy initiatives to ensure that the respective energy savings are realized, and so that adjustments can be made if necessary. To measure the success of energy efficiency strategies and to quantify the energy savings achieved, it is necessary to use several indicators, which together describe the performance of the transport system at all three levels of efficiency (Baedeker & Huging, 2012).

If indicators are assessed continuously, it is possible to monitor the long-term development of the transport system. Most indicators are based on local statistics, or they require passenger and household surveys. Limited data availability often impedes proper planning or adequate evaluation of energy efficiency measures.

Some of the main indicators assessed for analysis are described in Table 2.2.

Table 2.2: Indicators for Energy Efficiency of Transport

Category		Indicator		Description
1.	**System Efficiency** (urban structure, socio-economic factors)	1.1	Per Capita Trip Rate (PCTR)	Total number of trips undertaken by all the modes in an area divided by the total population of the area. Higher PCTR value implies that large numbers of trips are being undertaken in an area/city, hence signifying higher levels of mobility.
		1.2	Transport Energy Use per Capita (MJ/Person)	Total energy consumed by transport sector divided by total population of the study area.
		1.3	Average Trip Length	Distance people have to travel on an average. It can be defined as total trip length commuted in a day divided by total number of trips carried out in the city.
2.	**Travel Efficiency**	2.1	Average Occupancy	Average number of passengers traveling in a travel mode.
		2.2	Modal Share	Distribution of trips made by transport mode
		2.3	Energy Use per Passenger-km (MJ/pkm)	Energy consumed by a single passenger to travel one kilometer using a particular transport mode.
3.	**Vehicle Efficiency**	3.1	Fuel Efficiency	Distance the vehicle travels per unit volume of fuel consumed
		3.2	Energy Consumption per Vehicle-km (MJ/km)	Energy consumed by a vehicle, for every km driven.

Source: Baedeker and Huging (2012)

2.11 Energy Efficiency at Neighbourhood Level

The neighbourhood concept is perhaps one of the main basis for planning that shaped the urban form of the twentieth-century city in many countries (Patricios, 2002). The term neighbourhood is used to describe the sub-division of urban or rural settlement, which comes into existence, whenever a group of people shares a place (Meenakshi, 2011). Radburn Concept was originated from the design principles of Clarence Stein and Henry Wright from their neighbourhood planning of New Jersey in 1928 and their concept for the neighbourhood is referred to as the Radburn model. The intent was to create a self-contained settlement that is environmentally friendly, restricting the use of automobile with basic amenities nearby, within walking distance.

2.11.1 Radburn Concept

The urban design principles of Stein and Wright included the idea of a superblock of residential units grouped around a central green, the separation of vehicles and pedestrians, and a road hierarchy with culs-de-sac for local access roads. A cluster of superblocks was to form a self-contained neighbourhood. A group of neighbourhoods would then comprise the city (Patricios, 2002).

The primary innovation of Radburn was the separation of pedestrian and vehicular traffic. This was accomplished by doing away with the traditional grid-iron street pattern and replacing it with an innovation called the superblock. The superblock is a large block of land surrounded by main roads. The houses are grouped around small cul-de-sacs, each of which has an access road coming from the main roads (Rathore, n.d.).

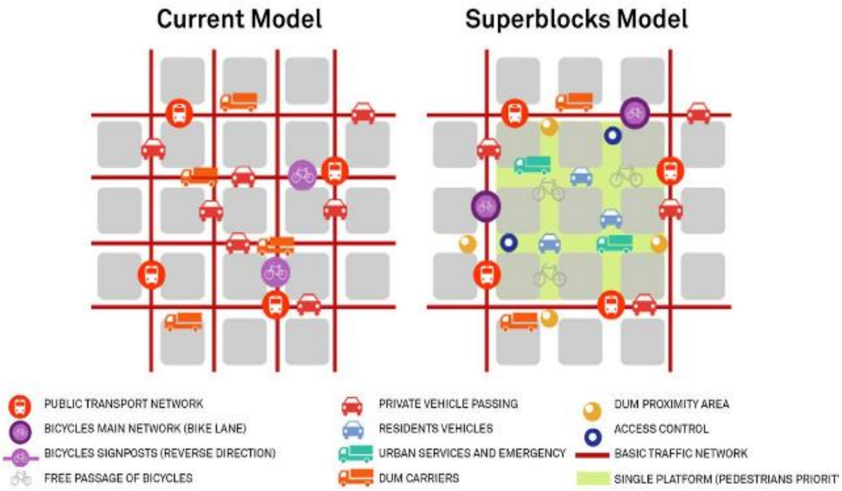


Figure 2.12: Superblock Model

Source: (Will Andrews Design, 2017)

The remaining land inside the superblock is park area, the backbone of the neighborhood. The living and sleeping sections of the houses face toward the garden and park areas, while the service rooms face the access road. Houses grouped around small Cul-de-Sacs- each accessed from main road. Living, bedroom faced gardens and parks, service areas to access roads. Walkways designed such that pedestrian can reach social places without crossing automobile street.

Figure 2.13: Radburn Concept Neighbourhood

Source: ZoningTheGardenState (2013)

Benefits of Radburn Concept

Compared to contemporary developments, the Radburn plan is more safe, orderly, convenient, spacious and peaceful. Many developers have used one or more aspects of the Radburn plan and its implementation in their own suburbs. Radburn idea is now the suburban model of choice. From a sociological point of view, Radburn not only exemplifies an ideally planned place to live, but it establishes a real mode or plan of living (Rathore, n.d.). Radburn planning allows saving of cost, as it requires less road area, with the provision of parks and greeneries and vehicle-free zone, for healthy and safe living. Radburn concept has been applied in different parts of the world, in the cities of US, England, Sweden, India, Brazil and other regions.

Case Study: Resilience challenges in a small market town, Frome, Somerset

(Centre for Sustainable Energy, 2018)

Frome is a small market town in Somerset, England. The vision in the Frome Neighbourhood Plan (made in 2016) is “to build a community that is resilient in its capacity to support the needs of residents in the face of global shocks such as economic downturns, rising energy prices and climate change”. The authors of the plan have identified resilience challenges – dependence on nearby towns and cities for services and employment, a lack of choice and affordability of housing, car dependence and rising energy prices – and have developed policies and initiatives to address them:

- Re-modeling of the town center to improve the environment for pedestrians and cyclists, reduce the impact of traffic and improve town center health.
- An integrated transport strategy seeking completion of missing cycle links, creation of links
- along the river corridor, environmental improvements around the station, provision of bus and coach stops, identifying clear and safe routes for pedestrians and cyclists.
- Seeking to ensure that land and buildings which generate local employment are protected.
- Creation of a community renewable energy company

Case Study: Knitting an inner city neighbourhood back together Old Market Neighbourhood Plan, Bristol

(Centre for Sustainable Energy, 2018)

Old Market is a historic inner-city suburb of Bristol. The broad street at the heart of the neighbourhood hosted markets outside the city walls and it was a major commercial and entertainment destination up until the middle of the 20th century. But the construction of the ring road and other major roads isolated it and other neighbourhoods from the city centre. The quality of the environment was damaged and the area went into decline. The Old Market Neighbourhood Plan focusses on improving the quality of the environment and movement routes through the area. Old Market lies on the Bristol to Bath cycle track, a strategically important cycle route and one of the busiest in the country. Similar to Frome, the plan aims to re-balance the layout of the main shopping street to focus on people, street activities and businesses instead of vehicles. The plan will also benefit the wider city by formalizing cycle routes from the cycle path to the city centre and linking up currently disconnected parks and public open spaces.

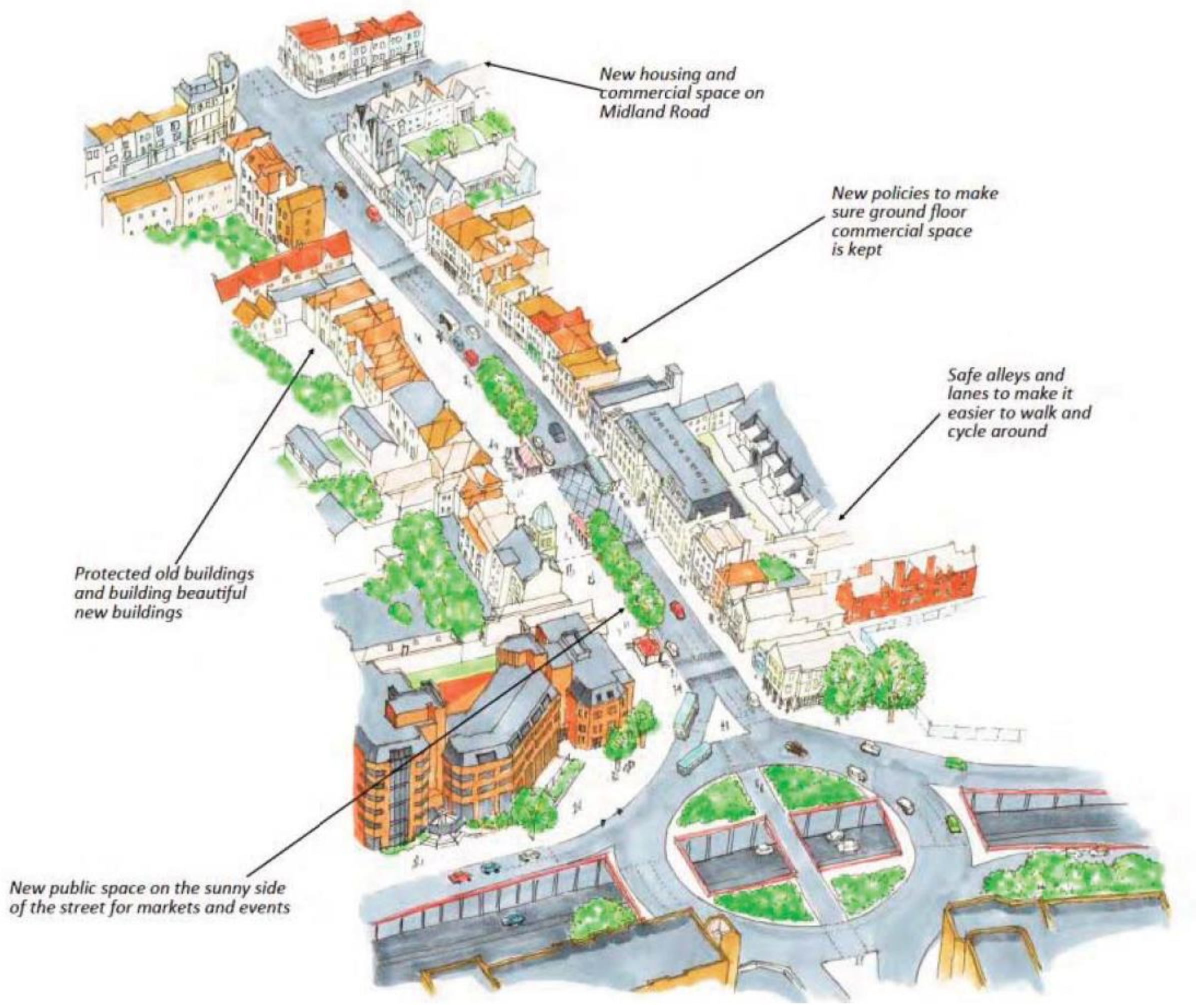


Figure 2.14: Neighbourhood Planning, Bristol

2.11.2 Settlement Pattern and Mobility in Ancient Cities of Kathmandu Valley

Amidst the fast-growing modern settlements, we also need to study the traditional settlements pattern, so as to observe the changes that took place, in the course of transformation from traditional to modern form. The traditional settlements of the Kathmandu Valley date back to pre-historic era. The three palaces in the three main cities, Kathmandu, Bhaktapur and Lalitpur, the squares and temples around them and the settlements surrounding them gives the valley its identity. The towns of Kathmandu Valley have traditionally been built as compact settlements that encouraged walking and the use of public open space. The towns of ancient Kathmandu Valley consist of a distinct set of public open spaces with a clear hierarchy of social and cultural activity. These are palaces (durbar) squares, market squares, residential neighbourhood and private residential squares (Tiwari, 1988). The central areas of all Newar settlements were indicated by open space in the form of squares where almost all major arteries converged. The temples and other monuments, the rest houses (sataa), retail shops and water pond or spring fountain were located here. Many of the daily activities were, and still are, carried out in and around these open squares (M. N. Shrestha, 1981).

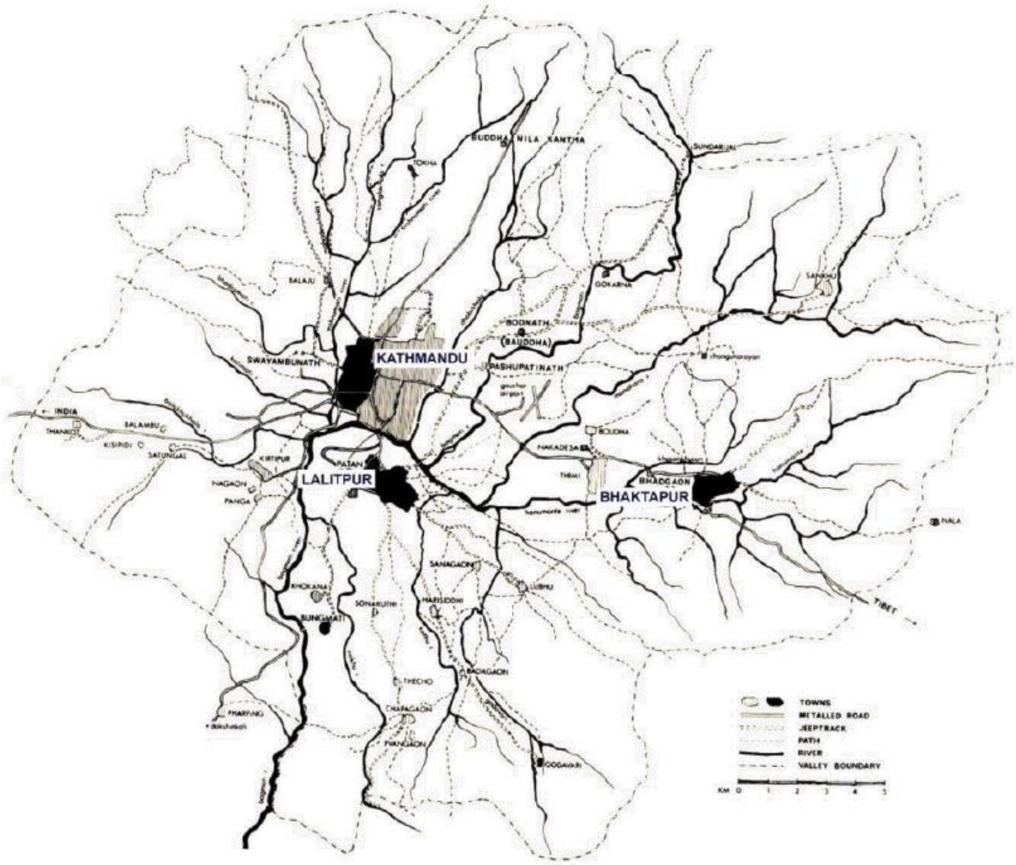


Figure 2.15: Three ancient cities of Kathmandu valley along with other towns.

Source: Hosken (1974)

Despite variations in size, location and economic activities, the Newar settlements are not radically different. It is the scale, not the structure, that separates a village from a town and a city. For the Newars, whether a house and a settlement, located in a village, town or city, are not only places where one resides but also sacred places where social and spiritual functions are performed (M. N. Shrestha, 1981).

Because of the historic necessity for defense and the efficient use of the limited agricultural land, the settlements were compact with row houses four to five stories high on both sides of the streets. At the same time, the needs for social cohesion and efficient interaction were also prime motivating factors in determining the layouts of the settlements (M. N. Shrestha, 1981).

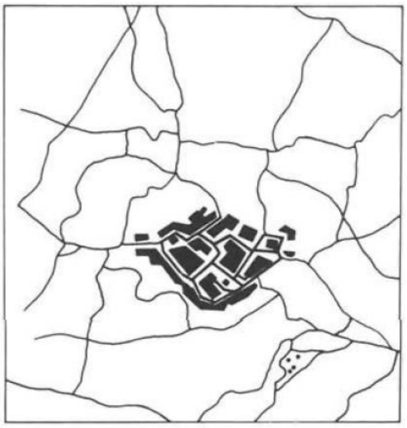


Figure 2.16: Newari Settlement Pattern (Khokana Village)

A city which dates back to prehistoric era and most of its physical form relying greatly on the Newar civilization, from past to the modern, and the spaces also as such that they create greater chances for social and cultural activities, street only accessible by foot or chariots during festivals (Weiler, 2009); (Pant & Funo, 2007). Most of the lanes of the cities are served as footpaths. The public space is widely used for individual purposes, such as visiting temples, playground for children or as a workplace. (Weiler, 2009). The cities of Patan (Lalitpur) and Bhaktapur still show this pattern (Pant & Funo, 2007). The old boundaries of Patan have extended to the new metropolitan area of the Kathmandu with its expansion. But its distinct characteristics in terms of both social and physical features separates it from the surrounding new developments (Figure 2.17).

The arrangement of a dense cluster of dwellings around the courtyards in the old city still exist and these can be identified with a traditional occupation (Figure 2.20). They are still using the open spaces (streets, courtyards) incorporated within the built form for activities such as utensil and clothes washing, grain drying, working place, sunbathing etc. which promotes social interaction among neighbours and the community as a whole (B. K. Shrestha & Shrestha).

Houses are clustered along the streets or around the courtyards. All the neighbourhoods have community squares with public amenities. According to Chitrakar (2006), these elements of urban forms give both functional and aesthetic purposes such as the temples, Pati (public rest house), water well and Dhungedhara (stone water spouts), Stupa and Chaitya (Buddhist shrines) and Dabali (an elevated platform).

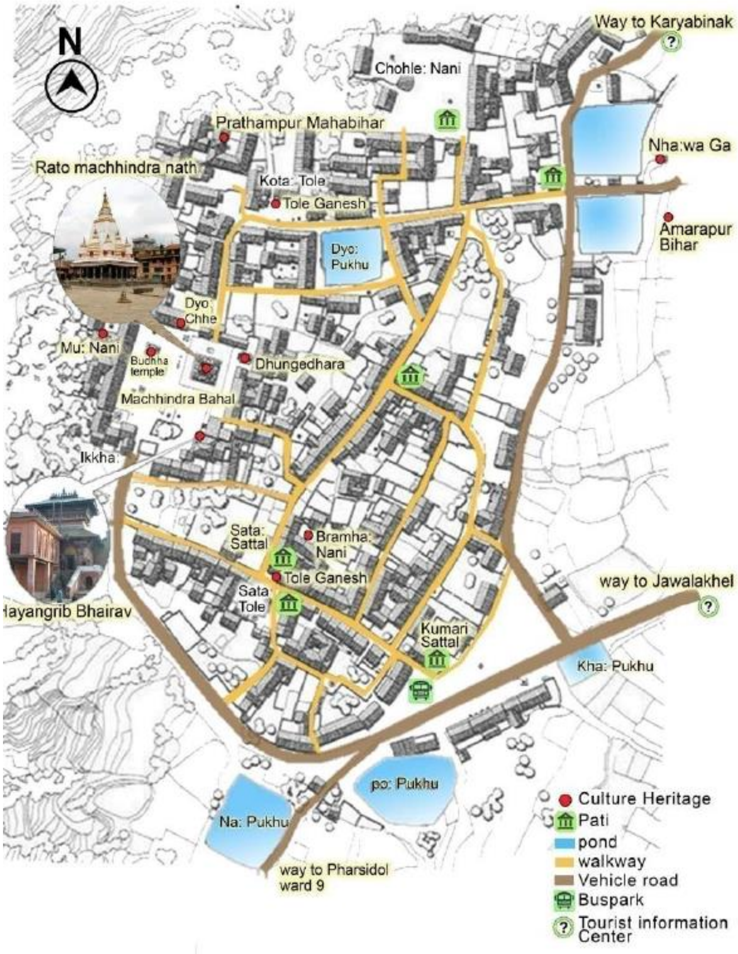


Figure 2.17: Bungmati Settlement

Source: Bungamati Area Reconstruction and Development Council (2016)

Figure 2.18: Streets and Open Spaces (Bungmati)

Source: S. Shrestha (2018)

Figure 2.19: Local Craft Industry (Bungmati)

Source: S. Shrestha (2018)

Figure 2.20: Open Space Usage as Work Place (Pottery, Ceramic, Carpentry- Madhyapur Thimi)

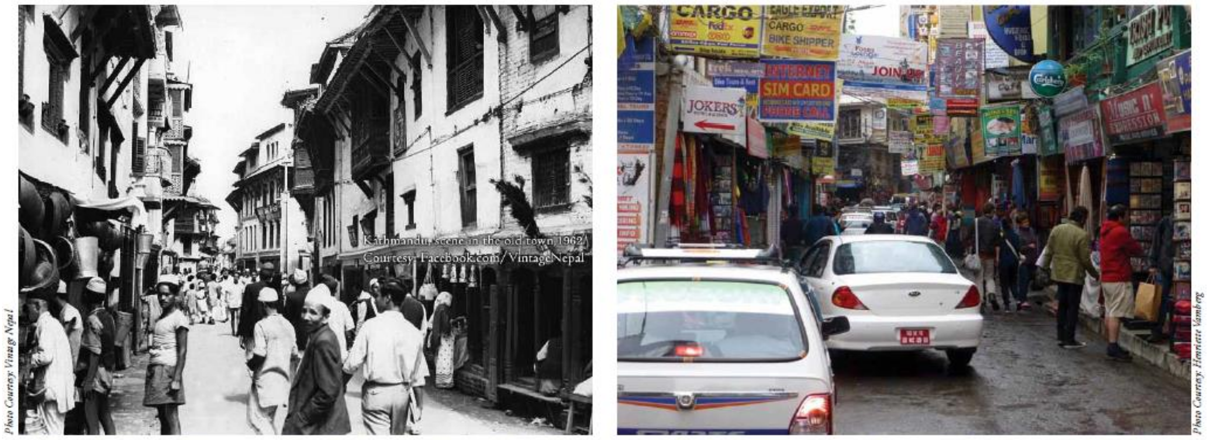
Figure 2.21: Open Spaces, Patis and Dabalis for Recreation and Social Interaction

Efficiency in Traditional Settlements

Traditional settlements reflect the integration of nature, economy and society in their landuse planning. The settlements are mostly compact, with dense population and climate responsive with well integration of open spaces, street layouts and activity locations, with urban fabric. This allowed all urban facility within walking distance and also prevented sprawl and preservation of agricultural land. Landuse is mixed, whereby residential, workplaces, recreational and social interaction spaces are within the near vicinity.

Present Context

Due to urbanization and rapid population growth, the traditional cities are in the stage of transformation. The pedestrian streets have now been converted to vehicular roads. City sprawl has increased and, in the process, much of the agricultural land has turned into building plots. Public spaces are losing its essence, due to encroachment by squatters, commercialization, and change in use (e.g. vehicle parking). This has hampered the usage of open spaces as a place for social interaction, traditional profession and recreation.



Cities in Kathmandu Valley were traditionally planned and designed for walking

Vehicular traffic in city core areas has made streets unsafe and inconvenient for pedestrians.

Figure 2.22: Transformation of Streets

Source: MaYA (2013)

2.12 Conclusion

This chapter describes the literature studied on different aspects of energy efficiency, urban landuse and transport planning. Urban form, more importantly, urban density and urban morphology have a crucial role in determining travel pattern and mode choice. The compact settlement allows promotion of public vehicles and use of walking and cycling, that helps to minimize transport energy consumption. In contrary, sparsely distributed settlements are seen to rely more on private vehicles and have longer trip distance, resulting in less energy efficient. Apart from urban form and urban density, many other factors have also an influence, such as the relative location of residential areas, employment locations, services and amenities, transport facilities and road connectivity. These factors also have a significant impact on the number and length of trips.

Achieving improvements in energy efficiency in transport planning is a key issue for urban sustainability. Land use, transport planning and promotion of public transport and non-motorized modes, have to be integrated to minimize the need to travel, to shift travel to more efficient modes. Along with urban form, it is also essential to look at neighbourhood level. Radburn concept can be applied for neighbourhood planning, whereby, all necessary amenities are kept within walking distance, for pedestrian friendly mobility, avoiding vehicles, for safety and clean environment. Settlement pattern of the traditional settlements of the Kathmandu Valley follows an energy efficient pattern, are compact, with dense population and climate responsive with well integration of open spaces, street layouts and activity locations, with urban fabric.

Chapter 3. Research Methodology

It is very important for a research to have a research paradigm that forms the main basis for research methodology and research methods. This chapter describes the research paradigm and methods followed in this research.

3.1 Research Paradigm:

A paradigm is a basic belief system and theoretical framework with assumptions about ontology, epistemology, methodology and methods that provides the way of understanding the reality of the world and studying it (Rehman & Khalid, 2016).

Various paradigms can be the basis for research, depending upon the objectivity and subjectivity of the research. Positivist and Post-Positivist paradigm are suitable for the research which is objective in nature, while for qualitative and subjective nature, Constructivism/ Interpretivism and Transformative paradigms are appropriate. This research is based on Post-Positivism, as it deals with the study of travel behavior and urban mobility, that is probabilistically apprehendable.

Post-Positivism

Urban mobility is a reflection of how people travel. So, travel behavior forms a key component in this research. Travel behavior and urban mobility are related to human behavior and it cannot be expressed in absolute terms, but in terms of probability and likelihoodness. Hence, post-paradigm forms the basis for this research. However, the methods adopted should have a representation, within the acceptable limit (90/95% Confidence Interval) for its validity.

Other Paradigms:

Positivism: This research does not deal with the phenomenon, that can be measured in absolute terms.

Transformative & Constructivism/ Interpretivism: The research is not related to social, political, cultural, economic, ethnic, and gender values. So, the paradigm for this research cannot be transformative. Also, the research is not intended to construct reality through interpretation and thus, Constructivism/ Interpretivism does not fit in. Moreover, both these paradigms are applicable to pure qualitative methods.

3.1.1 Ontology

Ontology refers to "the nature of our beliefs about reality" that leads a researcher to inquire, what kind of reality exists. (Patton, 2014; Richards, 2003). This research is aimed to study travel behavior and urban mobility and in that respect, from the ontological perspective, there is a reality, but it can be known only imperfectly or probabilistically. Currently, the Kathmandu valley is experiencing rapid growth in population and urbanization. As a result, travel demand is also in the steep rise, as more and more people are commuting, across the city, more specifically, the home-based daily trips. Energy efficiency is not given a priority, at the level of planning in landuse and transport and thus the level of energy consumption continues to escalate. The level of motorization has increased rapidly and more importantly, the growing number of private vehicles is becoming more of a concern. Distribution of urban activities and facilities are not planned, towards minimization of trip distance and use of public transport and NMT, that specifically applies to the peripheral regions of the valley, where new settlements are growing rapidly. Thus, shows that in the current urban planning practice, an integration of energy efficiency on urban form and urban mobility has not received adequate attention.

3.1.2 Epistemology

Epistemology refers to the branch of philosophy that studies the nature of knowledge and the process by which knowledge is acquired and validated (Gail et al., 2006). It is concerned with the nature and forms of knowledge, how it can be acquired and how communicated to other human beings. (L. Cohen et al., 2007).

The main prime factor, that influences the Urban Transport System is the Travel behavior of commuters. So, it needs to be studied at the household level as it is where the trip originates. There is a close relationship between the socio-economic and demographic character and the mobility pattern of the people. The more mobile a person is, the wider the circle of socioeconomic interaction that would be available to them. In turn, both mobility and socioeconomic status influence the type, frequency and the intensity of their participation in activities. Thus, to study the travel behavior, the survey was carried out at the household level, in different parts of the study area.

An aggregation of individual travel behavior will constitute an overall transport system. Understanding the travel choices of the people becomes a key factor, for the identification of urban transportation problems and potential solutions. Therefore, to analyze the overall travel pattern within the study area, a model is to be devised that makes it possible to assess the system in totality and helps to identify, inter-relationship among the units of analysis, i.e., urban transport, travel behavior, urban landuse and energy efficiency.

Logic System

This research follows the inductive approach to build generalizations out of the observation of specific events. The observations made from the survey sample has been generalized to the population. Sampling strategy has been adopted to make it a representative sample of the population. Inferential statistics and modeling methods were used for generalization of the findings of the sample to the whole population.

3.1.3 Methodology

It refers to the study and critical analysis of data production techniques. It is the "strategy, plan of action, process or design" that informs one's choice of research methods (Crotty, 1998). The research is based on mainly two methodological approaches to fulfill the knowledge gap, as described in epistemology.

- **Co-relational Research (Social Survey)**
  In this research, co-relational statistics was used to study the nature and the strength of the relationship between the variables of travel behavior, socio-economic characteristics and urban form. Cross-sectional Household Survey was carried out to study the travel characteristics of the population, using random sampling.

- **Simulation and Modeling Research**
  Landuse and Transport system of the study area in macro scale was studied with the application of the travel demand model. The four-step transport model was developed to predict travel pattern of the study area. Scenario analysis was done further, to assess the transport energy for each scenario.

3.1.4 Methods

Methods signify what we do in order to collect our data and carry out our investigations (Rehman & Khalid, 2016). The methods followed in this research are as follows:

- Literature Review
- Background study of Landuse and Transport system of Kathmandu Valley
- Data Collection – Primary and Secondary
- Data Analysis – Analytical methods are mainly quantitative, and some part of the analysis is qualitative, as shown in Table 3.1.

Table 3.1: Analysis Methods

A.	Description	Analysis Methods	Methodology
1	**Travel Behavior Study**		
1.1	Travel Characteristics of Home-based Daily trips	Descriptive Statistics	
1.2	Travel Behavior and Socio-economic Characteristics	Inferential Statistical Analysis	Co-relational Research
1.3	Travel Behavior, Urban Form and Travel Energy		
2	**Travel Pattern (Landuse and Transport System) and Transport Energy**		
2.1	Modeling of Travel Pattern for Work and Educational Trips	Urban Transport Model System (4-step model)	Simulation and Modeling Research
2.2	Scenario Analysis	Base and Proposed Scenarios	

3.2 Literature Review

The literature review forms an integral part of the entire research process and makes a valuable contribution to almost every operational step (Kumar, 2005). The literature review has been done to establish the theoretical roots of the study, clarify the ideas and develop the methodology and to integrate the findings with the existing body of knowledge. Literature was obtained from various sources, mainly from journals, books, internet websites.

3.3 Background Study of Landuse and Transport System of the Kathmandu Valley

The study area for this research is the Kathmandu Valley and the research problem is specific to urban landuse and transport planning of the area. For this research to commence, it is important to know about the background of the area to know about the landuse and transport system of the Kathmandu Valley that affects the travel pattern of daily trips.

3.4 Primary Data Collection

3.4.1 Household-based Survey

A household-based survey is widely used to study the travel behavior of a commuter (Zuidgeest & Maarseveen, 2007). This research follows a cross-sectional study, aimed to study the mobility pattern of the population at the given time. The cross-sectional household questionnaire survey was carried out with an objective to obtain data on the socio-economic and household characteristics of a household and travel characteristics of the household members who are workers and students in commuting their daily trips (work and educational trips).

The steps for the survey were as follows:

1. Questionnaire design
2. Determination of sample size
3. Formulation of sampling strategy

3.4.2 Questionnaire Design

The survey questionnaire is divided into 4 parts (Annex 1). As the number of samples to be collected in large, the survey form was designed to keep it simple, that required minimum writing and the questions were organized under different specific headings.

Part 1: Household Information

This section includes the household information that contains household size, monthly household income and household vehicle availability.

Part 2: Travel Characteristics of Workers and Students

For this research, the daily trips that constitute trips from home to work place and home to educational institution, were included. Home-based daily trips form a major proportion of total transport demand in the Kathmandu Valley and thus more importance is given to these trips. In this part, travel characteristic of a household member was collected, who are either a worker or student, in commuting their work trips and educational trips respectively. It includes the origin, destination, trip length, travel time and the travel mode used for the trip.

Part 3: Opinions about the attributes of the public transport system

This part consists of the list of important attributes of the public transport system and the respondent was asked to choose the one, that is the most relevant attribute of all. For private vehicle users, a second question was asked if the respondent is willing to shift from private to public transport, if the most relevant attribute, which the respondent ticked in the earlier question, is fulfilled.

Part 4: Opinions about Urban Transport of the Kathmandu Valley

The final part of the survey attempts to know the opinion of the respondent on how to improve the urban transport system of the Kathmandu valley and ways to make it energy efficient.

3.4.3 Sampling Strategy

It is essential to select an appropriate sampling strategy for household surveys. For the purpose of the research, Proportionate Stratified Random Sampling was adopted.

Stratified random sampling attempts to stratify the population in such a way that the population within a stratum is homogeneous with respect to the characteristic on the basis of which it is being stratified. It is important that the characteristics chosen as the basis of stratification are clearly identifiable in the study population. Then the sampling is separated into non-overlapping groups with the required number of elements from each stratum, using the simple random sampling technique. With proportionate stratified sampling, the number of elements from each stratum in relation to its proportion in the total population is selected (Kumar, 2005).

The procedure for selecting a proportionate stratified random sample is as follows:

- **Step 1:** Identification of all elements or sampling units in the sampling population.
- **Step 2**: Identification of the different strata (k) into which the population is to be stratified.
- **Step 3:** Placement of each element into the appropriate stratum.
- **Step 4:** Numbering of an element in each stratum separately.
- **Step 5:** Determination of total sample size (n).
- **Step 6:** Determine the proportion of each stratum in the study population (P)

$$P = \frac{\text{Element\# in each stratum}}{\text{total population size}}$$

- Number of elements to be selected from each stratum = (sample size) x (P)
- Selection of the required number of elements from each stratum with simple random sampling technique

3.4.3.1 Determination of Sample Size

For the household survey, the population includes all the households within the study area. Sample size was determined to make it a representative sample, as possible. Sample size was obtained, using the Equation (3.1) for the finite population (SurveyMonkey, 2018).

$$\text{Sample Size} = \frac{\dfrac{z^2 \times p(1-p)}{e^2}}{1+\left(\dfrac{z^2 \times p(1-p)}{e^2 N}\right)} \qquad \textbf{(3.1)}$$

Where,

Population Size (N)	: 792,300 HH (2017, projected from CBS (2011)
Response Distribution (p)	: 0.5
Confidence Interval	: 95 %
Margin of Error (e)	: 2 % = 0.02
z score (z)	: 1.96 (For 95 % confidence interval)

Sample size, using the above parameters, was found to be approximately 2300 and accordingly, same number of households were surveyed.

3.4.4 Identification of Strata

The sampling strategy was opted with an objective to collect samples from the study area, in proportionate to the population distribution. For proportionate stratified random sampling, 59 strata were identified. The stratum is either a TAZ or group of TAZs so that each stratum contains at least 20 samples. More samples were collected from the core city area where the population is concentrated and fewer samples from peripheral regions.

The formula used was as follows:

$$\text{No. of samples from each stratum} = \frac{\text{No. of Households in each Stratum}}{\text{Total Households no. in Study Area}} \times \text{Sample size}$$

$$= \frac{\text{No. of Households in each stratum}}{\text{Total Household no. in Study Area}} \times 2300$$

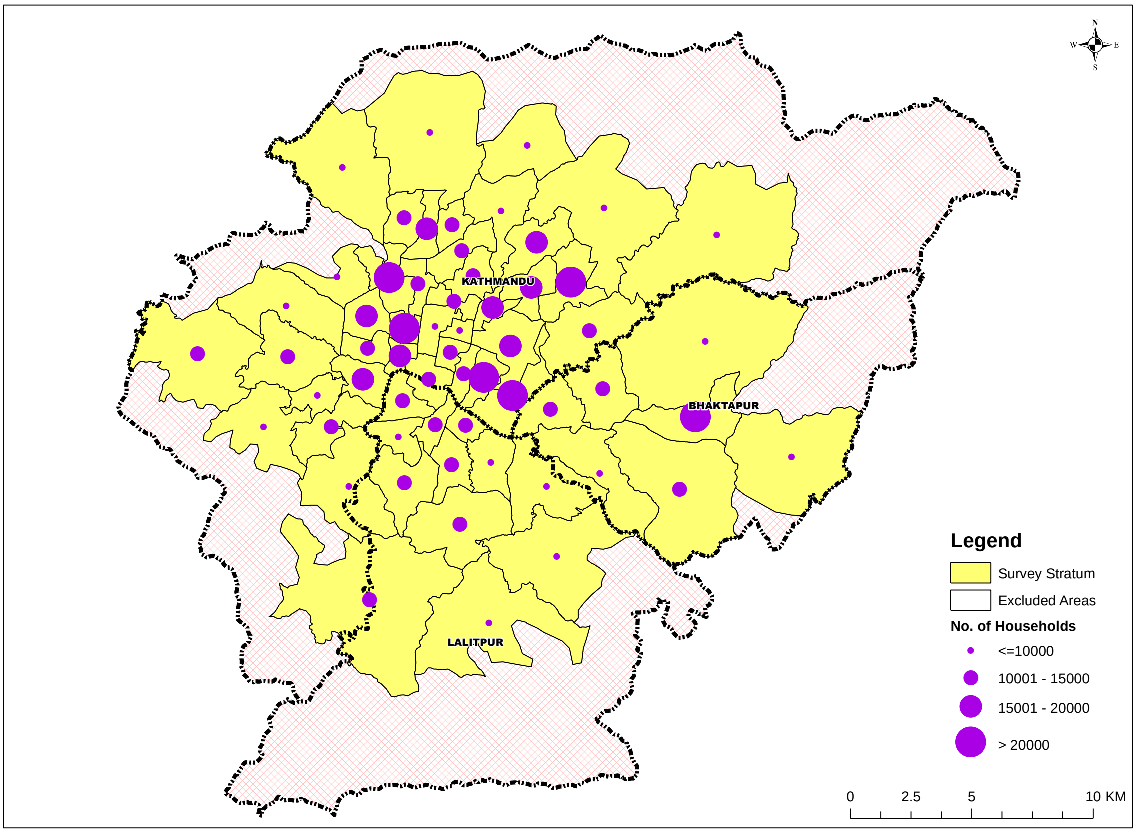


Figure 3.1: Survey Area

3.5 Limitations of the Household Survey

In any survey, the procedures and measuring instruments used for data collection influence the results and thus it is important to state the limitations and assumptions behind the data collection process. This helps to interpret the result accordingly. For household-based surveys carried out for travel data, some of the frequent criticisms as stated by Zuidgeest and Maarseveen (2007) are

- The survey measure average, rather than actual travel behavior of individuals
- Only part of the individual's movements can be investigated.
- Some information is often reported with less accuracy by the respondent (e.g. Travel distance, Travel times etc.). The ambiguous data are cross-checked with the location of origin and destination.

3.5.1 Non-Household Based Survey

Apart from the household survey, data was also collected from traffic counts and roadside surveys. During roadside surveys, drivers of the public transport were asked questions about the routes and fuel economy of the vehicle.

In traffic count survey, vehicle numbers were counted at the road section for the specific interval of time. The count values were used for the validation of FSM. Along with traffic count, vehicle occupancy data was also collected for different travel modes.

3.6 Secondary Data Collection

Transport studies are complex and require a lot of data. It is not possible to acquire all of the data from the survey and thus it is required to rely on data from several secondary sources for analysis. Secondary data was collected from various sources as mentioned below:

- For Population data, data was collected from the Census Bureau of Statistics, for the year 1981, 1991, 2001 and 2011
- Previous Transport Related Studies from JICA, CEN/CANN and KSUTP were referred for background study of the transport system of the Kathmandu Valley.
- For spatial analysis and for FSM, spatial data was acquired from different sources. Shape files were obtained from Department of Survey, GoN, 1996 and KVDA. GoN. These include spatial features such as – Road Networks, Administrative boundaries (Ward, VDC, Municipal Boundaries), Landuse, Land Cover.
- Open Street Map Database was the data source for the distribution of employment and educational facilities.

3.7 Statistical Analysis Methods for Travel Behavior Study

After the collection of data, the next step was to analyze the data. Descriptive and inferential statistical methods were used for analyzing the data, for the interpretation and presentation of the research findings. The statistical analysis gives meaning to the meaningless numbers, thereby breathing life into a lifeless data (Ali & Bhaskar, 2016).

3.7.1 Descriptive Statistical Analysis

Descriptive statistics is about the summarization and description of the important aspects of numerical data. The process consists of the condensation of data, their graphical displays and the computation of a few numerical quantities that provide information about the center of the data and indicate the spread of the observations (RaviMagazine, 2017). Descriptive statistics have been used to describe the travel characteristics of the sample population using graphs, tables, and general discussions, which is discussed in Chapter 5.

3.7.2 Inferential Statistical Analysis

Inferential statistics use a random sample of data taken from a population to describe and make inferences about the whole population. In inferential statistics, data are analyzed from a sample to make inferences in the larger collection of the population. The purpose is to answer or test the hypotheses. A hypothesis (plural hypotheses) is a proposed explanation for a phenomenon. Hypothesis tests are thus procedures for making rational decisions about the reality of observed effects (Ali & Bhaskar, 2016). Inferential statistical analyses were carried out using different parametric (ANOVA, Independent t-tests, Correlation) and non-parametric test (Pearson Chi-Square).

Test of Independence for Categorical Variables (Chi-Square)

Pearson Chi-square test was used to evaluate the relation between two categorical variables by cross-tabulation. This is an extremely elegant statistic based on the simple idea of comparing the frequencies observed in certain categories to the frequencies expected to get in those categories by chance (Field, 2009).

Chi-square statistic is sensitive to sample size. As sample size is large, the chi-square test was followed by Cramer's V measure, which gives a guidance in deciding, whether a relation is important and worth pursuing. Cramer's V equals 0 when there is no relationship between the two variables, and generally has a maximum value of 1, regardless of the dimension of the table or the sample size. This makes it possible to use Cramer's V to compare the strength of association between any two cross-classification tables. Tables which have a larger value for Cramer's V can be considered to have a strong relationship between the variables, with a smaller value for V indicating a weaker relationship. The value of 0.1 can be taken as small effect and 0.3 and 0.5 as medium and large effect respectively (J. D. Cohen, 1988).

For Bivariate Analysis, Odd's ratio was calculated as an additional measure of effect size. Odd's ratios are particularly useful for clear interpretation of comparison (Field, 2009).

In chapter 6, travel behavior was studied in relation with socio-economic and demographic characteristics based on Chi-square tests. Variables relating to socio-economic and demographic characteristics are taken as independent variables and those of travel characteristics are dependent variables for the analysis.

Comparing means

For comparison of means, independent t-test and ANOVA was carried out. Independent t-test can compare the means between two unrelated groups on the same continuous, dependent variable. The one-way analysis of variance (ANOVA) was used to determine whether there is any statistically significant differences between the means of three or more independent (unrelated) groups. Chapter 6 describes the use of independent t-test and ANOVA one-way test to compare the mean trip length for different groups.

Statistical Significance of tests

For making a conclusion about the hypothesis with 95% confidence, the p-value of the statistic should be less than .05. If p-value is greater than .05, we can conclude that the result is not significant.

Application Package

Statistical analyses were done in SPSS package. Data preparation and processing was done using MS Excel and MS Access.

3.7.3 Energy Performance Index (EPI)

Next level of analysis is to assess the travel energy using Energy Performance Index. Energy performance index is an indicator for assessing travel energy consumption, which gives an average energy consumed per trip. As per Kojima and Ryan (2010), energy-efficient transportation needs to be encouraged on three different levels i.e. System Efficiency, Travel Efficiency and Vehicle Efficiency. System efficiency is related to the landuse planning, whereby trip distance is the main factor. Travel efficiency relates to the modal share of different modes of transport and the load factor of a vehicle. Vehicle Efficiency is related to the technological and design parameters of a vehicle, which determines its fuel efficiency.

Energy performance index integrates all three above components in one measure. This index (expressed in MJ/travel) represents the mean energy consumed for a trip.

In Chapter 7, travel energy per work trip was quantified as the composite measure of travel distance and mode choice using EPI. Variation of travel energy and the relation between the variables of urban morphology and travel pattern was analyzed using Pearson Correlation Coefficient, to observe the nature and strength of relation.

Pearson Correlation:

Pearson correlation coefficient has been used to see how strongly pairs of variables are related. Correlation is a bivariate analysis that measures the strength of association between two variables and the direction of the relationship. In terms of the strength of the relationship, the value of the correlation coefficient (r) varies between +1 and -1. A value of ± 1 indicates a perfect degree of association between the two variables. As the correlation coefficient value goes towards 0, the relationship between the two variables will be weaker (S. Solutions, 2019).

Correlation explains the nature and strength of the relationship, assuming a linear relation. But it does not explain causation. There are other statistical methods for causal analysis and for non-linear relations whereby independent and dependent variables are accessed in more detail, which is not discussed in this paper.

In chapter 7, Pearson correlation coefficient was used to study the relationship between travel energy with urban form.

3.8 Modeling Approach for Landuse-Transport Study

In this research, four-step model (FSM) was used to model the transport component of the integrated land use and transport study. Chapter 8 describes the formulation of four-step model in detail. FSM helps to predict travel pattern of an urban area, which forms the basis for doing spatial analysis of urban mobility.

3.8.1 Background of modeling approaches for landuse-transport study

One of the key barriers to integration of land-use and transportation planning is the lack of a "common language", that is, tools, instruments and indicators that can support planners from both domains in developing integrated land-use and transportation strategies (Te Brommelstroet & Bertolini, 2008). Despite this barrier, there have been efforts by urban researchers to formalize the relationship between land use and transport using mathematical, statistical and logical models capable of predicting changes in transportation and land use systems as the result of policy measures in both fields (Iacono et al., 2008).

The fundamentals of transport modeling can be traced back to the Detroit and Chicago transportation studies in USA in the 1950s (Bates, 2000). The last 40 years has seen the development and application of a large number of statistical and mathematical procedures directed towards improving the understanding of the behaviour of agents who make decisions that impact the transport system (Hensher & Button, 2000).

It has become a major challenge for developing countries due to poor state of urban mobility because of their unplanned rapid development and thus researchers and planners in the field of transport planning and management have continually sought effective methodologies for analyzing and solving urgent transport issues in these cities (Fujiwara & Zhang, 2013). Advanced transport modeling approaches such disaggregate activity-based modeling methods have been efficiently applied for the study and improvement of urban transport conditions in cities in developed countries, in attempts to analyze and resolve the urban transport problems (McNally, 2000a). However, valid analyses of the urban transport studies of developing cities remain very difficult, because elementary trip survey data are still quite scarce, and the available data mostly are of very poor quality and often are not shared among planning agencies (Boyce & Xiong, 2007). Thus, advanced modeling techniques, which usually require more detailed trip and activity data, are very difficult to apply. Therefore, the conventional aggregate four-step modeling process, which is customarily estimated sequentially, is still the most widely applied method because of its practicability (McNally, 2000b; Siegel et al., 2006).

3.8.2 Travel Demand Modelling

Travel demand model is primarily used for estimation of travel behavior and travel demand for a specific time-frame, based on the number of assumptions. Travel demand model results can assist decision makers in making informed transportation planning decisions (VDOT, 2019).

The four-step model is the primary tool for forecasting future demand and performance of a transportation system, typically defined at a regional or sub-regional scale (McNally, 2007).

The following sections include some of the core concepts of Urban Transport Model System (UTMS, based on literature review. Details of each step is explained in Chapter 8.

3.8.3 Urban Transport Model System

The Urban Transport Model System (UTMS), also referred as the four-step model (FSM) is commonly used to predict the flows on the links of a particular transportation network as a function of the land-use activity system that generates the travel (Hanson, 1995). The model comprises of four sub-models that are employed in the sequential process: Trip generation, Trip distribution, Mode choice (or modal split) and trip assignment. In this research, the model was developed for estimating travel pattern of work and educational trips. The framework for the model is illustrated in Figure 3.2.

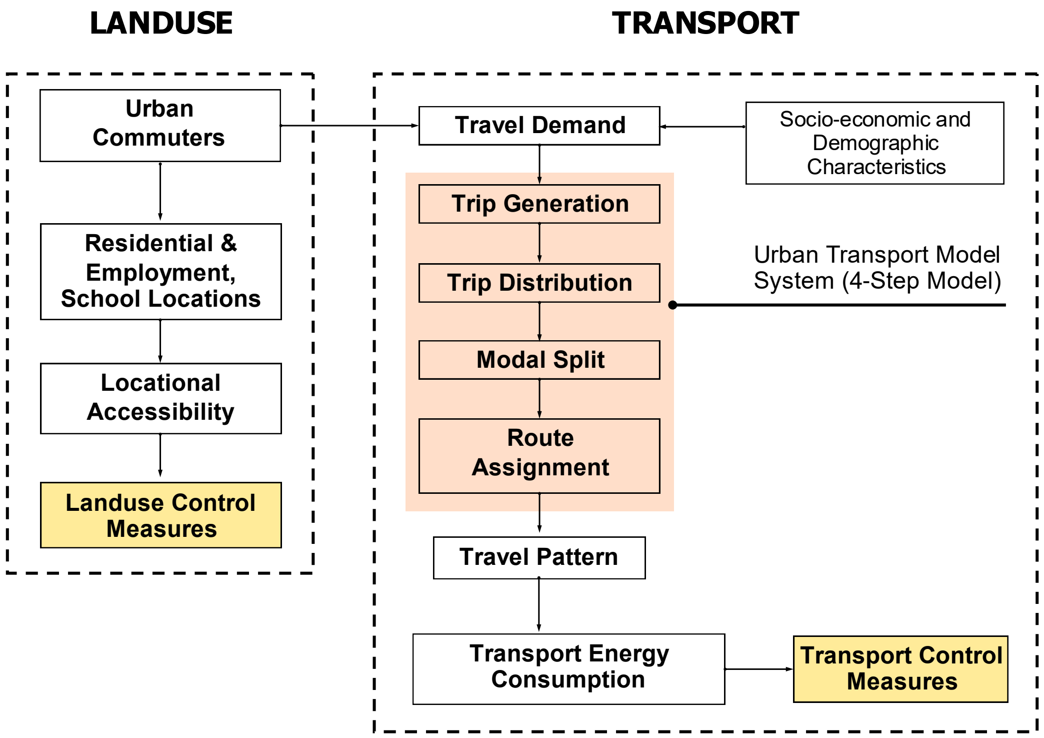


Figure 3.2: Framework of the Model

1. Trip Generation

This step is used for predicting the number of trips produced (Trip Production) and attracted to each traffic analysis zones (Trip Attraction) i.e. number of trips ending to each zone and number of trips originating from each zone, of the study area.

2. Trip Distribution

In trip distribution model, the origin and destination end of the trips are linked, obtained from the trip generation model. It shows from where the trip starts and where it ends. The Gravity model is commonly used for trip distribution model that is based on the production and attraction of each zone and the impedance, i.e. the cost incurred, in traveling from origin to destination zone.

3. Modal Choice (or Modal Split) analysis

Mode choice estimates the number of trips from each origin to each destination by the mode of transportation. In general, more importantly for urban areas, modal choice has considerable implications for urban transport policy.

4. Trip Assignment

Trip assignment is the final step that gives the number of trips from each origin to each destination by each mode for each route between the origin and destination zones. The portion of vehicle-trips assigned to each route between a particular origin-destination pair is dependent on a number of attributes like travel time, distance, number of stops / signals, aesthetic appeal etc. and available alternative routes. Travel time is the attribute that is most commonly considered in the route assignment models. There are different traffic assignment algorithms. Commonly used algorithms are i) All-or-Nothing assignment (AON), ii) Wardrop’s user Equilibrium assignment, iii) Method of successive averages, iv) Stochastic user-equilibrium assignment. For this research, AON has been applied, which assumes that, for any trip, a commuter will take the shortest route from origin to destination and any congestion effect is not considered.

3.8.4 Traffic Analysis Zones

Traffic Analysis Zones are the geographic areas dividing the planning region into relatively similar areas of land use and land activity. Zones represent the origins and destinations of travel activity within the region. Every household, place of employment, shopping center, and other activities are first aggregated into zones and then further simplified into a single node called a centroid (BAA & TRB, 1998). As per FHWA-NHI (2016) zones are typically defined to be compatible with:

- Study scope and purpose(s),
- Census geographies / Adminstrative boundaries.

- Land use homogeneity,
- Adjacent network geography,
- Other geographic features, such as rivers, lakes or railroads
- Network geography
- The number of zones in a study area generally increases as an urban area becomes denser,
- Zones tend to be smaller in denser areas (e.g. CBDs) and larger in areas of low density (e.g. rural areas), and
- Larger zones tend to yield a higher percentage of intra-zonal trips.

3.8.5 Justification of Modelling Approach

Planners require techniques and tools to improve the accuracy of their predictions and to support them in dealing with the problems of risk and uncertainty. Van Delden et al. (2009) noted that plans and policies should be designed to incorporate and work with a certain degree of uncertainty rather than ignore it.

Barredo and Demicheli (2003) observed that estimating future socioeconomic and environmental impacts of existing spatial plans and policies on urban development and the consideration of alternative planning and policy scenarios for impact minimization are of particular interest for urban planners. They further note that there are complex rules at work that make difficult the forecasting of urban dynamics. Given the complexity of urban dynamics, Te Brommelstroet and Bertolini (2008) suggest that focus should be on developing a common land use transport language.

A model can be defined as a simplified representation of a part of the real world, which concentrates on certain elements considered important for its analysis from a particular point of view. It is particularly important for transport planning as it is impossible to conduct experiments on existing infrastructure (Zuidgeest & Maarseveen, 2007).

De Bok (2009) mentions that integrated land use and transport models enable policymakers to foresee and evaluate the effects of transport and landuse plans hence enabling the solution of common planning problems. Geurs and van Wee (2004) stated that the use of land use and transportation interaction models is necessary because of the inclusion of feedback mechanisms between land-use, travel demand and accessibility. However, they noted that not many evaluation studies of the accessibility impacts of land-use and transport projects are based on such models.

This research demonstrates the application of FSM for landuse and transport study together with its strength and weakness and coming up with the possibilites for its improvement.

3.8.6 Scenario Planning (SP)

In this research, FSM has been used for scenario planning, which is described in Chapter 9. Scenarios provide visions of the future based on a specific framework and adopting specific assumptions (Reisi et al., 2016). Scenario planning is a practical way to explore a range of future states and consider alternative response options (Peterson et al., 2003). They do not provide planning solutions but give a clear idea about possible planning solutions to be used in the future (Banister, 2000). Scenarios can assist with decision analysis. They are laid out in advance so that the decision makers can see the expected impact of each course of action (Fairhurst, 2012). Decision-makers are embracing scenario planning (SP), that recognizes the limits of projections, acknowledges deep uncertainty, and helps managers prepare for future conditions outside currently observed trends (Maier et al., 2016; Walker et al., 2003). How close to reality these scenarios are really depends on the accuracy of the assumptions implicit in the model (P. Solutions, 2018).

3.8.6.1 Population Projection

Government policymakers and planners around the world use population projections to gauge future demand for food, water, energy, and services, and to forecast future demographic characteristics. Population projections can alert policymakers to major trends that may affect economic development and help policymakers craft policies that can be adapted for various projection scenarios (PRB, 2001).

Logistic Growth Method

In logistic growth, a population's per capita growth rate gets smaller and smaller as population size approaches a maximum imposed by limited resources in the environment, known as the carrying capacity. The formula for population forecasts using logistic growth is given in Equation (3.2) (Sawyer & Bassarsky, 2016).

$$P = \frac{K}{1 + Ae^{-bt}} \tag{3.2}$$

where,

K is the upper asymptote, i.e. the carrying capacity

A and b, are the parameters that determine the shape of the logistic curve

t is the time

In other population projection methods such as exponential growth or geometric growth, a population's per capita (per individual) growth rate stays the same regardless of population size, making the population grow faster and faster as it gets larger. However, in nature, populations may grow exponentially for some period, but they will ultimately be limited by resource availability. With Logistic method, the growth is limited by the carrying capacity and thus it does not grow steadily. Exponential growth produces a J-shaped curve, while logistic growth produces an S-shaped curve (Khan Academy, 2019).

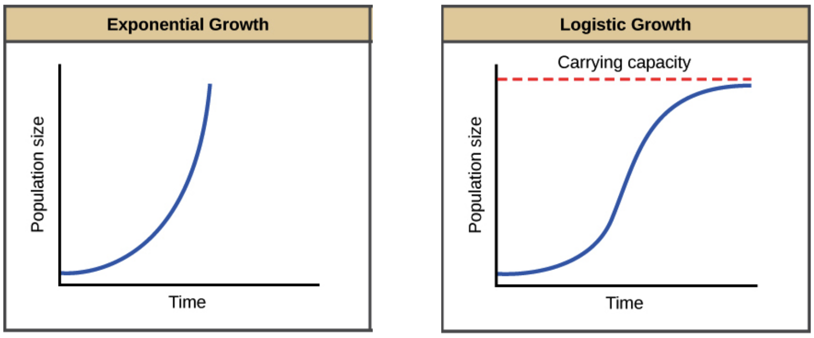


Figure 3.3: Population Growth Curve

Source: OpenStax (2013)

3.8.7 Sensitivity Analysis

Sensitivity analysis is also referred to as "what-if" or simulation analysis and is a way to predict the outcome of a decision given a certain range of variables. By creating a given set of variables, an analyst can determine how changes in one variable affect the outcome (Investopedia, 2018). For further analysis of scenario planning, sensitivity analysis was performed, using Local sensitivity method. Local sensitivity methods are based on an OAT (one parameter at a time) approach, where evaluation of output variability is based on the variation of one design parameter, while all other design parameters are held constant (Heiselberg et al., 2009).

3.9 Qualitative Analysis

For studying energy efficiency at neighbourhood level, qualitative study has been done. Different literatures in both local and global context were reviewed to study how energy efficient planning can be applied at the level of urban design for vehicle free mobility and pedestrian friendly environment. In local context, traditional settlements were studied as to how these settlements are sustainable in context of livelihood, activities and mobility. Field observations were also made at some sites to observe the settlements and the activities of the people.

3.10 Conclusion

This chapter describes the research paradigm, methodology and methods of this research. The research is based on post-positivist paradigm, with two methodological approach – co-relational and simulation/modeling approach. For primary data collection, the sampling strategy adopted for the household survey was stratified proportionate random sampling. The questionnaire was designed for collecting household and travel characteristics of the respondents. For quantitative analysis, two approaches are discussed. First is the statistical analysis to study the relation between the study variables and second is the modeling approaches for studying landuse and transport planning. In particular, four-step model is discussed for its applicability for the landuse/transport study. Each step of the model is briefly discussed along with the assumptions and limitations of the model. Qualitative analysis is done through review of literature and field observations.

Chapter 4. Study Area, the Kathmandu Valley

This chapter describes the urban form and urban transport system of the Kathmandu Valley and the current energy scenario of transport sector.

4.1 Background of the Kathmandu Valley

The study area for this research is the Kathmandu Valley that includes three districts - Kathmandu, Lalitpur and Bhaktapur and the total population of over 2.5 million (CBS, 2011). Kathmandu is the capital city of Nepal.

In the Kathmandu Valley, urbanization is pacing up rapidly and the continuation of urban sprawl and increasing level of auto-mobilization is becoming an issue of major concern, as travel demand continues to rise along with transport energy.

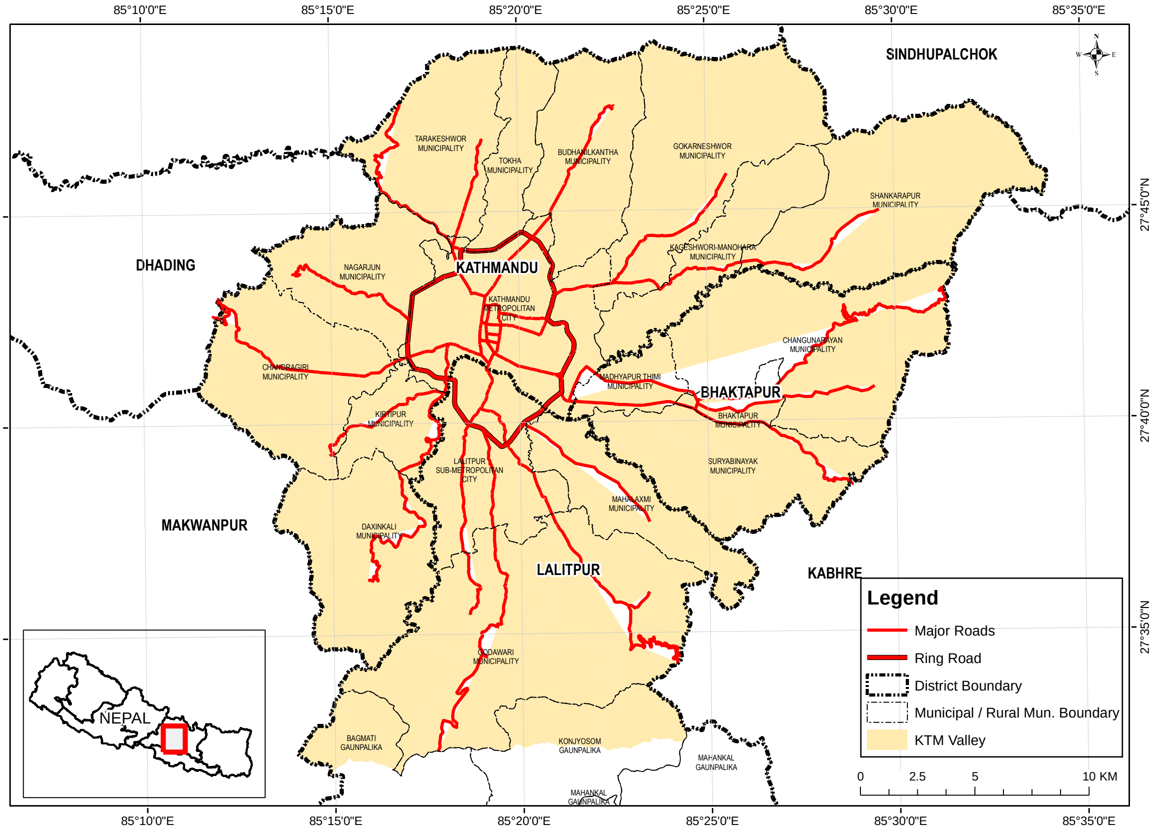
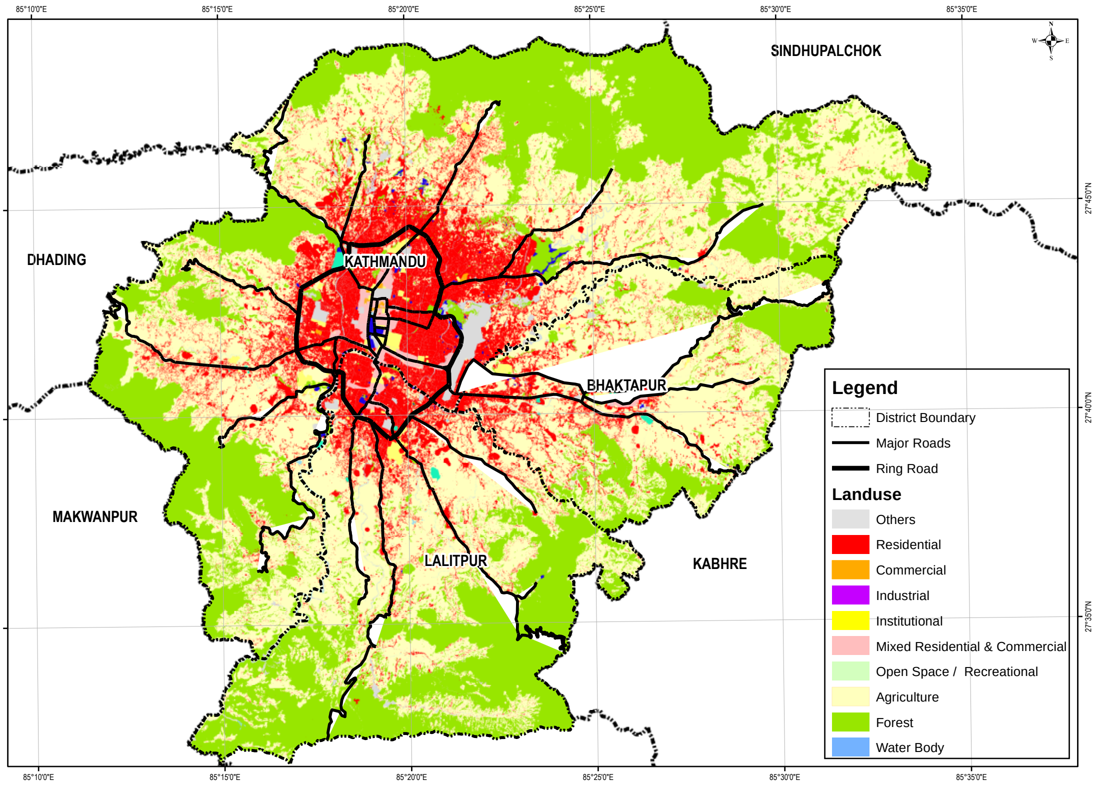


Figure 4.1: The Kathmandu Valley

4.2 Urban Landuse

Over the period of past few decades, urban morphology has drastically changed in the Kathmandu Valley with rapid urbanization and urban sprawl which is reflected in Figure 4.2. This change is the result of various social, economic and political factors. The influence of these factors and due to the continuation of haphazard and unplanned development, built-up has increased by almost 211 percent, from 38 sq. km in 1990 to 119 sq. km in 2012 in course of 22 years (Table 4.1).

The land use can be classified into various zones mainly residential, commercial, mixed, conservation, agricultural, industrial, institutional and urban expansion. The city core is very dense where much of the population and facilities are concentrated.



Map 4.1: Landuse of Kathmandu Valley (2012)

Source: KVDA (2014)

Agricultural land has declined from 421 sq.km to 342 sq.km, a drop of 19 percent over the period of 22 years (Table 4.1). When we look that the built-up areas, the share of mixed residential/commercial has increased by almost six times from 0.91 sq.km to 5.69 sq.km and that of the residential area has increased by over four folds, from 21.83 sq.km to 94.19 sq.km over the last two decades (Table 4.2). Currently, the built-up area covers 16 percent of the total area of the Kathmandu Valley. The cultivation land is about 47 percent and forests/vegetation, about 35 percent. Table 4.2 shows how the land use has change from 1990, 2000 and 2012.

Table 4.1: Built-up Area Increment Pattern: Year 1990 - 2012

Land Use Class	Area (Sq.km)			Percentage of Total KV Area		
	1990	2000	2012	1990	2000	2012
Agricultural	421.60	394.12	342.08	58.40	54.60	47.39
Built-up	38.09	66.54	118.65	5.28	9.22	16.44

Source: KVDA (2014)

Table 4.2: Land use Change: Year 1990 - 2012

Landuse Class	Area (sq. km)			Percentage		
	1990	2000	2012	1990	2000	2012
Commercial	0.2	0.37	0.37	0.03%	0.05%	0.05%
Industrial	0.79	1.01	1	0.11%	0.14%	0.14%
Institutional	3.7	4.29	4.45	0.51%	0.59%	0.62%
Military	1.21	1.21	1.2	0.17%	0.17%	0.17%
Mixed Residential/Commercial	0.91	2.76	5.69	0.13%	0.38%	0.79%
Public Utilities	0.26	0.3	0.3	0.04%	0.04%	0.04%
Residential	21.83	46.18	94.19	3.02%	6.40%	13.05%
Rural Settlement	1.17	1.13	1.86	0.16%	0.16%	0.26%
Special Area	0.87	0.87	0.87	0.12%	0.12%	0.12%
Transportation	7.15	8.41	8.71	0.99%	1.17%	1.21%
Forest	253.34	253.56	251.08	35.10%	35.12%	34.78%
Others	2.96	3.48	6.07	0.41%	0.48%	0.84%
Recreational/Open Space	2.39	2.03	2.01	0.33%	0.28%	0.28%
Water body	3.5	2.14	1.98	0.48%	0.30%	0.27%
Total	721.87	721.87	721.87	100.00%	100.00%	100.00%

Source: KVDA (2014)

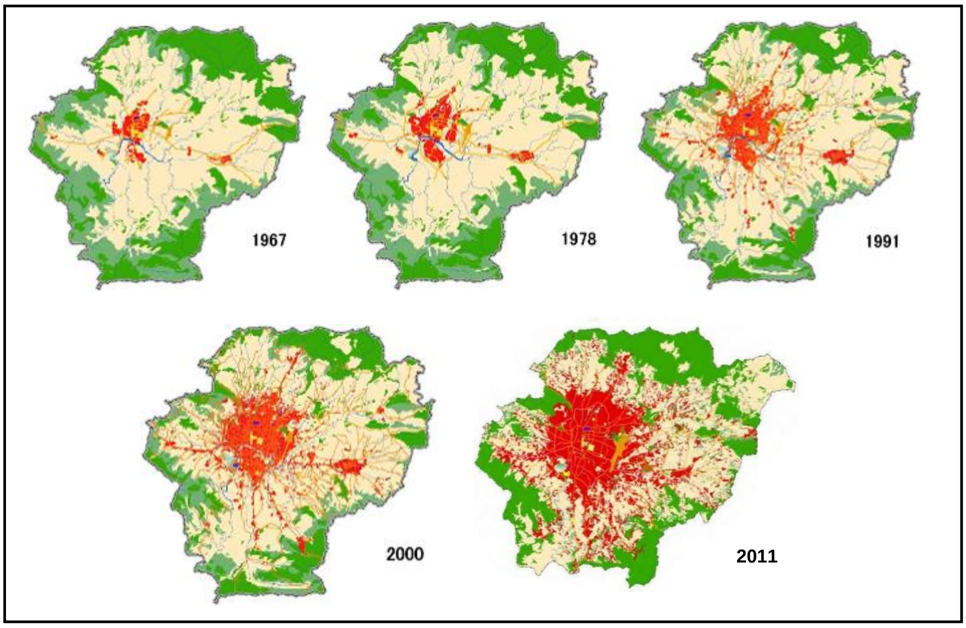
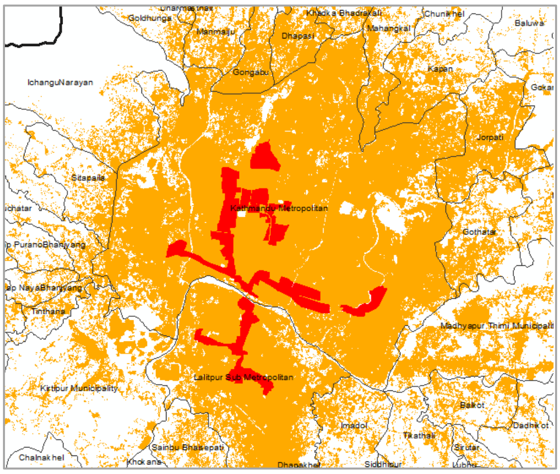


Figure 4.2: Urban Growth Pattern

Source: JICA (2012)

4.2.1 Economic Opportunities and Population Growth

Economic opportunities include wide varieties of economic activities like job and business opportunities, industries (Thapa & Murayama, 2010). The economic activities occur mainly in the Central Business District (CBD), located around the central region of the valley. Due to the pull factor of the CBD, urban development is concentrated around and gradually sprawling outwards from the CBD. Thus, the proximity to CBD and other market areas are the major economic factor which directs the growth of the valley. As such, the CBD is where commercial and financial activities occur, providing jobs in formal financial and banking sectors, providing opportunities for extended businesses and trade, as well as providing opportunities in informal sectors to support and sustain the formal sector activities and further, the central administrative services are also located within the CBD in the context of KV (KVDA, 2014). The CBD, therefore attracts as the area of major workforce.



Map 4.2: CBD in KV

Source: KVDA (2014)

4.2.2 Educational Services

Kathmandu Valley is also the main attraction center for educational opportunities and the demand for educational service is ever growing. Number of schools and colleges have grown rapidly. There are total 2181 schools in the valley with 594,458 students (Table 4.3).

Table 4.3: Total Number of Schools and Students

District	Total Schools (Grade 1 – 12)	Total Students
Kathmandu	1,362	394,651
Bhaktapur	344	71,898
Lalitpur	475	127,909
Total:	**2,181**	**594,458**

Source: MEST (2017)

According to the Ministry of Education, 15.8 per cent of all enrollment at the basic education level (grades 1-8) are in private schools and 29 per cent in higher secondary schools. In Kathmandu, nearly 70 per cent of the pupils attend private schools (THT, 2019). These private schools are delivering much higher quality education to the students compared to their public counterparts. However, most private schools operate like profit-oriented business firms. In the last three decades, Nepal has experienced a massive proliferation of private schools, with rising demand for schooling, along with population growth. As a result, school trips have a major share in the total trips and along, increasing trip distance and vehicular trips for educational trip purpose, is becoming a major concern. Due to the disparity in the quality of education offered by different schools, the students are not enrolled in the schools of their locality, but instead they choose the school of the different location. For instance, school bus of school located at Manbhawan, Lalitpur, reaches all the way to Maharajgunj, Kathmandu to pick the students, where the trip distance is over 12 km. Many school vans and buses are operating within the valley for pick-up and drop service. This has added the traffic volume, adding to the congestion, during peak hours and also resulted the trips to be more time and energy consuming. Difference in educational quality is especially evident between government and private schools and people like to opt private schools for quality education, at the cost of the distance.

4.3 Urban Transport

Urban transport system is currently affected by unmanaged roads, increasing use of private vehicles (Motorcycles and cars), lack of quality public transport service. Share of Private vehicles in the trips is growing rapidly. As a result, the roads are all the time congested, resulting in delays due to increased travel time along with air pollution, noise pollution and other problems. In Kathmandu, over the past 10 years, the population has increased by 4.32 % per year and motorization has increased by 12% per year (CBS, 2011; MoPIT/JICA, 2012) while the modal share of public transport has remained stagnant (MoPIT/JICA, 2012).

The number of vehicles has increased radically in the past few years. Furthermore, ownership of private vehicles is also rising rapidly (Table 4.4).

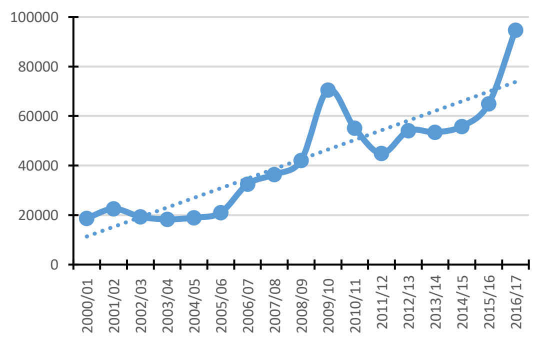
Figure 4.3: Increasing Traffic Volume and Road Congestion

(Location: Bhadrakali, Kathmandu)

Table 4.4: Vehicle Registration data (Cumulative) for Bagmati Zone (1989/90 - 2016/17)

Year	Bus	Mini Bus	Car/Jeep/Van	Micro Bus	Tempo	Motorcycle	Others	Total
1989/90	797	1,028	9,868	-	507	18,594	3,812	34,606
1999/00	2,126	2,219	29,697	-	2,133	94,081	12,822	143,078
2009/10	6,140	5,784	68,132	1,440	2,515	394,420	27,704	506,135
2016/17	**11,784**	**11,967**	**139,981**	**2,345**	**2,528**	**817,473**	**56,778**	**1,042,856**

Source: DoTM (2017)



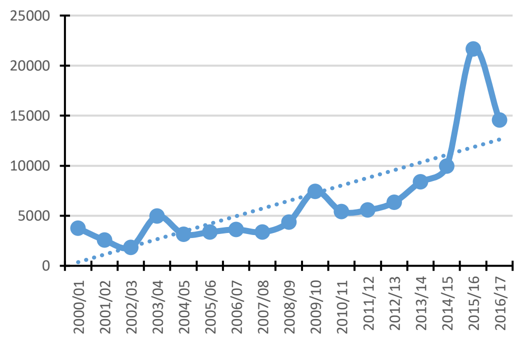


Figure 4.4: Annual Vehicle Registration in Bagmati Zone - Fiscal Year 2000/01 – 2016/17

Source: DoTM (2017)

4.4 Public Transportation in Kathmandu Valley

4.4.1 Historical background of Public Transport System in Kathmandu Valley (MaYA, 2014)

In September 1959, Nepal Transport Service started a local bus service between Kathmandu and Patan, marking the beginning of public transportation in Nepal. At its height, before being closed in 1966, it owned a fleet of 11 buses serving more than 10,000 passengers daily. Sajha Yatayat, a cooperative started mass transport service in Nepal in 1961/62 providing services inside the Kathmandu Valley as well as inter-district commuters. In 1975, electric trolley buses were introduced along the 13 km route from Tripureshwor to Suryabinayak. Although both Sajha Yatayat and the Trolleybuses provided effective public transport services in Kathmandu for many years, they failed to retain their glory post 1990, when they suffered from poor management and political interference while the private sector started coming aggressively in transportation sector. The privatization of public transport brought more operators, but services deteriorated with time as a result of syndicate system and lack of effective planning and regulation by the government.

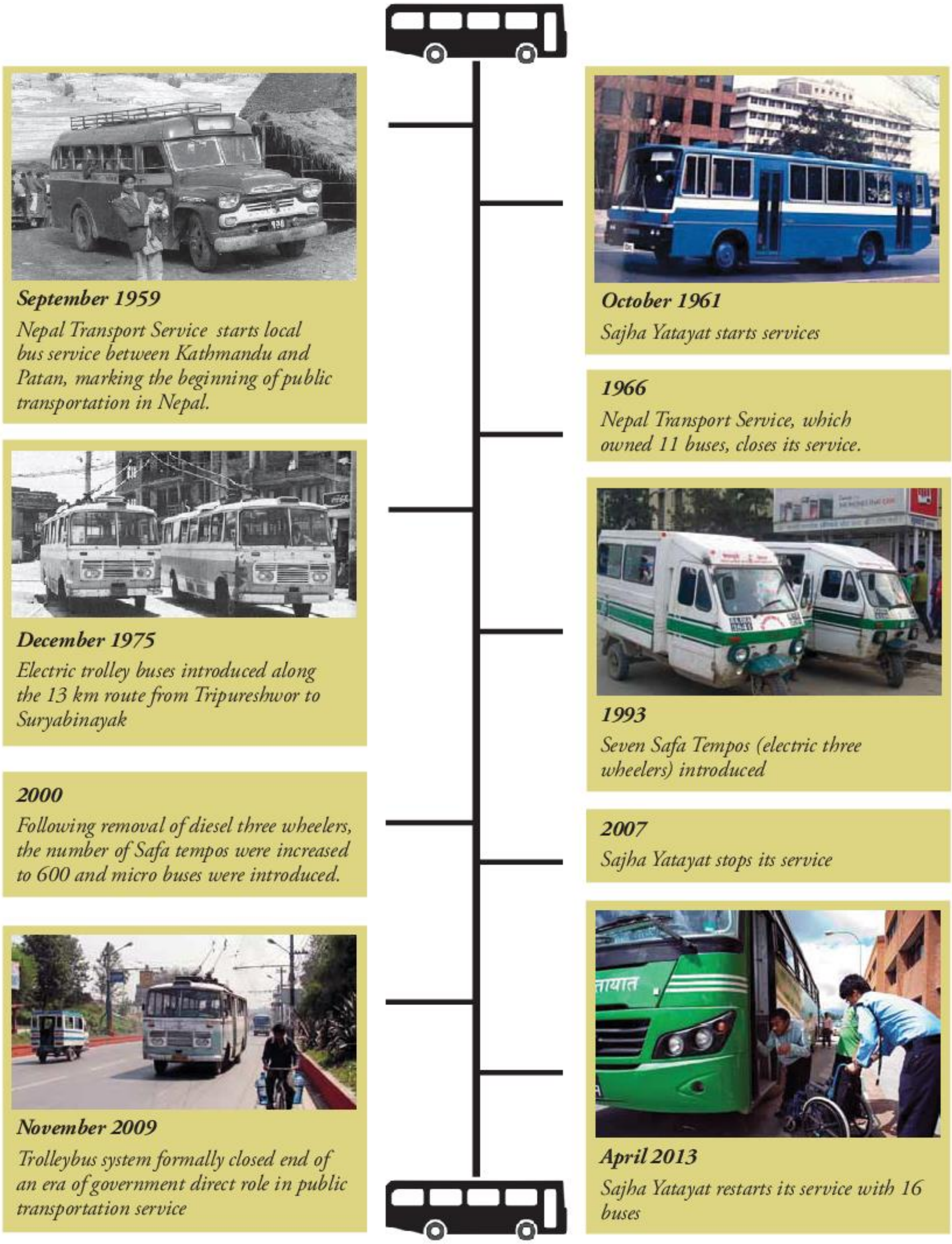


Figure 4.5: Timeline: History of public transportation development in PT

Source: (MaYA, 2014)

4.4.2 Status of current Public Transport system in Kathmandu Valley (MaYA, 2014)

The travel pattern is highly radial with most trips starting or ending in the central business district (CBD) of Kathmandu (Map 4.2). Public transport services are provided by several thousand private operators, which are organized into mode-specific associations and operate along over 200 routes. The share of low occupancy vehicles such as minibuses, microbuses and tempos operating within Kathmandu Valley accounts for 94% of total public transport vehicles, while share of large buses is only 6% (MoPIT/JICA, 2012).

A study conducted by Kathmandu Sustainable Urban Transport Project (KSUTP) has identified the following problems associated with the public transport operation and existing route structures:

- Overlapping or duplication of routes
- Inefficient vehicle
- Concentration of route terminals in the city center
- Poor passenger services at terminals
- Poor service quality

Public transportation improvement is one of the four components of the KSUTP, which is supported by the GoN and ADB. The project has proposed three-tier hierarchy of public transport routes based on the demand and width of the road infrastructures. The project has proposed 8 primary routes, 16 secondary routes and 40 tertiary routes plus 2 in historic areas. It has envisaged to operate higher capacity mass transit service with 12 meter or 18 meter articulated buses with dedicated bus-lanes, 9-10 meter buses in secondary routes providing feeder service to primary routes and low occupancy vehicles such as tempos, microbus and minibus in tertiary routes. The project is also planning to demonstrate formalization of operators and route contracting in two pilot routes.

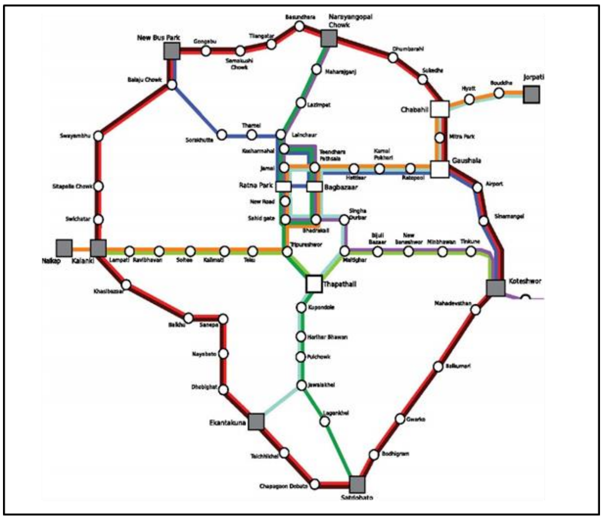


Figure 4.6: Primary public transport network in Kathmandu valley (KSUTP Project)

4.5 Some Initiations in Improving Public Transport

4.5.1 Reintroduction of Sajha Yatayat

(MaYA, 2014; Sajha Yatayat, 2016)

In April 2013, Sajha Yatayat resumed its services with 16 large 55-seater buses with Euro 3 emission standard bringing new hopes of quality public transport service in the city. The main objective of the Sajha Yatayat is to operate as model public transport service provider providing efficient, affordable and safer services to the city commuters. Sajha Yatayat is currently running its service in two routes passing through CBD with an average daily ridership of 8,000 passengers per day. The buses stop at designated stops and the passengers are required to enter through one door an exit through the other. All buses are fitted with closed circuit cameras for safety. This is the only public transport service provider that operates large buses inside Ring Road and provides service passing through CBD. The drivers and driver assistants are well trained and provide comparatively better customer-friendly services with ticketing system. It also employs women as driver and conductor making it safer and gender-friendly.

Figure 4.7: Sajha Bus

4.5.2 Safa Tempo - Electric Three-wheeler

(MaYA, 2014)

In 1993, seven electric three wheelers, locally known as “Safa Tempo” were introduced in Nepal, as part of a USAID supported project. The number of Safa Tempos increased significantly after diesel powered three wheelers were banned in 1999. Safa tempos are locally produced in Nepal. The introduction of electric vehicles in large masses for public transport is first kind in the world and has been a model for other cities. There are currently 600 Safa tempos operating in 17 routes within Kathmandu Valley, however this number has remained static since 2000 largely because of lack of proper support from the government. These Safa tempos provide environment-friendly mobility to about 100,000 commuters daily. Many of these three wheelers are operated by women.

Figure 4.8: Safa Tempo

4.5.3 Other Public Transport Services

Apart, from Sajha Yatayat public transport service, there are many other bus operators running along different routes of the Kathmandu Valley. Even though, public transport service is in the process of expanding, there are still many concerns that need to be addressed. Many commuters, find inconveniences, while using public transport, mainly due to overcrowding, along with personal insecurity, reckless driving and fear of accidents, problems travelling with children, unpredictability and length of journey (Bank, 2013).

4.6 Demographic Trend

As per the census data of 2011, the population of Kathmandu Valley is about 2.5 million. Kathmandu district has the highest population of just over 1 million, with the highest annual growth rate of 4.76%. Following Kathmandu are Lalitpur and Bhaktapur with a population of 337,785 and 225,461 respectively. With a growing population, we can expect future travel demand also to rise sharply and with it, the transport energy.

Table 4.5: Demographic Trend

District	Population (Yr. 2001)	Population (Yr. 2011)	No. of Households (Yr. 2011)	Average Household Size	Annual Exponential Growth Rate
Kathmandu	1,081,845	1,740,977	436,344	4.0	4.76%
Lalitpur	337,785	466,784	109,797	4.3	3.23%
Bhaktapur	225,461	303,027	68,636	4.4	2.96%
Total	1,645,091	2,510,788	614,777	4.1	4.23%

Source: CBS (2001, 2011)

4.7 Energy Consumption Situation in Nepal

As per WECS (2014) total energy consumed in national scale in 2011/12 is 376.3 million GJ. If we look at energy consumption by sector, transport sector consumes 7.12% of the total energy, currently at the third position in energy consumption, after residential and industrial sector (Figure 4.9). The share of transport sector in energy consumption could escalate with population growth and rising travel demand. This is also indicated by the increasing trend in the use of petroleum products in the past two decades (Figure 4.11) and fossil fuels are heavily consumed in transport sector. 57 % of the total petroleum products are used up by transport sector alone (Figure 4.10).

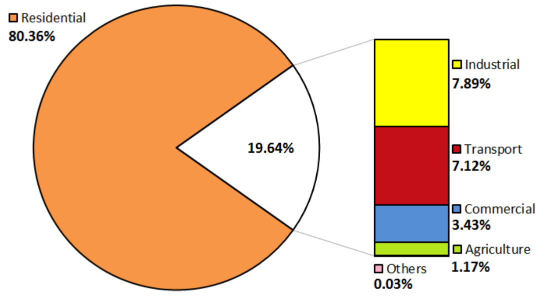


Figure 4.9: National Energy Consumption by Sector (2011/12)

Source: WECS (2014)

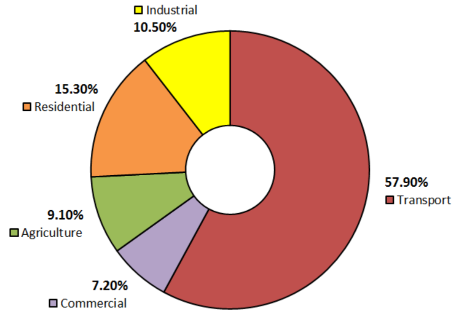


Figure 4.10: Consumption of Petroleum Product (2011/12)

Source: WECS (2014)

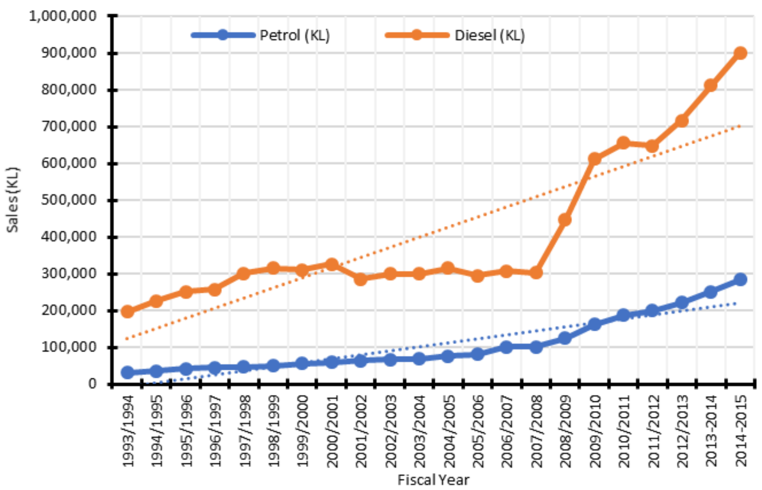


Figure 4.11: Sale of Petroleum Products (1993 – 2015)

Source: NOC (2016)

4.8 Existing Plans and Policies on Urban Transport and Landuse Planning

Several policies and regulations related to transport and landuse has been enacted, which are discussed below:

The Nepal Transport Policy 2001

It was formulated to develop a transport system that is sustainable, dependable, less expensive, safe, comfortable and self-reliant. However, the policy mainly focuses on road infrastructures rather than holistic approach of transport management. In the urban context, it recommends developing the transport infrastructure of the urban area in accordance with the master plan prepared for the urban development, to be implemented by local level with the support central level (MaYA, 2014).

National Transport Management Act

It was enacted in 1965 and traffic regulations that came into force in 1963 provide the legislation to license drivers and vehicle operators. The Vehicle and Transport Management act enacted in 1992 has regulations on operation of public transportation vehicles, insurance of passenger and driver, providing route permit and fare fixation.

Public Transport Code of Conduct

This code of conduct was brought in 2010 to ensure safe, easy and convenient ride especially for women, children and differently able people in public transport vehicles. It has also provision for implementation and monitoring of code of conduct by central and regional committee, however this has not implemented effectively.

National Land Use Policy 2069 (2012)

The need for national land use policy was envisaged for the optimum use of land, land classification and development of country in social, environment and economic aspects through land use planning. Similarly, for identification of safe areas for residential, agricultural and industrial activities with infrastructural facilities with proper consideration to sustainability of the environment. For Conservation of water recharge areas, forest areas, water sources and eco-diversity and wildlife habitat areas and for Identification of potential environmentally sensitive areas for landslide, flood prone areas and act towards mitigating the adverse impacts. The national land use policy has a vision for optimum use of the land resource for sustainable development of country through development in social, economic and environmental development. The National land use policy of Nepal has set the goal for ten years to classify all the land units in Nepal according to topography, capacity, utility and need, and five years goal for completing the same for municipal area, district headquarters, urbanizing VDCs and land adjacent to major roads. Similarly, the policy has a goal for establishing new institutional setup for monitoring, management and regularization of land units according to the aforementioned classification within two years of time.

National Urban Development Strategy (NUDS), 2017

The preparation of National Urban Development Strategy (NUDS) started in line with National Urban Policy (NUP), 2007, the Sustainable Development Goals (SDGs) and the New Urban Agenda. The aim was to address the critical issues and challenges of urbanization and explore the potential it holds in driving forward the national development by covering various sectors of urban areas such as infrastructure, environment, system, finance, economy, investment, land and governance. It mentions about the integration of urban landuse and transportation in towns and regional planning with preference to public transport and NMT. But it does not explain in detail, how it can be achieved. Therefore, there is a need of more elaboration in the urban development strategy to address the role of urban land use and transportation for sustainable development.

Chapter 5. Travel Characteristics of Home-based Daily Trips

In this chapter, using descriptive statistics, socio-economic and demographic characteristics and travel characteristics of the sample population were studied. It describes the household characteristics and travel characteristics of the respondents, who are workers and students, in commuting their daily trips.

5.1 Socio-Economic and Household Characteristics

Socio-economic and demographic characteristics such as sex, age, occupation, household size, household income, vehicle ownership have an important role in determining the travel characteristics. In total 2300 households were surveyed, and there were 6249 respondents. They are household members, who commute daily trips, belonging to either a worker or a student category. Table 5.1 shows the characteristics of the respondents on gender, occupation and Household monthly income. About 43% of the respondents are students and 57 % are workers. 67 % of the respondents are male and 33 % are female.

Regarding household monthly income, about 24 % of the households are having household income of over NRs. 75,000. The low income group, earning less than NRs. 25,000 per month in a household, is around 16% and those belonging to middle income group (NRs. 25,001 to 75,000) is about 65%. Average household size is 4.4.

Table 5.1: Gender, Occupation and HH Income

Sex	**N**	**%**
Female	2,043	32.70%
Male	4,206	67.30%
	6,249	
Occupation	**N**	**%**
Students	2,646	42.30%
Workers	3,602	57.60%
	6,248	
HH Monthly Income (NRs.)	**N**	%
≤ 10000	13	0.6%
10001 - 25000	357	15.6%
25001 - 50000	765	33.4%
50001 - 75000	730	31.9%
75000	424	18.5%
	2,289	
	Average	**Std. Dev**
HH Size	4.4	1.2

Table 5.2 shows the age distribution of workers and students. Most of the workers are between age 31 to 50, about 59%, while 26% are below 30 years and 15% are above 50 years of age. Likewise, 54.4%

of the students are between 11 – 20 years of age, while 22.8% are below 10 and 22,8 % are above 20 years of age.

Table 5.2: Age Group of Respondents

Occupation	Age Group		
Students	≤ 10	11 - 20	> 20
	22.8%	54.4%	22.8%
Workers	≤ 30	31 - 50	> 50
	25.7%	59.1%	15.2%

5.1.1 Vehicle Ownership

Vehicle ownership is regarded as one of the most vital household characteristics in determining travel behavior of the people. Household vehicle availability data is shown in Table 5.3. Average car ownership is found to be 0.3 per household, whereas for motorcycle, it is 1.0, meaning that, in average, each household owns at least one motorcycle. In contrast, ownership rate of bicycle far less, only 0.08 per household in average.

Table 5.3: Household Vehicle Ownership

No. of Vehicles Owned	Car		Motorcycle		Bicycle	
	N	%	N	%	N	%
0	1620	70.4%	485	21.1%	2123	92.3%
1	663	28.8%	1376	59.8%	172	7.5%
2	14	0.6%	416	18.1%	2	0.1%
≥ 3	3	0.1%	23	1.0%	3	0.1%
Average Ownership per HH	0.3		1.00		0.08	

5.2 Travel Characteristics

For studying trip characteristics, modal share, trip rate, time of trip origination and trip length data were collected for the daily trips.

5.2.1 Modal Split for Daily Trips

Modal split shows the share of each travel mode for daily trips, which is summarized in Table 5.4, categorized as Private, Public and Non-Motorized Modes of Transport (NMT). Share of private vehicles, i.e. car and motorcycle is about 49 %. Motorcycle has the highest usage overall, of about 36 %. Share of public transport is only about 31 %, which is the combined share of all public vehicles – bus, microbus and tempo. About 18 % of the trips are made by walking and share of bicycle is least, which is less than 1 %. Work trips have a comparatively higher share of private modes and less PT and NMT use, as compared to educational trips.

Table 5.4: Modal Split

S.N.	Mode Category	Travel Mode	Overall	Trip Purpose	
				Edu.	**Work**
1	**Private**	**Motorcycle**	35.7%	18.2%	48.6%
2		**Car**	13.2%	2.8%	20.8%
3	**Public Transport (PT)**	**Bus**	25.9%	45.9%	11.1%
4		**Microbus**	4.6%	5.0%	4.2%
5		**Tempo**	1.6%	1.7%	1.6%
6	**Non-Motorized Transport (NMT)**	**Walking**	18.4%	25.7%	13.0%
7		**Bicycle**	0.7%	0.7%	0.7%
		N	6261	2659	3602

5.2.2 Trip Rate

Work trip rate is found to be 1.51 per household per day for weekdays, whereas educational trip rate is 1.15 per household. The daily trips constitute, nearly 57 % work trips and 43 % educational trips. Total estimated number of work trips per day is estimated to be about 1.2 million and that of educational trip about 0.9 million, making total 2.1 million daily trips per day.

Table 5.5: Trip Rate per HH

Trip	Trips/HH/Day	Trips/ HH/Week	Share (per week) %	Total HH in KTM Valley	Estimated Total Person Trips per day
Work Trips	1.51	9.06	56.7%	792,300	1,196,373
Education Trips)	1.15	6.90	43.3%		911,145

5.2.3 Time of Trip Origination (Origin to Destination)

Time of trip origination is the time, when a household member leaves his/her home for the destination. Most of the work trips start between 8 am to 10 am. For educational trips, the time of trip starts from early in the morning from 6 am and goes up to 9 am and after that, there is a sharp decline.

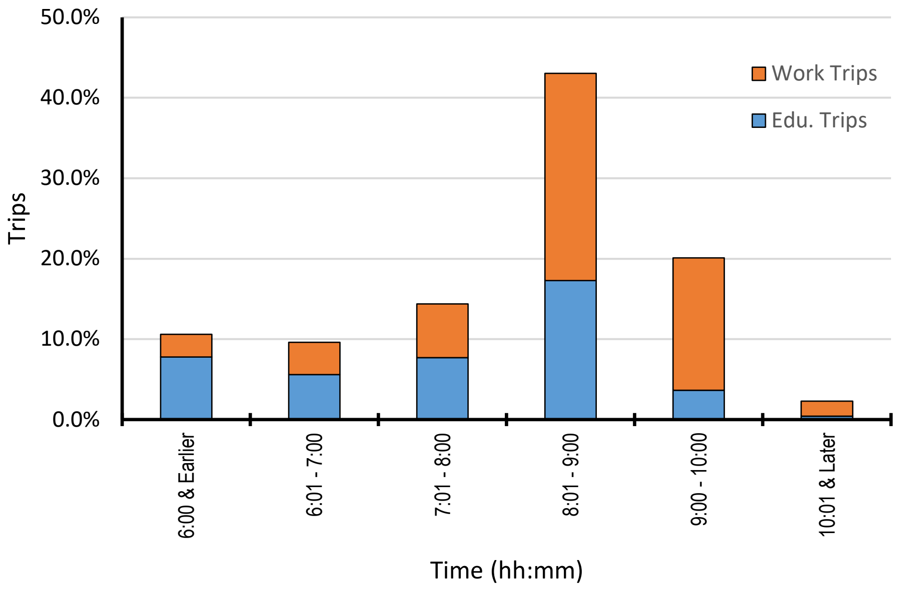


Figure 5.1: Time of Trip Origination

5.2.4 Average Trip Length and Average Journey Speed

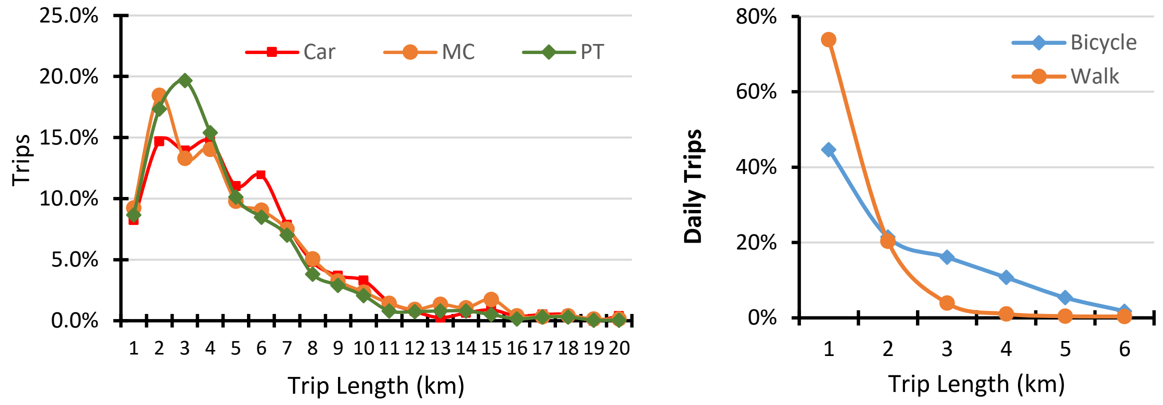
Table 5.6 shows the average trip length and journey speed. Average trip length is 4.56 km overall. For motorized modes, it is 4.9 km and 0.9 km for non-motorized modes. Motorcycle is having the highest average trip distance of about 5.1 km and for car, it is 5.0 km. For public modes, bus has the highest average trip distance, compared to microbus and tempo. Walk trips are mostly below 1 km. Most of the Bicycle users are travelling a distance of about 3 km in average. When we look at the figures of average journey speed, public modes have comparatively slower speed, as compared to private modes. Public vehicles take more time to travel due to their slow-moving speed and also more time is needed, with added out-vehicle time for walking and waiting.

Figure 5.2 shows trip length distribution for NMT and motorized modes, respectively. Motorized mode, here, denotes both private and public motorized vehicles. People are walking for short trips, mostly within a kilometer and gradually decreases, with increasing distance, showing a negative exponential trip distribution pattern. Because bicycle users are too few, in number, there are insufficient samples to represent the trip distribution pattern clearly.

For motorized modes, trip distances are vary mostly between 2 to 5 km. The distribution pattern is tending to be lognormal, where initially, for short trips, it is low and increases up to a certain distance to about 3 to 4 km and then again declines.

Table 5.6: Trip Length and Average Journey Speed

S.N	Mode Category	Mode	Average Trip Length (km)		Standard Deviation (km)	Average Journey Speed (km/hr)
1	**Private**	Car	4.90	5.0	3.1	15
2		Motorcycle		5.1	3.5	20
3	**Public**	Bus		4.7	3.1	12
4		Microbus		4.0	2.5	13
5		Tempo		3.3	1.9	13
6	**NMT**	Bicycle	0.9	2.9	1.8	10
7		Walking		0.9	0.8	



(A) (B)

Figure 5.2: Trip Length Distribution (A) Motorized Modes, (B) Non-Motorized Modes

Average trip length of work trip is 4.37 km and that of educational trips is 3.40 km. For Motorized modes only, trip lengths are 5.01 km and 4.75 km respectively. When categorizing trip length by education level, it shows that the length increases for higher educational level. For primary level, it 1.66 km, but for secondary and higher education, it is 2.96 km and 4.37 km respectively.

Table 5.7: Average Trip Length by Education Level

Age	Average Trip Length (km)	N	Level	%	Maximum	Minimum	Standard Deviation
<=8	1.66	406	Primary		13.00	0.10	1.87
9 - 18	2.96	1317	Secondary and Higher Secondary		14.00	0.10	2.55
>18	4.37	911	Higher Education		15.00	0.10	3.03

5.3 Attitude towards Urban Transport System

To study perception of the people towards the public transport system, the list of attributes were shown to the respondents and they were asked to choose the most important attribute out of all. It shows that most of the people opted for the reliable and timely service, chosen by 37% of the respondents.

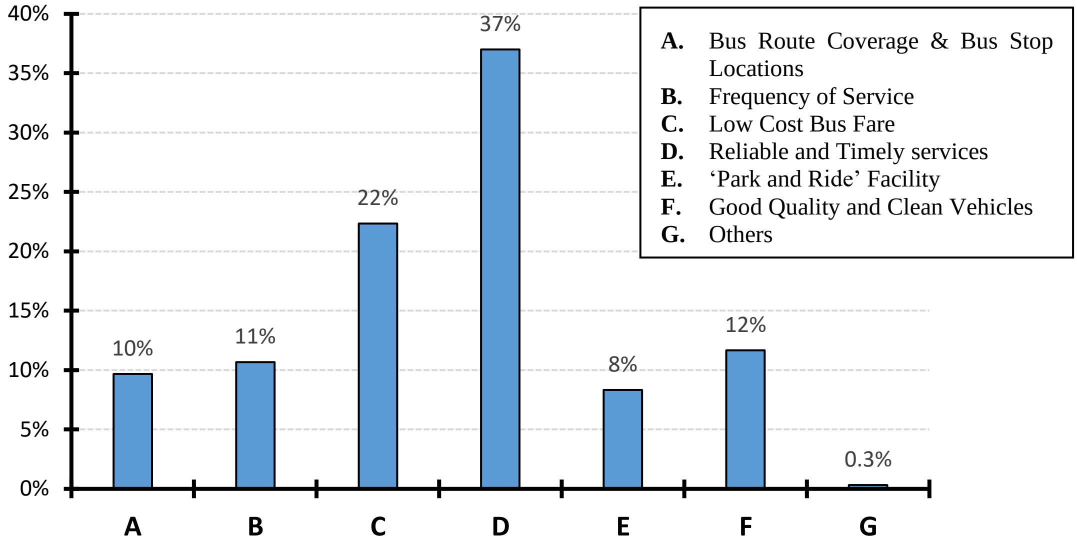


Figure 5.3: Preference on Attribute of Public Transport

5.3.1 Willingness to shift

Willingness to shift from private mode to public mode, indicates the willingness of the current private vehicle user, either car or motorcycle, for their daily trips to shift to public transport. It shows that about 56% of the car users and 72% of the motorcycle users are willing to shift to public transport, if pubic transport provides quality and timely service.

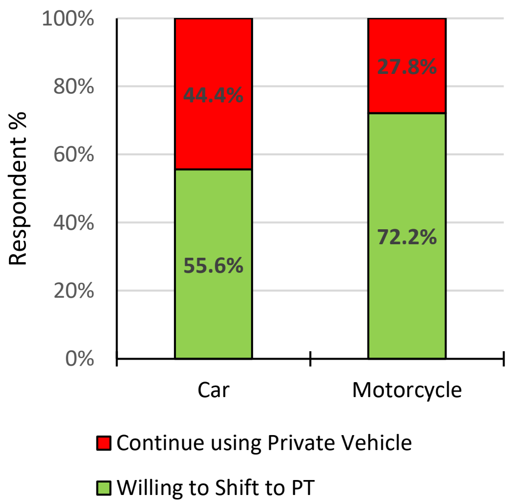


Figure 5.4: Willingness to Shift from Private to Public Mode

5.3.2 Preference on Travel Parameters

About 60% of the respondents said that travel time is the most important travel parameter. About 27%, think that comfort and safety are their main concern. Only 13 % opted for travel cost as their preference.

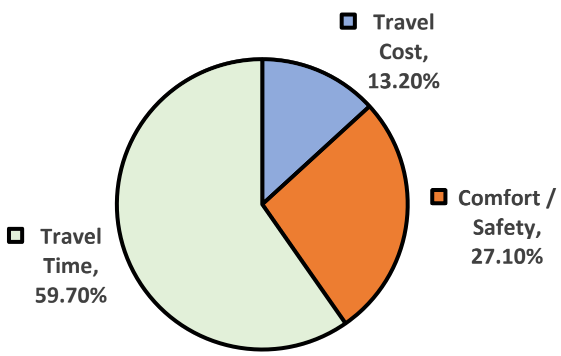


Figure 5.5: Preference on Travel Parameters

5.3.3 Concerns over Energy Efficient Urban Transportation

In response to the question of reducing transport energy consumption, most of the people think that good public transport system plays a major role, with 33 % of the respondents, opting for it. Secondly, the preference is given to the proper city planning, followed by, need of good roads and maintaining vehicle standards. People gave the least importance to non-motorized modes of transport. Only 4% of the respondents think that promotion of NMT has an influence in reducing transport energy.

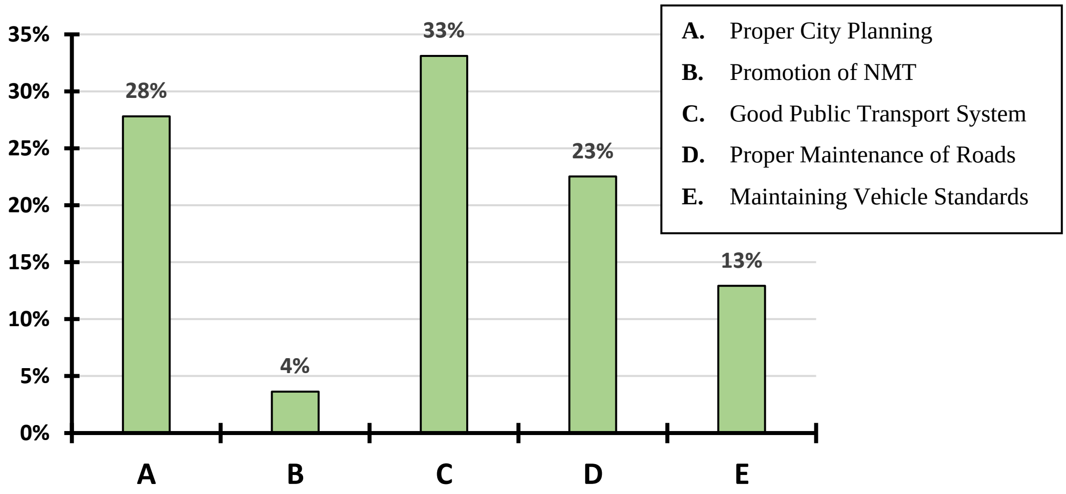


Figure 5.6: Ways to Improve Urban Transport

5.4 Conclusion

This chapter presents the socio-economic, demographic and travel characteristics of the sample population of the study area. The data presented in this chapter were used further, for travel behavior analysis and four step model, that has been described in the subsequent chapters.

Chapter 6. Analysis of Travel Behavior and Socio-Economic Background

This chapter analyzes the relationship between travel behavior and the socio-economic and demographic characteristics using statistical measures.

6.1 Influence of Socio-economic and demographic background on Travel behavior

Travelers try to optimize their outcomes in the context of the benefits and costs that they personally incur (Zhang & Zhao, 2016). According to Handy (2005), there are four main theories, related to travel behavior. They are (i) utility-maximizing theory, (ii) activity-based approach, (iii) theory of planned behavior, and (iv) social-cognitive theory. The first two theories refer to the mechanism determining travel behavior, whereas the latter two theories define factors influencing travel behavior.

The analysis done in this chapter is based on the fourth theory i.e. social-cognitive theory, whereby the influencing factors determining travel behavior were studied for work and educational trips. The social-cognitive theory postulates relationships among the individual's characteristics, the individual's behavior and the social environment in which this behavior is performed (Bandura, 1986).

For studying the travel behavior of the workers and students, four key variables - gender, age and income and household vehicle ownership, were identified for statistical analysis. Mode choice analysis was carried out, using the Pearson Chi-square test, for bivariate and tri-variate analysis. For trip length analysis, independent t-test and one-way independent ANOVA test were used, to compare trip length mean, among different groups.

6.2 Bivariate Analysis

For bi-variate analysis, two categorical variables were cross-tabulated. The dependent variable is the choice of the motorized modes of travel, that is either a private or a public mode. The independent variables are the variables of socio-economic background and personal characteristics. Mode choice was tested against Household Income, Household Vehicle Ownership, Gender and Age group using Pearson Chi Square. The variables are described in Table 6.1.

Table 6.1: Variable Description

S.N.	Variables	Description
1.	**Sociodemographic Variables: (Independent Variable)**	
a.	Gender	Gender of a worker /student
b.	Age Group	Age of a worker / student
c.	Household Monthly Income	Total household income earned in a month, in Nepalese Rupees (NRs)
d.	Household Vehicle Ownership	Total number of private vehicles owned in a household, both 2-wheeler (Motorcycle) and 4-wheeler (Car), together

S.N.	**Variables**	**Description**
2.	**Variables of Mode Choice: (Dependent Variable)**	
a.	Private	Trips made by private vehicle – either car or motorcycle.
b.	Public	Trips made by public transport – either bus, microbus or tempo.
c.	Trip Length	Length of work / educational trip for Motorized Mode

6.2.1 Household Vehicle Ownership

Table 6.2 shows that there is a significant relationship between the two variables. The relation is more prominent for work trips than for educational trips. People with no vehicles are mere captive travelers and they are fully dependent on public transport, except in few cases. Those people, owning 2 or more vehicles in a household, are hardly using public transport for work trips. Less than 5 % of the people, belonging to these categories are using public transport. For educational trips, the share of the public vehicle goes down gradually with an increase in vehicle ownership, but does not decline sharply as in the case of work trips.

Table 6.2: HH Vehicle Ownership × Mode Choice

No. of Household Vehicle Owned	**Work trips**				**Educational trips**			
	Private		**Public**		**Private**		**Public**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
No Vehicle	46	14.7%	266	85.3%	8	3.5%	226	96.5%
1	1068	80.1%	266	19.9%	111	12.2%	798	87.8%
2	1129	94.5%	66	5.5%	328	48.3%	351	51.7%
≥ 3	249	95.4%	12	4.6%	105	76.1%	33	23.9%
Test Results	γ^2 = 1038.5, P < 0.01, Cramer's V = 0.579				γ^2 = 473.7, P < 0.01, Cramer's V = 0.493			

6.2.2 Household Income

Table 6.3 shows the cross-tabulation between monthly household income and mode choice. For work trips, the chi-square test is significant (p<0.01), which indicates that there is an association between income level and the choice of the mode, with medium effect (Cramer's V = 0.352). The low-income group is more dependent on public mode (55.8%), than private mode (44.2%). With the rise in income level, there is an increased tendency in private vehicle usage and a decrease in the use of public transport. Only 6.5% of the workers belonging to the high-income group, earning more than NRs. 75,000, are traveling by public transport for their work trips. For educational trips, income and mode choice have a weak relation, shown by Cramer's V of small effect.

Table 6.3: HH Income × Mode Choice

Household Monthly Income (NRs.)	**Work trips**				**Educational trips**			
	Private		**Public**		**Private**		**Public**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
≤ 25000	145	44.2%	183	55.8%	30	14.1%	183	85.9%
25001 - 50000	745	76.5%	229	23.5%	151	24.8%	459	75.2%
50001 - 75000	951	86.5%	148	13.5%	214	31.5%	465	68.5%
> 75000	621	93.5%	43	6.5%	156	36.5%	271	63.5%
Test Results	γ^2 = 379, P < 0.01, Cramer's V = 0.352				γ^2 = 42.4, P < 0.01, Cramer's V = 0.148			

One of the main reasons behind the increment in private vehicle use with rising income level is the increasing vehicle ownership (Table 6.4). This applies specially to work trips. Few of the households earning less than NRs. 25,000, have their own vehicle. However, with increasing affordability, more of the households are owning private vehicles and accordingly its ownership rate is high for both middle and high-income groups.

Table 6.4: HH Income × HH Vehicle Ownership

Household Monthly Income (NRs.)	No. of Vehicles (car/motorcycle) owned in a Household			
	No Vehicle	1	2	≥ 3
≤ 25000 (N / %)	196	150	16	0
	59.4%	13.8%	2.2%	0.0%
25001 - 50000	99	497	154	13
	30.0%	45.6%	21.1%	10.5%
50001 - 75000	22	365	282	57
	6.7%	33.5%	38.6%	46.0%
> 75000	13	77	279	54
	3.9%	7.1%	38.2%	43.5%

$\gamma^2 = 996.0.$, $P < 0.01$, Cramer's V = 0.382

6.3 Income Group and Trip Length Variation

Table 6.5 shows that the difference of mean trip length of work trips, for different income groups, is significant (P-value < 0.01). For comparison of trip length among the income groups, Tukey post-hoc test was carried out, which is tabulated in Table 6.6. It shows that in general, work trip distance increases with an increase in income level. For the high-income group, mean trip length difference with other income groups is significant and vice versa. For educational trips, Levene's test is significant (p < 0.05), which shows that the variances are significantly different, which violates one of the assumptions of ANOVA. So, the ANOVA test cannot be done for educational trips.

Table 6.5: Summary of ANOVA, - Income Group and Trip Length of work trips

Income Group	N	Mean	Std. Deviation	Std. Error	Levene Statistic	ANOVA (one-way) Result		
						DF - total	F	P Value
1	466	3.80	3.91	0.18	1.227 (P value: 0.298)	3512	12.53	< 0.01
2	1133	4.10	3.81	0.11				
3	1227	4.05	3.63	0.10				
4	687	4.97	3.72	0.14				
Total	3513	4.21	3.76	0.06				

**Household Income Group- NRs.(IG) - 1: ≤25000, 2: 25001 – 50000; 3: 50001 – 75000; 4: > 75000*

Table 6.6: Post-hoc test (Tukey)- Income Group and Trip Length

Income Group * I	J	Mean Difference (I-J)	Std. Error	Sig.
1	2	-0.02	0.18	1.00
	3	-0.51*	0.18	0.03
	4	-1.67*	0.21	0.00
2	1	0.02	0.18	1.00
	3	-0.49*	0.14	0.00
	4	-1.65*	0.17	0.00
3	1	0.51*	0.18	0.03
	2	0.49*	0.14	0.00
	4	-1.16*	0.17	0.00
4	1	1.67*	0.21	0.00
	2	1.65*	0.17	0.00
	3	1.16*	0.17	0.00

**Household Income Group- NRs.(IG) - 1: ≤25000, 2: 25001 – 50000; 3: 50001 – 75000; 4: > 75000*

6.3.1 Age Group

Regarding the age group, Table 6.7 reveals that the share of public transport decreases with age. The relation is statistically significant as shown by the chi-square test, significant at $p < 0.01$, which indicates that mode choice and age group are related. For work trips, the effect is very small (Cramer's V = 0.156) whereas for education trips, there is considerable variation. 87% of the students below age 10 years and 79.6 % between 11 to 20 years are using public transport. For the age group, above 20 years, the share of public transport is 46.6 % is less than the share of a private vehicle (53.4 %).

Table 6.7: Age Group × Mode Choice

Age Group	Work trips				Age Group	Educational trips			
	Private		Public			Private		Public	
	N	%	N	%		N	%	N	%
≤ 30	516	69.3%	229	30.7%	≤ 10	46	13.0%	309	87.0%
31 - 50	1577	83.2%	319	16.8%	11 - 20	215	20.4%	840	79.6%
> 50	402	85.7%	67	14.3%	> 20	290	53.4%	253	46.6%
Test Results	γ^2 = 75.6., P < 0.01, Cramer's V = 0.156					γ^2 = 242.9, P < 0.01, Cramer's V = 0.353			

6.4 Gender

Difference in travel behavior for men and women was studied to know how the travel characteristics of daily trips varied by gender.

6.4.1 Trip Rate

The trip rate helps to assess the extent of mobility. Table 6.8 shows the trip rate per household per day for work and educational trips. Work trip rate of men per household is found to be more, almost three times, that of women. It shows that men are more involved in employment as compared to women. It also reflects that level of employment of women is low, meaning that they are mostly involved in household activities. For educational trips, the difference is marginal, but still, the trip rate of males is higher. For females, educational trip rate per household per day is 0.49, whereas for males, it is 0.67.

Table 6.8: Trips per HH per Day

Gender	Work Trip Rate	Edu. Trip Rate	Aggregate
Female (F)	0.40	0.49	0.89
Male (M)	1.17	0.67	1.83

6.4.2 Modal Share

The modal share of work and educational trips is shown in Table 6.9 by gender. For educational trips, there is minimal variation in modal shares of males and females. For work trips, there is a considerable difference in modal share by gender. The difference by gender for each travel mode is further whereby statistical tests were done to study the nature of the relationship between a particular mode choice and gender.

Table 6.9: Modal Share by Trip Purpose

Mode Category	Travel Mode	Female (F)		Male (M)	
		Edu. Trips	Work Trips	Edu. Trips	Work Trips
Private	Car	2.7%	7.5%	2.5%	25.2%
	Motorcycle/Scooter	13.8%	32.1%	21.4%	54.3%
Public	Tempo	1.8%	4.3%	1.6%	.6%
	Microbus	5.7%	8.1%	4.5%	2.9%
	Bus	47.0%	18.5%	45.5%	8.8%
Non-Motorized	Bicycle	0.2%	0.0%	1.1%	1.0%
	Walking	28.9%	29.4%	23.5%	7.3%

6.4.2.1 Car Users

Table 6.10 shows the cross-tabulation between the choice of a car and the gender for work and educational trips. The result of the chi-square test shows the relation to be significant for work trips with medium effect size (Cramer's V = 0.2), meaning that the use of a car is dependent on gender. More of the Men are using a car for their work trips, shown by odd's ratio of 4.22, which indicates that men are over 4 times more likely to use a car, as compared to females.

The relation is, however, not significant for educational trips. The figures show very few cases, less than 3 % of the students, using a car for their trips.

Table 6.10: Car × Gender

Trip Purpose	Gender	User		Non-User		Pearson Chi Square	P-Value	Cramer's V	Odds Ratio (M:F)
Work	F	7.2%	65	92.8%	838	130.0	< 0.05	0.2	4.22
	M	24.9%	652	75.1%	1964				
Educational	F	2.7%	30	97.3%	1084	0.4	Not Significant.	N/A	N/A
	M	2.6%	39	97.4%	1483				

6.4.2.2 Motorcycle / Scooter Users

For motorcycle users, the results of the chi-square test (Table 6.11) show the relation to be significant for both work and educational trips. The difference is more observed for work trips, with a medium effect size of 0.2 and the odds ratio of 2.5, indicating that men have more tendency to use motorcycles, as compared to women. For educational trips, the extent of variation is less in the use of motorcycles, whereby males still have a slight high tendency in its use, shown by odd’s ratio of 1.7. But the use of scooters is becoming popular among female students, as well, and its use could possibly rise in future. Overall, motorcycles or scooters are becoming very common for both males and females, and we can expect its share to rise in future if the current trend continues.

Table 6.11: Motorcycle × Gender

Trip Purpose	Gender	User		Non-User		Pearson Chi Square	P-Value	Cramer's V	Odds Ratio (M:F)
		%	N	%	N				
Work	F	32.20%	291	67.80%	612	132.5	< 0.05	0.2	2.5
	M	54.40%	1424	45.60%	1192				
Educational	F	13.60%	151	86.40%	963	25.6	< 0.05	0.1	1.7
	M	21.20%	323	78.80%	1199				

6.4.2.3 Public Transport Users

When analyzing the use of public transport by gender, for work trips, it reveals that women are more dependent on its use, as compared to men. It is reflected in Table 6.12, which shows the result of chi-square to be significant with medium effect and odd’s ratio of 0.31. It indicates that females are near about three times more likely to use public transport for work trips as compared to males. The relation is, however, not significant for educational trips, which shows that both male and female students have somewhat similar tendency to use public transport. Table 6.12 shows over 50 % of both male and female students are using public transport.

Table 6.12: Public Transport × Mode Choice

Trip Purpose	Gender	User		Non-User		Pearson Chi Square	P-Value	Cramer's V	Odds Ratio (M:F)
		%	N	%	N				
Work	F	31.00%	286	69.00%	636	170.3	< 0.05	0.22	0.31
	M	12.30%	329	87.70%	2352				
Educational	F	54.50%	607	45.50%	507	2.3	Not Significant	N/A	N/A
	M	51.40%	783	48.60%	739				

6.4.2.4 Non-motorized Modes – Walking and Cycling

When analyzing walking trips, also, in this case, more women are walking to reach their workplaces as compared to men. The odds ratio of 0.19 infers that women are over five times more likely to walk as compared to males. For educational trips, both males and females, the share of walk trips does not differ much [Odd’s Ratio = 0.8] and as such gender is not an influencing factor for walking trips, in case of students. It is indicated by the chi-square statistic which is although significant, it is very weak. The value of Cramer's V for the relation is only 0.06.

Table 6.13: Walking × Mode Choice

Trip Purpose	Gender	User		Non-User		Pearson Chi Square	P-Value	Cramer's V	Odds Ratio (M:F)
Work	F	30.00%	271	70.00%	632	295	< 0.05	0.3	0.19
	M	7.50%	196	92.50%	2420				
Educational	F	29.10%	324	70.90%	790	9.8	< 0.05	0.06	0.8
	M	23.70%	360	76.30%	1162				

No. of bicycle users are least of all modes, as shown by its modal share. For work trips, none of the females are found to use bicycles in the surveyed sample. The results of the Chi-square test are also not giving any meaning information, as the number of cases of bicycle use is very few and the value of Cramer's V is very small. It shows that it is the least attractive option for both work and educational trips for both sexes.

Table 6.14: Bicycle × Mode Choice

Trip Purpose	Gende r	Us er		Non-User		Pearson Chi Square	P-Value	Cramer's V	Odds Ratio (M:F)
Work	F	0.00%	0	100.00%	903	9	< 0.05	0.05	N/A
	M	1.00%	26	99.00%	2590				
Educational	F	0.20%	2	99.80%	1112	7.9	< 0.05	0.06	6.2
	M	1.10%	17	98.90%	1505				

6.4.3 Gender and Trip Length Variation

For comparing the trip distance of males and females, an independent sample t-test was carried out. The dependent variable is the Gender and the independent variable is the Trip Length. To discover whether the effect is substantive, effect size (r) is also calculated. In general effect size of 0.5 or above is taken as a strong effect (Field, 2009).

Table 9 shows the independent t-test test carried out to compare mean trip length for males and females for work and educational trips.

For work trips, the difference of the average mean trip length between males and females is quite significant ($p < 0.01$) with medium effect size ($r = 0.20$). From the table, it shows that males are commuting longer trip distances as compared to females. The average trip distance for a male is 4.6 km, whereas for females, it is 3.4 km.

For educational trips, the difference is not significant and thus we can say that there is no substantive difference in average trip length for educational trips between males and females. It shows that there is not much variation in the distribution of trip length patterns of male and female students. For males, it is around 3.5 km and for females, 3.3 km, showing only minimal difference.

Table 6.15: Independent Sample t-test for Trip Length

Trip Purpose	Gender	N	Mean (km)	Std. Dev.	t	P-value (2-tailed)	DF	Effect Size (r)	Remarks
Work	M	2601	4.6	4.4	8.3	< 0.01	1804	0.20	Equal variance not assumed
	F	896	3.4	3.2					
Educational	M	1505	3.5	3.1	1.6	Not Significant	2653	N/A	Equal variance assumed
	F	1108	3.3	2.8					

6.5 Multivariate Analysis

For multi-variate analysis, tri-variable analysis was done whereby three categorical variables were cross-tabulated. Mode choice is the dependent variable, gender as an independent variable and income group as the control variable.

Table 6.16 and Table 6.17 shows the cross-tabulation of income group, gender and mode choice for educational and work trips respectively. In the case of educational trips, only for the lower-income group, the relation between gender and mode choice is significant, with medium effect size (Cramer's V = 0.27). It shows that for this group, male students are seven times more likely to use private modes than females. For the middle-income group, the relation is weak, shown by small effect size. For the high-income group, the relation is not significant, which shows that mode choice and gender are not dependent.

Table 6.16: Edu. Trips: Income Group × Gender × Mode Choice

Income Group	Gender	Private		Public		Pearson Chi Square	P-value	Cramer's V	Odd's Ratio (M:F)
		N	%	N	%				
1	F	4	4.0%	95	96.0%	15.42	< 0.01	0.27	7.02
	M	26	22.8%	88	77.2%				
2	F	42	17.1%	204	82.9%	13.06	< 0.01	0.15	2.08
	M	109	29.9%	255	70.1%				
3	F	67	24.9%	202	75.1%	9.02	< 0.01	0.12	1.69
	M	147	35.9%	263	64.1%				
4	F	72	42.1%	99	57.9%	3.82	N.S.		
	M	84	32.8%	172	67.2%				

**Household Income Group- NRs. (IG) - 1: ≤25000, 2: 25001 – 50000; 3: 50001 – 75000; 4: > 75000*

For work trips, it shows that for all income groups, males have a greater tendency than females to use private vehicles compared to public vehicles. The trend increases as the income level goes up. Odd's ratio rises from 4.4 for low-income group to 10.46 for high-income group.

Table 6.17: Work Trips: Income Group × Gender × Mode Choice

Income Group	Gender	Private		Public		Pearson Chi Square	P-value	Cramer's V	Odd's Ratio (M:F)
		N	%	N	%				
1	F	11	18.3%	49	81.7%	19.93	< 0.01	0.25	4.40
	M	134	50.0%	134	50.0%				
2	F	75	41.2%	107	58.8%	154.91	< 0.01	0.40	7.83
	M	670	84.6%	122	15.4%				
3	F	150	61.7%	93	38.3%	164.72	< 0.01	0.39	9.03
	M	801	93.6%	55	6.4%				
4	F	123	79.9%	31	20.1%	61.72	< 0.01	0.30	10.46
	M	498	97.6%	12	2.4%				

**Household Income Group- NRs.(IG) - 1: ≤25000, 2: 25001 – 50000; 3: 50001 – 75000; 4: > 75000*

6.6 Conclusion

In this chapter, the relationship between the socio-economic background and demographic background of the people and their daily trip characteristics was studied. The analysis shows that income group, gender, age-group and vehicle ownership are the persuading factors, on travel behavior of daily trips. The statistical analysis done in this chapter has helped in the understanding of nature and the strength of the relationship between the variables and accordingly influencing factors of travel behavior were discussed.

Chapter 7. Travel Behavior, Urban Form and Travel Energy

In this chapter, linkage of travel behavior and urban form with travel energy of the trips was studied, using Energy Performance Index as an indicator.

7.1 Introduction

Transport energy demand is one of the major issues for the Kathmandu Valley, with rapid increment in auto-mobilization and urban sprawl. In this context, in this chapter, analysis has been made to study the role of urban form on travel energy of work trips and educational trips for the Kathmandu Valley. As per (Stead & Marshall, 2001), there are nine aspects of urban form. For analysis, three aspects were considered. They are distance to central business district (CBD), population density and accessibility to public transport.

7.2 Calculation of Travel Energy

Boussauw and Witlox (2009) investigated the link between spatial structure and energy consumption for home-to-work travel using the concept of a commute-energy performance index for Flanders, Belgium. Marique et al. (2012) used this index, further to study travel energy of Walloon region of Belgium for work and student trips.

Energy performance index (EPI) was used as an indicator for assessing energy consumption, which gives the average energy consumed per trip. EPI has been calculated at the level of survey zones. These survey zones were used as traffic analysis zones (TAZ) for spatial analysis. There are altogether 59 survey zones identified, as described in Chapter 2, in sampling strategy.

The formula of EPI has been adapted from Boussauw and Witlox (2009) and Marique et al. (2012), whereby, a similar study was carried out for Flanders and Walloon region of Belgium, respectively. This index takes into account, the distances traveled, the means of transport used and their relative consumption rates. It is expressed as

$$EPI_i = ATL_i \times \sum_{j=1}^{n} \left(MS_{i,j} \times EM_j \right) \quad \textbf{(7.1)}$$

Where,

$EPI_{i,}$ = Energy performance index for a TAZ ‘i’, per trip (MJ).

$ATL_{i,}$ = Average trip length for a TAZ, ‘i’ (km)

$MS_{i,j}$ = Modal share of travel mode ‘j’, of a TAZ, ‘i’ (%)

EM_j = Mean energy consumption per passenger km, for the travel mode, ‘j’ (MJ/p-km)

Table 7.1 shows the mean energy consumption per passenger-km for different modes obtained from various sources. The variation of vehicle type within a mode category was not considered. For instance, there are different kinds of buses in operation and all these were aggregated into one group with the average figure of fuel economy. The same applies to other modes as well. For cars and motorcycles, the fuel economy was obtained from the household survey, and for bus, it was from the survey of bus drivers. Tempos, are three-wheeler electric public vehicle, having a maximum capacity of ten passengers, that is operated along specific routes. The fuel economy data collected from the survey is an approximate figure. However, it still reflects the local driving conditions. The standard values of fuel economy are often high, which does not consider actual driving conditions. For walking and bicycle, energy consumed is taken as zero.

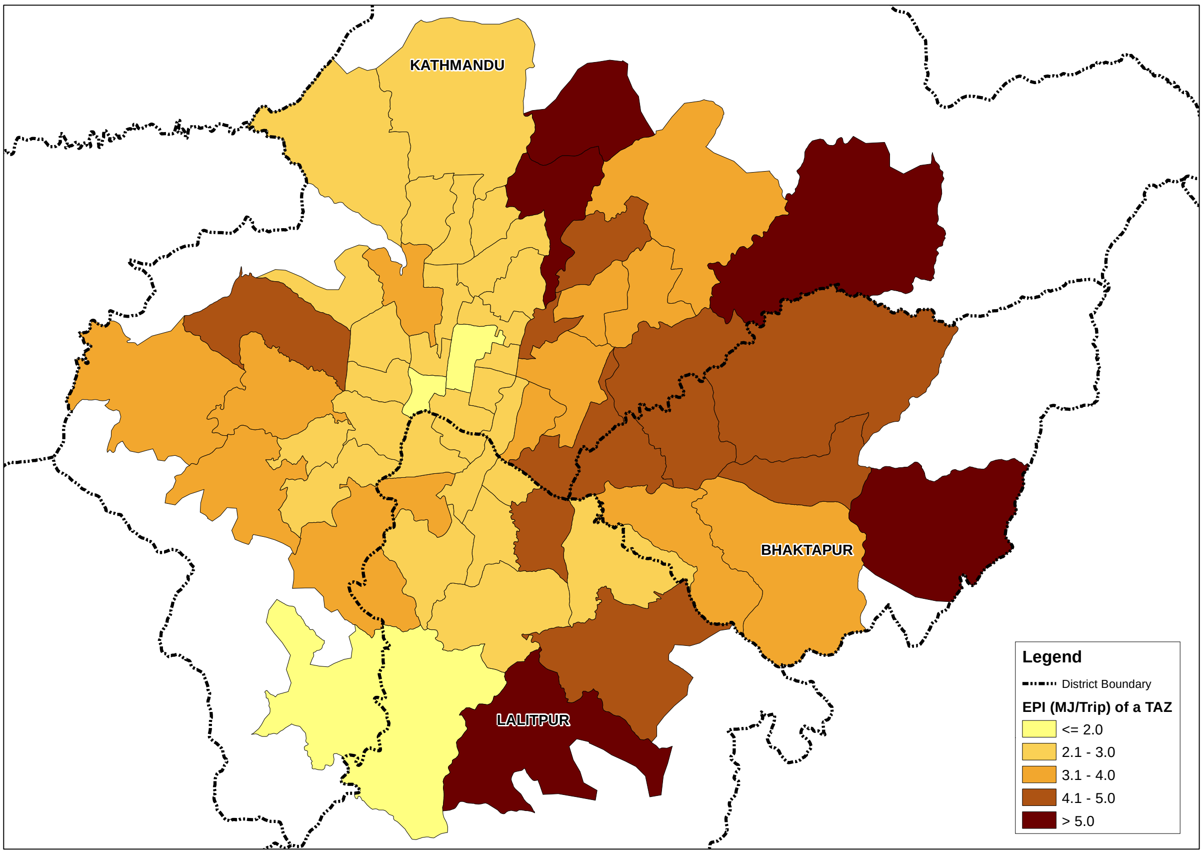
Table 7.1: Fuel Efficiency of Vehicles

Mode Category	Travel Mode	Fuel Economy (km/L)	Average Occupancy [b]	Fuel	Energy Density (MJ/L) [c]	Energy per km (MJ/km)	Energy per Passenger -km (MJ/p-km)
Private	Car	10.0 [a]	1.80	Gasoline	34.56	3.46	1.92
	Motorcycle	31.0 [a]	1.50	Gasoline	34.56	1.11	0.74
Public Transport (PT)	Bus	3.5 [b]	35.00	Diesel	38.77	11.08	0.32
	Microbus	7.5 [b]	15.00	Diesel	38.77	5.17	0.34
	Tempo	0.18 kwh/ km [d]	8.00	Electricity		0.65	0.08
Non-Motorized Transport NMT)	Walking						0
	Bicycle						0

Source: [a] Household Survey, [b] Roadside Survey, [c] The Engineering Toolbox (2017),
[d] Moulton and Cohen (1998)

7.3 EPI Analysis

EPI was calculated at the level of TAZ for work and educational trips. It shows the average energy per trip, in a TAZ. The variation of EPI by TAZ is seen more in work trips as compared to educational trips, shown by the standard deviations, 1.27 and 0.57 respectively. For the work trips, further analysis was carried out to see how the EPI of these trips is related to population density, accessibility to public transport and distance to CBD, which are discussed in the following sections. Map 7.1 shows the EPI of a TAZ for work trips.

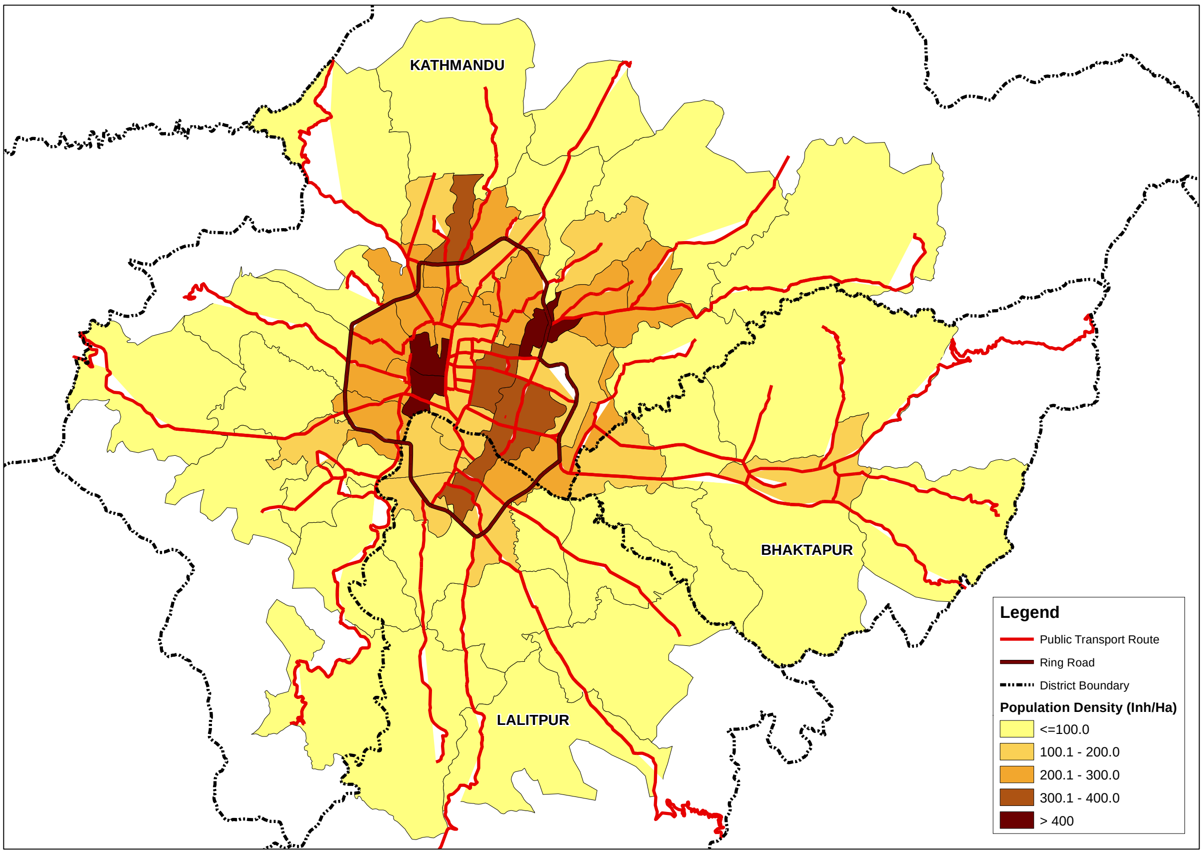


Map 7.1: EPI by TAZ, Home to Work trips

7.3.1 Population Density

Population density of a TAZ was derived as the number of inhabitants, per hectare (Map 7.2) based on population data of CBS (2011). Most of the densely populated areas are located around the central region.

There is a negative correlation (r = 0.320) between population density and EPI of the TAZ, which shows some indication of the decrease in travel energy, with an increase in population density. But the relation is not very strong. It shows that urban population density has a little impact on travel energy of work trips and as such, the density is not influencing much, in the travel pattern of work trips. This result is not found to be consistent with the findings of Newman and Kenworthy (1999), Banister et al. (1997) and Susilo and Stead (2008). According to them, urban density has a strong influence on reducing travel energy. However, our finding is similar to what Kitamura et al. (1997) and Van de Coevering and Schwanen (2006) had found, whereby they have stated that the impact of urban density on travel pattern is negligible.



Map 7.2: Population Density

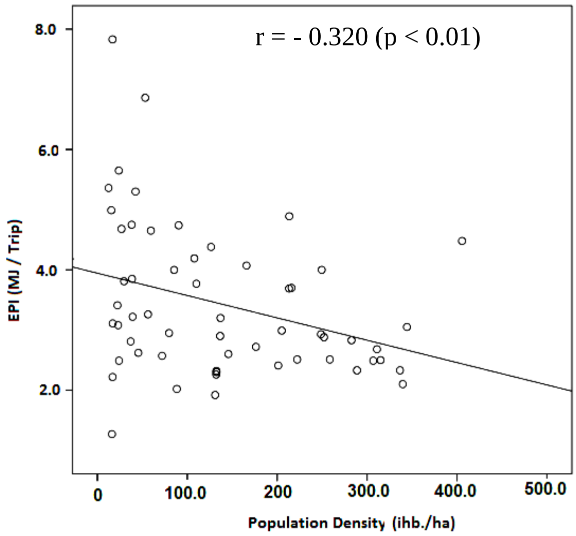


Figure 7.1: Scatter Plot Diagram: EPI and Population Density

Further, population density is correlated with the share of public transport, private vehicle, NMT and average trip length (Table 7.2).

Population density is having a negative correlation with PT share and positive with private vehicle share. It reveals that even in dense areas, people are dependent more on the use of private modes for their work trips, rather than PT. This result differs from the findings of Newman and Kenworthy (1999) and Bertaud and Malpezzi (2003), which state that low-density areas have high usage of automobiles and high density, being more favourable to public transport. Regarding NMT, there is no significant relation between NMT share and population density. Similar findings were revealed in the study of Rodriguez and Joo (2004), whereas Cervero and Kockelman (1997) found the positive correlation between NMT use and high density. Average trip length is having a negative correlation with the population density. In dense areas, work trip length is short, and it increases as density decreases. These dense areas are located mostly around CBD as revealed by Table 6, which shows a negative correlation between population density and distance to CBD. Job locations are concentrated around CBD and thus areas near it have short work trip length.

Table 7.2: Correlation Table for Population Density

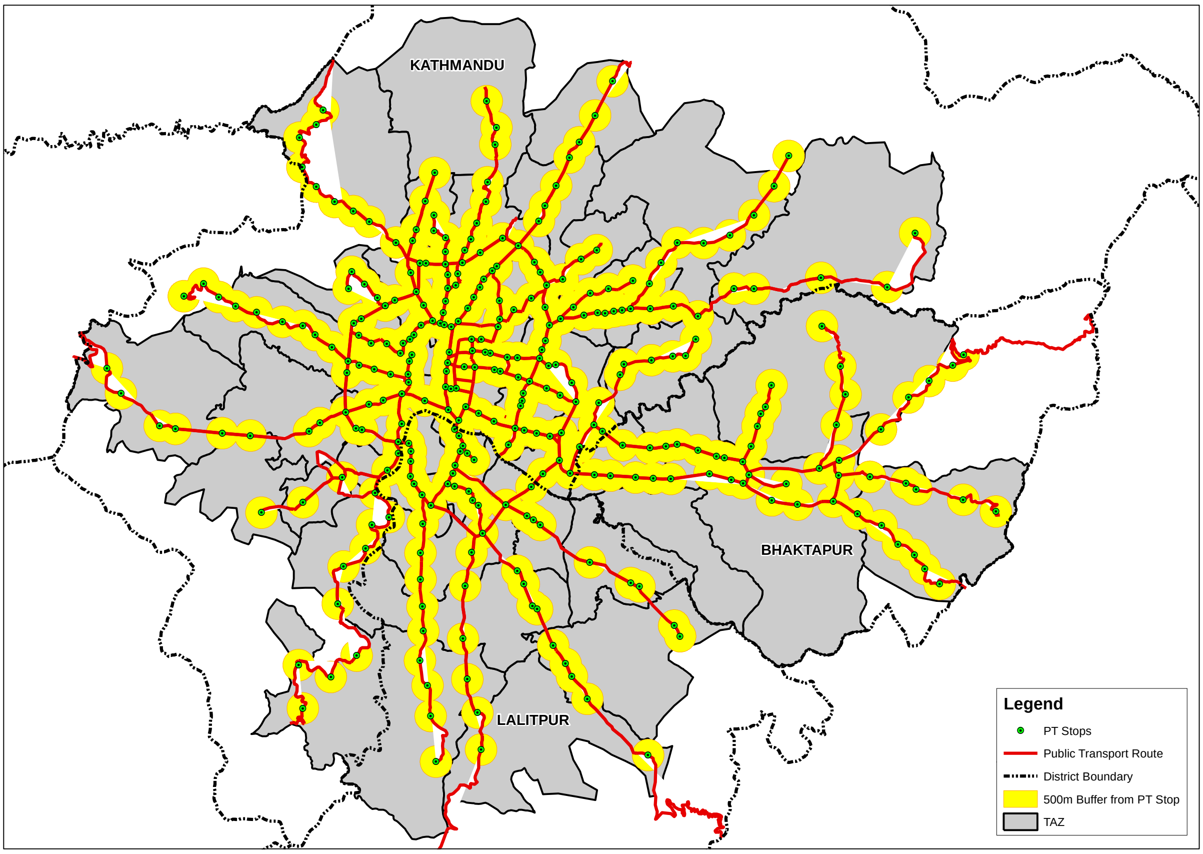
Variable 1	Variable 2	Unit	Pearson Correlation Coefficient (r)	p-value
Population Density (Inhabitants/Ha)	Public Transport Share	%	-0.361	**
	Private Vehicle Share	%	0.346	**
	Average Trip Distance	km	-0.459	**
	NMT Share	%	N.S.	

N=59. ** Correlation is significant at 0.01 level (2-tailed); * Significant at 0.05 level (2-tailed) N.S – Not Significant

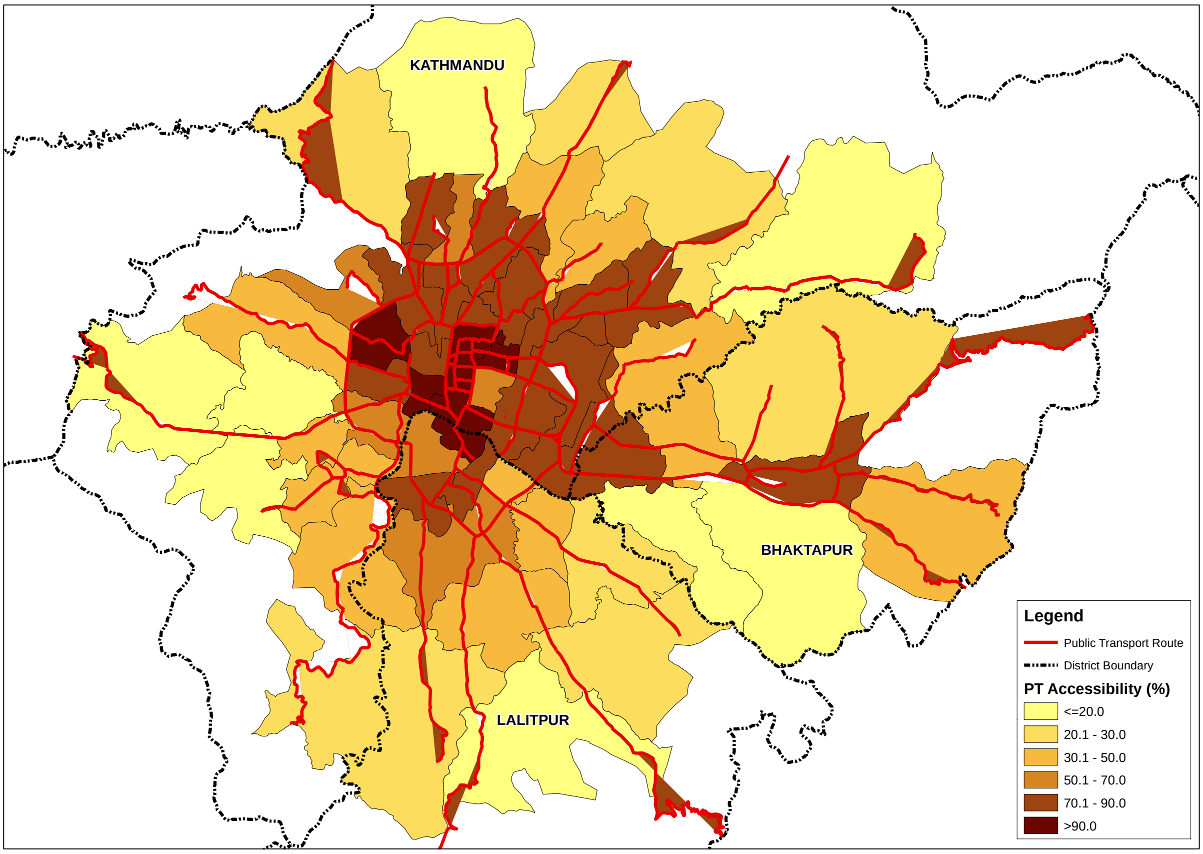
7.3.2 Public Transport Accessibility

Spatial accessibility of public transport service is one of the key characteristics with direct impact on the quality and utilization of public transport in cities (Alqhatania et al., 2012; Beirão & Cabral, 2007; Cervero, 2001). Public transport accessibility is defined here as the percentage of area in a TAZ, that is within 500m from the public transport stop (Map 7.3, Map 7.4). The routes, shown here belong to either one or multiple public transport mode, that includes bus, tempo and/or microbus. The method approximately defines the coverage of public transport. It is assumed that the population within the TAZ is uniformly distributed.

In the analysis, it is found to have a negative correlation between PT accessibility and EPI ($r = -0.309$, $p < 0.01$), however, the strength of the correlation is weak (Figure 7.2). It reveals that PT accessibility does not contribute much, in minimizing travel energy of work trips. Even in areas with high accessibility to PT service, many people are still dependent on private modes, indicated by a positive correlation ($r = +0.363$, $P<0.01$) between the share of private vehicles and PT accessibility. There is also a negative correlation between PT accessibility and PT share ($r = -0.35$, $p < 0.01$). This indicates that spatial accessibility is not the main aspect of PT share in the Kathmandu valley. Apart from coverage of PT service, it is also essential to look at the quality of the service. The level of service of the current PT system is not proving to be good enough, more importantly, in terms of travel time. Traveling by PT takes a longer time, as compared to private modes, as indicated by the average journey speed of different modes (Table 5.6). From the household survey, it was found that people give prime importance to travel time over other travel attributes. About 60% of the respondents opted travel time as the most important attribute as compared to travel cost (13%) and comfort/safety (27%).



Map 7.3: Public Transport Routes and Stop Locations



Map 7.4: Public Transport Accessibility

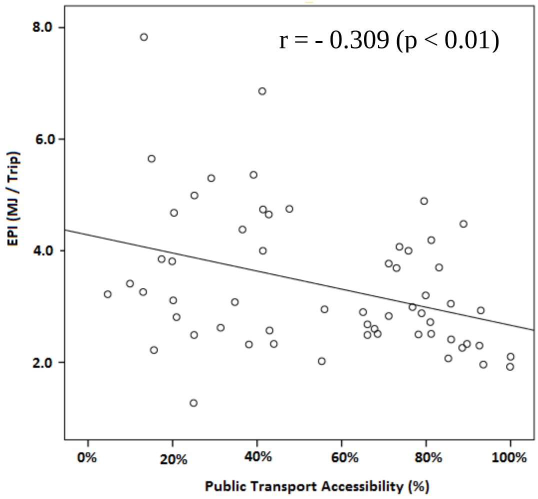
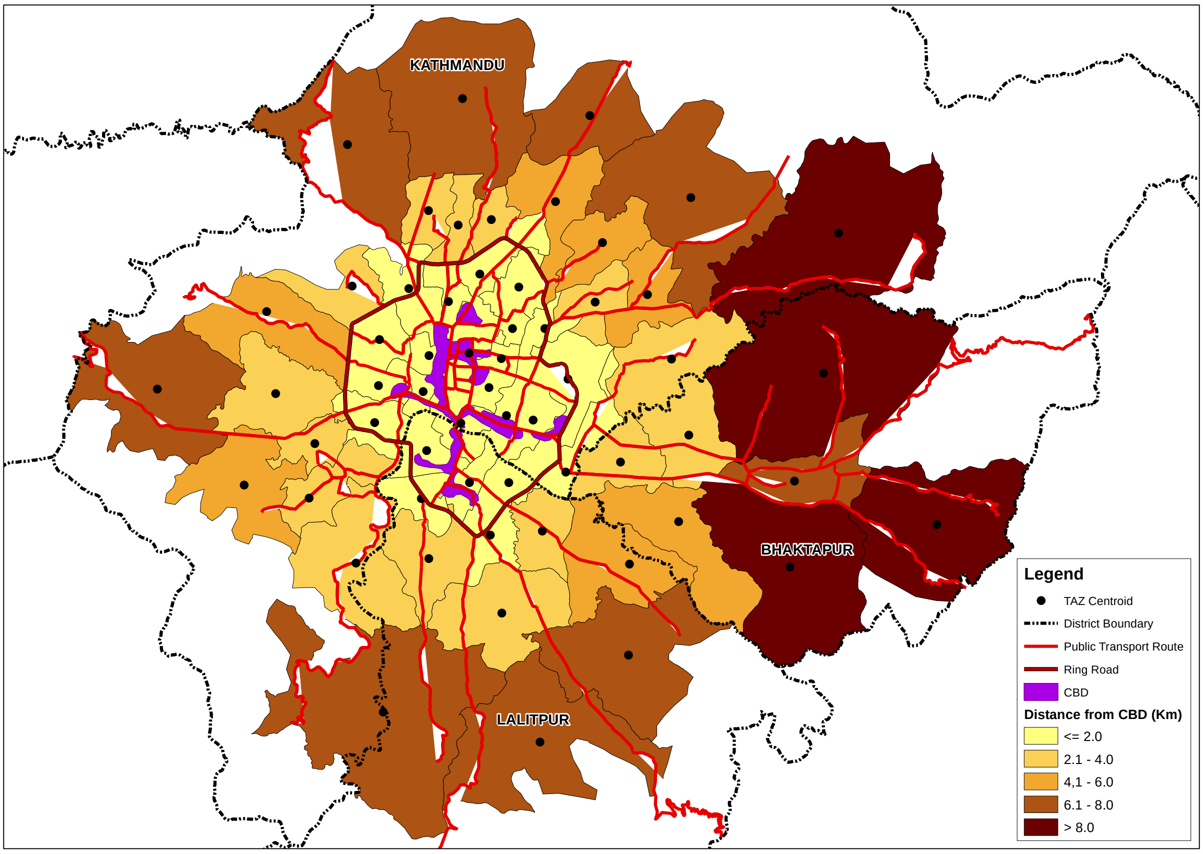


Figure 7.2: Scatter Plot Diagram: EPI and PT Accessibility

7.3.3 Distance from Central Business District (CBD)

CBD is the city center, where most of the urban activities are concentrated and is located at the central region of the valley (Map 7.5). It is the main center for job opportunities and other urban activities of the valley (KVDA, 2014)

Distance to CBD is the Euclidian distance between the centroid of the TAZ to the CBD, which is thus, representing an approximate distance. With increasing distance from CBD, EPI tends to increase, shown by the positive correlation between the two, of moderate strength (r= + 0.549).



Map 7.5: Distance of TAZ from CBD

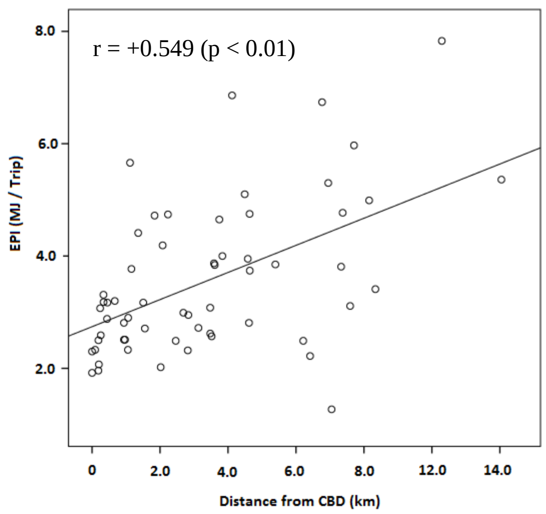


Figure 7.3: Scatter Plot Diagram - Distance of TAZ from CBD and EPI

Table 7.3 shows the correlation table for distance to CBD, whereby it is correlated with other variables.

Table 7.3: Correlation Table for Distance from CBD

Variable 1	Variable 2	Unit	Pearson Correlation Coefficient (r)	p-value
Distance from CBD (km)	Population Density	Inhabitants / Ha	-0.654	**
	Average Trip Distance	km	0.676	**
	Public Transport Accessibility	%	-0.760	**
	Public Transport Share	%	0.433	**
	Private Vehicle Share	%	-0.451	**
	NMT Share	%	N.S.	
	Avg. Private Vehicle Ownership rate per HH		-0.457	**
	Average Monthly HH Income	NRs.	-0.299	*

N=59. ** Correlation is significant at 0.01 level (2-tailed); * Significant at 0.05 level (2-tailed) N.S – Not Significant

Population density is high close to CBD and decreases towards the peripheral region as indicated by a negative correlation between the two. The work trip length is shorter close to CBD, compared to that of the peripheral region, where people have to travel longer, to reach their workplace. Accordingly, we see a positive correlation between distance to CBD and average trip distance.

When we look at the mode choice, the share of private vehicles is high close to CBD and it goes down further away. This is reflected by a negative correlation between the share of private vehicles and distance from CBD. Private vehicle ownership rate is also high close to CBD which has resulted in a high modal share of private vehicles around CBD. Share of PT is seen to be lower in central region, as compared to those of the peripheral region, shown by a positive correlation between PT share and distance to CBD (r=0.433). Although there is high spatial accessibility of PT, around CBD, its share is less. People living in the outskirts are more dependent on PT, but the level of accessibility is lower in those areas. For work trips, people living in the peripheral regions are facing inconvenience, as their trip distance is longer and also dependent more on PT, with limited access to it.

This result is contrary to the findings of Naess (2012). According to the author, people living close to CBD, tend to use more PT and less private modes as compared to areas further away from CBD.

There is a negative correlation between average income of a household in a TAZ and its distance from CBD. It shows that there is some indication for high income group to live close to CBD. But, the strength of correlation is very weak, and thus, the distribution pattern of different income groups, with respect to CBD location, is not definitive.

Regarding NMT use, it has no significant relation with the CBD location. Whether close to CBD or away from it, NMT share is not affected. Share of NMT should have been higher in the dense areas, around CBD as trip distance is short. But very few people are willing to walk or use bicycle for their work trips. The overall modal share also shows the least share of NMT, about 13.7 % (Table 5.4). Thus, along with density and trip length, we also need to look at the infrastructural provision and safety to understand the reason behind the decrease in NMT share (Hopkinson & Wardman, 1996; Wardman et al., 2007).

7.4 Conclusion

Energy Performance Index, measures the average energy consumption, based on generalized parameter values of fuel consumption, vehicle occupancy and travel characteristics. Pearson correlation coefficient was used to study the relationship between travel energy with urban population density, accessibility to PT and distance from CBD. Further, mode choice and trip length of work trips were analyzed to study the variation of travel energy.

About the method, Energy Performance Index, even though this index is only showing the average energy consumption, based on generalized parameter values of fuel consumption, vehicle occupancy and travel characteristics, it provides important insights on the role of individual urban factor, in transport energy consumption and its effect on overall energy demand. Further, regarding the analysis part, one of the limitations of the correlation is that it only explains the nature and strength of the relationship, but it does not explain causation. For causal analysis, it requires a regression model to be developed, whereby independent and dependent variables are accessed, which is not discussed in this research. This also requires the sample size to be larger.

Chapter 8. Development of Urban Transport Model System (UTMS)

This chapter explains the sequence followed in the development of UTMS, also called FSM. It describes the data collected and its preparation, and steps implemented in different stages of the model, followed by its calibration and validation.

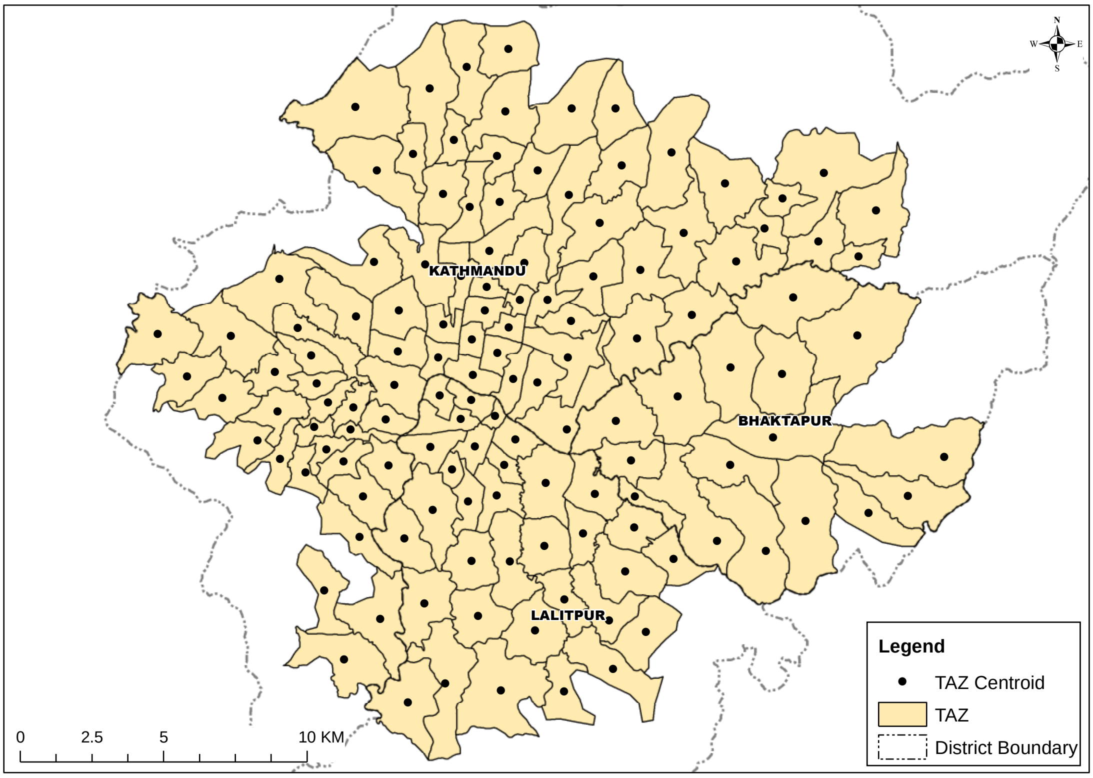
8.1 Data Acquisition and Preparation

All the necessary data, both spatial and non-spatial data were acquired from various sources listed as follows.

8.1.1 Spatial Dataset for UTMS

8.1.1.1 Traffic Analysis Zones (TAZ)

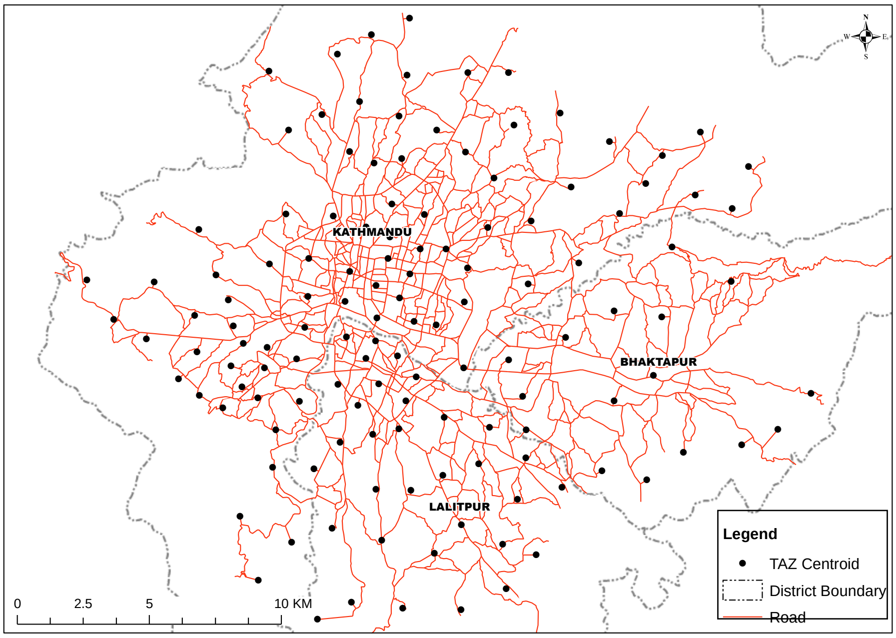
There are in total, 131 traffic analysis zones within the study area (Map 8.1). These TAZs are derived from the census boundary of 2011, which is either a VDC or a group of wards. (Annex 3).



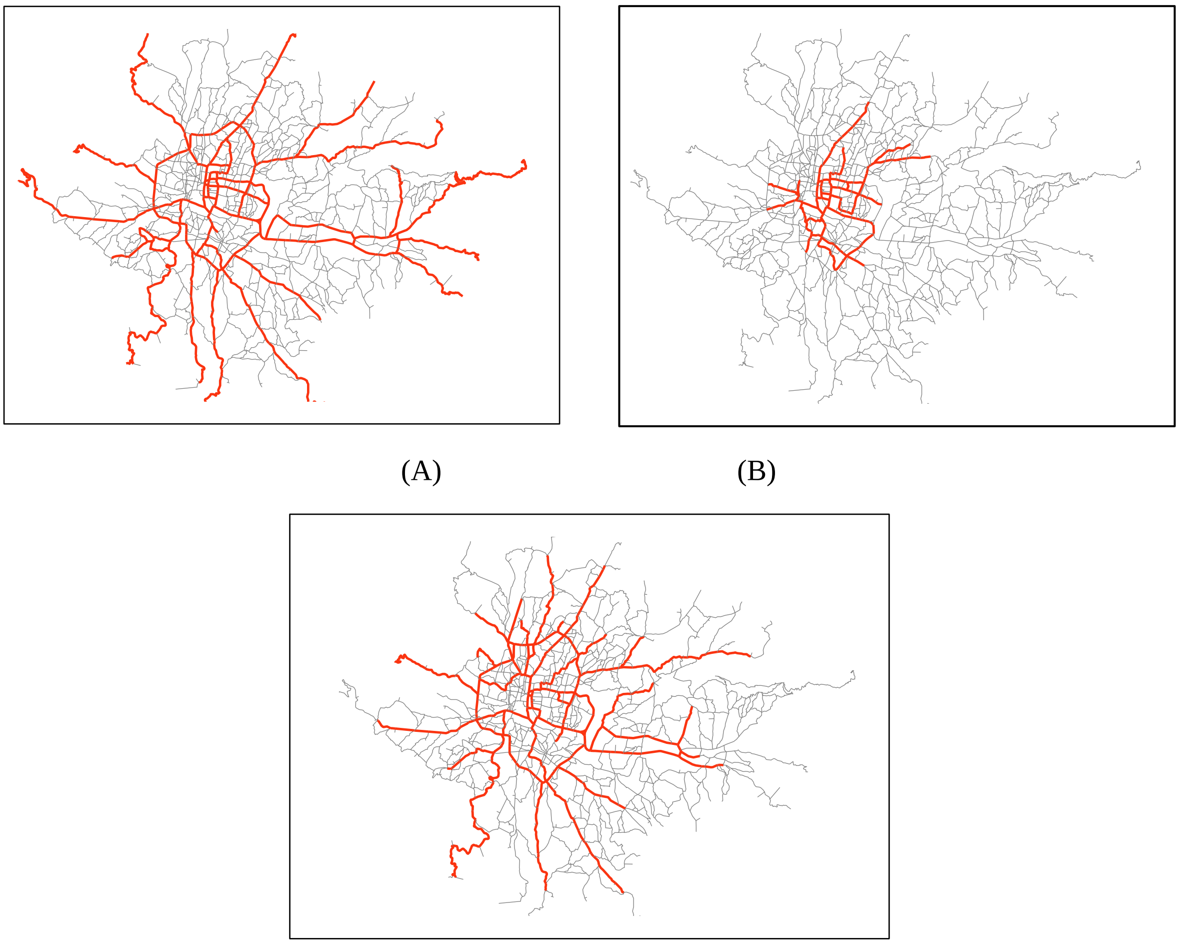
Map 8.1: Traffic Analysis Zones

8.1.1.2 Road Networks and Connectors

The roads used for the network analysis are the main road of the city (Map 8.2). The minor roads were not included. The road network data is checked for any topological errors, which is a preliminary step to be done, before performing network analysis. Public transport routes were further classified as per the type of public transport. Routes were identified for buses, microbuses and tempos (Map 8.3). The connectors are the line joining the centroid of the TAZ to the nearest road.



Map 8.2: Road Networks



(A) (B)

(C)

Map 8.3: Public Transport Routes: (A) Bus / Minibus, (B) Tempo, (C) Microbus

Source: DoTM (2017), Roadside Surveys

8.1.1.3 Distribution of Work and Educational facilities

Since the data on the distribution of work and educational facilities were not available, they were obtained from the open street map database. Work areas include all industrial, commercial, institutions and other service areas. Educational areas include all schools and colleges.

8.1.2 Non-Spatial Data

Trip characteristics data were obtained from the household survey, that includes trip rate, average trip distance and modal share. For population data, the figures were projected to the current year from the data of the 2011 census, using a current growth rate (Annex 3). The number of households for each TAZ was derived from the projected population of each TAZ. It was assumed that the average household size in a TAZ, remains unchanged over time.

8.1.3 Application Package

For transport modeling, OmniTRANS software was used. Mapping and Data Visualization were carried out using ArcGIS and QGIS. Database management was done using MS Excel and MS Access.

8.2 Steps in UTMS

Each step carried out in the FSM is explained below:

8.2.1 Trip Generation

This step estimates the number of trips produced (Trip Production) from and attracted (Trip Attraction) to each traffic analysis zones. Since trips, which originate somewhere, always have to end somewhere, there is always a condition that Trip Production is equal to Trip Attraction. Normally production data is more accurate and therefore, zonal attractions are normally adjusted to balance the equality.

Trip classification is done for daily trips, which is a one-way trip from origin to destination. It includes work trips and educational trips.

8.2.1.1 Trip Production

To estimate trip production, commonly adopted methods are Category Analysis, Regression Model and Growth Factor method (Zuidgeest & Maarseveen, 2007). In this research, category analysis was used to estimate trip production of work and educational trips. The category-analysis model is based on the assumption that the number of trips generated by similar households or households belonging to the same category is the same (Zuidgeest & Maarseveen, 2007). The number of work trips and educational trips, originating from each TAZ was calculated using trip rate per household, for each TAZ (Annex 4) using the formula below:

$$T_{t,p,k} = H_k \times AT_{p,k} \qquad \textbf{(8.1)}$$

Where,

$T_{t,\, p,,k}$ is the total trips of purpose 'p' (work and educational), generated from TAZ, 't', lying in strata 'k',

H_k is the total number of households in strata 'k'

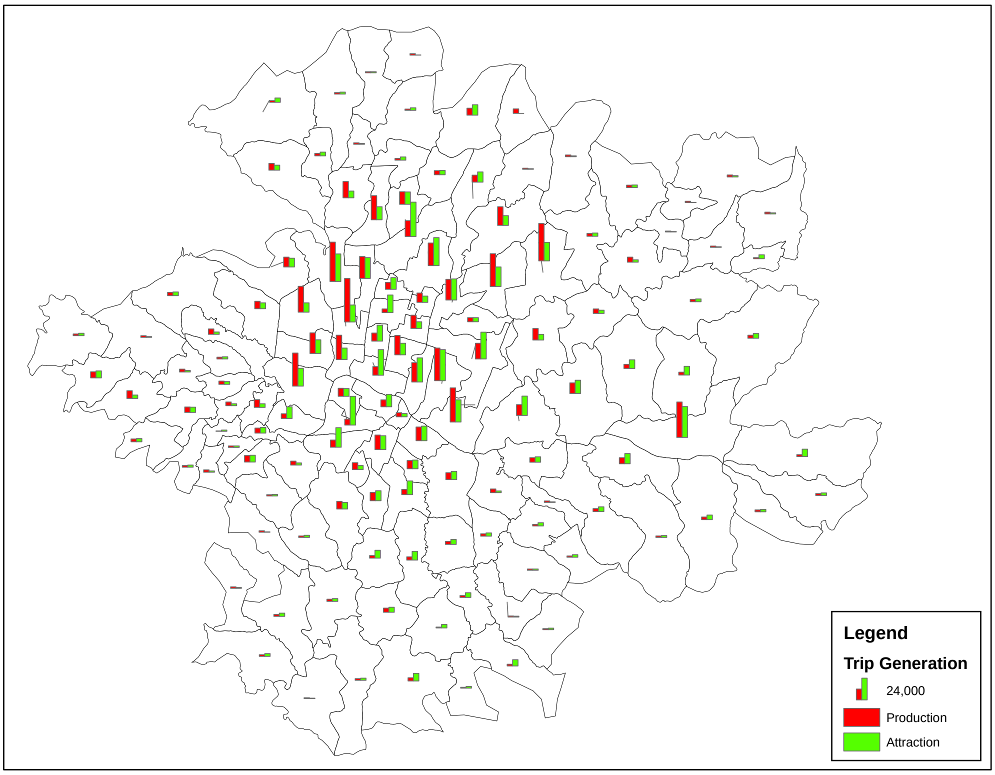
$AT_{p,k}$ is the trip rate of purpose 'p' generated from each household in strata 'k'

8.2.1.2 Trip Attraction

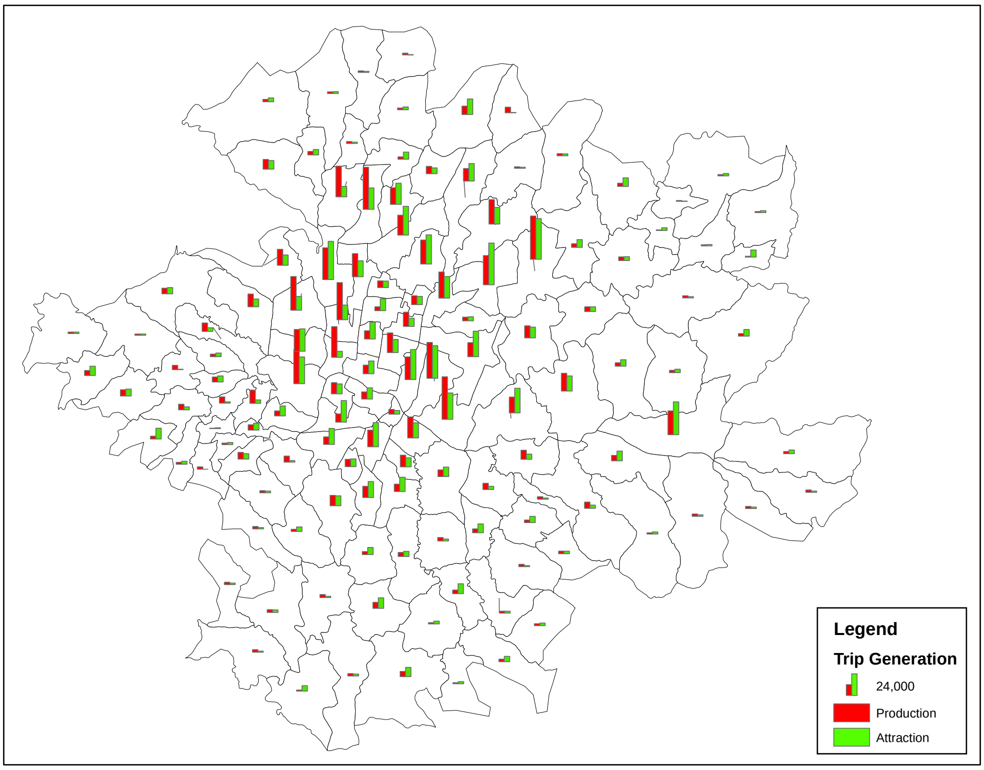
The trip attraction for work trips is dependent on job availability and for educational trips, the availability of educational facilities. Trip Attraction of work trips of a TAZ was calculated for each mode using Equation (8.5). A similar equation was developed for educational trips for the distribution of the trips, in accordance with the educational area in a TAZ, for each mode.

$$\text{Trip Attration}_{\text{WorkTrips}} = \text{Total Trip Producton}_{\text{WorkTrips}} \times \frac{\text{Work Place Area in a TAZ}}{\text{Total Work Place Area}} \qquad \textbf{(8.2)}$$

Detail tabulation of trip production and attraction is provided in Annex 4. Map 8.5 shows the trip generation for work and educational trips.



Map 8.4: Trip Production and Attraction for Work Trips



Map 8.5: Trip Production and Attraction for Educational Trips

8.2.2 Modal Split

Mode Split shows the number of trips by travel mode, originating from a TAZ. For deriving this modal share, TAZs were classified into three categories (Figure 8.1), based on its accessibility to the public transport service. They are

M : Microbus - Zones with access to the microbus

MT: Microbus and Tempo - Zones with access to microbus and tempo

O : Others - Rest of the zones

Modal split for each zone category is shown in Table 8.1

Table 8.1: Zone Category and Modal Split

Mode	Category: M		Category: MT		Category: O	
	Edu. Trips	Work Trips	Edu. Trips	Work Trips	Edu. Trips	Work Trips
Car	0.5%	16.8%	0.4%	24.9%	0.0%	17.8%
Motorcycle	13.6%	49.6%	21.8%	55.4%	16.8%	39.6%
Microbus	11.0%	6.5%	5.7%	6.7%	0.0%	0.0%
Bus	48.5%	13.5%	43.4%	9.4%	48.1%	23.4%
Tempo	0.0%	0.0%	2.9%	2.7%	0.0%	0.0%
Bicycle	0.3%	0.7%	1.1%	0.9%	3.8%	0.5%
Walk Trips	26.0%	12.9%	24.7%	14.2%	31.3%	18.8%

(Source: HH Survey)

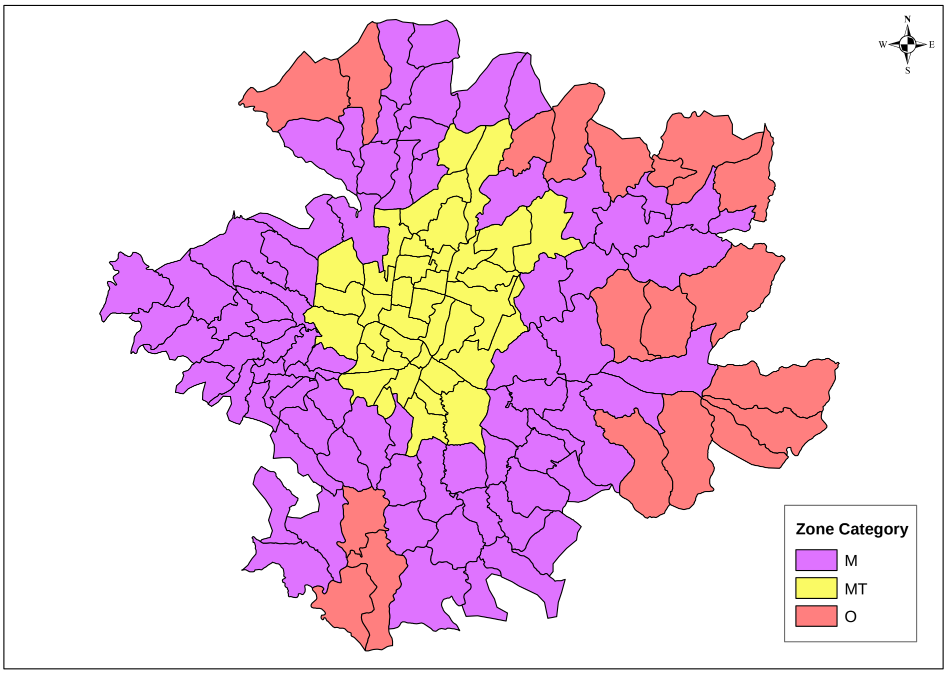


Figure 8.1: Zone Category

(Source: HH Survey)

8.2.3 Intrazonal Trips

Intra-zonal trips are the trips that have their origin and destination within the same zone. Assuming that population within a zone is evenly spread with a fixed density and roughly circular in shape, using the formula given by Batty (1976), intrazonal trip distance can be estimated by the formula -

$$ITD = \sqrt{\frac{A}{2\pi}} = \frac{r}{\sqrt{2}} \qquad \textbf{(8.3)}$$

Where,

ITD = Intrazonal Trip Distance

A = Area of a TAZ

R = Radius of a TAZ, assumed as a circle

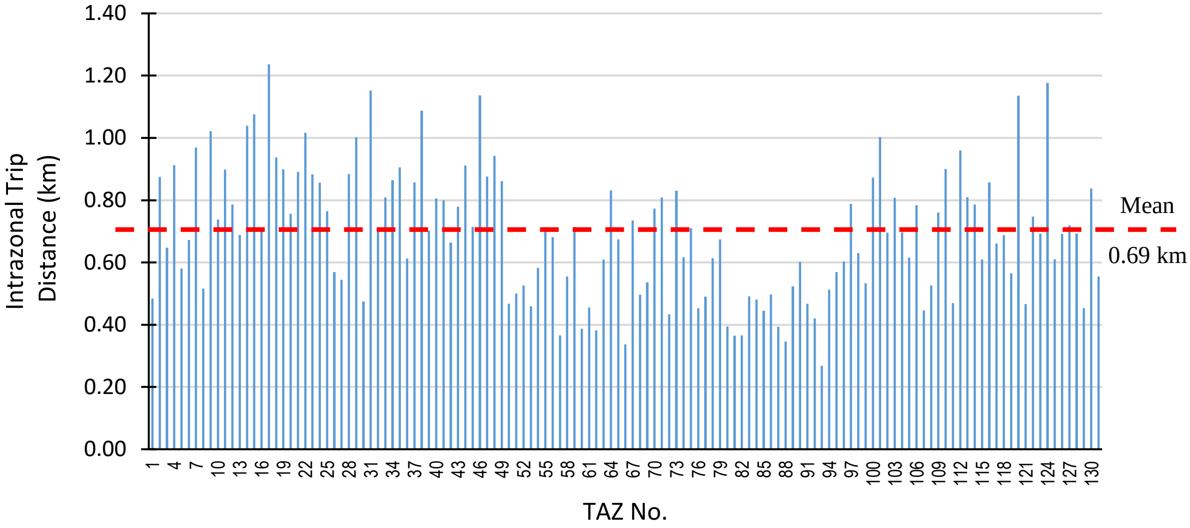


Figure 8.2: Intrazonal Trip Distance by TAZ

Average intrazonal trip distance is found to be 0.69 km (Figure 8.2). Intrazonal trip distance for most of the TAZ is below 1 km, except few cases. All of the walk trips and bicycle trips are assumed to be intrazonal. So, these trips have not been included in the model. For all motorized modes, intrazonal trips are restricted, as from the household survey, the minimum trip distance for the motorized modes was found to be 1 km.

8.2.4 Trip Distribution

In this stage, the origin and destination ends of the trips i.e. trip production and attraction, that is generated from the trip generation model are linked, for each motorized mode. Gravity model is developed for the trip distribution model.

According to the gravity model, the total number of trips between any two zones is calculated by:

$$T_{i-j} = K \frac{P_i \times A_j}{d^n} \tag{8.4}$$

Where,

$T_{i\text{-}j}$ is the number of trips from zone i to j

K and n are constant

P_i is the production of zone i

A_j is the attraction of zone j.

d is the distance between zone i and j

Further, the model can be generalized as

$$T_{i,j} = a_i \, b_j \, P_i \, A_j \, f(c_{ij}) \tag{8.5}$$

Where,

a_i, b_j are the scaling factors

f (c_{ij}) is the distribution function

C_{ij} is the generalized cost of travelling between the zones.

8.2.4.1 Distribution Function

The distribution function helps to measure accessibility between two zones in terms of impedance. Larger the impedance, the lower the accessibility and vice versa. For this model, the standard distribution function (OmniTRANS, 2011) used is shown in Equation (8.6) and travel time is the impedance.

$$f\,(c_{ij}) = \alpha\, e^{\beta . \ln^2 (c_{ij}+1)} \qquad \textbf{(8.6)}$$

where,

f (c_{ij}) : Distribution Function

c_{ij} : Impedance from zone i to j (travel time)

α, β : Parameters

Trip Restrictions:

All intrazonal trips for motorized mores are restricted. Other restriction includes the minimum trip distance, which is 1 km for Private modes and for public modes, it is 1 km along its route. This restriction is applied on the basis of minimum trip length data, obtained from the survey (Figure 5.2).

Estimation of Travel Times

Travel times for private and public mode was derived, using distance traveled, average journey speed (Table 5.6), waiting and walking times, as follows:

For private modes

Travel Time (TT) = In-vehicle Time (IVT) = Average Journey Speed (AJS) × Distance Travelled in Vehicle

For Public modes

Travel Time = Out-vehicle Time (OVT) + In-vehicle Time (IVT)

OVT = Walking Time + Waiting Time

IVT = AJS × Distance Travelled in Vehicle

Walking Time = (Distance from Origin Zone Centroid to Bus Stop + Distance from Bus Stop to Destination Zone Centroid) × Walking Speed (4km/hr.)

Average Waiting Time = 5 mins (Source: HH Survey)

8.2.5 Gravity Model Calibration

Model calibration adjusts parameter values until the predicted travel pattern matches the observed travel pattern within the given study area for the base year. For purposes of forecasting, it is assumed these parameters will remain constant over time (FHWA-NHI, 2002). The calibration of the trip distribution model is often performed using a comparison of regional trip length frequency distribution and mean trip lengths, between observed and model-estimated figures (Wegmann & Everett, 2016).

8.2.5.1 Parameter Estimates

During calibration, parameter values of α and β of the distribution function [Equation(8.6)] are estimated. During the calibration process, two parameters are checked, to match between modeled and observed figures. Observed figures were obtained from the data of the household survey. They are average trip length and frequency of trip distribution, measured by Coincidence Ratio. After repeated trial and error process, working with parameter values, an attempt was made to have the closest match between the modeled measure and observed measure. Table 8.2 shows the derived parameter values.

Table 8.2: Parameter Value Estimates

S.N.	Mode	Parameters	
		α	β
1.	Car	2.0	-0.45
2.	Motorcycle	2.0	-0.48
3.	Bus	2.0	-0.50
4.	Microbus	2.0	-0.68
5.	Tempo	2.0	-0.70

8.2.5.2 Average Trip Length

During calibration of trip distribution models, the observed and estimated trip lengths are both calculated. If the modeled and observed average trip lengths are within 5%, then it is typically considered reasonable (TFR, 2017a). Table 8.3 displays the comparison of average trip lengths between estimated and observed values.

Table 8.3: Average Trip Length - Observed and Estimated

S.N.	Mode	Mean Trip Length - km (Estimated)	Mean Trip Length - km (Observed)	Difference (%)
1.	Car	5.10	5.00	- 2.0 %
2.	Motorcycle	5.14	5.10	- 0.8 %
3.	Bus	4.79	4.70	- 1.80 %
4.	Microbus	4.00	4.08	1.60 %
5.	Tempo	3.30	3.32	0.40 %

8.2.6 Trip Length Frequency

The comparison of distributions of trip length frequency of the model result with the observed data is an effective method for calibration and validation. A quantitative measure which can be used to evaluate distribution validation is the coincidence ratio (FHA, 2017).

Coincidence Ratios (CR)

Coincidence ratios measure the closeness of the estimated trip frequency distribution with the observed distribution. The coincidence ratio is measured by the percent of the total area in common between two distributions. The coincidence ratio lies between 0 and 1, where a ratio of 0 indicates two disjoint distributions and 1 indicates similar distributions. It is desirable to have a value of 0.7 or higher coincidence ratio for each purpose (TFR, 2017b).

The procedure to calculate the coincidence of distributions is as follows (TFR, 2017b)

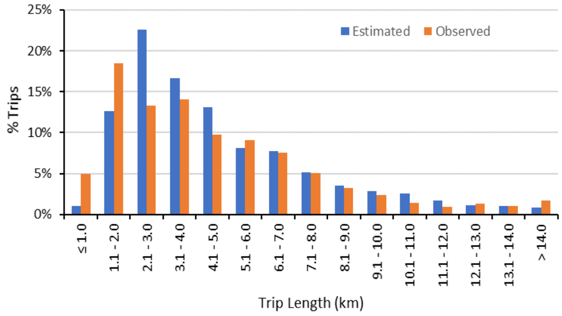
$$\mathrm{CR} = \frac{\sum [\min\left(\mathrm{PM_T}, \mathrm{PO_T}\right)}{\sum [\max\left(\mathrm{PM_T}, \mathrm{PO_T}\right)} \qquad \textbf{(8.7)}$$

where CR is the Coincidence Ratio; PM_T is the proportion of modeled distribution in interval T; PO_T is the proportion of observed distribution in interval T; and T is the histogram interval for distance.

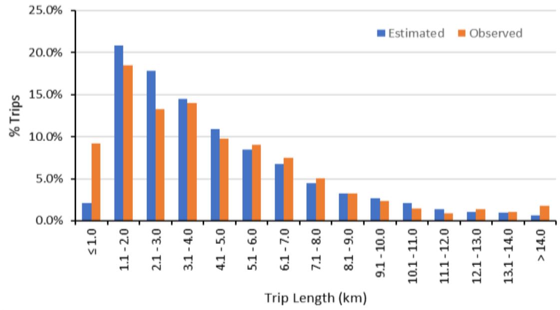
Table 8.4 shows the Coincidence Ratio calculated for each mode as per the comparison between the modeled (estimated) and the observed trip length distribution (Figure 8.3).

Table 8.4: Coincidence Ratio

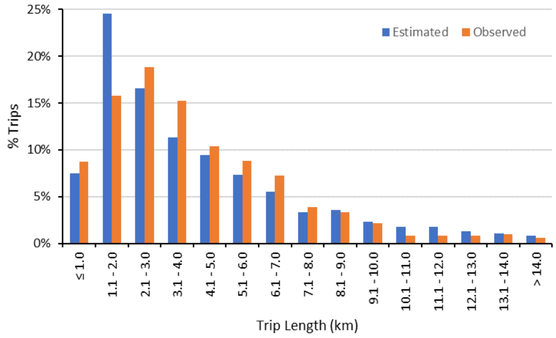
S.N.	Mode	Coincidence Ratio
1.	Car	0.71
2.	Motorcycle	0.80
3.	Bus	0.74
4.	Microbus	0.74
5.	Tempo	0.56



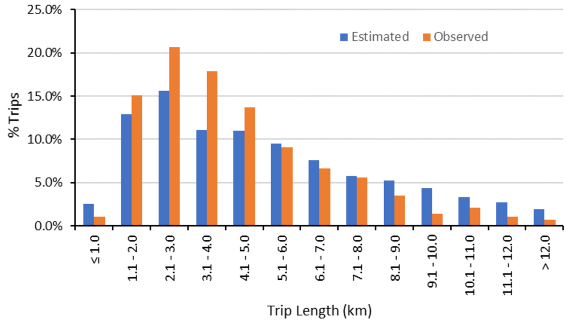
Car



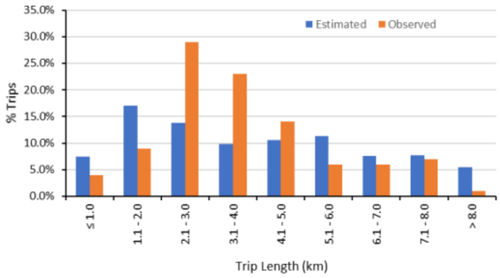
Motorcycle



Bus



Micro



Tempo

Figure 8.3: Trip Length Frequency for Coincidence Ratio

The resulting person trip distribution is converted to vehicular trips using average vehicle occupancy using Table 8.5.

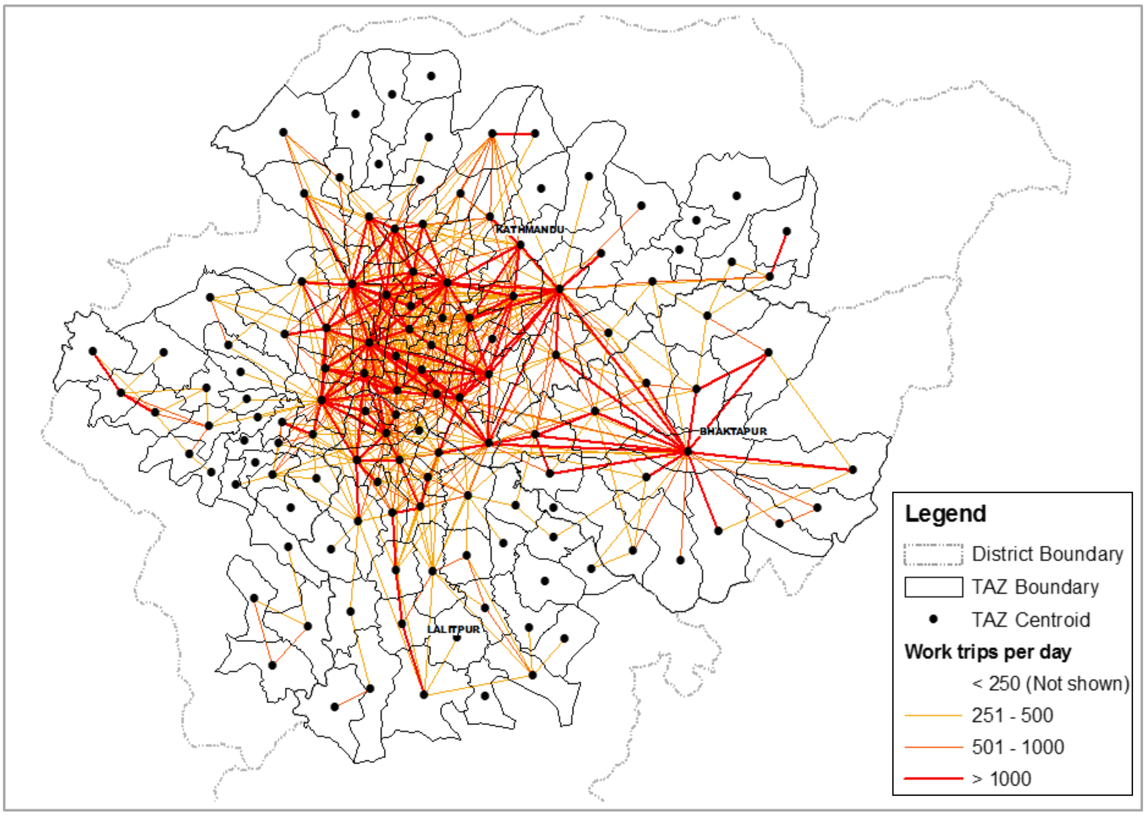
Table 8.5: Average Vehicle Occupancy

Travel Mode	Fuel Economy (L/km)	Average Occupancy
Car	10	1.8
Motorcycle	31	1.5
Bus	3.5	35
Micro	7.5	15
Tempo	0.20	8

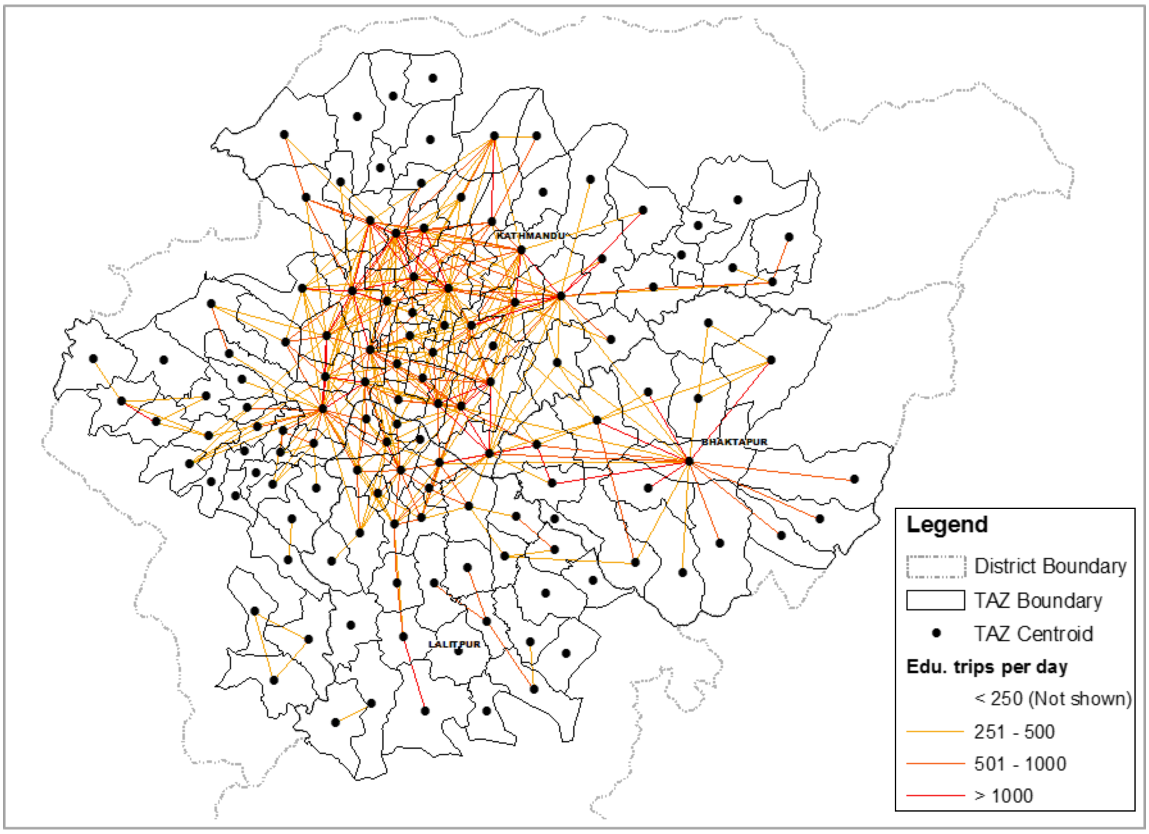
Source: HH Survey

8.2.7 Origin-Destination Matrix

The origin-destination matrix obtained from trip distribution for work and educational trips are shown in Map 8.7 and Map 8.7 respectively, in the form of desire line diagram.



Map 8.6: Desire Line Diagram of Work Trips

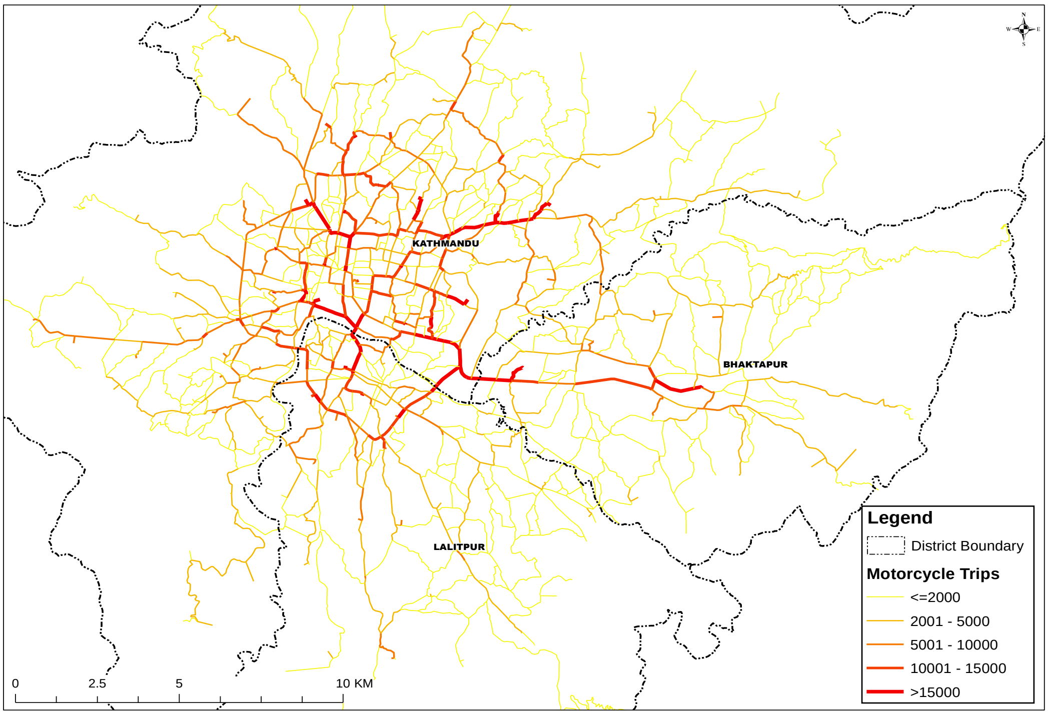


Map 8.7: Desire Line Diagram of Edu. Trips

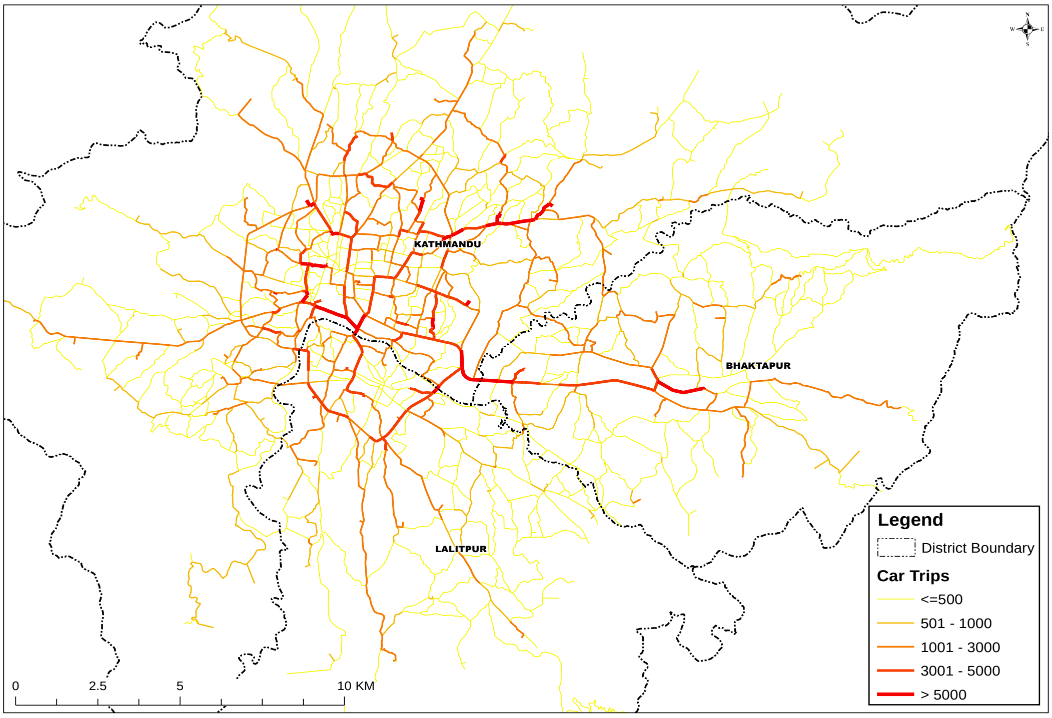
For each mode, trip distribution has 131 × 131 = 17161 Origin-Destination Pairs.

8.2.8 Route Assignment

For route assignment, All or Nothing (AON) method has been used, which assumes that there are no congestion effects, that all drivers consider the same attributes for route choice and that they perceive and weigh them in the same way (Zuidgeest & Maarseveen, 2007). It takes the shortest route in terms of travel time, from an origin to a destination in flow assignment.



Map 8.8: Route Assignment for Motorcycle



Map 8.9: Route Assignment for Car

8.2.9 Route Assignment Validation

Model validation tests the ability of the model to predict future behavior. Validation requires comparing the model predictions with data other than that used in estimating the model. Validation is an iterative process, typically linked to calibration (Pedersen & Sandahl, 1982).

Trip assignment validation involves a comparison of link volumes, derived from the model with the actual traffic counts. The model was validated using traffic counts, taken at the major road segments. The difference is calculated between observed and estimated values. FHWA-NHI (2002) suggests that all simulated links volumes should be within 5-10% of observed traffic volumes on the networks.

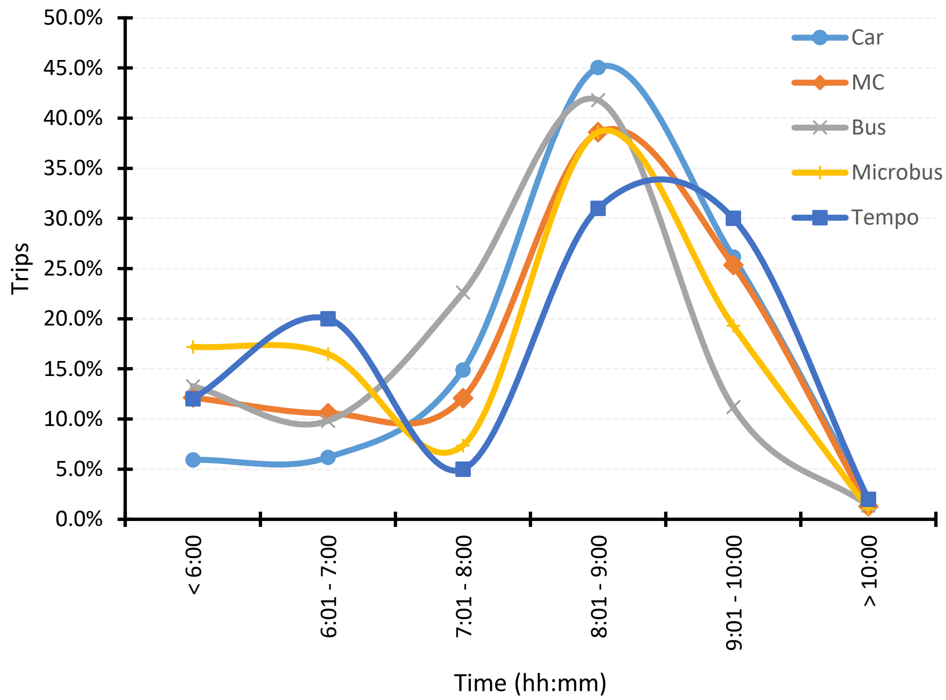


Figure 8.4: Time of morning trip - Home to Destination

Source: HH Survey

For the validation of the model, estimated and observed traffic counts of 9 am to 10 am is compared for four locations, as shown in Table 8.6. 9 am to 10 am is the peak hour for daily trips and thus comparison is made for this specific hour for validation. It is assumed that most of the traffic count observed in this hour belongs to work and educational trips. It is possible that some of the counts could belong to other trips that are not considered. The observed count is obtained from the screen line survey at specific locations.

Estimated trips from 9 am to 10 am is calculated for each mode using the following formulae, with reference to Figure 8.4:

$$\text{Share of total trips for 9 to 10 (S)} = \frac{(\text{\% trips - 8 am to 9 am}) + (\text{\% trips - 9 am to 10 am})}{2}$$

Estimated Trips of 9 am to 10 am = S × total trips of the day.

Table 8.6: Traffic Count - Hourly (9am - 10am)

Mode	Location 1: Tinkune -			Location 2: Thapathali - Kupondole			Location 3: Narayangopal Chowk - Basundhara Chowk			Location 4: Lanichaur - Kesharmahal			Location 5: Lagankhel - Satdobato Chowk		
	Obs.	Est.	Diff. (%)	Obs.	Est.	Diff. (%)	Obs.	Est.	Diff. (%)	Obs.	Est.	Diff. (%)	Obs.	Est.	Diff. (%)
Car	1287	1526	18.6%	1411	1608	14.0%	470	582	23.9%	820	1085	32.3%	648	768	18.6%
Motorcycle	4268	4810	12.7%	4442	4438	-0.1%	1880	2274	21.0%	3667	3790	3.4%	2436	1965	-19.3%
Bus	495	475	-4.1%	113	148	31.0%	280	221	-20.9%	193	181	-6.2%	92	91	-0.7%
Microbus	127	152	19.5%	177	132	-25.4%	140	106	-24.4%	193	155	-19.6%	68	71	4.3%
Tempo				133	93	-30.1%				43	103	138.8%	52	31	-40.3%

8.3 Limitations in UTMS

- FSM, as it is an aggregated model, it deals travel pattern of the group of people, instead of individuals to make forecasts. Behavior would have been captured better if modeling were done on the individual level. However, when studying at city scale, dealing with individual trips becomes virtually impracticable as there would largely voluminous and thus aggregation becomes necessary.
- Intrazonal trips are not considered in the model. So, as TAZ size increases, more of the intrazonal trips would be neglected.
- For trip distribution, the gravity model distributes trips , based on the size of trip ends (trip production and trip attractions) and travel time as impedance. Eventhough travel time is the most important attribute, there is some influence from the qualitative attribute associated with traveling, such as comfort, safety, reliability which is not considered in this model.
- The model assumes the study area as a closed system. This assumption restricts the possibility of trip exchange between zones within the study area and external zones, outside study area. Thus all trips are confined to internal zones only.

8.4 Possibilities of Further Improvements in the model

- For trip attraction, educational trips and work trips are based on floor area of schools and employment locations in TAZs, derived from Open Street Map. This is an approximate method to determine trip attraction. For trip attraction, For more accurate results, it is required to do the survey for trip attraction.
- For the trip assignment, All-or-Nothing assumes people to use the shortest route to travel, not taking into consideration, the congestion effect, thus giving a reasonably accurate flow pattern. In order to use equilibrium method for trip assignment, there is a need of total flow of vehicles,

that includes all trip purposes and freight transport. The modeling of only daily trips and lack of trip data for other trips made the equilibrium method inapplicable for the model developed.

- For the better derivation of a modal split, it is preferred to apply the discrete choice model using logit models, using choice set surveys. Also, for modal shift, logit model can be developed for willingness to shift using stated preference surveys, that compare the choice between their existing and proposed alternatives.
- The average journey speed, derived from the survey data, is the average speed of travel. The use of same journey speed to all the routes ignores the difference across various road segments, depending upon the traffic volume.

8.5 Conclusion

FSM helps to foresee the travel patterns in an urban area and the consequences of different alternative course of action, that provides the basis for formulating strategies of urban transportation planning . The output generated by the FSM is the travel flow pattern of work and educational trips for each mode, giving a picture of how the trips are distributed over the area. Using FMS, scenario analysis was done, which is explained in the next chapter, whereby, the role of modal shift and landuse change on transport energy consumption is analyzed.

Chapter 9. Formulation of Scenarios and Transport Energy Analysis

In this chapter, scenarios are formulated and transport energy derived for each scenario were analyzed.

9.1 Estimation of Annual Transport Energy

Total energy consumption was calculated for each mode and then it is summed to get total transport energy. Vehicular distance for each mode was derived from the route assignment step of the FSM. Transport Energy for a one-way trip from home to the destination is obtained Equation (9.1) and then it was converted to annual energy (Table 9.1).

$$TE_{one-way} = \sum_{i-1}^{n}\sum_{j=1}^{n} V_{i,j} \times E_j \tag{9.1}$$

Where,

$V_{i,j}$ = Vehicular distance for trip purpose 'i' (work and educational trips) for mode 'j' (motorized modes)

E_j = Energy consumed per km by a mode 'j' (Table 7.1)

Table 9.1: Calculation of Annual Transport Energy Consumption

SN	Particulars	Energy	Calculation	Remarks
1	Daily one–way Energy	E1	From Equation (9.1)	
2	Daily two-way Energy	E2	E1 × 2	It is assumed that, the way commuters travel for going to from home to work plase or school and return home trip is same.
3	Annual Energy Consumption	E3	E2 × 280	Out of 365 days, Saturdays) and (Public Holidays are deducted to get approximate annual working days.

9.2 Scenario Development

Scenarios were developed to assess the impact of modal shift and landuse change on transport energy. Base scenario and proposed scenarios formulated for analyzing transport energy are discussed below.

9.3 Base Scenario

The base scenario presents the current situation of the transport system, for the base year, 2017. From the result of the model, total annual transport energy consumption for work and education trips combined is found to be 3,666.9 TJ (Table 9.2 and Table 9.3) in the base scenario. When we analyze the energy consumption by mode, private vehicles have quite a high figure. Motorcycle contributes to about 46% share and car, 38% (Table 9.2). In contrary, public vehicles have far less share, only about 16%, combined.

Table 9.2: Daily Energy Consumption (One-way)

Travel Mode	Daily Vehicle - km			Energy per km (MJ/km)	Total Energy (MJ)	Total Energy (GJ)	Percentage
	Edu. Trips	Work Trips	Total				
Car	19415.8	1288449.4	726,591.8	3.46	2,514,007.5	2,514.0	38.4%
Motorcycle	828714.1	3225341.4	2,702,703.7	1.11	3,000,001.1	3,000.0	45.8%
Bus	1920901.0	679262.2	74,290.4	11.08	823,137.4	823.1	12.6%
Micro	283949.8	303087.5	39,135.8	5.17	202,332.2	202.3	3.1%
Tempo	46099.8	58360.9	13,057.6	0.65	8,487.4	8.5	0.1%
			Total Energy Consumed:		**6,547,965.6**	**6,548.0**	

Table 9.3: Annual Energy Consumption

SN	Particulars	Notation	Total Energy	Calculation
1	Daily Transport Energy (One–way) GJ	E1	6,548.0	From Table 4
2	Daily Transport Energy (Two Way)	E2	13,095.9	E1 × 2
3	Annual Energy Consumption	E3	3,666,860.7	E2 × 280
4	Annual Energy Consumption (TJ)	E4	3,666.9	E3 / 1,000
Energy Units - MJ: Mega Joule; GJ: Giga Joule; TJ: Tera Joule				

9.3.1 Transport Energy at the TAZ level

This measure gives the total annual transport energy of a TAZ and it shows the variation of energy consumption pattern of the zones over the study area. The energy of a TAZ is annual transport energy consumed by the vehicular trips originating from it.

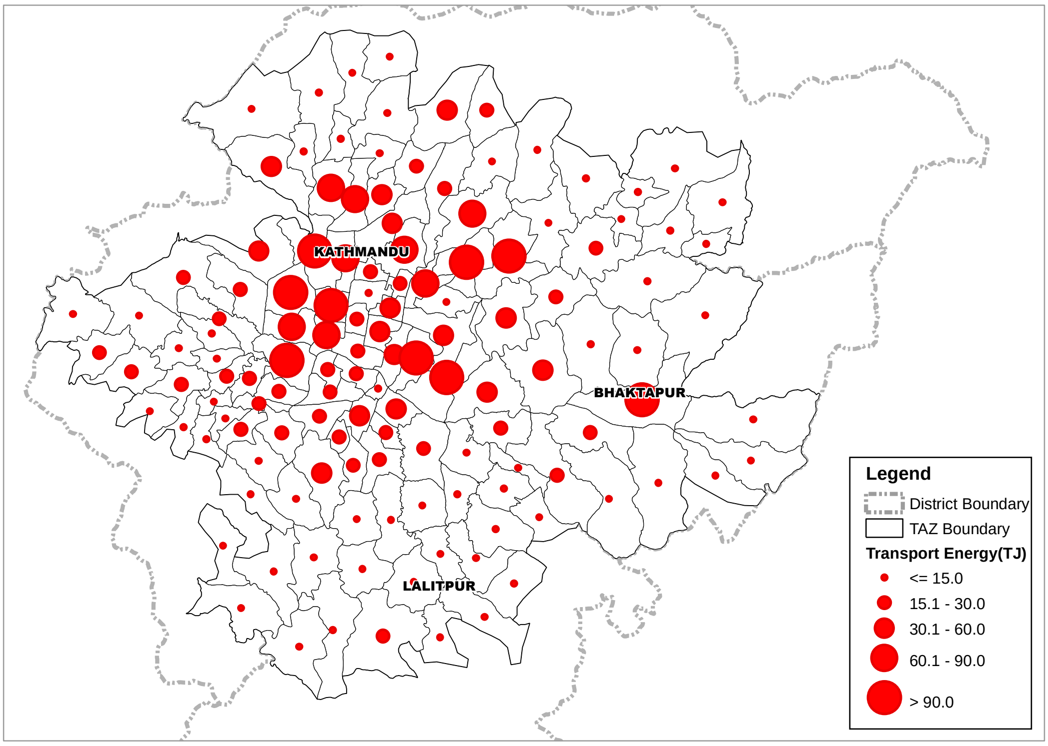
$$\mathrm{TAZ}_{\mathrm{TE}} = \sum_{i-1}^{n}\sum_{j=1}^{n} \mathrm{AV}_{i,j} \times \mathrm{E}_{j} \tag{9.2}$$

where,

$AV_{i,j}$ = Annual vehicular distance for trip purpose ‘i’ (work and educational trips) for mode ‘j’ of all trips originating from a TAZ.

E_j = Energy consumed per km by a mode ‘j’ (Table 7.1)

Map 9.1 shows the distribution pattern of the TAZ transport energy. TAZs, around the central region have high energy consumption level. This is because currently, the trips are more concentrated around the central region, where population density is high and most of the services and facilities are located. This is reflected in Map 8.6 and Map 8.7, showing the origin-destination matrix for work and educational trips respectively.



Map 9.1: Annual Transport Energy Consumption per TAZ (Base Scenario)

9.3.2 Average Trip Distance

For base scenario, average trip distance for motorized modes is found to be 4.9 km, as per the household survey data. For work trips, it is 5.01 km and for educational trips, 4.75 km.

9.4 Business as Usual: Future Scenario

9.4.1 Future Population Growth Pattern

Kathmandu Valley is in the stage of rapid population growth and its population is expected to rise accordingly across all the areas of the valley. This scenario assumes business as usual scenario to predict the future of transport energy demand. With a growing population, more of the peripheral region of the valley, which are currently agricultural and vacant land (Map 4.1), are being converted to the built-up area. If this trend continues in the future, the population is expected to rise more rapidly in the peripheral region than in the central area. Accordingly, the additional future population is distributed in accordance with the vacant land available. It is assumed that the trip rate per household, average household size, modal split and landuse pattern remains the same over time. Figure 9.1 shows the population projection of the valley based on logistic growth method with the estimated carrying capacity of the Kathmandu Valley to be around 8.0 million population (Annex 7).

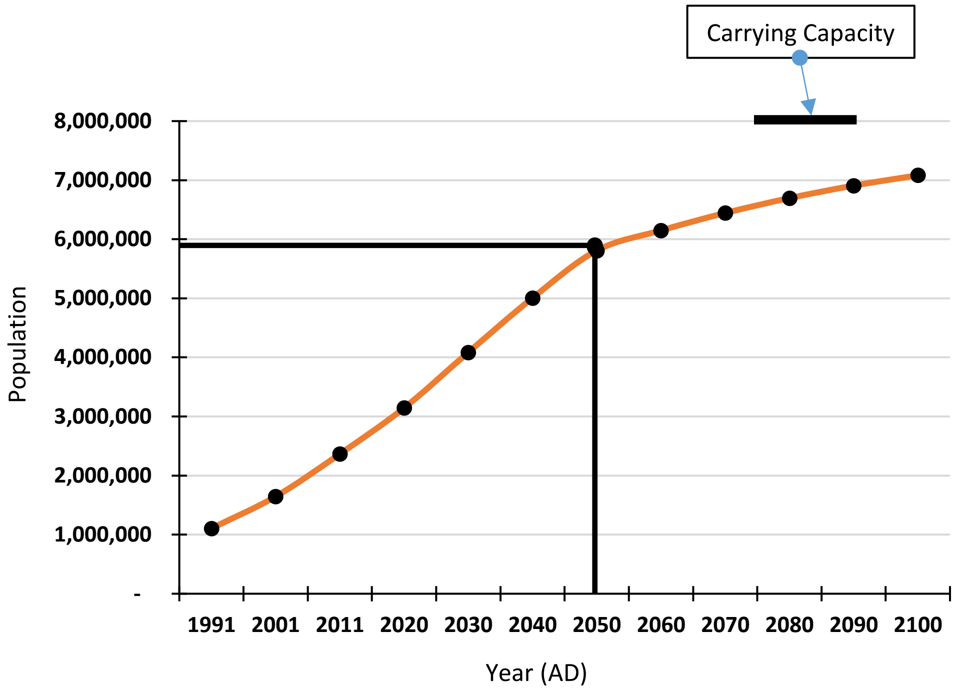
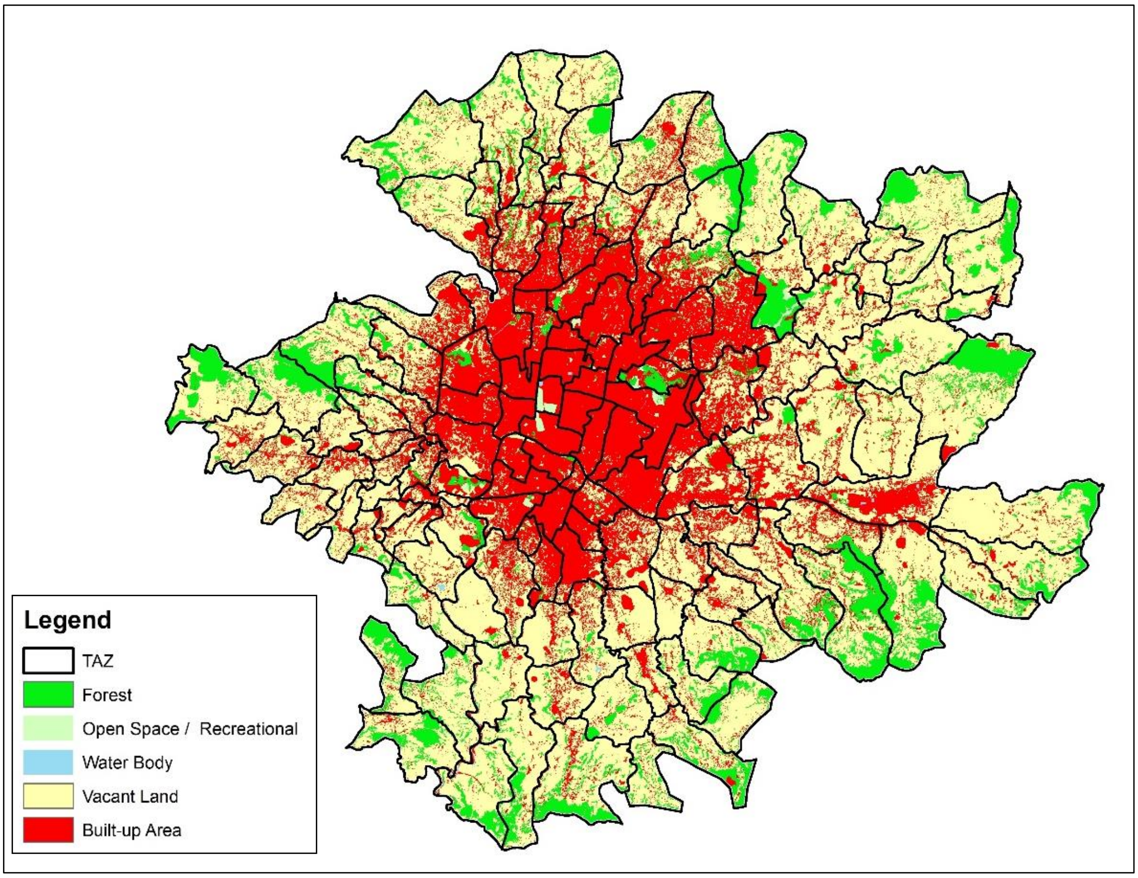
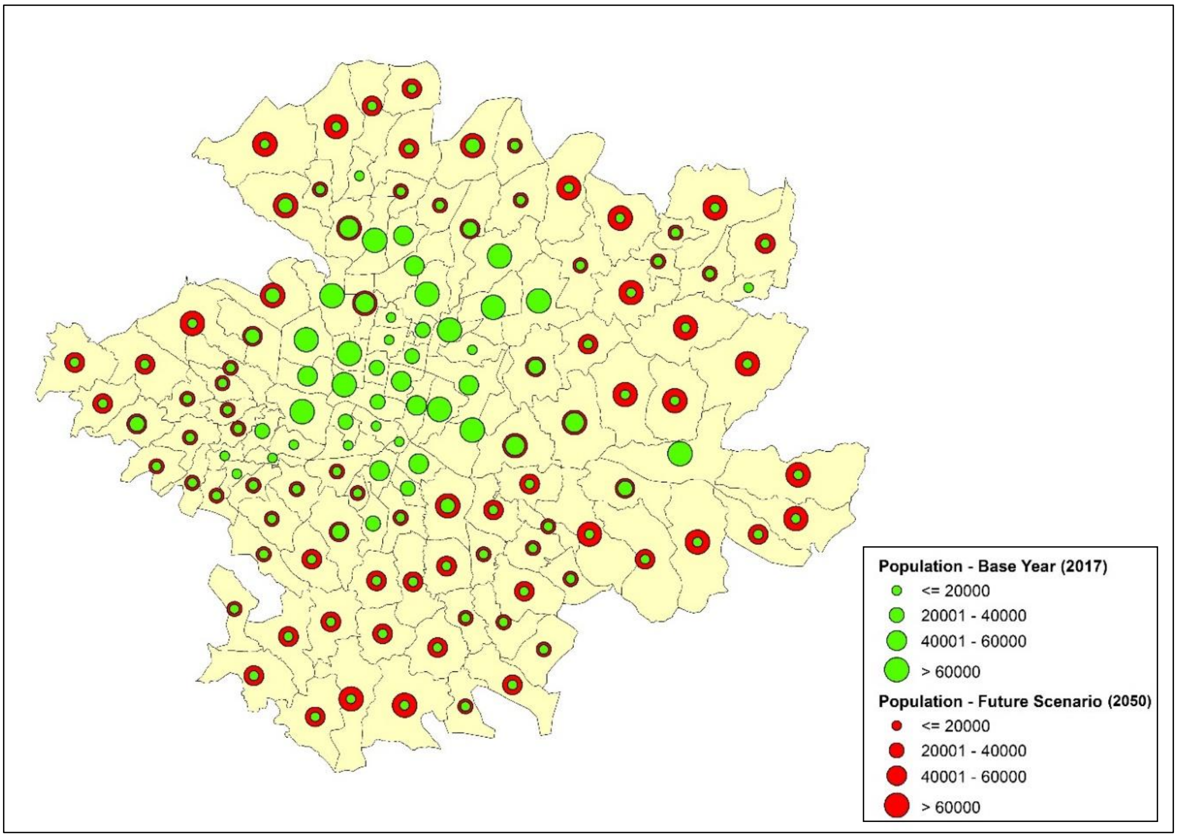


Figure 9.1: Future Population Projection



Map 9.2: Built-up and Vacant Land

For future scenario, year 2050 was selected. From the projection, it is estimated to have around 5.8 million population in the valley by 2050 AD. The distribution of the population pattern is shown in Map 9.3.



Map 9.3: Future Population (2050)

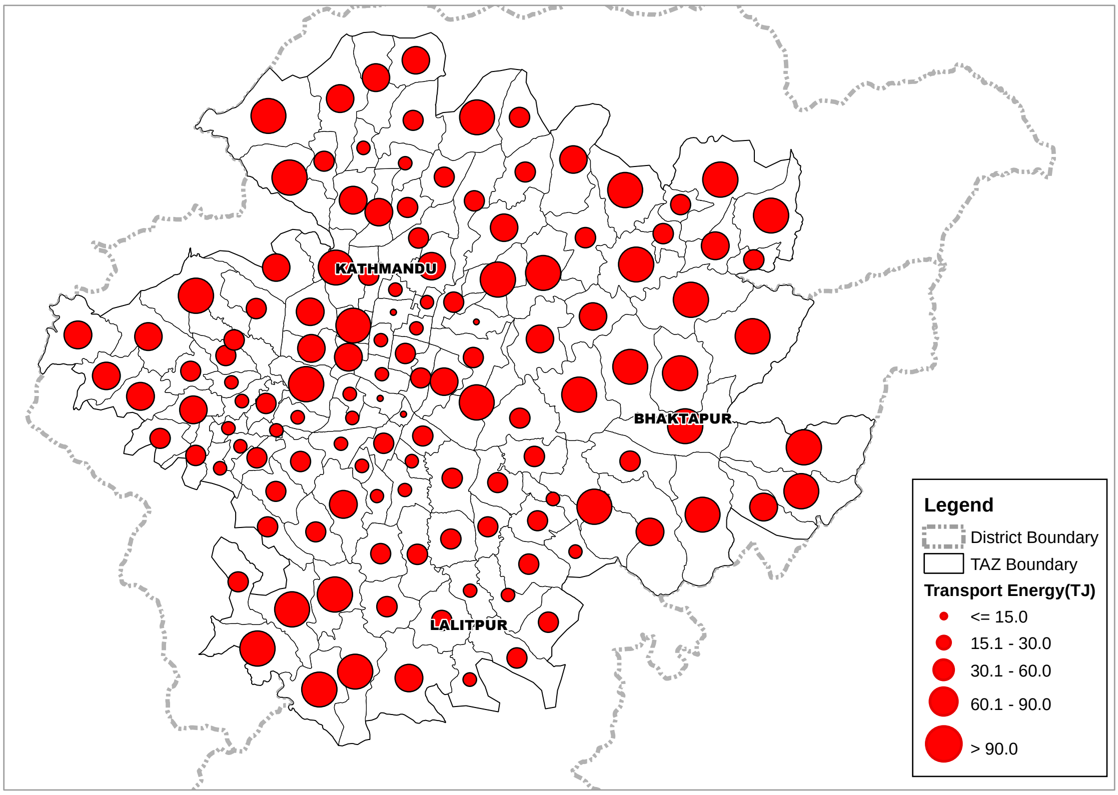
9.4.2 Future Transport Energy Consumption

With a growing population, travel demand is also expected to rise accordingly and with it, the transport energy consumption. If the current trend continues, by 2050 AD, annual energy consumption is expected to be 8522 TJ. It is about 133%, increment, as compared to the base scenario.

Table 9.4: Transport Energy Consumption (2050)

Travel Mode	Daily Vehicle - km			Energy per km (MJ/km)	Total Energy (MJ)
	Edu. Trips	Work Trips	Total		
Car	42330.2	2884278.7	2926608.9	3.46	5625592.6
Motorcycle	1772071.5	7519333.5	9291405.1	1.11	6875639.7
Bus	4872850.9	2256127.7	7128978.5	11.08	2256830.9
Micro	695698.3	610145.1	1305843.3	5.17	450080.7
Tempo	52109.3	63555.3	115664.6	0.65	9397.7
Total Energy Consumed (MJ):					**15,217,541.67**
Total Annual Energy (TJ):					**8522**

Map 9.4 shows the variation of annual energy consumption by a TAZ. TAZ transport energy is expected to rise for peripheral TAZ with population growth and increased travel distance.



Map 9.4: Annual Transport Energy Consumption per TAZ (2050)

9.4.3 Average Trip Distance

Average trip length of motorized modes is expected to increase, overall from 4.9 km in the base scenario to 6.06 km by 2050, as estimated from the model. For work trips, there is an increment from 5.01 km to 6.65 km and for educational trips, from 4.75 km to 6.14 km.

9.5 Proposed Scenarios on modal shift

Public transports can help reduce transport energy significantly if more commuters start to use them. Bus Rapid Transit system (BRTS) is a high-quality bus-based transit system that delivers fast, comfortable and cost-effective urban mobility through the provision of a segregated lane or right of-way. It combines the best features of the metro rail with the flexibility and cost advantage of the road transit system (MaYA, 2014).

Kathmandu Sustainable Urban Transport Project (KSUTP), initiated by the Government of Nepal (GoN) and Asian Development Bank (ADB) has identified major routes for public transport for efficiently operating public transport system. As in this research, the route feasibility study is not within the scope, the primary PT routes (Figure 4.6) proposed by KSUTP has been used for the formulation of scenarios, and these are identified as BRTS routes. For the scenario formulation, it was proposed to have improved public transport system with Bus Rapid Transit System (BRTS) along the BRTS routes, with following features:

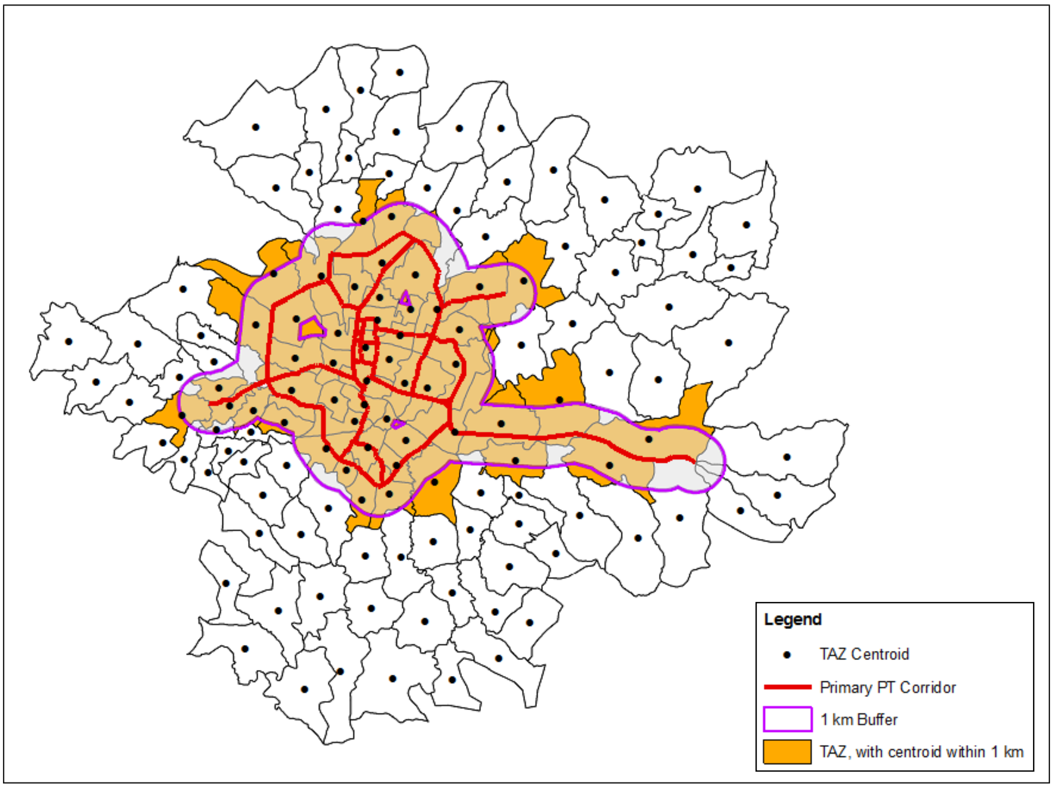
- High Occupancy, Mass Transit Service along primary routes, as proposed by KSUTP.
- Average Occupancy: 50
- Energy Consumption by BRTS bus: 12.9 MJ per km (3 km per liter). It is derived from the average fuel economy of currently operating high occupancy bus, of Sajha Yatayat, one of the operators of public transport in Kathmandu Valley

TAZs, that have their centroid within 1 km from the route are assumed to the zones accessible to BRTS, for both origin and destination. There are in total 50 traffic analysis zones that are within 1km buffer range from the BRTS route. These are regarded as the zones that are within the service area of the BRTS service.

For this scenario analysis, trips are categorized in two sets, as follows:

- **U: Universal set:** This set includes trips of all zones. The total O-D pairs generated is 131×131, that equals to 17416 O-D pairs (Map 8.6 and Map 8.7)
- **S: Subset of U:** This set includes the trips which takes place within 50 TAZs, that have their centroid, within 1 km distance from the proposed BRT route. This set consists of 50×50, i.e. 2500 O-D pairs (Map 9.5).
- $\mathbf{S_{Pr}}$: **Subset of S:** This is the subset of S, that includes all trips between the 50 TAZs for private modes. Only to this subset, the modal shift is applied for scenario analysis

Based on potential shift to public transport from private modes, two scenarios were formulated. The purpose of formulation of scenarios is to estimate the reduction in transport energy consumption, based on a potential shift from private to the new BRTS system. For applying the modal shift, only the trips along the corridors were selected. This excludes the possibility of the BRTS use via feeder route, which in reality, may constitute some share of the BRTS trips.



Map 9.5: BRTS Route and TAZs within 1 km

9.5.1 Scenario 1: Shifting to BRTS Routes from private modes, based on willingness to shift

From the household survey, it was found that 55.6 % of the car users and 72.2 % of the motorcycle users are willing to shift to public transport, if service is good enough, in terms of punctuality, comfort and safety. Assuming that, the new proposed BRTS meets their expectations, the shift is assumed to be the same. All of the existing buses are assumed to be replaced by BRTS. However, the share of other public modes – microbus and tempo, is assumed to be the same.

Comparing Transport Energy of two scenarios, overall

Overall, when we consider all of 131 TAZ (Universal set: U), it is showing a difference of 20 % reduction in energy consumption (Table 9.5. Annex 8). This comparison is for all areas in the valley and not all zones have the BRTS accessible.

Comparison Transport Energy for trips along the corridor zones

For the zones, that have no access to the BRTS system, no change is observed in their trip characteristics, in both scenarios. Therefore, to have a better understanding of the change, the comparison is made for only trips along corridor zones that includes trips within 50 TAZs, having access to BRTS service (Subset S). In this case, there is a considerable difference of 44% reduction with respect to the base scenario (Table 9.5).

9.5.2 Scenario 2: 90% shift along BRTS Routes

In this scenario, a hypothetical situation, whereby an ideal scenario is proposed, assuming that 90 % the private vehicle users shift to BRTS, since achieving 100 % is never possible. In this case, we have a reduction of 31% overall and by 68 % for 50 TAZs, when comparing with the base scenario.

Table 9.5: Scenario Analysis

S. N	Scenario	Trips: Overall (Univ. Set- U: 131 × 131)			Trips: Subset – S (50 × 50)		
		Annual Energy Consumption (TJ)	Difference		Annual Energy Consumption (GJ)	Difference	
			TJ	%		TJ	%
1	**Base Scenario**	3,666.9			1,686.3		
2	**Scenario 1** (Willingness to Shift)	2,927.3	739.6	20%	946.7	739.6	44%
3	**Scenario 2** (90% Shift)	2625.4	1041.4	28%	644.9	1041.4	62%

9.6 Scenario 3: Change in Distribution of Facilities (Job Location and Schools)

The benefits of urban land use mix have been studied in several fields, most notably in transportation, public health, and urban economics. From a transportation point of view, the benefits of mixed uses come primarily from bringing a variety of origins and destinations closer together, therefore enabling shifts to nonmotorized modes and/or shorter travel distances (Song et al., 2013).

9.6.1 Base Scenario

Bertaud (2001), presented four city models to represent the urban spatial structure (Figure 2.4) and currently, the city pattern follows the first model, i.e. the monocentric model with strong high-density center with high concentration of jobs and amenities. There is radial movement of people from the periphery towards the center (Figure 9.2).

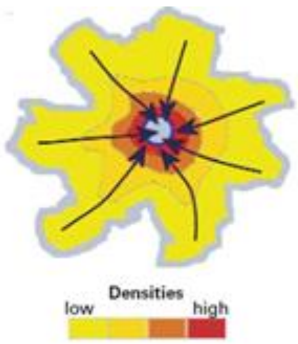


Figure 9.2: Monocentric City Model

As described in Section 9.3, for the base scenario, the overall average trip length for motorized modes is found to be 4.9 km. For work trips, it is 5.01 km and for educational trips, 4.75 km. Annual transport energy consumed is 3667 TJ. With business as usual, by 2050, annual transport energy is expected to rise by 133 % up to 8526 TJ (Section 9.4.2) with average trip length reaching up to 6.06 km.

9.6.2 Polycentric Model – Balanced Distribution

This scenario is based on the polycentric model, as one of the models mentioned by Bertaud (2001), whereby there is no dominant center, but with some sub-centers. Jobs and amenities are distributed in a near uniform matter across the built-up area, with random movement of people across the urban area.

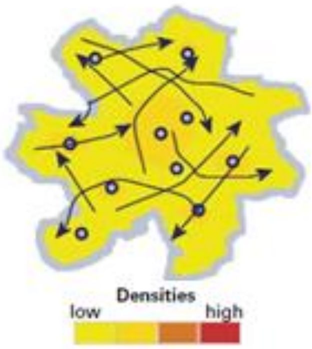
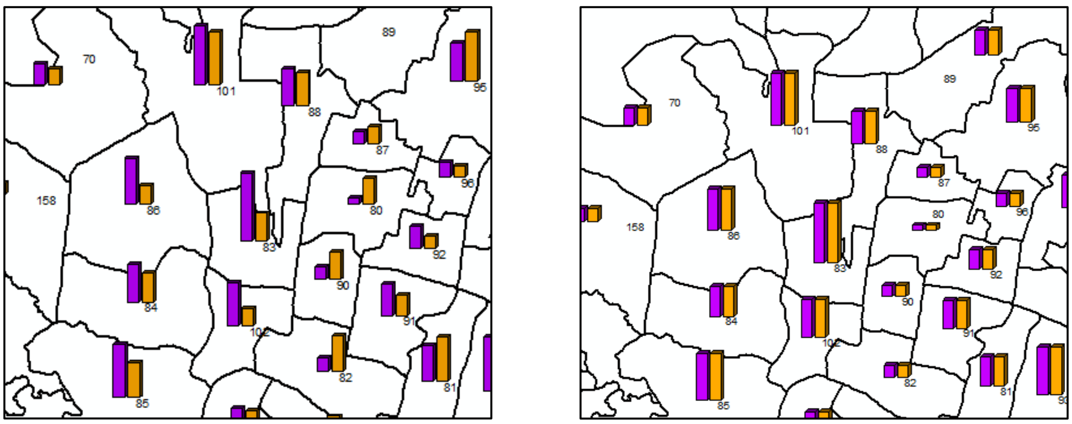


Figure 9.3: Polycentric Model

This concept is implemented in the scenario developed. Trip production is related to travel demand, that provides how many trips originate from a TAZ. It is related to the population of a TAZ and level of mobility. Trip attraction, specifying trip ends, refers to the supply side, that is dependent on facilities available in a TAZ. In this scenario, travel demand is assumed to remain unchanged, while the supply of facilities is changed so that it meets the travel demand created in a TAZ. For this, the distribution of work and employment areas are adjusted in accordance with the trip production in a TAZ. This is achieved by making trip attraction equal to trip production as shown in Map 9.6.



Base Scenario　　Balanced Scenario

Trip Generation
Production
Attraction

Map 9.6: Trip Production and Attraction (Balanced)

Average Trip Length

In this scenario, work trip length is estimated to be 4.73 km, while that of education trip as 4.67 km. There is some decrement in the trip length of work trips while that of educational trips remains fairly same, with only slight decrement, when comparing with the base scenario.

Transport Energy Consumption

In this scenario, the annual transport energy consumption is found to be 3439 TJ (Annex 8). It shows the reduction by 227.2 TJ with respect to the base scenario. Only 6.2 % reduction is achieved in this case. In both the scenarios, the modal share is assumed to be the same and trips by non - motorized modes are interzonal. As a result, the effect of the distribution of facilities, in accordance with travel demand is not proving to be effective. For more reduction in energy, more of the trips need to be intrazonal, with the shift to the non-motorized modes of transport. The influence of shift to intrazonal NMT from motorized mode is further analyzed by sensitivity analysis.

9.6.3 Sensitivity Analysis

As per the limitations of FSM, intrazonal trips, which are assumed to be NMT, are not modeled. Hence, for further analysis of the mixed landuse scenario (Scenario 3), a sensitivity analysis was performed to identify the effect of modal shift from motorized private mode (car and motorcycles) to non-motorized modes. Table 9.6 shows the change in transport energy with the shift from motorized private mode to NMT. It ranges from 6 % reduction in transport energy, with no shift to 85% reduction, with 100% shift to NMT.

Table 9.6: Sensitivity Analysis (Modal shift to NMT)

S.N.	% shift from private mode to NMT	Annual Transport Energy (TJ)	% reduction with respect to base scenario
1	0%	3439	6.2 %
2	25%	2720	25.8 %
3	50%	2002	45.4 %
4	75%	1284	65.0 %
5	100%	565	84.6 %

9.7 Energy Efficiency at Neighbourhood Level

As shown by the sensitivity analysis (Table 9.6), shift from motorized to non-motorized modes can have a significant reduction in transport energy consumption. Currently, NMT has a share of only about 20 % (Table 5.4) for daily trips. It shows that NMT is not a preferred option for commuters. To promote NMT use, it is important to have short trip length, through mixed landuse and create a favourable environment for pedestrian and bicycle users. Radburn concept, as described in Section 2.11.1, helps to promote the use of NMT at a neighbourhood level, by restricting motorized vehicles and keeping basic amenities and services, in close proximity to the residential blocks.

Traditional settlements of the Kathmandu Valley are energy efficient in neighbourhood planning, activity locations and mobility and it forms important basis for making environment suitable for pedestrians and cyclists as described in Section 2.11.2.

9.8 Conclusion

This chapter demonstrates the applicability of a 4-step travel demand model for the assessment of transport energy by formulating scenarios. Scenario analysis was done for the base year (2017) and future (2050) – business as usual. As a measure for the reduction in transport energy, two scenarios were developed. The first is the modal shift from private to public mode. Secondly, it was proposed to have mixed landuse, whereby creating a balance between employment and educational facilities in accordance to demand for work and educational trips. Further, along with the balanced distribution, the importance of neighbourhood planning, that is friendly to non-motorized modes, i.e. walking and cycling was discussed with reference to Radburn concept and traditional settlement pattern of the Kathmandu valley.

In the model, travel pattern was generated for interzonal trips, but NMT trips are assumed intrazonal and thus, it is not represented in the model. Hence, for analyzing shift to NMT, sensitivity analysis was performed instead of scenario analysis for shift from private modes to NMT.

There is a possibility of doing more of the scenario analysis on transport system and landuse for exploring more of the alternative solutions to minimize transport energy use. For scenario analysis, intervention is made on one system, while other system is assumed to remain unchanged. For instance, in Scenario 1, transport system is intervened my modal shift, while landuse system is assumed to remain unchanged. Same applies for landuse change scenario, whereby transport system is unchanged. This allows to study how the role of each system has an impact on transport energy, separately.

For analyzing the simultaneous effect of changes in both system, more advanced models that incorporates the integration of landuse and transport can be used for the study of complex interaction of landuse and transport system that deals more in detail with demand, supply and state of equilibrium. However, it requires advanced mathematical models and voluminous data of economic and spatial interaction, real estate market, physical and operative transport data.

Chapter 10. Conclusions and Recommendations

10.1 Conclusions

The research illustrates the benefits of using travel behavior analysis and transport model for studying daily trips in macro scale, to promote energy efficiency in landuse and transport planning, in context of the Kathmandu Valley. Conclusions are drawn specific to research objectives, that are discussed below.

Specific Objective 1: To assess travel behavior of people, in commuting their daily trips

Overall, in daily trips share by trip purpose, work trips constitute about 56 % and educational trips, about 46 %. From the current trip rate, it shows that about 2.1 million estimated daily trips occur each day, resulting from work and educational trips combined.

Many of the daily commuters are using private vehicles for their daily trips. Overall, private vehicles have the highest modal share, next to PT and NMT. Work trips have a comparatively higher share of private modes and less PT and NMT use, compared to educational trips. The level of service of the current PT system is not proving to be good enough, more importantly, in terms of travel time. Traveling by PT takes a longer time, as compared to private modes, as indicated by the average journey speed of different travel modes and people are giving prime importance to travel time over other travel attributes. About 60% of the respondents opted travel time as the most important attribute as compared to travel cost (13%) and comfort/safety (27%).

Vehicle ownership rate in a household is also a factor behind the use of private vehicles. Motorcycle is very popular and on average, each household owns at least one motorcycle. Ownership of a car is found to be one, in every three households. Ownership of a bicycle is least, only 0.08 per HH on average.

In response to the opinion survey on energy efficiency in urban planning, most of the respondents opted for public transport, followed by proper city planning regulations. Very few respondents, only 4 %, think that NMT can be opted for travel to minimize transport energy.

Further, influence of household characteristics and personal attributes on the choice of travel mode for work and educational trips was studied in travel behavior analysis. The analysis was aimed to analyze the relationship between travel behavior and the socio-economic, demographic characteristics of workers and students, using statistical measures. Four factors - income group, gender, age-group, vehicle ownership was analyzed in relation to mode choice and trip length.

With the rise in income level, there is an increased tendency in private vehicle usage and a decrease in the use of public transport, more prominently for work trips. For educational trips, income and mode choice have comparatively weak relation. For work trips, upper- and middle-income groups are less dependent on public transport as they are relying on their private vehicles.

For work and educational trips, the share of a public vehicle goes down gradually with an increase in vehicle ownership. For work trips, there is a sharp decline in PT share and an increase in private vehicle share with rising income levels. One of the main reasons behind the increment in private vehicle use with rising income level is increasing vehicle ownership.

When analyzing average trip length with respect to the income group, it shows that in general, work trip distance increases with an increase in income level. Longer trip length for the high-income group is also one of the reasons, to have a preference for private modes to public modes. This is because of the travel-time factor, as public vehicles have a comparatively slower journey speed. For educational trips, the relation of trip length with income group is not significant.

Regarding the age group, it reveals people have more preference for private vehicles over public transport, with age. For work trips, the effect is minimal, whereas, for educational trips, there is a considerable variation.

When we look at the trip rate of men and women, for both work and educational trips, it is higher for men. Work trip rate of men is almost three times that of women.

For educational trips, the variation of a modal split between males and females is less observed whereas the difference is more observed by gender, for work trips. The modal share shows more men using private modes of transport as compared to women, both car and motorcycles. However, motorcycles or scooters are becoming very common for both males and females, both for educational and work trips.

For all income groups, males have a greater tendency than females to use private vehicles compared to public vehicles for work trips. For educational trips, only for lower income group, there is some relation between gender and mode choice, whereby more males are using private vehicles as compared to females. For other income groups, the relation is not significant. When analyzing the use of public transport by gender, for work trips, it reveals that women are more dependent on public transport, as compared to men. The relation is, however, not significant for educational trips, which shows that both male and female students have somewhat equal tendency to use public transport.

It is revealed that more women are walking to reach their workplaces as compared to men. For educational trips, both males and females, who walk are almost the same. In the case of use of bicycles, it is found to be the least attractive option for both work and educational trips for both men and women.

Regarding trip distance, it shows that males are commuting longer trip distance as compared to females for their work trips. For educational trips, there is not much variation in the distribution of trip length patterns of male and female students.

Specific Objective 2: To analyze how travel behavior and urban form is related to travel energy

In the second part of the analysis, the relationship between travel energy of daily trips and urban form were analyzed using Energy Performance Index as a measure of travel energy using correlation analysis.

Travel energy of work trips is observed to vary more spatially than educational trips. Further, the travel energy of the work trips was studied with respect to distance from CBD, population density and accessibility to public transport.

From the analyses, it is found that there is influence from both mode choice and trip distance on travel energy. There is a significant link between the distance to CBD and travel energy, whereby travel energy increases with an increase in distance from CBD. Areas close to CBD have high private vehicle share and less public transport usage for their work trips. Although there is good spatial accessibility of PT around CBD, people are less dependent on PT for work trips. On the other hand, people living in the outskirts of the Kathmandu Valley are relying more on PT, but the level of accessibility is lower in those areas. It shows that for work trips, people living in the peripheral regions are facing inconvenience, as their trip distance is longer and also depending more on PT, with limited access to it. These findings differ from what most of the previous researches, that mentions, people living close to CBD, tend to use more PT and less private modes as compared to areas further away from CBD.

Trip distance of work trips gets longer as the distance from CDB increases. This shows that trip distance is more a determining factor for the rise in travel energy with an increase in distance from CBD. This indicates a monocentric character of the Kathmandu valley with more of the employment facilities located close to CBD. Population density is high in the central region which shows that people prefer to live close to CBD due to ease in access to the workplace.

The study shows that there is some indication of decrement in travel energy with an increase in urban population density and PT accessibility, but both have little impact on travel energy, which is shown by correlations of weak strength. Average trip distance in dense areas is shorter as compared to regions with a sparsely distributed population. However, both population density and PT accessibility are having negative effect on PT use and positive effect on private vehicle use. The finding differs from many of the previous studies, which suggest that both increasing density and PT accessibility will have a positive effect on PT use and negative effect on private vehicle use. This implies that just having a dense area or increasing PT accessibility may not necessarily reduce travel energy. To increase the share of public transport, apart from spatial accessibility, level of service and equity in access also needs to be considered.

The role of NMT is found to have a negligible effect on urban mobility as its share is only minimal for work trips. In correlation analyses with urban population density and distance to CBD, the relations with the NMT use, are not significant.

Specific Objective 3: To assess the role of modal shift and mixed landuse on transport energy demand.

FSM was developed to predict the travel pattern of work and educational trips and to assess transport energy by analyzing scenarios. The result of the base scenario shows that currently, daily trips consume

3,666 TJ annually. Cars and motorcycles contribute to most of the consumption, accounting for over 80% of the total transport energy.

Scenario analysis was done for the base year (2017) and future (2050) – business as usual. The result of the base scenario shows that currently, daily trips consume 3,666 TJ annually. Cars and motorcycles contribute to most of the consumption, accounting for over 80% of the total transport energy. With business as usual, by 2050, the transport energy of daily trips is expected to rise to 8526 TJ, which is 133 % higher than the base scenario. It is a steep rise, within the period of about 30 years in the future.

As a measure for the reduction in transport energy, different scenarios were developed for modal shift and change in the distribution of facilities to observe its impact on transport energy. Accessibility to public transport and its level of service, have an important role to play in its ridership. More is the ridership, more is the reduction in energy consumption. 90% shift from private to BRTS can reduce transport energy consumption by 62 % for trips, along the zones with access to the service. This may be difficult to achieve. However, as per the current willingness to shift, the reduction can be up to 44 %.

In the next scenario analysis, concept of mixed landuse was developed to study the effect proportionate distribution of work and educational areas in accordance to travel demand in each TAZ. Modal share was assumed to be the same in both scenarios. In this case, the reduction achieved is 6 %. Trips by motorized modes are assumed to be interzonal and thus even though in each TAZ, trip production and attraction are equal, as most trips are interzonal, it is not contributing to a significant reduction in transport energy.

Further, a sensitivity analysis was carried out, to study the effect of turning interzonal motorized trips to intrazonal non-motorized trips. With the rise in the share of intrazonal NMT trips, transport energy is expected to go down significantly. With 100 % shift from motorized mode to NMT, the transport energy would be only 565 TJ, which is 85 % reduction, as compared to 6 % reduction, with no shift.

Radburn concept allows neighbourhood planning, to be NMT friendly, by making streets, vehicle free planning, and having basic facilities nearby. In the context of the Kathmandu valley, traditional settlements are more energy-efficient, in contrast to modern settlements. Settlement pattern follows mixed use, whereby, different activity location - workplace, recreation, education or social interaction are within near vicinity. This has made the settlement, more pedestrian-friendly. But with time, these traditional settlements are in the course of transformation and much of the pedestrian roads are being converted to vehicular roads and settlement pattern is also changing.

10.2 Recommendations

Escalating transport energy demand is one of the major issues for Kathmandu Valley, with rapid increment in auto-mobilization and urban sprawl. Transport contributes the highest in energy consumptions, with over 57 % of the fossil fuel consumed in this sector alone. As Nepal is solely, relying on imported fuel, the high demand for fossil fuel, adds more to the problem, environmentally and economically. The Kathmandu Valley is the center for economic activities, where work and educational trips have the dominant share. With growing population, travel demand is expected to rise and with it, rise in the number of work and educational trips. With business as usual, the transport energy of the valley, resulting from the daily trips is expected to rise by 2.5 times the current figure by 2050 AD (Table 9.4). So, the optimization of transport energy for daily trips is to be given the utmost priority. Different measures are recommended to address the issue, based on the findings of this research, which are discussed below.

10.2.1 Promotion of Transit Oriented Development

Modal shift to energy efficient modes and minimization of travel distance are the two key components behind landuse and transport planning. In context of Kathmandu Valley, the private vehicle ownership has a major influencing factor in travel patterns. The use of private automobiles can be expected to rise with increasing affordability. The consequence is that , more and more people, including middle - and low-income group commuters are shifting towards private vehicles, especially motorcycles. When comparing the modal share figures from the surveyed data and the figures of 2011 from JICA, it shows that in the course of six years, the share of private vehicles, both motorcycles and car has gone up, while share of public transport, walking and cycling has declined for both work and educational trips. The continuation of this movement will have a negative impact on the usage of the public transport and NMT.

As per the context of the Kathmandu Valley, public transport has relatively slower speed as compared to public mode and this makes travelling by public transport longer. Travel time is the most important parameter for travel as indicated by the preference of the respondents, and the current PT system lacks the timely service. Most of the core regions of the valley have good access to the public transport system. However, even in these areas, we see public transport not being attractive for their daily trips. For work trips, we have a negative correlation between PT accessibility and PT use. Instead there is a positive correlation with private vehicle use.

Thus, along with accessibility, quality of public transport is also the prime factor that attracts commuters towards it. More importantly, there is a need of PT, efficient in terms of travel time for encouraging more modal shift to PT.

To achieve better reductions in transport energy, the routes are to be expanded, from core areas to peripheral areas to avoid inequality in accessibility. This is especially important for peripheral regions, as more people are dependent on public transport here, but have limited access currently.

Introduction of mass transit system such as BRTS can be regarded as a step towards a sustainable transport system in terms of cost-effective solutions for minimization of transport energy and fossil fuel consumption. BRTS can be implemented along major ring road and other major corridors that are undergoing road expansion. The BRTS service provides good service to the public in terms of timely service, comfort and safety. The service should especially target work trips and educational trips, as these trips will have a major share. The valley is and will be the main center for employment and educational opportunities.

As it is not possible to implement BRTS in all routes of the valley, it is essential to incorporate existing public transport system via feeder routes to BRTS. Microbuses and Tempos, even though, these are low occupancy public vehicles, it plays an important role in providing access to PT users in feeder routes, where large high occupancy buses could not operate. Private vehicles can also be incorporated with public transport by introducing Park and Ride system. The current willingness to shift is 55 % for car and 72 % for motorcycles. More of the shift can be expected, once the BRTS service comes in operation, that will help to minimize transport energy significantly.

10.2.2 Promotion of Sectorial Development Plan and Polycentricity with Mixed Landuse

The spatial distribution of residential areas, activities and landuse within an urban area have a significant impact on travel pattern of the region. In the short term, the landuse activity system can be considered to remain unchanged, but in long run, the landuse, itself is affected by the travel patterns and by changes in the transportation system and vice versa. Thus, the landuse and transportation systems are interdependent. The travel pattern of work and educational trips, depends on the distribution of work and educational facilities respectively. In the present context, there is an imbalance in trip production and trip attraction of the daily trips, as revealed by trip generation of the model. This shows an imbalance in demand of work and educational trips to availability of employment and educational facilities respectively in the given zone. This has resulted in the trips to be inter-zonal that constitute motorized modes having a share of over 80%, with average trip length of 4.9km. NMT, assumed to be intrazonal are less than 20%, having average trip length, 0.9km.

To ensure the balance between the demand and supply, the concept of Sectoral Development Plan, taking an administrative region as a sector, whether a municipal or ward, depending upon its coverage, with an equality in access with employment and educational facilities for its residence area needs to be initiated. The objective should be to seek a balance between demand and supply. Based on the assessment of travel demand, the facilities are to be provided, to avoid the condition of over and under facilitation. This allows, the residence, workplace and educational institutions in close proximity in a given sector, that will help to reduce trip distance.

From the perspective of the education system, the concept of school districts can be introduced, whereby each community or settlement will have a primary and a secondary school in its vicinity, that avoids the need to go to another area for schooling. From the survey, it was found that average trip distance for primary school is 1.66 and that of secondary school is almost 3km, both having a share of 65 % share in total educational trips (Table 5.7). It shows that most of the primary schools are within walking distance. However, for secondary schooling, many of the students are making a longer trip, which requires them to use a school bus or van or any other means of motorized transport. The sector development plan should have both primary and secondary level schools, with good education standard, for the community and make that accessible within walking distance. This can significantly reduce motorized trips and reduce traffic volume by cutting down school bus trips, during pickup and drop hours. Additionally, a tariff system can be brought into effect, whereby, students enrolling from the same sector gets a subsidy, whereas those enrolling from the different sector have to pay higher. This policy can help to encourage students to get admission in the school available in the local area.

Regarding work trips, it is necessary to have job-housing balance, which refers to roughly equal distribution of employment locations and workers living across an area.

Although it is difficult to have a perfect job-housing balance, there should be an attempt to seek this balance, that will help to reduce commute distance of work trips. In the present context, job access is not planned for balance, rather, it is the product of urban development process and as such, it is not governed by any planning polices as such. There a weak link between where the people live and where they are employed. Although it is very difficult to have a perfect job-housing balance and relation is very complex as there are many other factors, that determine job locations, apart from the ease in access, there should be an attempt to seek this balance, that will help to reduce commute distance of work trips.

The dominance of jobs in the core region of the valley has resulted the spatial mismatch in the city, that has resulted in an increased work trip distance and travel time for suburbs, as revealed by correlation analysis (Table 7.3). As a result, transforming the urban form by job decentralization and improving the access to work places, have become a major issue to be addressed.

Only the condition of balance between travel demand and supply is not sufficient to reduce transport energy of the trips as shown by the scenario 3 (Section 9.6). This has to be accompanied by a modal shift to sustainable modes. For that, accessibility to quality PT system and considerations for NMT friendly neighbourhood planning are essential, that encourages long trips by PT and short trips by NMT. The combined effect has high possibility to reduce transport energy, as revealed by Sensitivity Analysis (Section 9.6.3).

However, promotion in the use of NMT is a major challenge in Kathmandu Valley. NMT has the least modal share. Also, as per the perception of the people, for improving the energy efficiency of the transport system, people have chosen NMT as the least preferred option. The major factors are the current trip distance, that exceeds walking distance, thus dependent on motorized modes and the streets, that are not friendly to NMT users. Thus, in order to have walking and cycling as a real alternative for the trips, the policy of the transport system needs to be reformed to encourage walking and cycling, by providing necessary infrastructure, facilities and safety provision for bicycle riders and pedestrians.

10.2.3 Measures to Encourage Behavioral Change

Apart from planning measures, we also need to look at regulatory (norms and standards), economic (road pricing, taxations), information (public awareness, mobility management) and incentives as additional measures for the promotion in the use of public vehicles. These strategies could additionally help to minimize use of the private vehicles that promotes the use of more of the public transport. These policy initiatives can help to bring change in the travel behavior to opt for more sustainable modes of travel.

10.2.4 Environmental and Economic Perspective

In the present context, Nepal is solely relying on imported fuel. Energy-efficient landuse and transport planning can minimize of fossil fuel consumption that will help both environmentally and economically. At the same time, there is a need to look for improved fuels and alternative sources of fuel such as electric vehicles, so that dependence on fossil fuel is minimized, that will help to cut down GHG emissions and fuel imports significantly.

10.2.5 Emphasis on Travel Demand Management

In this research, for energy efficiency measures, in landuse and transport planning, emphasis is given more in reducing transport demand. Vehicle-km and Passenger-km can be reduced by both modal shift and minimization of trip distance with appropriate interventions in landuse and transport system.

Along with planning and policy measures, we can further explore the ways to minimize trip rate. Currently, about 2.1 million daily trips are estimated to take place daily (Table 5.5). The home-based trip productions can be reduced with the introductions of the systems like distance learning or working online, wherever and whenever applicable, that eliminates the need to make a trip.

But in the current planning practice, controlling the demand side is not given a priority. Instead, measures are taken in increasing supply. For instance, widening of road is very much practiced in the present context, to minimize traffic congestion. However, due to the ineffective measures to control travel demand, an increase in supply is not at all, being able to keep up with escalating travel demand. As a result, the problem of traffic congestion is still evident and continues to add up. Equilibrium in demand and supply is coming at a high cost. Transport energy consumption is high and at the same time, causing delays in movement due to road congestion. Journey speeds of travel modes are slower and even slower is the movement of public vehicles (Table 5.6).

Thus, an increase in supply, has only short-term effect on improving the system, whereas minimizing demand has long term effect. The proper travel demand management, thus allows to minimize transport energy and helps to cut down the investments in the development of transport infrastructure. Thus, to promote sustainable urban mobility, priority should be given to manage travel demand that will be beneficial, in terms of energy, environment and economy.

10.2.6 Contribution of the research to Urban Planning Policy Formulations

This research can be viewed as the departure point for exploring urban landuse and transport that helps the policymakers to focus on the strategies to minimize urban transport energy. In the current practice, we see the gap in the integration of landuse and transport planning policies that has resulted in the in-efficiency in urban planning. Use of travel behavior analysis and landuse-transport modeling techniques makes it possible for planners and policymakers to have a vision on the present and the future scenarios and propose an alternative course of actions to minimize transport energy. This provides important insights in formulating planning measures, policies and goals for sustainable urban development.

There is a possibility to apply the methods of this research in different urban territories, as minimizing travel energy consumption is one of the main concerns in urban planning. Urbanization trend and urban population will continue to grow in Nepal with the declaration of new municipalities. It is very important that the integration of landuse and transport planning issues are taken into consideration at the very early stage of planning for its effective implementation.

10.3 Areas of Further Research

Studying travel behavior, urban landuse and transport systems is very complex and it is very difficult to generalize the factors of travel behavior and travel pattern in relation to urban form as it is influenced by many factors. This research can be extended for further investigation, which are discussed here.

- The analysis and findings of this research focusses on daily trips, that constitute work trip and educational trips. Apart from daily trips, other trip purpose such as shopping trips, recreational trips, visit trips can also be studied, so as to have overall picture of the person trip characteristics. Along with it, other landuses, such as commercial, recreational areas can also be included in the analysis. Also fright transport will also have share in transport energy which has not been included in this research. Further, educational trips can be classified into different categories, based on the education level, instead of one generalized student trip purpose.
- Regulatory, Information, Incentives measures and technological aspects, discussed in the recommendations, which are not planning based, could be further explored in detail for their effective implementation.
- In this research, analysis is done at macro scale, using aggregated FSM. Analysis can be done at disaggregate level, to study in detail, at the level of individual trips.
- Introduction of a new public transport system can also be studied further, like metro system and monorails. However, these systems cannot be the complete replacement for the bus-based public transport system .
- Along with planning and energy efficiency issues, the problem of air pollution and environmental degradation is also becoming more evident in the transport sector. The model developed in this research can also be used to study emissions and air quality, further.

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Annexes

Annex 1: Household Questionnaire Survey Form

Household Survey Form

Objective of the survey:

This survey is done for the Ph.D. research of Mr. Ashim Bajracharya, titled "Energy Efficient Urban Planning: An Integration of Urban Landuse and Transport Planning Policy, A Case Study of Kathmandu Valley", Institute of Engineering, Pulchowk Campus. The objective of the survey is to collect socio-economic characteristics and family structure of a household and information about the travel behavior of commuters for daily and other trips.

Questionnaire #: _________________/___________________________/______________________

(Date / Initials of interviewer / Serial #.)

Survey Zone ID: _ _ _ _ _

Part 1: HOUSEHOLD INFORMATION

Respondent's Name: _ **Head of HH :** ☐

Respondent's Sex: Male ☐ / Female ☐ **Respondent's Age:** _ _ _ _ _ **yrs**

1. Household size: _ _ _ _ _ _ _ _ _ _ _ _ _ _

2. Address:

_ _

_ _

_ _

_ _

2. Household monthly income:

- □ > Rs. 70000
- □ Rs. 50000 - 70000
- □ Rs. 30000 - 50000
- □ Rs. 10000 - 30000
- □ <= Rs. 10000

3. Household vehicle(s) availability:

(Please specify a number if more than one of same vehicle-type is owned)

- □ Car : ______
- □ Motorscooter : ______
- □ Bicycle : ______
- □ Others *(please specify)*: ________________
- □ No vehicle

Page 1

Part 2: TRIP CHARACTERISTICS

1. Please fill the following table for workers and students for trip data, in commuting their work and educational trips

Trip Data for Work and Educational Trips

HH Mem#	Sex	Age	Occupation	Destination	Travel Mode used (Ref Mode ID)[1]	Time of day of making trip	Distance Travelled (Km)	Average Mileage – Km (For Private Modes)	Avg Travel Time (mins)
			(W / S)	(Address of Office / School)					
1									
2									
3									
4									
5									
6									

Note:

- If the travel mode varies, indicate the one that is mostly used.
- If more than one travel mode is used for the trip, indicate the mode, used for the longest distance
- For Average travel time for public mode, indicate time as out vehicle time (walking + waiting) and in-vehicle time (travelling in vehicle). For eg if a person walks 5 mins to bus stop, waits for 10 mins and travels in bus for 15 mins, indicate is as 5+10+15.

Notations to be used for above table
W: Worker; **S**: Student (Secondary Level)

Mode ID	Travel Mode	Mode ID	Travel Mode
1	Car/Jeep/Van (Petrol)	7	Microbus
2	Car/Jeep/Van (Diesel)	8	Bus
3	Motorscooter [2-stroke]	9	Bicycle
4	Motorscooter [4-stroke]	10	Walking
5	Tempo	11	School Bus
6	Taxi	12	Others *(please specify in table)*

Any remarks from Enumerator:

_ _

_ _

_ _

Page 2

2. Other trip purpose:

Number of times a week a family makes other trips (Shopping, Family/Friends visit/ Recreation):

_ _ _ _ _ _ _ _ _ _

Which is the shopping area most visited?

_ _ _ _ _ _ _ _ _ _

3. Non-Home Based Trips
Number of times a week, a respondent makes non-home based trips (Trips that neither begins or ends at home - like from office to other places)

_ _ _ _ _ _ _ _ _ _

Part 3: OPINION ABOUT TRAVEL ATTRIBUTES

This part is to be filled by the respondent

1. Which factor do you think is most important while you commute?

- ☐ Travel Time
- ☐ Travel Cost
- ☐ Comfort
- ☐ Others *(Please specify)* _ _ _ _ _ _ _ _ _ _

2. Which mode are you using now for commuting daily trips *(For Private Vehicle Users)***?**

_ _ _ _ _ _ _ _ _ _

3. Have you recently (past one month) used public transport (Bus) for any trip?
(For Private Vehicle Users)

☐ Yes ☐ No

4. What aspects of the public transport do you think is/are important?
(Tick one or multiple options that apply)

A. Good choice of Bus Routes & Bus Stops
B. Frequent services
C. Low cost bus travel
D. Reliable and punctual services
E. Free parking at 'park and ride' locations
F. Good quality and clean vehicles
G. Other *(please specify)*: _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

3. From the above list, which one is the most important to you? *(Circle one only)*

[A] [B] [C] [D] [E] [F] [G]

4. Are you willing to shift to public transport if above facility is available (For Private Vehicle Users)**?**

☐ Yes ☐ No

Page 3

What do you think, could be the best way to reduce Overall Urban Transport Energy (Fuel) Consumption?

- □ Maintaining Vehicle Standards [Proper Maintenance / Emission Standards]
- □ Proper Maintenance of Roads
- □ Good Public Transport System
- □ Promotion of Non-Motorized modes (Walking / Cycling)
- □ Proper City Planning
- □ Others (Please Specify) _ _ _ _ _ _ _ _ _ _ _ _ _

Any remarks from the respondent on urban transport system and urbanization trend of Kathmandu Valley

_ _

_ _

_ _

_ _

_ _

_ _

_ _

_ _

THANK YOU

Page 4

Field Data Collection of Public Vehicles

Form ID (S.No./date): __________ **Interview Location:** ______________

Mode: Microbus ☐ Bus ☐ Tempo ☐ Others ☐

Route Information:

Start Location: __________________________________

End Location: __________________________________

Average time taken from Start to End: __________ mins

Average time taken from End to Start: __________ mins (Return Route)

Average Vehicle Occupancy: _______ no's of passengers

Mileage: ____ km per liter of Petrol ☐ /Diesel ☐

Form ID (S.No./date): __________ **Interview Location:** ______________

Mode: Microbus ☐ Bus ☐ Tempo ☐ Others ☐

Route Information:

Start Location: __________________________________

End Location: __________________________________

Average time taken from Start to End: __________ mins

Average time taken from End to Start: __________ mins (Return Route)

Average Vehicle Occupancy: _______ no's of passengers

Mileage: ____ km per liter of Petrol ☐ /Diesel ☐

Field Data Collection of Average Vehicle Occupancy

Location: ______________

Start Time: ______________

End Time: ______________

S.No	Mode	Observations
1.	Car/Jeep/Van	
2.	Motorcycle	
3.	Tempo	
4.	Bus	
5.	Microbus	

Questionnaire Survey Form (Filled)

Household Survey Form

Objective of the survey:
This survey is done for the Ph.D. research of Mr. Ashim Bajracharya, titled "Energy Efficient Urban Planning: An Integration of Urban Landuse and Transport Planning Policy, A Case Study of Kathmandu Valley" at Institute of Engineering, Pulchowk Campus, Tribhuvan University. The objective of the survey is to collect socio-economic characteristics of a household and information about the travel behavior of the people.

Questionnaire #: 2073-5-30 / Kushal / 09
(Date / Initials of interviewer / Serial #.)

Survey Zone ID: 55

Part 1: HOUSEHOLD INFORMATION

Respondent's Name: Anusha Kayastha **Head of HH :** 9
Respondent's Sex: Male ☐ / Female ☑ **Respondent's Age:** 19 yrs

1. Household size: 3

2. Address:
Sundhara - 22, Kathmandu

2. Household monthly income:
- ☑ > Rs. 75000
- ☐ Rs. 50000 - 75000
- ☐ Rs. 25000 - 50000
- ☐ Rs. 10000 - 25000
- ☐ <= Rs. 10000

3. Household vehicle(s) availability:
(Please specify a number if more than one of same vehicle-type is owned)
- ☐ Car :
- ☑ Motorscooter : 2
- ☐ Bicycle :
- ☐ Others *(please specify)*:
- ☐ No vehicle

Page 1

Part 2: TRIP CHARACTERISTICS

1. Please fill the following table for workers and students for trip data, in commuting their work and educational trips

Trip Data for Work and Educational Trips

HH Mem#	Sex	Age	Occupation (W / S)	Destination (Address of Office / School)	Travel Mode used (Ref Mode ID)	Time of day of making trip	Distance Travelled (Km)	Average Mileage – Km (For Private Modes)	Avg. Travel Time (mins)
1	M	52	W	Chuchepati	4	8:00AM	2.0	40	10
2	F	19	S	Bagbazar	4	8:30AM	1.5	45	5-7
3									
4									
5									
6									

Note:
- If the travel mode varies, indicate the one that is mostly used.
- If more than one travel mode is used for the trip, indicate the mode, used for the longest distance
- For Average travel time for public mode, indicate time as out vehicle time (walking + waiting) and in-vehicle time (travelling in vehicle). For eg if a person walks 5 mins to bus stop, waits for 10 mins and travels in bus for 15 mins, indicate is as 5+10+15.

Notations to be used for above table
- **For Occupation** - W: Worker; S: Student
- **For Mode ID, Refer to table below:**

Mode ID	Travel Mode	Mode ID	Travel Mode
1	Car/Jeep/Van (Petrol)	7	Microbus
2	Car/Jeep/Van (Diesel)	8	Bus
3	Motorscooter [2-stroke]	9	Bicycle
4	Motorscooter [4-stroke]	10	Walking
5	Tempo	11	School Bus
6	Taxi	12	Others *(please specify in table)*

Any remarks from Enumerator:

Page 2

2. Other trip purpose:

Number of times a week a family makes other trips (Shopping, Family/Friends visit/ Recreation):
12 times

Which is the shopping area most visited?
New road

3. Non-Home Based Trips
Number of times a week, a respondent makes non-home based trips (Trips that neither begins or ends at home - like from office to other places)
9

Part 3: RESPONDENT' OPINION

This part is to be filled by a respondent

1. Which factor do you think is most important, while you travel?
- ☐ Travel Time
- ☐ Travel Cost [Willingness to pay : Rs. ____ / trip] ☐ Private / ☐ Public
- ☑ Comfort
- ☐ Others *(Please specify)* ________

2. Which mode are you using now for commuting daily trips *(For Private Vehicle Users)*?
Scooter

3. Have you recently (past one month) used public transport (Bus) for any trip?
(For Private Vehicle Users)
☑ Yes ☐ No

4. What aspects of the public transport do you think are important?
(Tick one or multiple options that apply)
- ☑ A. Good choice of Bus Routes & Bus Stops
- ☑ B. Frequent services
- ☑ C. Low cost bus travel
- ☑ D. Reliable and punctual services
- E. Free parking at 'park and ride' locations [Parking facility for private vehicles at bus stops]
- F. Good quality and clean vehicles
- G. Other *(please specify)*:

3. From the above list, which one is the most important to you? *(Circle one only)*
[A] [B] (C) [D] [E] [F] [G]

4. Are you willing to shift to public transport if above facility is available (For Private Vehicle Users)?
☐ Yes ☑ No

Page 3

What do you think, could be the best way to reduce Overall Urban Transport Energy (Fuel) Consumption?
- ☐ Maintaining Vehicle Standards [Proper Maintenance / Emission Standards]
- ☑ Proper Maintenance of Roads
- ☐ Good Mass-Transit system (eg. Sajha bus)
- ☐ Promotion of Non-Motorized modes (Walking / Cycling)
- ☐ Proper City Planning
- ☐ Others (Please Specify) ___________

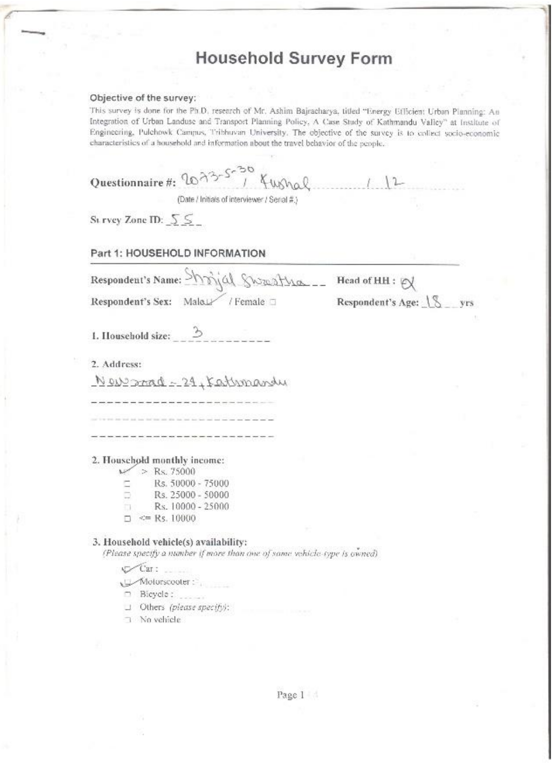
Any remarks from the respondent on urban transport system and urbanization trend of Kathmandu Valley

Proper Maintenance of roads
Maintaining Vehicle Standards

THANK YOU

Page 4

Questionnaire Survey Form (Filled)



Household Survey Form

Objective of the survey:
This survey is done for the Ph.D. research of Mr. Ashim Bajracharya, titled "Energy Efficient Urban Planning: An Integration of Urban Landuse and Transport Planning Policy, A Case Study of Kathmandu Valley" at Institute of Engineering, Pulchowk Campus, Tribhuvan University. The objective of the survey is to collect socio-economic characteristics of a household and information about the travel behavior of the people.

Questionnaire #: 2073-5-30 / Kushal / 12
(Date / Initials of interviewer / Serial #.)

Survey Zone ID: 55

Part 1: HOUSEHOLD INFORMATION

Respondent's Name: Shrijal Shrestha **Head of HH :** ✗
Respondent's Sex: Male ☑ / Female ☐ **Respondent's Age:** 18 yrs

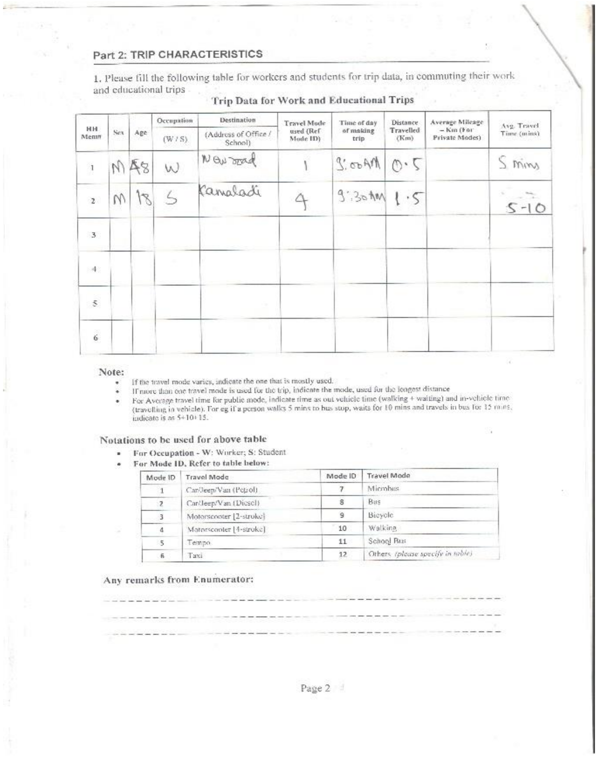
1. Household size: 3

2. Address:
New road - 24, Kathmandu

2. Household monthly income:
- ☑ > Rs. 75000
- ☐ Rs. 50000 - 75000
- ☐ Rs. 25000 - 50000
- ☐ Rs. 10000 - 25000
- ☐ <= Rs. 10000

3. Household vehicle(s) availability:
(Please specify a number if more than one of same vehicle type is owned)
- ☑ Car :
- ☑ Motorscooter :
- ☐ Bicycle :
- ☐ Others *(please specify)*:
- ☐ No vehicle

Page 1



Part 2: TRIP CHARACTERISTICS

1. Please fill the following table for workers and students for trip data, in commuting their work and educational trips

Trip Data for Work and Educational Trips

HH Memb	Sex	Age	Occupation (W / S)	Destination (Address of Office / School)	Travel Mode used (Ref Mode ID)	Time of day of making trip	Distance Travelled (Km)	Average Mileage – Km (For Private Modes)	Avg. Travel Time (mins)
1	M	48	W	New road	1	9:00AM	0.5		5 mins
2	M	18	S	Kamaladi	4	9:30AM	1.5		5-10
3									
4									
5									
6									

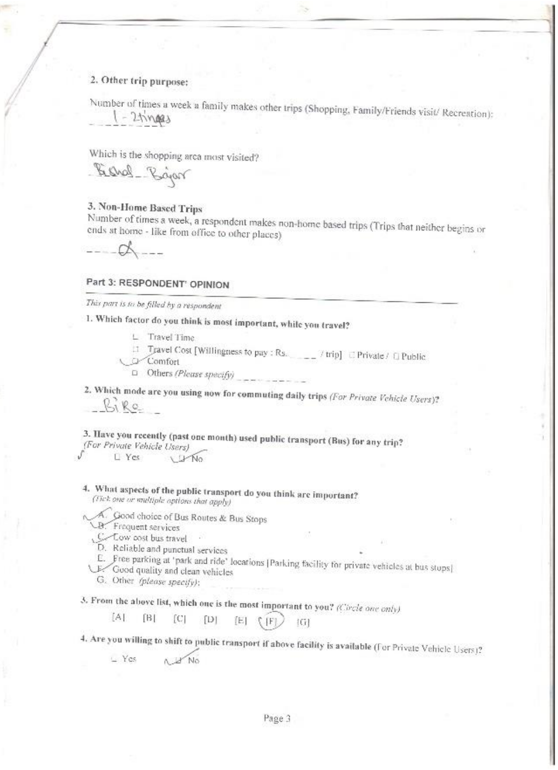
Note:
- If the travel mode varies, indicate the one that is mostly used.
- If more than one travel mode is used for the trip, indicate the mode, used for the longest distance
- For Average travel time for public mode, indicate time as out vehicle time (walking + waiting) and in-vehicle time (travelling in vehicle). For eg if a person walks 5 mins to bus stop, waits for 10 mins and travels in bus for 15 mins, indicate is as 5+10+15.

Notations to be used for above table
- **For Occupation - W:** Worker; **S:** Student
- **For Mode ID, Refer to table below:**

Mode ID	Travel Mode	Mode ID	Travel Mode
1	Car/Jeep/Van (Petrol)	7	Microbus
2	Car/Jeep/Van (Diesel)	8	Bus
3	Motorscooter [2-stroke]	9	Bicycle
4	Motorscooter [4-stroke]	10	Walking
5	Tempo	11	School Bus
6	Taxi	12	Others *(please specify in table)*

Any remarks from Enumerator:

Page 2



2. Other trip purpose:

Number of times a week a family makes other trips (Shopping, Family/Friends visit/ Recreation): 1-2 times

Which is the shopping area most visited?
Bishal Bajar

3. Non-Home Based Trips
Number of times a week, a respondent makes non-home based trips (Trips that neither begins or ends at home - like from office to other places)
✗

Part 3: RESPONDENT' OPINION

This part is to be filled by a respondent

1. Which factor do you think is most important, while you travel?
- ☐ Travel Time
- ☐ Travel Cost [Willingness to pay : Rs. ___ / trip] ☐ Private / ☐ Public
- ☑ Comfort
- ☐ Others *(Please specify)*

2. Which mode are you using now for commuting daily trips *(For Private Vehicle Users)*?
Bike

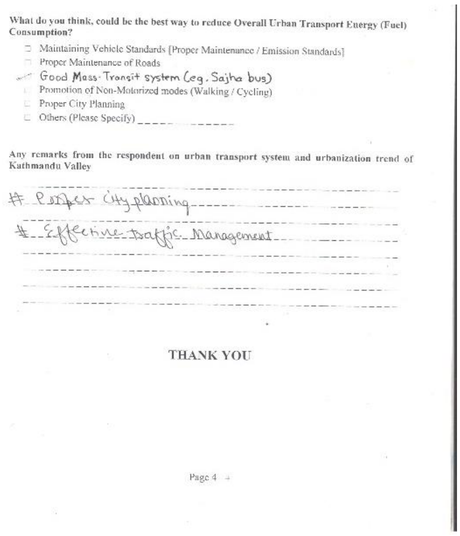
3. Have you recently (past one month) used public transport (Bus) for any trip?
(For Private Vehicle Users)
☐ Yes ☑ No

4. What aspects of the public transport do you think are important?
(Tick one or multiple options that apply)
- ☑ A. Good choice of Bus Routes & Bus Stops
- ☑ B. Frequent services
- ☑ C. Low cost bus travel
- D. Reliable and punctual services
- E. Free parking at 'park and ride' locations [Parking facility for private vehicles at bus stops]
- ☑ F. Good quality and clean vehicles
- G. Other *(please specify)*:

3. From the above list, which one is the most important to you? *(Circle one only)*
[A] [B] [C] [D] [E] ([F]) [G]

4. Are you willing to shift to public transport if above facility is available (For Private Vehicle Users)?
☐ Yes ☑ No

Page 3



What do you think, could be the best way to reduce Overall Urban Transport Energy (Fuel) Consumption?
- ☐ Maintaining Vehicle Standards [Proper Maintenance / Emission Standards]
- ☐ Proper Maintenance of Roads
- ☑ Good Mass Transit system (eg. Sajha bus)
- ☐ Promotion of Non-Motorized modes (Walking / Cycling)
- ☐ Proper City Planning
- ☐ Others (Please Specify)

Any remarks from the respondent on urban transport system and urbanization trend of Kathmandu Valley

Proper City planning
Effective traffic Management

THANK YOU

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Annex 2: Survey Zones

Survey Zone No.	Population	No. of Households	No. of Samples	TAZ
1	33,499	7,336	20	30,45,48,114,130,131,
2	35,320	8,031	22	27,35,46
3	31,313	7,049	20	7,20,34,110,
4	41,482	9,102	24	1,4,8,21,31,42,111
5	33,301	7,992	22	11,16,
6	36,486	8,885	24	74,113
7	44,495	10,364	28	2,23,102,126
8	33,834	8,197	22	112,122
9	42,153	10,335	28	5,107,108,117,
10	33,546	8,167	22	82,84,99,105,115
11	35,882	9,768	25	76,129
12	36,723	11,955	39	77,80,81,83
13	35,551	9,036	30	88,95
14	26,484	6,830	20	13,75,78,79
15	43,915	9,848	25	12,18,24,28,116,118,127
16	37,439	8,539	23	3,15,33,43
17	38,038	8,663	23	10,32,96,97,125
18	36,899	8,574	23	98,119,121,128
19	39,398	9,774	33	25,39,123
20	48,155	12,277	33	89,113
21	43,710	10,657	29	87,90
22	40,655	9,539	33	38,73,120
23	31,898	7,754	21	6,22
24	19,510	4,363	20	19,109,124
25	37,710	8,388	23	14,17,29,44
26	38,972	9,838	33	92,94
27	40,162	10,247	34	52,85
28	30,727	7,649	25	50,60
29	40,304	10,623	35	57,66
30	54,580	12,851	44	91,93
31	64,842	16,734	55	69,70
32	94,788	20,453	69	9
33	39,845	10,406	28	26
34	69,030	18,340	49	36
35	48,098	11,921	32	37,106
36	30,988	7,978	21	40
37	32,133	8,111	22	41
38	107,291	27,737	73	47
39	61,485	15,636	41	49
40	50,520	13,412	45	51
41	133,570	32,360	107	53
42	51,327	12,950	42	54
43	74,213	19,629	65	55
44	69,114	17,880	59	56
45	57,158	15,544	51	58
46	44,235	11,602	39	59
47	42,268	11,796	39	61
48	32,598	8,724	29	62
49	83,888	22,548	75	63
50	96,801	26,379	87	64
51	60,089	15,263	50	65
52	76,559	19,581	65	67
53	65,441	17,202	57	68
54	107,131	28,819	95	71
55	84,001	20,384	67	72
56	44,230	10,758	36	86
57	49,251	13,016	44	100
58	47,030	10,525	35	101
59	51,276	13,891	37	104
Total:	**2,991,342**	**752,208**	**2314**	

Annex 3: TAZ Data

	TAZ Boundary Reference			Year 2011			Year 2017		Built-up Area (Sq.m)		
TAZ No	**VDC /Municipality**	**Aggregated Wards**	**District ***	**No. of House-holds**	**Total Popula-tion**	**Growth Rate (Exponential)**	**Total Popula-tion**	**No. of House-holds**	**Work Places**	**Edu. Inst.**	**Area (Sq. Km)**
1	Alapot		K	671	3,159	4.8%	4,203	894	1,474.5	1,108.2	1.47
2	Baad Bhanjyang		K	817	3,779	4.8%	5,028	1,093	27,564.1	10,329.0	4.8
3	Badikhel		L	791	3,576	3.2%	4,758	1,057	20,492.3	13,773.2	2.63
4	Bajrayogini (Sankhu)		K	928	4,333	4.8%	5,765	1,227	14,475.8	14,060.5	5.24
5	Balambu		K	1,734	7,323	4.8%	9,744	2,320	19,489.4	2,523.9	2.12
6	Balkot		B	3,999	15,881	3.0%	21,131	5,283	63,628.0	34,440.5	2.84
7	Baluwa		K	1,204	5,467	4.8%	7,274	1,616	13,152.8	14,834.5	5.9
8	Bhadrabas		K	503	2,388	4.8%	3,177	676	7,388.6	19,067.8	1.67
9	Bhaktapur Municipality		B	17,639	81,748	3.0%	108,771	23,646	369,136.9	222,002.9	6.56
10	Bisankhunarayan		L	1,047	4,484	3.2%	5,966	1,387	16,561.3	17,465.9	3.42
11	Budanilkantha		K	3,725	15,421	4.8%	20,519	5,005	123,159.2	105,069.8	5.07
12	Bungamati		L	1,304	5,966	3.2%	7,938	1,726	34,738.7	9,758.7	3.89
13	Chalnakhel		K	1,005	4,365	4.8%	5,808	1,351	6,994.6	8,652.2	2.98
14	Changunarayan		B	1,374	6,211	3.0%	8,264	1,836	34,532.2	9,161.0	6.78
15	Chapagaun		L	3,710	16,420	3.2%	21,848	4,965	89,624.3	61,696.9	7.27
16	Chapali Bhadrakali		K	2,574	10,827	4.8%	14,406	3,430	1,022.5	1,452.4	3.16
17	Chhaling		B	1,817	8,129	3.0%	10,816	2,404	61,344.9	50,449.8	9.61
18	Chhampi		L	1,071	4,753	3.2%	6,324	1,437	29,088.0	15,124.4	5.52
19	Chitapol		B	1,274	5,619	3.0%	7,476	1,699	32,554.8	9,390.0	5.08
20	Chunikhel		K	859	4,449	4.8%	5,920	1,138	9,850.2	7,900.2	3.6
21	Daanchhi		K	2,593	11,246	4.8%	14,963	3,480	28,140.0	26,477.2	4.99
22	Dadhikot		B	2,688	11,629	3.0%	15,473	3,598	56,638.9	21,001.9	6.5
23	Dahachok		K	878	4,036	4.8%	4,964	1,056	10,781.6	9,281.9	4.89
24	Daxinkali		K	984	4,755	4.8%	6,327	1,318	34,550.0	8,019.4	4.6
25	Dhapakhel		L	3,178	12,678	3.2%	16,869	4,217	103,888.7	34,791.6	3.67
26	Dhapasi		K	8,202	31,406	4.8%	41,788	10,997	146,147.4	142,699.1	2.04
27	Dharmasthali		K	1,421	6,530	4.8%	8,689	1,889	45,499.2	36,754.6	1.86
28	Dukuchhap		L	555	2,669	3.2%	3,551	740	4,824.0	42,228.5	4.91
29	Duwakot		B	2,412	10,461	3.0%	13,919	3,237	111,192.1	48,953.7	6.3
30	Futung		K	1,064	4,792	4.8%	6,376	1,417	10,466.4	9,457.2	1.42
31	Gagalphedi		K	1,166	5,533	4.8%	7,362	1,566	16,698.8	18,352.1	8.34
32	Godamchaur		L	1,094	4,914	3.2%	6,538	1,453	9,424.0	13,382.8	3.13
33	Godawari		L	1,825	7,558	3.2%	10,056	2,453	74,348.7	35,841.7	4.11
34	Gokarneswor		K	1,768	7,508	4.8%	9,990	2,379	37,614.4	52,512.3	4.69
35	Goldhunga		K	3,806	16,174	4.8%	21,520	5,124	60,759.5	57,931.8	5.15
36	Gonggabu		K	14,456	54,410	4.8%	72,396	19,052	157,294.8	143,483.6	2.36
37	Gothatar		K	6,749	26,169	4.8%	34,819	8,928	65,655.9	72,494.7	4.61
38	Gundu		B	1,257	5,689	3.0%	7,570	1,682	23,300.7	16,047.5	7.43
39	Harisiddhi		L	2,737	10,736	3.2%	14,285	3,663	59,633.1	13,587.5	3.1
40	IchangNarayan		K	6,288	24,425	4.8%	32,499	8,333	105,800.4	70,473.0	4.08
41	Imadol		L	6,898	27,327	3.2%	36,360	9,090	95,546.2	61,435.8	4.02
42	Indrayani		K	717	3,361	4.8%	4,472	951	7,420.6	7,789.5	2.77
43	Jharuwarasi		L	936	4,286	3.2%	5,703	1,240	41,490.9	18,240.4	3.81
44	Jhaukhel		B	1,631	7,721	3.0%	10,273	2,186	110,391.0	25,411.5	5.22
45	JhorMahankal		K	873	4,103	4.8%	5,459	1,162	325.3	402.2	3.2
46	Jitpurphedi		K	1,103	5,135	4.8%	6,237	1,327	56,890.8	29,529.7	8.12
47	Jorpati		K	21,862	84,567	4.8%	102,714	26,337	213,659.9	263,026.9	4.82
48	Kabhresthali		K	1,007	4,774	4.8%	6,352	1,352	23,544.3	14,101.6	5.58
49	Kapan		K	12,324	48,463	4.8%	58,862	15,093	117,240.6	112,436.3	4.66
50	Kathmandu Metropolitan City	49	K	1,917	8,008	4.8%	10,655	2,537	204,195.4	76,628.1	1.37
51	Kathmandu Metropolitan City	50	K	10,571	39,820	4.8%	52,983	13,943	279,496.0	194,197.7	1.57
52	Kathmandu Metropolitan City	51	K	4,416	17,765	4.8%	21,577	5,394	297,041.5	82,315.5	1.74
53	Kathmandu Metropolitan City	17,18,19,24, 25,26,27,28, 30	K	19,421	80,256	4.8%	97,477	23,775	195,489.7	95,560.6	1.33
54	Kathmandu Metropolitan City	53	K	10,207	40,456	4.8%	53,829	13,457	160,408.9	145,265.6	2.14
55	Kathmandu Metropolitan City	54	K	15,472	58,495	4.8%	71,047	18,697	206,405.9	173,383.5	3.2
56	Kathmandu Metropolitan City	55	K	14,093	54,476	4.8%	72,484	18,586	108,705.6	89,764.2	2.92
57	Kathmandu Metropolitan City	56	K	3,599	13,448	4.8%	17,893	4,836	137,931.6	42,502.2	0.84
58	Kathmandu Metropolitan City	57	K	12,252	45,052	4.8%	54,719	14,789	241,725.6	103,580.4	1.94
59	Kathmandu Metropolitan City	58	K	9,145	34,866	4.8%	42,348	11,144	398,222.9	186,130.3	3.2
60	Kathmandu Metropolitan City	59	K	4,112	16,211	4.8%	19,690	5,049	184,314.0	109,193.1	0.94
61	Kathmandu Metropolitan City	60	K	9,298	33,316	4.8%	40,465	11,240	132,526.3	85,417.2	1.3
62	Kathmandu Metropolitan City	61	K	6,876	25,694	4.8%	31,207	8,434	78,399.9	53,245.6	0.92
63	Kathmandu Metropolitan City	62	K	17,772	66,121	4.8%	80,309	21,705	361,594.0	211,809.6	2.33
64	Kathmandu Metropolitan City	63	K	20,792	76,299	4.8%	92,671	25,046	256,760.6	170,327.2	4.34
65	Kathmandu Metropolitan City	64	K	12,030	47,362	4.8%	57,525	14,750	324,617.0	188,373.5	2.86
66	Kathmandu Metropolitan City	65	K	4,774	18,320	4.8%	22,251	5,856	71,641.1	52,459.9	0.71
67	Kathmandu Metropolitan City	66	K	15,434	60,344	4.8%	73,293	18,793	225,539.9	269,627.0	3.39
68	Kathmandu Metropolitan City	67	K	13,559	51,581	4.8%	62,649	16,487	243,111.5	139,074.1	1.54
69	Kathmandu Metropolitan City	68	K	2,773	10,738	4.8%	13,042	3,344	48,495.4	26,076.4	1.81
70	Kathmandu Metropolitan City	69	K	10,417	40,371	4.8%	48,217	12,363	309,099.0	164,304.4	3.76
71	Kathmandu Metropolitan City	70	K	22,715	84,441	4.8%	102,561	27,719	330,639.4	257,150.7	4.11

	TAZ Boundary Reference			Year 2011			Year 2017		Built-up Area (Sq.m)		
TAZ No	**VDC /Municipality**	**Aggregated Wards**	**District ***	**No. of House-holds**	**Total Popula-tion**	**Growth Rate (Exponential)**	**Total Popula-tion**	**No. of House-holds**	**Work Places**	**Edu. Inst.**	**Area (Sq. Km)**
72	Kathmandu Metropolitan City	12,20,21,22, 23	K	12,647	52,013	4.8%	63,174	15,408	132,257.7	38,722.8	1.18
73	Kautunje		B	4,692	19,497	3.0%	23,681	5,638	121,293.8	65,120.6	4.33
74	Khadka Bhadrakali		K	2,582	10,761	4.8%	13,070	3,112	48,677.2	36,853.6	2.39
75	Khokana		L	1,056	4,927	3.2%	5,984	1,273	24,587.8	30,886.1	3.17
76	Kirtipur Municipality	1,2,5,6	K	5,192	18,556	4.8%	22,538	6,260	44,800.4	22,739.9	1.29
77	Kirtipur Municipality	9,10,11,12	K	3,386	10,964	4.8%	13,317	4,161	80,758.0	37,008.9	1.51
78	Kirtipur Municipality	13,14,18	K	2,550	8,176	4.8%	9,930	3,103	24,255.6	9,349.9	2.36
79	Kirtipur Municipality	15	K	850	3,767	4.8%	4,499	1,023	15,651.4	11,437.7	2.85
80	Kirtipur Municipality	16	K	792	2,510	4.8%	2,998	937	17,288.6	14,054.2	0.98
81	Kirtipur Municipality	4,17	K	2,743	8,128	4.8%	9,708	3,236	69,108.9	46,624.5	0.83
82	Kirtipur Municipality	19	K	222	985	4.8%	1,176	267	16,006.2	5,314.7	0.84
83	Kirtipur Municipality	3	K	2,502	7,343	4.8%	8,770	3,024	140,042.8	68,232.2	1.52
84	Kirtipur Municipality	8	K	1,204	5,173	4.8%	6,178	1,437	16,763.2	-	1.45
85	Lalitpur Sub-metropolitan City	1,10	L	3,950	14,988	3.2%	17,901	4,711	143,219.2	72,364.7	1.24
86	Lalitpur Sub-metropolitan City	7,8,9,11	L	9,149	37,615	3.2%	44,925	10,957	168,176.9	98,067.0	1.56
87	Lalitpur Sub-metropolitan City	6,12,17	L	5,583	23,315	3.2%	27,846	6,630	99,976.4	58,688.9	0.97
88	Lalitpur Sub-metropolitan City	13	L	3,772	14,867	3.2%	17,756	4,553	48,593.7	50,114.6	0.75
89	Lalitpur Sub-metropolitan City	14	L	5,438	21,232	3.2%	25,358	6,502	119,474.1	107,411.6	1.72
90	Lalitpur Sub-metropolitan City	15	L	3,480	13,858	3.2%	16,551	4,138	158,002.6	92,533.4	2.28
91	Lalitpur Sub-metropolitan City	5,16,18,19, 20,21	L	8,469	36,308	3.2%	44,099	10,256	160,839.2	156,593.1	1.38
92	Lalitpur Sub-metropolitan City	2	L	4,839	19,061	3.2%	23,151	5,936	90,740.4	64,431.1	1.11
93	Lalitpur Sub-metropolitan City	22	L	2,460	10,109	3.2%	13,451	3,281	38,966.8	24,478.1	0.45
94	Lalitpur Sub-metropolitan City	3	L	3,528	14,082	3.2%	17,104	4,276	331,506.0	138,816.9	1.65
95	Lalitpur Sub-metropolitan City	4	L	3,913	15,367	3.2%	20,447	5,243	226,390.6	104,366.1	2.04
96	Lamatar		L	1,473	6,909	3.2%	9,193	1,956	32,413.0	16,943.0	2.28
97	Lubhu	3,4,8	L	1,330	5,823	3.2%	7,748	1,761	15,953.0	7,634.6	3.91
98	Lubhu	1,2,5,6,7	L	1,035	4,551	3.2%	6,055	1,376	39,000.1	42,952.4	2.49
99	Machhegaun		K	872	3,849	4.8%	4,675	1,062	25,579.8	19,325.3	1.79
100	Madhyapur Thimi Municipality	15,16,17	B	11,225	42,476	3.0%	51,591	13,576	231,444.5	165,888.1	4.78
101	Madhyapur Thimi Municipality	1,2,3,4,5,6,7, 8,9,10,11,12, 13,14	B	9,077	40,560	3.0%	53,968	11,993	156,297.4	101,126.9	6.33
102	Mahadevathan		K	3,731	15,514	4.8%	20,642	4,915	42,496.0	46,700.3	3.04
103	Mahankal		K	4,421	17,997	4.8%	21,495	5,243	116,409.6	111,912.5	4.1
104	Manmaiju		K	10,949	40,416	4.8%	53,776	14,534	81,270.5	69,977.0	3.05
105	Matatirtha		K	1,413	5,982	4.8%	7,959	1,895	39,811.0	72,868.2	2.38
106	Mulpani		K	2,647	11,742	4.8%	15,623	3,551	38,892.8	31,598.9	3.86
107	Naikap Naya Bhanjyang		K	1,980	7,944	4.8%	10,570	2,642	34,225.2	40,883.4	1.25
108	Naikap Purano Bhanjyang		K	1,054	4,546	4.8%	6,049	1,407	24,435.5	24,529.1	1.74
109	Nankhel		B	1,225	5,509	3.0%	6,691	1,487	30,992.1	11,007.1	3.63
110	Nayapati		K	1,725	7,257	4.8%	9,656	2,299	32,427.2	65,043.6	5.09
111	Pukhulachhi		K	596	2,676	4.8%	3,561	791	46,391.1	48,299.7	1.38
112	Ramkot		K	1,937	8,759	4.8%	11,654	2,590	42,987.7	41,193.4	5.79
113	Sainbu		L	5,003	19,721	3.2%	26,240	6,728	79,402.3	67,517.9	4.12
114	Sangla		K	808	3,622	4.8%	4,819	1,071	14,061.9	7,079.7	3.89
115	Satungal		K	2,726	10,452	4.8%	13,907	3,660	63,603.2	20,335.8	2.33
116	Setidevi		K	1,039	4,248	4.8%	5,652	1,379	38,439.1	17,181.6	4.62
117	Seuchatar		K	3,378	13,412	4.8%	17,845	4,461	29,606.9	24,784.6	2.74
118	Sheshnarayan		K	844	3,855	4.8%	5,129	1,115	9,843.6	10,088.7	2.97
119	Siddhipur		L	1,484	6,147	3.2%	8,179	1,995	38,067.9	60,128.0	2.01
120	Sipadol		B	2,278	9,876	3.0%	13,141	3,056	60,129.3	11,867.6	8.11
121	Sirutar		B	1,033	4,790	3.0%	6,373	1,386	8,583.8	9,150.2	1.37
122	Sitapaila		K	4,524	17,909	4.8%	23,829	5,957	71,424.9	52,469.1	3.51
123	Sunakothi		L	2,397	10,092	3.2%	13,428	3,197	94,340.7	47,851.9	3.02
124	Tathali		B	1,264	5,698	3.0%	7,582	1,685	95,149.3	28,115.7	8.7
125	Thaiba		L	1,982	8,261	3.2%	10,992	2,617	56,984.0	66,007.9	2.34
126	Thankot		K	2,820	12,047	4.8%	16,029	3,728	83,027.5	62,018.5	3.01
127	Thecho		L	2,352	10,086	3.2%	13,420	3,121	57,783.9	71,107.4	3.25
128	Tikathali		L	2,424	10,136	3.2%	12,311	2,931	21,377.3	21,386.9	3.01
129	Tinthana		K	2,507	9,726	4.8%	11,616	2,979	25,391.4	8,829.3	1.29
130	Tokha Chandeswori		K	841	3,961	4.8%	4,731	1,007	31,303.8	18,804.0	4.41
131	Tokha Sarswoti		K	1,189	5,152	4.8%	6,855	1,594	40,837.2	48,802.6	1.93
			Total	**594,745**	**2,366,096**		**2,987,014**	**749,560**	**11,889,564**	**7,876,416**	**431.6**

* K: Kathmandu, B: Bhaktapur, L: Lalitpur

Annex 4: Trip Generation Data

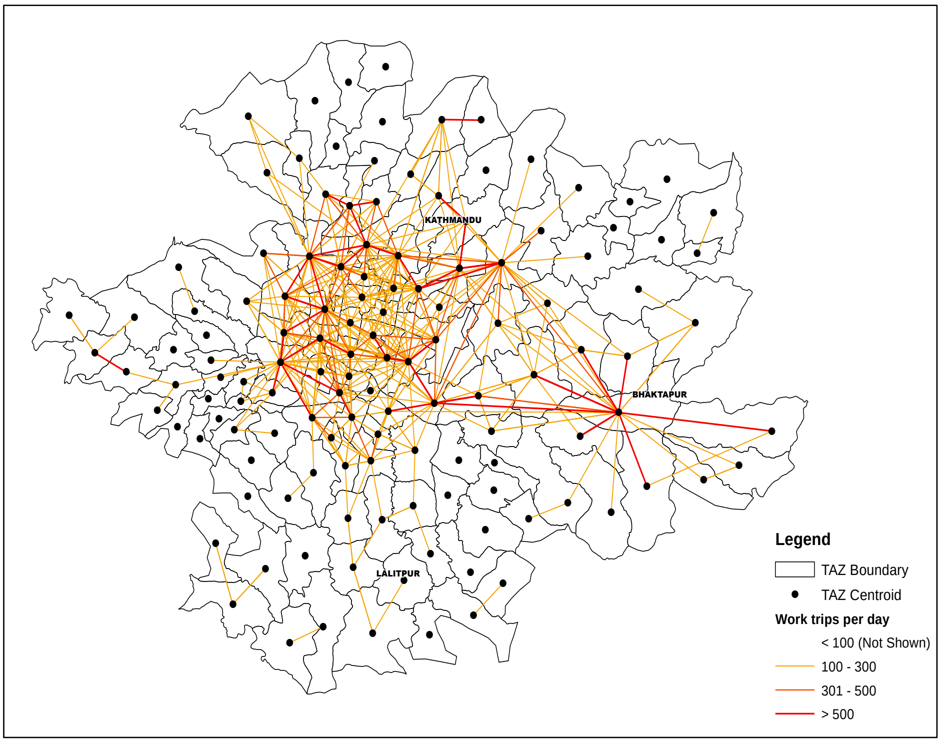
Work Trips

												Work Trip Productions							Work Trip Attraction						
TAZ ID	Survey Zone	HH Size	Zone Category	HH_2017	Work Place Area (Sq.m)	Edu. Inst. Area (Sq.m)	Work Trip Rate (Trips/HH)	Edu Trip Rate (Trips/HH)	Work Trips	Edu Trips		BYC	Bus	Car	Micro	MC	Tempo	Walk	BYC	Bus	Car	Micro	MC	Tempo	Walk
1	4	4.7	O	894	1475	1108	1.79	0.79	1601	707		8.1	373.8	284.4	0.0	633.8	0.0	300.7	1.2	17.4	31.3	0.0	77.3	0.0	20.5
2	7	4.6	M	1093	27564	10329	2.07	0.96	2263	1049		15.3	305.8	380.7	146.8	1122.2	0.0	292.0	21.7	325.1	585.5	186.0	1444.3	0.0	383.3
3	16	4.5	M	965	20492	13773	0.91	0.83	878	801		5.9	118.7	147.8	57.0	435.6	0.0	113.4	16.1	241.7	435.3	138.3	1073.7	0.0	284.9
4	4	4.7	O	1227	14476	14060	1.79	0.79	2196	969		11.1	512.7	390.1	0.0	869.4	0.0	412.4	11.4	170.7	307.5	0.0	758.5	0.0	201.3
5	9	4.2	M	2320	19489	2524	1.54	1.39	3573	3225		24.1	482.8	601.1	231.7	1771.9	0.0	461.1	15.3	229.9	414.0	131.5	1021.2	0.0	271.0
6	23	4	M	4742	63628	34440	1.19	1.43	5643	6781		38.1	762.5	949.4	366.0	2798.5	0.0	728.2	50.0	750.5	1351.4	429.3	3333.9	0.0	884.8
7	3	4.5	O	1616	13153	14834	1.45	1.15	2344	1859		11.9	547.3	416.4	0.0	928.0	0.0	440.2	10.3	155.1	279.4	0.0	689.2	0.0	182.9
8	4	4.7	M	676	7389	19068	1.79	0.79	1210	534		8.2	163.5	203.6	78.5	600.1	0.0	156.2	5.8	87.2	156.9	49.9	387.1	0.0	102.7
9	32	4.6	M	21225	369137	222003	2.13	0.84	45209	17829		305.5	6109.4	7606.2	2932.5	22421.5	0.0	5834.5	290.1	4354.2	7840.4	2490.6	19341.6	0.0	5132.9
10	17	4.3	M	1267	16561	17466	0.96	1.09	1216	1381		8.2	164.3	204.6	78.9	603.0	0.0	156.9	13.0	195.3	351.8	111.7	867.8	0.0	230.3
11	5	4.1	M	5005	123159	105070	1.73	1.23	8658	6156		58.5	1170.0	1456.6	561.6	4293.8	0.0	1117.3	96.8	1452.7	2615.9	831.0	6453.1	0.0	1712.5
12	15	4.6	O	1575	34739	9759	1.80	1.56	2835	2457		14.4	662.1	503.8	0.0	1122.7	0.0	532.5	27.3	409.8	737.8	0.0	1820.2	0.0	483.0
13	14	4.3	M	1351	6995	8652	1.45	1.30	1958	1756		13.2	264.7	329.5	127.0	971.3	0.0	252.7	5.5	82.5	148.6	47.2	366.5	0.0	97.3
14	25	4.5	M	1648	34532	9161	1.96	1.00	3231	1648		21.8	436.6	543.6	209.6	1602.4	0.0	417.0	27.1	407.3	733.5	233.0	1809.4	0.0	480.2
15	16	4.4	M	4533	89624	61697	0.91	0.83	4125	3762		27.9	557.4	693.9	267.5	2045.6	0.0	532.3	70.4	1057.2	1903.6	604.7	4696.0	0.0	1246.2
16	5	4.2	M	3430	1023	1452	1.73	1.23	5934	4219		40.1	801.9	998.3	384.9	2942.9	0.0	765.8	0.8	12.1	21.7	6.9	53.6	0.0	14.2
17	25	4.5	O	2158	61345	50450	1.96	1.00	4229	2158		21.5	987.4	751.3	0.0	1674.3	0.0	794.2	48.2	723.6	1303.0	0.0	3214.3	0.0	853.0
18	15	4.4	O	1312	29088	15124	1.80	1.56	2362	2047		12.0	551.4	419.6	0.0	935.1	0.0	443.6	22.9	343.1	617.8	0.0	1524.1	0.0	404.5
19	24	4.4	O	1525	32555	9390	1.80	1.30	2745	1983		13.9	641.1	487.8	0.0	1087.0	0.0	515.6	25.6	384.0	691.5	0.0	1705.8	0.0	452.7
20	3	5.2	O	1138	9850	7900	1.45	1.15	1651	1309		8.4	385.4	293.3	0.0	653.6	0.0	310.0	7.7	116.2	209.2	0.0	516.1	0.0	137.0
21	4	4.3	M	3480	28140	26477	1.79	0.79	6229	2749		42.1	841.8	1048.0	404.0	3089.2	0.0	803.9	22.1	331.9	597.7	189.9	1474.4	0.0	391.3
22	23	4.3	M	3230	56639	21002	1.19	1.43	3844	4619		26.0	519.4	646.7	249.3	1906.3	0.0	496.0	44.5	668.1	1203.0	382.2	2967.7	0.0	787.6
23	7	4.7	M	1056	10782	9282	2.07	0.96	2186	1014		14.8	295.5	367.8	141.8	1084.3	0.0	282.2	8.5	127.2	229.0	72.7	564.9	0.0	149.9
24	15	4.8	M	1318	34550	8019	1.80	1.56	2373	2056		16.0	320.6	399.2	153.9	1176.7	0.0	306.2	27.2	407.5	733.8	233.1	1810.3	0.0	480.4
25	19	4	M	3850	103889	34792	1.12	0.79	4312	3041		29.1	582.6	725.4	279.7	2138.3	0.0	556.4	81.6	1225.4	2206.6	701.0	5443.4	0.0	1444.6
26	33	3.8	M	10997	146147	142699	1.46	1.14	16055	12536		108.5	2169.6	2701.2	1041.4	7962.5	0.0	2072.0	114.9	1723.9	3104.1	986.1	7657.6	0.0	2032.2
27	2	4.6	M	1889	45499	36755	1.68	1.41	3173	2663		21.4	428.8	533.9	205.8	1573.7	0.0	409.5	35.8	536.7	966.4	307.0	2384.0	0.0	632.7
28	15	4.8	O	675	4824	42228	1.80	1.56	1216	1054		6.2	283.9	216.0	0.0	481.3	0.0	228.3	3.8	56.9	102.5	0.0	252.8	0.0	67.1
29	25	4.3	O	2906	111192	48954	1.96	1.00	5695	2906		28.9	1329.8	1011.8	0.0	2254.9	0.0	1069.6	87.4	1311.6	2361.7	0.0	5826.1	0.0	1546.1
30	1	4.5	M	1417	10466	9457	1.50	1.10	2125	1559		14.4	287.2	357.6	137.9	1054.1	0.0	274.3	8.2	123.5	222.3	70.6	548.4	0.0	145.5
31	4	4.7	O	1566	16699	18352	1.79	0.79	2804	1237		14.2	654.7	498.1	0.0	1110.1	0.0	526.6	13.1	197.0	354.7	0.0	875.0	0.0	232.2
32	17	4.5	M	1326	9424	13383	0.96	1.09	1273	1446		8.6	172.1	214.2	82.6	631.5	0.0	164.3	7.4	111.2	200.2	63.6	493.8	0.0	131.0
33	16	4.1	M	2239	74349	35842	0.91	0.83	2037	1858		13.8	275.3	342.8	132.2	1010.5	0.0	262.9	58.4	877.0	1579.1	501.6	3895.6	0.0	1033.8
34	3	4.2	M	2379	37614	52512	1.45	1.15	3449	2735		23.3	466.1	580.2	223.7	1710.5	0.0	445.1	29.6	443.7	798.9	253.8	1970.9	0.0	523.0
35	2	4.2	M	5124	60760	57932	1.68	1.41	8608	7225		58.2	1163.3	1448.3	558.4	4269.2	0.0	1110.9	47.8	716.7	1290.5	410.0	3183.6	0.0	844.9
36	34	3.8	M	19052	157295	143484	1.61	1.65	30673	31435		207.2	4145.0	5160.5	1989.6	15212.1	0.0	3958.5	123.6	1855.4	3340.9	1061.3	8241.7	0.0	2187.2
37	35	3.9	M	8928	65656	72495	1.63	1.00	14553	8928		98.3	1966.6	2448.4	944.0	7217.4	0.0	1878.1	51.6	774.4	1394.5	443.0	3440.2	0.0	913.0
38	22	4.5	O	1510	23301	16047	1.36	0.73	2053	1102		10.4	479.5	364.8	0.0	813.1	0.0	385.7	18.3	274.8	494.9	0.0	1220.9	0.0	324.0
39	19	3.9	M	3344	59633	13587	1.12	0.79	3745	2641		25.3	506.0	630.0	242.9	1857.2	0.0	483.3	46.9	703.4	1266.6	402.4	3124.6	0.0	829.2
40	36	3.9	M	8333	105800	70473	1.52	1.43	12666	11916		85.6	1711.7	2131.0	821.6	6281.8	0.0	1634.6	83.2	1248.0	2247.2	713.9	5543.6	0.0	1471.2
41	37	4	MT	8298	95546	61436	0.91	0.59	7551	4896		67.4	709.7	1882.1	503.1	4182.0	206.6	1073.6	75.1	1127.0	2029.4	644.7	5006.3	253.6	1328.6
42	4	4.7	M	951	7421	7789	1.79	0.79	1703	752		11.5	230.2	286.5	110.5	844.7	0.0	219.8	5.8	87.5	157.6	50.1	388.8	0.0	103.2
43	16	4.6	M	1132	41491	18240	0.91	0.83	1030	939		7.0	139.2	173.3	66.8	510.7	0.0	132.9	32.6	489.4	881.3	279.9	2174.0	0.0	576.9
44	25	4.7	O	1962	110391	25411	1.96	1.00	3846	1962		19.5	898.0	683.2	0.0	1522.6	0.0	722.3	86.8	1302.1	2344.7	0.0	5784.1	0.0	1535.0
45	1	4.7	M	1162	325	402	1.50	1.10	1742	1278		11.8	235.4	293.1	113.0	864.1	0.0	224.9	0.3	3.8	6.9	2.2	17.0	0.0	4.5
46	2	4.7	O	1454	56891	29530	1.68	1.41	2442	2050		12.4	570.3	433.9	0.0	967.0	0.0	458.7	44.7	671.1	1208.3	0.0	2980.9	0.0	791.1
47	38	3.9	MT	28852	213660	263027	1.44	1.11	41546	32025		370.7	3905.0	10355.7	2768.1	23009.9	1136.9	5907.0	167.9	2520.2	4538.1	1441.6	11195.1	567.1	2971.0
48	1	4.7	O	1352	23544	14102	1.50	1.10	2027	1487		10.3	473.4	360.2	0.0	802.7	0.0	380.8	18.5	277.7	500.1	0.0	1233.6	0.0	327.4
49	39	3.9	M	16534	117241	112436	1.44	1.10	23809	18187		160.9	3217.4	4005.7	1544.4	11808.0	0.0	3072.7	92.1	1382.9	2490.2	791.0	6143.0	0.0	1630.3
50	28	4.2	MT	2537	204195	76628	1.64	1.12	4161	2841		37.1	391.1	1037.0	277.2	2304.3	113.9	591.5	160.5	2408.6	4337.1	1377.7	10699.2	541.9	2839.4
51	40	3.8	MT	13943	279496	194198	1.53	1.20	21333	16731		190.4	2005.1	5317.3	1421.3	11814.8	583.8	3033.0	219.7	3296.8	5936.4	1885.8	14644.7	741.8	3886.4
52	27	4	MT	5909	297042	82316	1.62	1.09	9573	6441		85.4	899.8	2386.2	637.8	5302.0	262.0	1361.1	233.5	3503.8	6309.1	2004.2	15564.0	788.3	4130.4
53	41	4.1	MT	26045	195490	95561	1.85	1.06	48184	27608		430.0	4528.9	12010.1	3210.3	26685.9	1318.5	6850.6	153.6	2305.9	4152.2	1319.0	10243.0	518.8	2718.3
54	42	4	MT	13457	160409	145266	1.71	1.21	23012	16283		205.3	2162.9	5735.9	1533.2	12744.9	629.7	3271.8	126.1	1892.1	3407.0	1082.3	8404.9	425.7	2230.5
55	43	3.8	MT	20482	206406	173384	1.78	1.23	36458	25193		325.3	3426.7	9087.3	2429.1	20191.6	997.7	5183.5	162.2	2434.7	4384.0	1392.7	10815.0	547.8	2870.1
56	44	3.9	MT	18586	108706	89764	1.54	1.34	28622	24905		255.4	2690.2	7134.1	1907.0	15851.8	783.2	4069.4	85.4	1282.2	2308.9	733.5	5695.8	288.5	1511.6
57	29	3.7	MT	4836	137932	42502	1.60	1.03	7738	4981		69.0	727.3	1928.7	515.5	4285.4	211.7	1100.1	108.4	1627.0	2929.6	930.6	7227.2	366.1	1918.0
58	45	3.7	MT	16201	241726	103580	1.51	1.06	24464	17173		218.3	2299.4	6097.8	1629.9	13549.0	669.4	3478.2	190.0	2851.3	5134.2	1631.0	12665.6	641.5	3361.2
59	46	3.8	MT	12208	398223	186130	1.44	1.21	17580	14772		156.9	1652.4	4381.9	1171.3	9736.4	481.1	2499.5	313.0	4697.2	8458.2	2686.9	20865.6	1056.9	5537.4
60	28	3.9	MT	5531	184314	109193	1.64	1.12	9070	6194		80.9	852.5	2260.8	604.3	5023.5	248.2	1289.6	144.9	2174.1	3914.8	1243.6	9657.5	489.2	2562.9
61	47	3.6	MT	12314	132526	85417	1.74	1.18	21426	14530		191.2	2013.8	5340.5	1427.5	11866.3	586.3	3046.2	104.2	1563.2	2814.8	894.2	6943.9	351.7	1842.8
62	48	3.7	MT	9240	78400	53246	1.59	1.14	14691	10533		131.1	1380.9	3661.9	978.8	8136.6	402.0	2088.8	61.6	924.8	1665.2	529.0	4107.9	208.1	1090.2
63	49	3.7	MT	23778	361594	211810	1.52	1.12	36142	26631		322.5	3397.1	9008.7	2408.1	20016.9	989.0	5138.6	284.2	4265.2	7680.2	2439.7	18946.4	959.7	5028.0
64	50	3.7	MT	27438	256761	170327	1.38	1.15	37864	31554		337.9	3558.9	9437.9	2522.8	20970.7	1036.1	5383.5	201.8	3028.6	5453.5	1732.4	13453.4	681.4	3570.3
65	51	3.9	MT	16158	324617	188374	1.54	1.10	24884	17774		222.0	2338.9	6202.5	1657.9	13781.7	680.9	3537.9	255.1	3829.0	6894.8	2190.2	17008.9	861.5	4513.9
66	29	3.8	MT	6415	71641	52460	1.60	1.03	10264	6607		91.6	964.7	2558.2	683.8	5684.3	280.9	1459.2	56.3	845.0	1521.6	483.4	3753.8	190.1	996.2
67	52	3.9	MT	20588	225540	269627	1.77	1.05	36440	21617		325.2	3425.0	9082.9	2427.9	20181.8	997.2	5180.9	177.3	2660.4	4790.4	1521.8	11817.6	598.6	3136.2
68	53	3.8	MT	18061	243112	139074	1.26	1.07	22757	19325		203.1	2138.9	5672.3	1516.2	12603.6	622.7	3235.5	191.1	2867.6	5163.6	1640.3	12738.3	645.2	3380.5
69	31	3.9	MT	3663	48495	26076	1.25	0.75	4579	2748		40.9	430.4	1141.4	305.1	2536.2	125.3	651.1	38.1	572.0	1030.0	327.2	2541.0	128.7	674.3
70	31	3.9	MT	13773	309099	164304	1.25	0.75	17217	10330		153.6	1618.2	4291.4	1147.1	9535.2	471.1	2447.8	242.9	3646.0	6565.2	2085.5	16195.8	820.3	4298.1
71	54	3.7	M	30366	330639	257151	1.65	0.78	50104	23685		338.5	6770.8	8429.6	3250.0	24848.7	0.0	6466.1	259.9	3900.1	7022.7	2230.9	17324.4	0.0	4597.6
72	55	4.1	MT	16880	132258	38723	1.60	1.34	27007	22619		241.0	2538.5	6731.8	1799.4	14957.7	739.0	3839.8	103.9	1560.0	2809.1	892.4	6929.9	351.0	1839.1
73	22	4.2	M	5544	121294	65121	1.36	0.73	7540	4047		50.9	1019.0	1268.6	489.1	3739.6	0.0	973.1	95.3	1430.7	2576.3	818.4	6355.4	0.0	1686.6
74	6	4.2	MT	3409	48677	36854	1.29	1.58	4398	5386		39.2	413.3	1096.2	293.0	2435.6	120.3	625.3	38.3	574.2	1033.9	328.4	2550.5	129.2	676.9
75	14	4.7	M	1273	24588	30886	1.45	1.30	1846	1655		12.5	249.5	310.6	119.8	915.6	0.0	238.3	19.3	290.0	522.2	165.9	1288.3	0.0	341.9
76	11	3.6	M	6858	44800	22740	1.48	1.44	10150	9876		68.6	1371.7	1707.7	658.4	5034.0	0.0	1309.9	35.2	528.4	951.6	302.3	2347.4	0.0	623.0
77	12	3.2	M	4559	80758	37009	1.82	1.10	8297	5015		56.1	1121.2	1395.9	538.2	4114.9	0.0	1070.8	63.5	952.6	1715.3	544.9	4231.5	0.0	1123.0
78	14	3.2	M	3400	24256	9350	1.45	1.30	4929	4419		33.3	666.1	829.3	319.7	2444.7	0.0	636.2	19.1	286.1	515.2	163.7	1270.9	0.0	337.3
79	14	4.4	M	1139	15651	11438	1.45	1.30	1652	1481		11.2	223.2	277.9	107.1	819.2	0.0	213.2	12.3	184.6	332.4	105.6	820.1	0.0	217.6
80	12	3.2	M	1044	17289	14054	1.82	1.10	1899	1148		12.8	256.7	319.6	123.2	942.0	0.0	245.1	13.6	203.9	367.2	116.6	905.9	0.0	240.4
81	12	3	M	3605	69109	46625	1.82	1.10	6561	3965		44.3	886.6	1103.8	425.6	3253.9	0.0	846.7	54.3	815.2	1467.9	466.3	3621.1	0.0	961.0
82	10	4.4	M	298	16006	5315	1.91	1.14	569	340		3.8	76.9	95.7	36.9	282.2	0.0	73.4	12.6	188.8	340.0	108.0	838.7	0.0	222.6
83	12	2.9	M	3369	140043	68232	1.82	1.10	6132	3706		41.4	828.6	1031.6	397.7	3041.0	0.0	791.3	110.1	1651.9	2974.5	944.9	7337.8	0.0	1947.3
84	10	4.3	M	1601	16763	0	1.91	1.14	3057	1825		20.7	413.2	514.4	198.3	1516.3	0.0	394.6	13.2	197.7	356.0	113.1	878.3	0.0	233.1
85	27	3.8	MT	4791	143219	72365	1.62	1.09	7761	5222		69.3	729.4	1934.4	517.1	4298.2	212.4	1103.4	112.6	1689.3	3041.9	966.3	7504.2	380.1	1991.5
86	56	4.1	MT	11143	168177	98067	1.36	1.39	15155	15489		135.2	1424.4	3777.4	1009.7	8393.1	414.7	2154.6	132.2	1983.7	3572.0	1134.7	8811.9	446.3	2338.5
87	21	4.2	MT	6742	99976	58689	1.38	1.28	9304	8630		83.0	874.5	2319.2	619.9	5153.2	254.6	1322.9	78.6	1179.3	2123.5	674.6	5238.4	265.3	1390.2
88	13	3.9	MT	4630	48594	50115	1.67	1.17	7732	5417		69.0	726.8	1927.3	515.2	4282.4	211.6	1099.3	38.2	573.2	1032.1	327.9	2546.2	129.0	675.7
89	20	3.9	M	6612	119474	107412	1.58	1.27	10447	8398		70.6	1411.8	1757.7	677.7	5181.4	0.0	1348.3	93.9	1409.3	2537.6	806.1	6260.1	0.0	1661.3
90	21	4	MT	4208	158003	92533	1.38	1.28	5807	5386		51.8	545.8	1447.4	386.9	3216.1	158.9	825.6	124.2	1863.7	3355.9	1066.1	8278.8	419.3	2197.1
91	30	4.3	MT	10256	160839	156593	1.57	1.20	16101	12307		143.7	1513.4	4013.3	1072.8	8917.5	440.6	2289.2	126.4	1897.2	3416.2	1085.2	8427.5	426.9	2236.5
92	26	3.9	MT	5936	90740	64431	1.48	1.39	8786	8251		78.4	825.8	2189.9	585.4	4865.8	240.4	1249.1	71.3	1070.3	1927.3	612.2	4754.5	240.8	1261.8
93	30	4.1	MT	2995	38967	24478	1.57	1.20	4702	3594		42.0	441.9	1171.9	313.3	2604.0	128.7	668.5	30.6	459.6	827.6	262.9	2041.7	103.4	541.8
94	26	4	MT	4276	331506	138817	1.48	1.39	6328	5944		56.5	594.8	1577.4	421.6	3504.9	173.2	899.8	260.5	3910.3	7041.1	2236.7	17369.8	879.8	4609.6
95	13	3.9	MT	4786	226391	104366	1.67	1.17	7992	5599		71.3	751.2	1992.1	532.5	4426.4	218.7	1136.3	177.9	2670.4	4808.5	1527.5	11862.1	600.8	3148.0
96	17	4.7	M	1785	32413	16943	0.96	1.09	1714	1946		11.6	231.6	288.4	111.2	850.1	0.0	221.2	25.5	382.3	688.4	218.7	1698.3	0.0	450.7
97	17	4.4	M	1607	15953	7635	0.96	1.09	1543	1752		10.4	208.5	259.6	100.1	765.3	0.0	199.1	12.5	188.2	338.8	107.6	835.9	0.0	221.8
98	18	4.4	M	1256	39000	42952	1.61	1.61	2023	2023		13.7	273.3	340.3	131.2	1003.1	0.0	261.0	30.7	460.0	828.4	263.1	2043.5	0.0	542.3
99	10	4.4	M	1164	25580	19325	1.91	1.14	2223	1327		15.0	300.4	374.0	144.2	1102.5	0.0	286.9	20.1	301.7	543.3	172.6	1340.3	0.0	355.7
100	57	3.8	M	13350	231445	165888	1.05	0.89	14018	11882		94.7	1894.3	2358.4	909.3	6952.1	0.0	1809.1	181.9	2730.0	4915.8	1561.6	12126.9	0.0	3218.3
101	58	4.5	M	10765	156297	101127	1.26	1.23	13564	13241		91.6	1833.0	2282.0	879.8	6727.0	0.0	1750.5	122.8	1843.6	3319.7	1054.6	8189.5	0.0	2173.3
102	7	4.2	M	4915	42496	46700	2.07	0.96	10174	4718		68.7	1374.8	1711.7	659.9	5045.6	0.0	1313.0	33.4	501.3	902.6	286.7	2226.7	0.0	590.9
103	6	4.1	MT	5841	116410	111912	1.29	1.58	7534	9228		67.2	708.2	1878.0	502.0	4172.8	206.2	1071.2	91.5	1373.1	2472.5	785.4	6099.5	309.0	1618.7
104	59	3.7	M	14534	81270	69977	1.43	1.57	20784	22818		140.4	2808.6	3496.7	1348.1	10307.6	0.0	2682.2	63.9	958.6	1726.2	548.3	4258.3	0.0	1130.1
105	10	4.2	M	1895	39811	72868	1.91	1.14	3620	2160		24.5	489.1	609.0	234.8	1795.1	0.0	467.1	31.3	469.6	845.6	268.6	2086.0	0.0	553.6
106	35	4.4	M	3551	38893	31599	1.63	1.00	5788	3551		39.1	782.1	973.8	375.4	2870.4	0.0	746.9	30.6	458.8	826.1	262.4	2037.9	0.0	540.8
107	9	4	M	2642	34225	40883	1.54	1.39	4069	3673		27.5	549.9	684.7	264.0	2018.2	0.0	525.2	26.9	403.7	726.9	230.9	1793.3	0.0	475.9
108	9	4.3	M	1407	24436	24529	1.54	1.39	2166	1955		14.6	292.7	364.5	140.5	1074.4	0.0	279.6	19.2	288.2	519.0	164.9	1280.3	0.0	339.8
109	24	4.5	O	1462	30992	11007	1.80	1.30	2632	1901		13.4	614.5	467.6	0.0	1042.1	0.0	494.3	24.4	365.6	658.3	0.0	1623.9	0.0	431.0
110	3	4.2	O	2299	32427	65044	1.45	1.15	3334	2644		16.9	778.4	592.3	0.0	1319.9	0.0	626.1	25.5	382.5	688.7	0.0	1699.1	0.0	450.9
111	4	4.5	M	791	46391	48300	1.79	0.79	1416	625		9.6	191.4	238.3	91.9	702.4	0.0	182.8	36.5	547.2	985.3	313.0	2430.7	0.0	645.1
112	8	4.5	M	2590	42988	41193	1.59	1.59	4118	4118		27.8	556.5	692.8	267.1	2042.2	0.0	531.4	33.8	507.1	913.0	290.0	2252.4	0.0	597.8
113	20	3.9	M	6142	79402	67518	1.58	1.27	9704	7800		65.6	1311.3	1632.6	629.4	4812.6	0.0	1252.3	62.4	936.6	1686.5	535.7	4160.4	0.0	1104.1
114	1	4.5	M	1071	14062	7080	1.50	1.10	1606	1178		10.9	217.1	270.3	104.2	796.7	0.0	207.3	11.1	165.9	298.7	94.9	736.8	0.0	195.5
115	10	3.8	M	3660	63603	20336	1.91	1.14	6990	4172		47.2	944.6	1176.0	453.4	3466.7	0.0	902.1	50.0	750.2	1350.9	429.1	3332.6	0.0	884.4
116	15	4.1	M	1379	38439	17182	1.80	1.56	2481	2151		16.8	335.3	417.5	161.0	1230.7	0.0	320.2	30.2	453.4	816.4	259.4	2014.1	0.0	534.5
117	9	4	M	4461	29607	24785	1.54	1.39	6871	6201		46.4	928.4	1155.9	445.7	3407.4	0.0	886.7	23.3	349.2	628.8	199.8	1551.3	0.0	411.7
118	15	4.6	M	1115	9844	10089	1.80	1.56	2007	1740		13.6	271.2	337.7	130.2	995.4	0.0	259.0	7.7	116.1	209.1	66.4	515.8	0.0	136.9
119	18	4.1	M	1821	38068	60128	1.61	1.61	2932	2932		19.8	396.2	493.3	190.2	1454.0	0.0	378.4	29.9	449.0	808.6	256.9	1994.6	0.0	529.3
120	22	4.3	O	2743	60129	11868	1.36	0.73	3731	2002		18.9	871.1	662.8	0.0	1477.1	0.0	700.7	47.3	709.3	1277.1	0.0	3150.6	0.0	836.1
121	18	4.6	M	1244	8584	9150	1.61	1.61	2002	2002		13.5	270.6	336.9	129.9	993.0	0.0	258.4	6.7	101.2	182.3	57.9	449.8	0.0	119.4
122	8	4	M	5957	71425	52469	1.59	1.59	9472	9472		64.0	1280.0	1593.6	614.4	4697.6	0.0	1222.4	56.1	842.5	1517.0	481.9	3742.4	0.0	993.2
123	19	4.2	M	2918	94341	47852	1.12	0.79	3269	2306		22.1	441.7	549.9	212.0	1621.1	0.0	421.8	74.1	1112.8	2003.8	636.5	4943.1	0.0	1311.8
124	24	4.5	O	1512	95149	28116	1.80	1.30	2722	1966		13.8	635.6	483.6	0.0	1077.8	0.0	511.3	74.8	1122.3	2020.9	0.0	4985.5	0.0	1323.1
125	17	4.2	M	2389	56984	66008	0.96	1.09	2293	2604		15.5	309.9	385.9	148.8	1137.4	0.0	296.0	44.8	672.2	1210.3	384.5	2985.8	0.0	792.4
126	7	4.3	M	3728	83027	62018	2.07	0.96	7716	3579		52.1	1042.8	1298.2	500.5	3826.9	0.0	995.8	65.3	979.3	1763.5	560.2	4350.4	0.0	1154.5
127	15	4.3	M	2849	57784	71107	1.80	1.56	5128	4444		34.6	693.0	862.8	332.6	2543.2	0.0	661.8	45.4	681.6	1227.3	389.9	3027.7	0.0	803.5
128	18	4.2	M	2931	21377	21387	1.61	1.61	4719	4719		31.9	637.7	794.0	306.1	2340.5	0.0	609.0	16.8	252.2	454.0	144.2	1120.1	0.0	297.3
129	11	3.9	M	3318	25391	8829	1.48	1.44	4911	4778		33.2	663.6	826.2	318.5	2435.6	0.0	633.8	20.0	299.5	539.3	171.3	1330.4	0.0	353.1
130	1	4.7	M	1121	31304	18804	1.50	1.10	1682	1233		11.4	227.3	283.0	109.1	834.2	0.0	217.1	24.6	369.2	664.9	211.2	1640.2	0.0	435.3
131	1	4.3	M	1594	40837	48803	1.50	1.10	2391	1754		16.2	323.1	402.3	155.1	1186.0	0.0	308.6	32.1	481.7	867.4	275.5	2139.7	0.0	567.8
				770703	11889564	7876416			1192689	885698		9344.4	140243.2	252531.5	75078.0	622974.7	17353.6	165326.5	9344.4	140243.2	252531.5	75078.0	622974.7	17353.6	165326.5

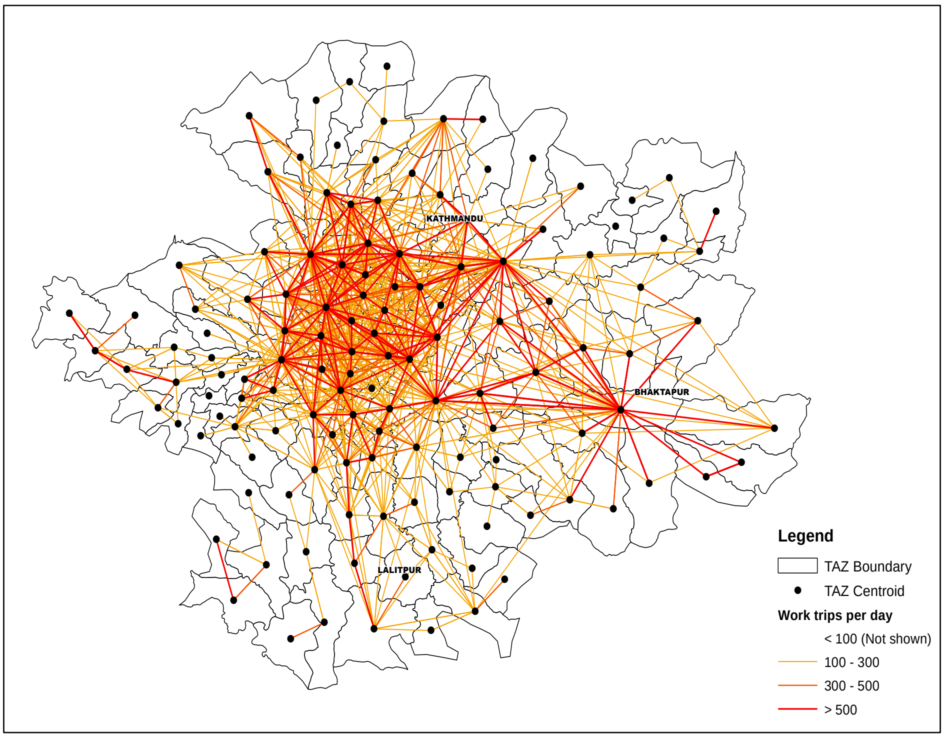
Educational Trips

												Edu Trip Productions								Edu Trip Attraction						
TAZ ID	Survey Zone	HH Size	Zone Category	HH_2017	Work Place Area (Sq.m)	Edu. Inst. Area (Sq.m)	Work Trip Rate (Trips/HH)	Edu Trip Rate (Trips/HH)	Work Trips	Edu Trips		BYC	Bus	Car	Micro	MC	Tempo	Walk		BYC	Bus	Car	Micro	MC	Tempo	Walk
1	4	4.7	O	894	1475	1108	1.79	0.79	1601	707		27.0	339.8	0.0	0.0	118.6	0.0	221.1		1.1	57.0	0.5	0.0	22.6	0.0	31.8
2	7	4.6	M	1093	27564	10329	2.07	0.96	2263	1049		2.9	509.4	5.7	115.9	142.7	0.0	272.9		10.0	531.4	4.9	95.2	210.6	0.0	296.3
3	16	4.5	M	965	20492	13773	0.91	0.83	878	801		2.2	388.9	4.4	88.4	108.9	0.0	208.3		13.4	708.6	6.5	127.0	280.8	0.0	395.1
4	4	4.7	O	1227	14476	14060	1.79	0.79	2196	969		37.0	466.0	0.0	0.0	162.7	0.0	303.3		13.7	723.4	6.7	0.0	286.6	0.0	403.3
5	9	4.2	M	2320	19489	2524	1.54	1.39	3573	3225		8.8	1565.3	17.7	356.0	438.4	0.0	838.5		2.5	129.8	1.2	23.3	51.4	0.0	72.4
6	23	4	M	4742	63628	34440	1.19	1.43	5643	6781		18.6	3291.4	37.1	748.6	921.9	0.0	1763.3		33.5	1771.8	16.3	317.5	702.1	0.0	987.9
7	3	4.5	O	1616	13153	14834	1.45	1.15	2344	1859		71.0	894.0	0.0	0.0	312.2	0.0	581.8		14.4	763.2	7.0	0.0	302.4	0.0	425.5
8	4	4.7	M	676	7389	19068	1.79	0.79	1210	534		1.5	259.2	2.9	59.0	72.6	0.0	138.9		18.5	981.0	9.0	175.8	388.7	0.0	546.9
9	32	4.6	M	21225	369137	222003	2.13	0.84	45209	17829		48.8	8654.3	97.6	1968.4	2423.8	0.0	4636.2		215.7	11421.3	105.1	2046.8	4525.6	0.0	6367.8
10	17	4.3	M	1267	16561	17466	0.96	1.09	1216	1381		3.8	670.1	7.6	152.4	187.7	0.0	359.0		17.0	898.6	8.3	161.0	356.0	0.0	501.0
11	5	4.1	M	5005	123159	105070	1.73	1.23	8658	6156		16.8	2987.9	33.7	679.6	836.8	0.0	1600.7		102.1	5405.5	49.8	968.7	2141.9	0.0	3013.8
12	15	4.6	O	1575	34739	9759	1.80	1.56	2835	2457		93.8	1181.8	0.0	0.0	412.7	0.0	769.1		9.5	502.1	4.6	0.0	198.9	0.0	279.9
13	14	4.3	M	1351	6995	8652	1.45	1.30	1958	1756		4.8	852.3	9.6	193.9	238.7	0.0	456.6		8.4	445.1	4.1	79.8	176.4	0.0	248.2
14	25	4.5	M	1648	34532	9161	1.96	1.00	3231	1648		4.5	800.2	9.0	182.0	224.1	0.0	428.7		8.9	471.3	4.3	84.5	186.7	0.0	262.8
15	16	4.4	M	4533	89624	61697	0.91	0.83	4125	3762		10.3	1826.1	20.6	415.3	511.4	0.0	978.3		59.9	3174.1	29.2	568.8	1257.7	0.0	1769.7
16	5	4.2	M	3430	1023	1452	1.73	1.23	5934	4219		11.5	2047.9	23.1	465.8	573.6	0.0	1097.1		1.4	74.7	0.7	13.4	29.6	0.0	41.7
17	25	4.5	O	2158	61345	50450	1.96	1.00	4229	2158		82.3	1037.6	0.0	0.0	362.3	0.0	675.3		49.0	2595.5	23.9	0.0	1028.4	0.0	1447.1
18	15	4.4	O	1312	29088	15124	1.80	1.56	2362	2047		78.1	984.3	0.0	0.0	343.7	0.0	640.6		14.7	778.1	7.2	0.0	308.3	0.0	433.8
19	24	4.4	O	1525	32555	9390	1.80	1.30	2745	1983		75.7	953.6	0.0	0.0	333.0	0.0	620.6		9.1	483.1	4.4	0.0	191.4	0.0	269.3
20	3	5.2	O	1138	9850	7900	1.45	1.15	1651	1309		50.0	629.6	0.0	0.0	219.9	0.0	409.7		7.7	406.4	3.7	0.0	161.0	0.0	226.6
21	4	4.3	M	3480	28140	26477	1.79	0.79	6229	2749		7.5	1334.4	15.0	303.5	373.7	0.0	714.9		25.7	1362.2	12.5	244.1	539.7	0.0	759.5
22	23	4.3	M	3230	56639	21002	1.19	1.43	3844	4619		12.6	2242.0	25.3	509.9	627.9	0.0	1201.1		20.4	1080.5	9.9	193.6	428.1	0.0	602.4
23	7	4.7	M	1056	10782	9282	2.07	0.96	2186	1014		2.8	492.2	5.6	111.9	137.9	0.0	263.7		9.0	477.5	4.4	85.6	189.2	0.0	266.2
24	15	4.8	M	1318	34550	8019	1.80	1.56	2373	2056		5.6	998.1	11.3	227.0	279.5	0.0	534.7		7.8	412.6	3.8	73.9	163.5	0.0	230.0
25	19	4	M	3850	103889	34792	1.12	0.79	4312	3041		8.3	1476.2	16.6	335.8	413.4	0.0	790.8		33.8	1789.9	16.5	320.8	709.2	0.0	997.9
26	33	3.8	M	10997	146147	142699	1.46	1.14	16055	12536		34.3	6085.1	68.6	1384.0	1704.3	0.0	3259.9		138.7	7341.4	67.6	1315.6	2909.0	0.0	4093.1
27	2	4.6	M	1889	45499	36755	1.68	1.41	3173	2663		7.3	1292.7	14.6	294.0	362.1	0.0	692.5		35.7	1890.9	17.4	338.9	749.3	0.0	1054.2
28	15	4.8	O	675	4824	42228	1.80	1.56	1216	1054		40.2	506.7	0.0	0.0	176.9	0.0	329.7		41.0	2172.5	20.0	0.0	860.8	0.0	1211.3
29	25	4.3	O	2906	111192	48954	1.96	1.00	5695	2906		110.9	1397.3	0.0	0.0	488.0	0.0	909.4		47.6	2518.5	23.2	0.0	997.9	0.0	1404.2
30	1	4.5	M	1417	10466	9457	1.50	1.10	2125	1559		4.3	756.5	8.5	172.1	211.9	0.0	405.3		9.2	486.5	4.5	87.2	192.8	0.0	271.3
31	4	4.7	O	1566	16699	18352	1.79	0.79	2804	1237		47.2	595.1	0.0	0.0	207.8	0.0	387.3		17.8	944.2	8.7	0.0	374.1	0.0	526.4
32	17	4.5	M	1326	9424	13383	0.96	1.09	1273	1446		4.0	701.7	7.9	159.6	196.5	0.0	375.9		13.0	688.5	6.3	123.4	272.8	0.0	383.9
33	16	4.1	M	2239	74349	35842	0.91	0.83	2037	1858		5.1	902.0	10.2	205.2	252.6	0.0	483.2		34.8	1843.9	17.0	330.4	730.6	0.0	1028.1
34	3	4.2	M	2379	37614	52512	1.45	1.15	3449	2735		7.5	1327.7	15.0	302.0	371.9	0.0	711.3		51.0	2701.6	24.9	484.1	1070.5	0.0	1506.2
35	2	4.2	M	5124	60760	57932	1.68	1.41	8608	7225		19.8	3506.9	39.6	797.6	982.2	0.0	1878.7		56.3	2980.4	27.4	534.1	1181.0	0.0	1661.7
36	34	3.8	M	19052	157295	143484	1.61	1.65	30673	31435		86.0	15258.6	172.1	3470.5	4273.6	0.0	8174.2		139.4	7381.7	68.0	1322.9	2924.9	0.0	4115.6
37	35	3.9	M	8928	65656	72495	1.63	1.00	14553	8928		24.4	4333.7	48.9	985.7	1213.8	0.0	2321.6		70.4	3729.6	34.3	668.4	1477.8	0.0	2079.4
38	22	4.5	O	1510	23301	16047	1.36	0.73	2053	1102		42.1	530.1	0.0	0.0	185.1	0.0	345.0		15.6	825.6	7.6	0.0	327.1	0.0	460.3
39	19	3.9	M	3344	59633	13587	1.12	0.79	3745	2641		7.2	1282.1	14.5	291.6	359.1	0.0	686.9		13.2	699.0	6.4	125.3	277.0	0.0	389.7
40	36	3.9	M	8333	105800	70473	1.52	1.43	12666	11916		32.6	5784.2	65.2	1315.6	1620.0	0.0	3098.7		68.5	3625.6	33.4	649.7	1436.6	0.0	2021.4
41	37	4	MT	8298	95546	61436	0.91	0.59	7551	4896		55.0	2123.2	17.2	278.3	1068.5	144.3	1209.3		59.7	3160.7	29.1	566.4	1252.4	213.2	1762.2
42	4	4.7	M	951	7421	7789	1.79	0.79	1703	752		2.1	364.9	4.1	83.0	102.2	0.0	195.5		7.6	400.7	3.7	71.8	158.8	0.0	223.4
43	16	4.6	M	1132	41491	18240	0.91	0.83	1030	939		2.6	455.9	5.1	103.7	127.7	0.0	244.2		17.7	938.4	8.6	168.2	371.8	0.0	523.2
44	25	4.7	O	1962	110391	25411	1.96	1.00	3846	1962		74.9	943.6	0.0	0.0	329.5	0.0	614.1		24.7	1307.3	12.0	0.0	518.0	0.0	728.9
45	1	4.7	M	1162	325	402	1.50	1.10	1742	1278		3.5	620.2	7.0	141.1	173.7	0.0	332.3		0.4	20.7	0.2	3.7	8.2	0.0	11.5
46	2	4.7	O	1454	56891	29530	1.68	1.41	2442	2050		78.2	985.7	0.0	0.0	344.2	0.0	641.5		28.7	1519.2	14.0	0.0	602.0	0.0	847.0
47	38	3.9	MT	28852	213660	263027	1.44	1.11	41546	32025		359.6	13888.9	112.4	1820.4	6989.4	943.9	7910.8		255.6	13531.8	124.6	2425.0	5361.9	912.9	7544.5
48	1	4.7	O	1352	23544	14102	1.50	1.10	2027	1487		56.7	715.0	0.0	0.0	249.7	0.0	465.3		13.7	725.5	6.7	0.0	287.5	0.0	404.5
49	39	3.9	M	16534	117241	112436	1.44	1.10	23809	18187		49.8	8828.2	99.6	2007.9	2472.6	0.0	4729.4		109.2	5784.5	53.3	1036.6	2292.0	0.0	3225.1
50	28	4.2	MT	2537	204195	76628	1.64	1.12	4161	2841		31.9	1232.3	10.0	161.5	620.1	83.7	701.9		74.5	3942.2	36.3	706.5	1562.1	266.0	2198.0
51	40	3.8	MT	13943	279496	194198	1.53	1.20	21333	16731		187.9	7256.2	58.7	951.1	3651.6	493.1	4133.0		188.7	9990.8	92.0	1790.4	3958.8	674.0	5570.2
52	27	4	MT	5909	297042	82316	1.62	1.09	9573	6441		72.3	2793.4	22.6	366.1	1405.8	189.8	1591.1		80.0	4234.8	39.0	758.9	1678.0	285.7	2361.1
53	41	4.1	MT	26045	195490	95561	1.85	1.06	48184	27608		310.0	11973.1	96.9	1569.3	6025.3	813.7	6819.6		92.9	4916.3	45.3	881.0	1948.0	331.7	2741.0
54	42	4	MT	13457	160409	145266	1.71	1.21	23012	16283		182.8	7061.8	57.1	925.6	3553.8	479.9	4022.3		141.1	7473.4	68.8	1339.3	2961.3	504.2	4166.7
55	43	3.8	MT	20482	206406	173384	1.78	1.23	36458	25193		282.9	10925.7	88.4	1432.0	5498.2	742.5	6223.0		168.5	8920.0	82.1	1598.5	3534.5	601.8	4973.2
56	44	3.9	MT	18586	108706	89764	1.54	1.34	28622	24905		279.6	10800.7	87.4	1415.6	5435.3	734.0	6151.9		87.2	4618.1	42.5	827.6	1829.9	311.6	2574.7
57	29	3.7	MT	4836	137932	42502	1.60	1.03	7738	4981		55.9	2160.2	17.5	283.1	1087.1	146.8	1230.4		41.3	2186.6	20.1	391.9	866.4	147.5	1219.1
58	45	3.7	MT	16201	241726	103580	1.51	1.06	24464	17173		192.8	7447.8	60.3	976.2	3748.0	506.2	4242.1		100.6	5328.8	49.1	955.0	2111.5	359.5	2971.0
59	46	3.8	MT	12208	398223	186130	1.44	1.21	17580	14772		165.9	6406.4	51.8	839.7	3223.9	435.4	3648.9		180.9	9575.7	88.2	1716.0	3794.3	646.0	5338.8
60	28	3.9	MT	5531	184314	109193	1.64	1.12	9070	6194		69.6	2686.4	21.7	352.1	1351.9	182.6	1530.1		106.1	5617.6	51.7	1006.7	2225.9	379.0	3132.0
61	47	3.6	MT	12314	132526	85417	1.74	1.18	21426	14530		163.1	6301.4	51.0	825.9	3171.1	428.3	3589.2		83.0	4394.4	40.5	787.5	1741.2	296.5	2450.1
62	48	3.7	MT	9240	78400	53246	1.59	1.14	14691	10533		118.3	4568.2	37.0	598.7	2298.9	310.5	2601.9		51.7	2739.3	25.2	490.9	1085.4	184.8	1527.3
63	49	3.7	MT	23778	361594	211810	1.52	1.12	36142	26631		299.0	11549.5	93.4	1513.8	5812.1	784.9	6578.4		205.8	10896.9	100.3	1952.8	4317.8	735.2	6075.4
64	50	3.7	MT	27438	256761	170327	1.38	1.15	37864	31554		354.3	13684.3	110.7	1793.6	6886.4	930.0	7794.3		165.5	8762.7	80.7	1570.4	3472.2	591.2	4885.6
65	51	3.9	MT	16158	324617	188374	1.54	1.10	24884	17774		199.6	7708.4	62.4	1010.3	3879.2	523.9	4390.6		183.0	9691.2	89.2	1736.7	3840.0	653.8	5403.2
66	29	3.8	MT	6415	71641	52460	1.60	1.03	10264	6607		74.2	2865.4	23.2	375.6	1442.0	194.7	1632.1		51.0	2698.9	24.8	483.7	1069.4	182.1	1504.7
67	52	3.9	MT	20588	225540	269627	1.77	1.05	36440	21617		242.7	9374.9	75.8	1228.7	4717.8	637.1	5339.8		262.0	13871.4	127.7	2485.9	5496.4	935.8	7733.8
68	53	3.8	MT	18061	243112	139074	1.26	1.07	22757	19325		217.0	8381.0	67.8	1098.5	4217.6	569.6	4773.7		135.1	7154.9	65.9	1282.2	2835.1	482.7	3989.1
69	31	3.9	MT	3663	48495	26076	1.25	0.75	4579	2748		30.9	1191.6	9.6	156.2	599.7	81.0	678.7		25.3	1341.5	12.4	240.4	531.6	90.5	748.0
70	31	3.9	MT	13773	309099	164304	1.25	0.75	17217	10330		116.0	4480.0	36.2	587.2	2254.5	304.5	2551.7		159.6	8452.9	77.8	1514.8	3349.4	570.3	4712.8
71	54	3.7	M	30366	330639	257151	1.65	0.78	50104	23685		64.8	11496.9	129.7	2614.9	3220.0	0.0	6159.1		249.9	13229.5	121.8	2370.8	5242.1	0.0	7375.9
72	55	4.1	MT	16880	132258	38723	1.60	1.34	27007	22619		254.0	9809.4	79.4	1285.7	4936.4	666.7	5587.2		37.6	1992.2	18.3	357.0	789.4	134.4	1110.7
73	22	4.2	M	5544	121294	65121	1.36	0.73	7540	4047		11.1	1964.6	22.2	446.8	550.2	0.0	1052.5		63.3	3350.2	30.8	600.4	1327.5	0.0	1867.9
74	6	4.2	MT	3409	48677	36854	1.29	1.58	4398	5386		60.5	2336.0	18.9	306.2	1175.5	158.8	1330.5		35.8	1896.0	17.5	339.8	751.3	127.9	1057.1
75	14	4.7	M	1273	24588	30886	1.45	1.30	1846	1655		4.5	803.4	9.1	182.7	225.0	0.0	430.4		30.0	1589.0	14.6	284.8	629.6	0.0	885.9
76	11	3.6	M	6858	44800	22740	1.48	1.44	10150	9876		27.0	4793.8	54.1	1090.3	1342.6	0.0	2568.1		22.1	1169.9	10.8	209.7	463.6	0.0	652.3
77	12	3.2	M	4559	80758	37009	1.82	1.10	8297	5015		13.7	2434.1	27.5	553.6	681.7	0.0	1304.0		36.0	1904.0	17.5	341.2	754.4	0.0	1061.5
78	14	3.2	M	3400	24256	9350	1.45	1.30	4929	4419		12.1	2145.2	24.2	487.9	600.8	0.0	1149.2		9.1	481.0	4.4	86.2	190.6	0.0	268.2
79	14	4.4	M	1139	15651	11438	1.45	1.30	1652	1481		4.1	718.8	8.1	163.5	201.3	0.0	385.1		11.1	588.4	5.4	105.5	233.2	0.0	328.1
80	12	3.2	M	1044	17289	14054	1.82	1.10	1899	1148		3.1	557.3	6.3	126.7	156.1	0.0	298.5		13.7	723.0	6.7	129.6	286.5	0.0	403.1
81	12	3	M	3605	69109	46625	1.82	1.10	6561	3965		10.9	1924.8	21.7	437.8	539.1	0.0	1031.2		45.3	2398.7	22.1	429.9	950.5	0.0	1337.3
82	10	4.4	M	298	16006	5315	1.91	1.14	569	340		0.9	164.8	1.9	37.5	46.2	0.0	88.3		5.2	273.4	2.5	49.0	108.3	0.0	152.4
83	12	2.9	M	3369	140043	68232	1.82	1.10	6132	3706		10.1	1798.9	20.3	409.1	503.8	0.0	963.7		66.3	3510.3	32.3	629.1	1390.9	0.0	1957.1
84	10	4.3	M	1601	16763	0	1.91	1.14	3057	1825		5.0	885.8	10.0	201.5	248.1	0.0	474.5		0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	27	3.8	MT	4791	143219	72365	1.62	1.09	7761	5222		58.6	2264.6	18.3	296.8	1139.6	153.9	1289.9		70.3	3722.9	34.3	667.2	1475.2	251.2	2075.7
86	56	4.1	MT	11143	168177	98067	1.36	1.39	15155	15489		173.9	6717.3	54.3	880.4	3380.4	456.5	3826.0		95.3	5045.2	46.4	904.1	1999.1	340.4	2812.9
87	21	4.2	MT	6742	99976	58689	1.38	1.28	9304	8630		96.9	3742.8	30.3	490.6	1883.5	254.4	2131.8		57.0	3019.3	27.8	541.1	1196.4	203.7	1683.4
88	13	3.9	MT	4630	48594	50115	1.67	1.17	7732	5417		60.8	2349.3	19.0	307.9	1182.3	159.7	1338.1		48.7	2578.2	23.7	462.0	1021.6	173.9	1437.5
89	20	3.9	M	6612	119474	107412	1.58	1.27	10447	8398		23.0	4076.2	46.0	927.1	1141.6	0.0	2183.7		104.4	5525.9	50.9	990.3	2189.6	0.0	3080.9
90	21	4	MT	4208	158003	92533	1.38	1.28	5807	5386		60.5	2335.9	18.9	306.2	1175.5	158.7	1330.5		89.9	4760.5	43.8	853.1	1886.3	321.2	2654.2
91	30	4.3	MT	10256	160839	156593	1.57	1.20	16101	12307		138.2	5337.2	43.2	699.5	2685.9	362.7	3040.0		152.2	8056.2	74.2	1443.7	3192.2	543.5	4491.6
92	26	3.9	MT	5936	90740	64431	1.48	1.39	8786	8251		92.6	3578.5	29.0	469.0	1800.8	243.2	2038.2		62.6	3314.8	30.5	594.0	1313.4	223.6	1848.1
93	30	4.1	MT	2995	38967	24478	1.57	1.20	4702	3594		40.3	1558.5	12.6	204.3	784.3	105.9	887.7		23.8	1259.3	11.6	225.7	499.0	85.0	702.1
94	26	4	MT	4276	331506	138817	1.48	1.39	6328	5944		66.7	2577.6	20.9	337.8	1297.2	175.2	1468.2		134.9	7141.6	65.7	1279.8	2829.8	481.8	3981.7
95	13	3.9	MT	4786	226391	104366	1.67	1.17	7992	5599		62.9	2428.3	19.6	318.3	1222.0	165.0	1383.1		101.4	5369.3	49.4	962.2	2127.5	362.2	2993.6
96	17	4.7	M	1785	32413	16943	0.96	1.09	1714	1946		5.3	944.7	10.7	214.9	264.6	0.0	506.1		16.5	871.7	8.0	156.2	345.4	0.0	486.0
97	17	4.4	M	1607	15953	7635	0.96	1.09	1543	1752		4.8	850.4	9.6	193.4	238.2	0.0	455.6		7.4	392.8	3.6	70.4	155.6	0.0	219.0
98	18	4.4	M	1256	39000	42952	1.61	1.61	2023	2023		5.5	981.8	11.1	223.3	275.0	0.0	525.9		41.7	2209.8	20.3	396.0	875.6	0.0	1232.0
99	10	4.4	M	1164	25580	19325	1.91	1.14	2223	1327		3.6	644.1	7.3	146.5	180.4	0.0	345.0		18.8	994.2	9.2	178.2	394.0	0.0	554.3
100	57	3.8	M	13350	231445	165888	1.05	0.89	14018	11882		32.5	5767.4	65.0	1311.8	1615.3	0.0	3089.7		161.2	8534.4	78.6	1529.4	3381.7	0.0	4758.2
101	58	4.5	M	10765	156297	101127	1.26	1.23	13564	13241		36.2	6427.2	72.5	1461.8	1800.1	0.0	3443.1		98.3	5202.6	47.9	932.4	2061.5	0.0	2900.7
102	7	4.2	M	4915	42496	46700	2.07	0.96	10174	4718		12.9	2290.2	25.8	520.9	641.4	0.0	1226.9		45.4	2402.6	22.1	430.6	952.0	0.0	1339.5
103	6	4.1	MT	5841	116410	111912	1.29	1.58	7534	9228		103.6	4002.0	32.4	524.5	2014.0	272.0	2279.5		108.7	5757.5	53.0	1031.8	2281.4	388.4	3210.0
104	59	3.7	M	14534	81270	69977	1.43	1.57	20784	22818		62.5	11076.1	124.9	2519.2	3102.1	0.0	5933.6		68.0	3600.1	33.1	645.2	1426.5	0.0	2007.2
105	10	4.2	M	1895	39811	72868	1.91	1.14	3620	2160		5.9	1048.7	11.8	238.5	293.7	0.0	561.8		70.8	3748.8	34.5	671.8	1485.4	0.0	2090.1
106	35	4.4	M	3551	38893	31599	1.63	1.00	5788	3551		9.7	1723.6	19.4	392.0	482.7	0.0	923.3		30.7	1625.7	15.0	291.3	644.1	0.0	906.4
107	9	4	M	2642	34225	40883	1.54	1.39	4069	3673		10.1	1782.9	20.1	405.5	499.3	0.0	955.1		39.7	2103.3	19.4	376.9	833.4	0.0	1172.7
108	9	4.3	M	1407	24436	24529	1.54	1.39	2166	1955		5.4	949.1	10.7	215.9	265.8	0.0	508.4		23.8	1261.9	11.6	226.1	500.0	0.0	703.6
109	24	4.5	O	1462	30992	11007	1.80	1.30	2632	1901		72.5	914.1	0.0	0.0	319.2	0.0	594.9		10.7	566.3	5.2	0.0	224.4	0.0	315.7
110	3	4.2	O	2299	32427	65044	1.45	1.15	3334	2644		100.9	1271.5	0.0	0.0	444.0	0.0	827.5		63.2	3346.3	30.8	0.0	1325.9	0.0	1865.7
111	4	4.5	M	791	46391	48300	1.79	0.79	1416	625		1.7	303.4	3.4	69.0	85.0	0.0	162.5		46.9	2484.8	22.9	445.3	984.6	0.0	1385.4
112	8	4.5	M	2590	42988	41193	1.59	1.59	4118	4118		11.3	1998.8	22.5	454.6	559.8	0.0	1070.8		40.0	2119.3	19.5	379.8	839.7	0.0	1181.6
113	20	3.9	M	6142	79402	67518	1.58	1.27	9704	7800		21.4	3786.1	42.7	861.1	1060.4	0.0	2028.3		65.6	3473.6	32.0	622.5	1376.4	0.0	1936.6
114	1	4.5	M	1071	14062	7080	1.50	1.10	1606	1178		3.2	571.8	6.4	130.1	160.2	0.0	306.3		6.9	364.2	3.4	65.3	144.3	0.0	203.1
115	10	3.8	M	3660	63603	20336	1.91	1.14	6990	4172		11.4	2025.1	22.8	460.6	567.2	0.0	1084.9		19.8	1046.2	9.6	187.5	414.5	0.0	583.3
116	15	4.1	M	1379	38439	17182	1.80	1.56	2481	2151		5.9	1043.9	11.8	237.4	292.4	0.0	559.2		16.7	883.9	8.1	158.4	350.3	0.0	492.8
117	9	4	M	4461	29607	24785	1.54	1.39	6871	6201		17.0	3010.1	33.9	684.6	843.1	0.0	1612.6		24.1	1275.1	11.7	228.5	505.2	0.0	710.9
118	15	4.6	M	1115	9844	10089	1.80	1.56	2007	1740		4.8	844.4	9.5	192.0	236.5	0.0	452.3		9.8	519.0	4.8	93.0	205.7	0.0	289.4
119	18	4.1	M	1821	38068	60128	1.61	1.61	2932	2932		8.0	1423.1	16.0	323.7	398.6	0.0	762.4		58.4	3093.4	28.5	554.4	1225.7	0.0	1724.7
120	22	4.3	O	2743	60129	11868	1.36	0.73	3731	2002		76.4	963.0	0.0	0.0	336.3	0.0	626.7		11.5	610.5	5.6	0.0	241.9	0.0	340.4
121	18	4.6	M	1244	8584	9150	1.61	1.61	2002	2002		5.5	971.9	11.0	221.1	272.2	0.0	520.7		8.9	470.7	4.3	84.4	186.5	0.0	262.5
122	8	4	M	5957	71425	52469	1.59	1.59	9472	9472		25.9	4597.7	51.9	1045.7	1287.7	0.0	2463.1		51.0	2699.4	24.9	483.7	1069.6	0.0	1505.0
123	19	4.2	M	2918	94341	47852	1.12	0.79	3269	2306		6.3	1119.1	12.6	254.5	313.4	0.0	599.5		46.5	2461.8	22.7	441.2	975.5	0.0	1372.6
124	24	4.5	O	1512	95149	28116	1.80	1.30	2722	1966		75.0	945.5	0.0	0.0	330.2	0.0	615.3		27.3	1446.5	13.3	0.0	573.1	0.0	806.5
125	17	4.2	M	2389	56984	66008	0.96	1.09	2293	2604		7.1	1264.0	14.3	287.5	354.0	0.0	677.1		64.1	3395.9	31.3	608.6	1345.6	0.0	1893.3
126	7	4.3	M	3728	83027	62018	2.07	0.96	7716	3579		9.8	1737.1	19.6	395.1	486.5	0.0	930.6		60.3	3190.6	29.4	571.8	1264.3	0.0	1778.9
127	15	4.3	M	2849	57784	71107	1.80	1.56	5128	4444		12.2	2157.3	24.3	490.7	604.2	0.0	1155.7		69.1	3658.2	33.7	655.6	1449.5	0.0	2039.6
128	18	4.2	M	2931	21377	21387	1.61	1.61	4719	4719		12.9	2290.7	25.8	521.0	641.6	0.0	1227.2		20.8	1100.3	10.1	197.2	436.0	0.0	613.4
129	11	3.9	M	3318	25391	8829	1.48	1.44	4911	4778		13.1	2319.4	26.2	527.5	649.6	0.0	1242.5		8.6	454.2	4.2	81.4	180.0	0.0	253.3
130	1	4.7	M	1121	31304	18804	1.50	1.10	1682	1233		3.4	598.7	6.8	136.2	167.7	0.0	320.8		18.3	967.4	8.9	173.4	383.3	0.0	539.4
131	1	4.3	M	1594	40837	48803	1.50	1.10	2391	1754		4.8	851.2	9.6	193.6	238.4	0.0	456.0		47.4	2510.7	23.1	449.9	994.9	0.0	1399.8
				770703	11889564	7876416			1192689	885698		7653.0	405213.8	3730.4	68622.8	160562.5	13993.1	225922.1		7653.0	405213.8	3730.4	68622.8	160562.5	13993.1	

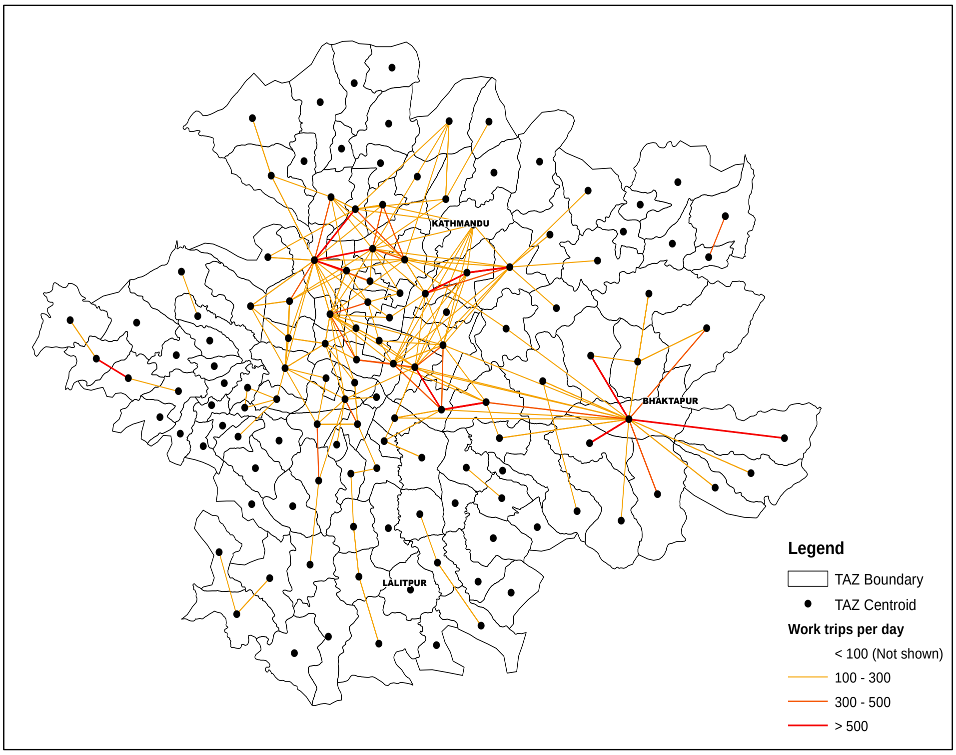
Annex 4: Origin Destination Matrix – Work Trips



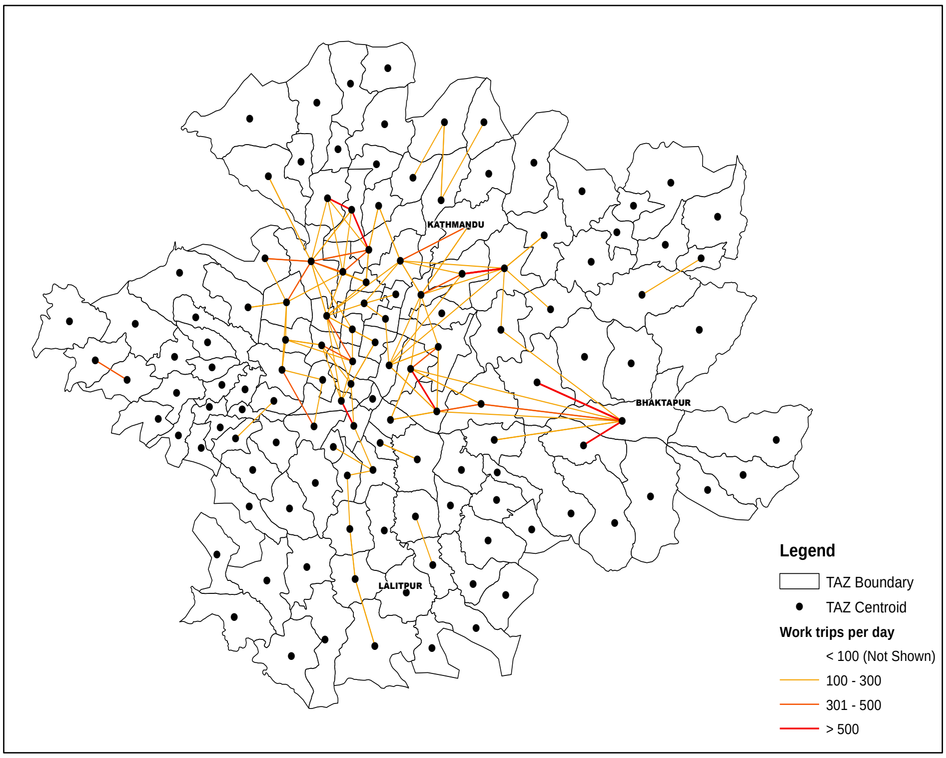
Car



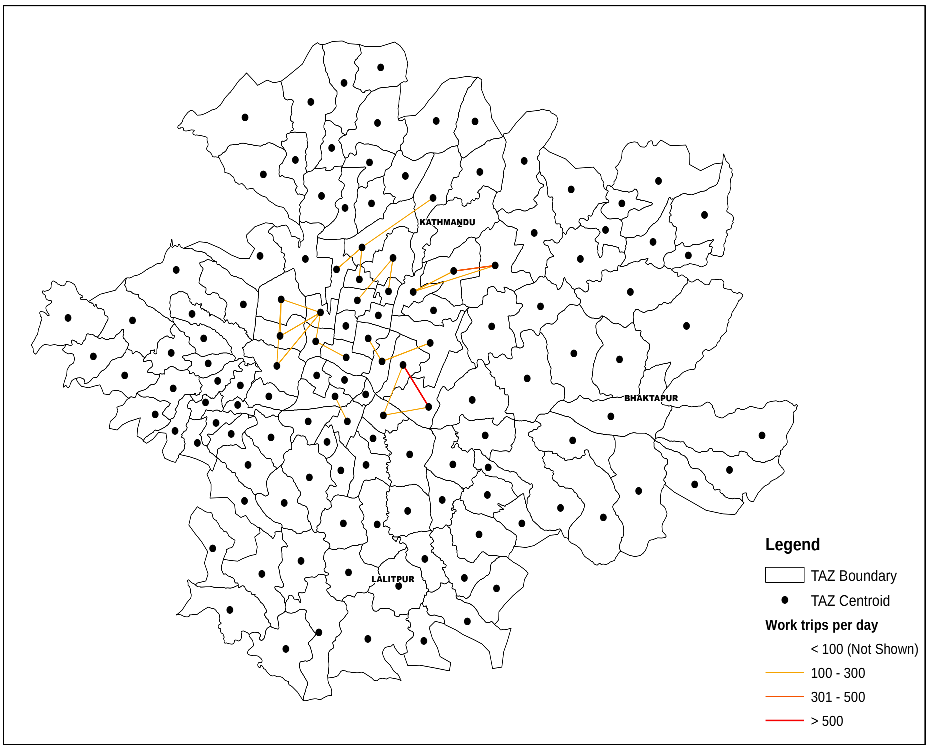
Motorcycle



Bus

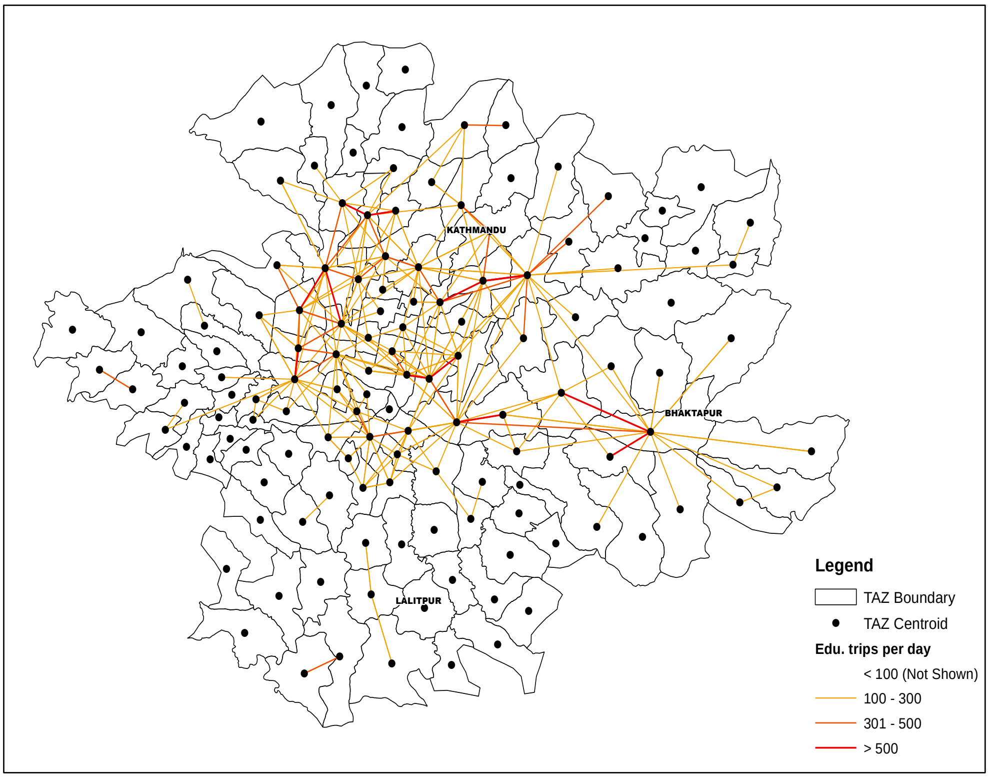


Microbus

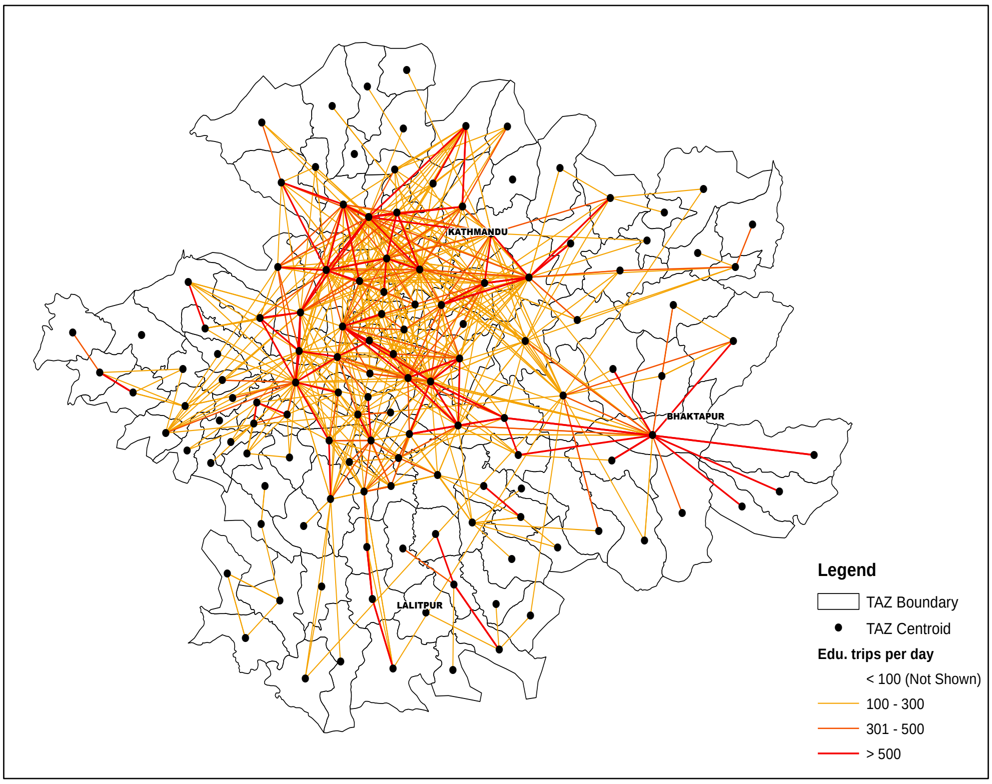

KATHMANDU
BHAKTAPUR
LALITPUR
Legend
TAZ Boundary
TAZ Centroid
Work trips per day
< 100 (Not Shown)
100 - 300
301 - 500
> 500

Tempo

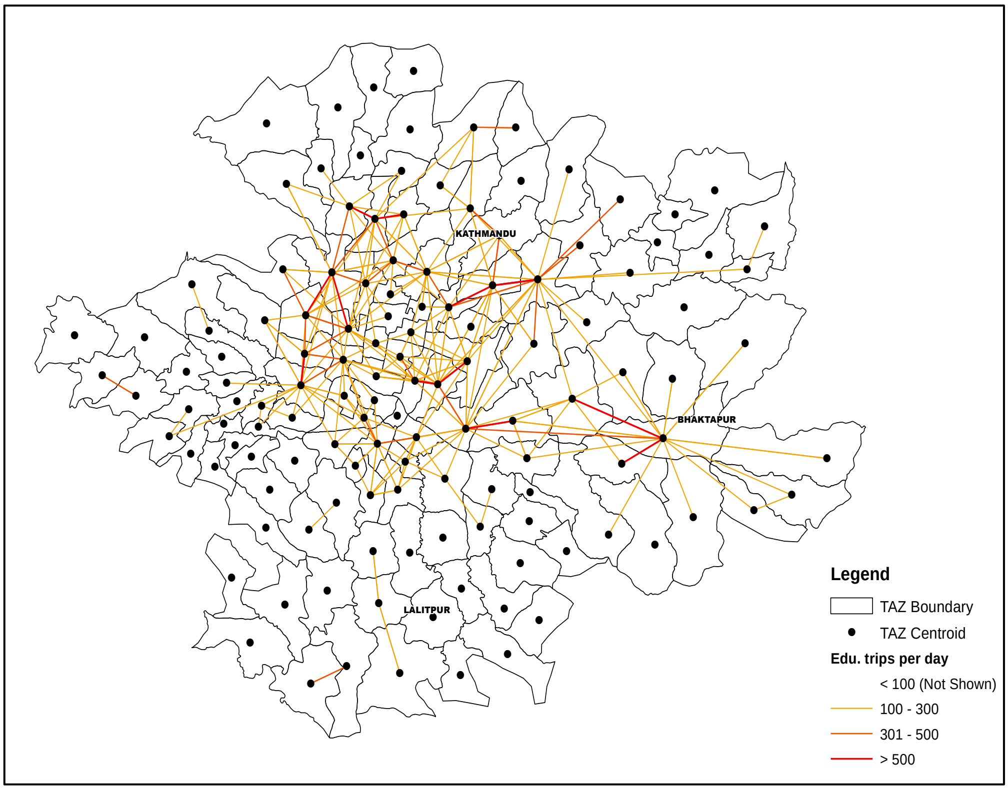
Annex 4: Origin Destination Matrix – Educational Trips



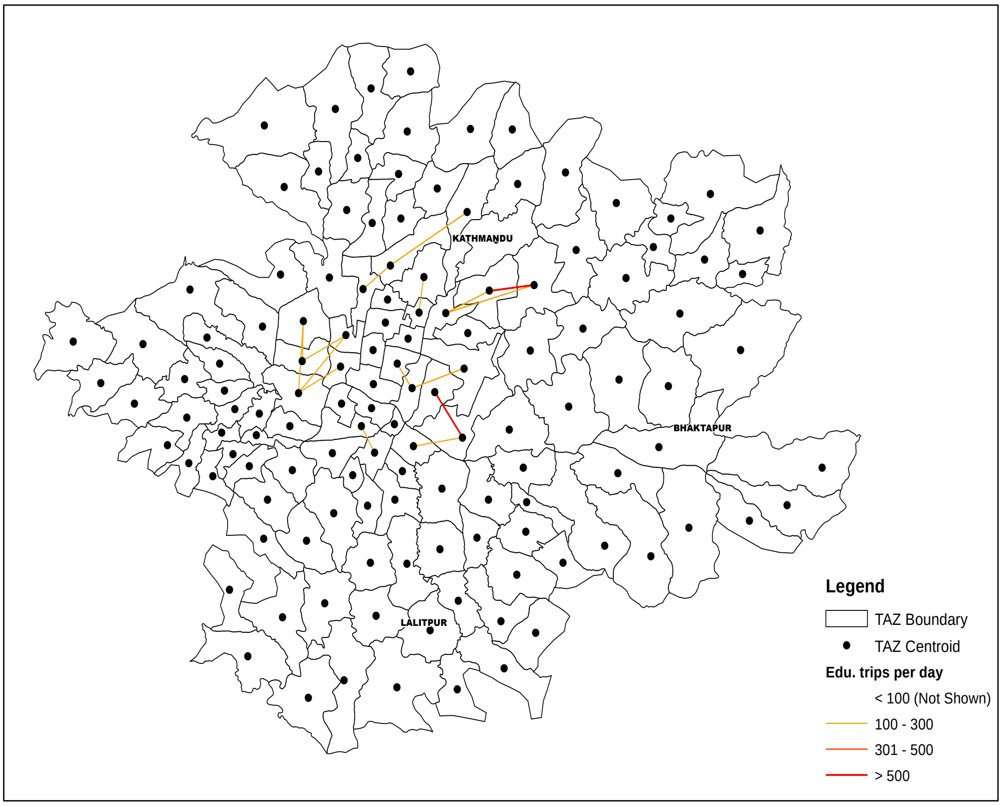
MC



Bus



Microbus



Tempo

Annex 5: RUBY Scripts used in OmniTRANS

Transport modelling software – OmniTRANS v4.3

Skim Matrix Generation

```
for j in [1,2]                  # Work & Educational trips
    for i in [1,2,3,4,5]        # Modes
        genSkim = OtTraffic.new
        genSkim.skimMatrix = [j, i, 1,1, [11,12],1]
        genSkim.skimFactors = [0.001,0.06,1]   # Display distance in KM, time in minutes
        genSkim.execute

        for r in [11,12]       #Distance, travel time
            sc = OtSkimCube.open
            skm = sc[j, i,1,1,r,1]
            #ok = skm.fillIntra(5)
            skm = skm.replaceEq(0,999999)      # Make intrazonal trips impossible
            sc[j, i,1,1,r,1] = skm
        end
    end
end
```

Gravity Model (Trip Distribution)

```
# Create trip distriution based on travel time skim and an
# exponential distritbuion function
# PMTURI = [1,1,1,1,12,1]

Writeln "Computing trip distribution ..."

for j in [1,2]                  # 1: Work trips, 2: Educational trips
    for i in [1,2,3,4,5,6]      # Modes
        sgm = OtGravityModel.new              # generate new GravityModel object
        sgm.skimMatrix = [j,i,1,1,12,1]       # use the travel time skim matrix
        sgm.odMatrix = [j,i,1,1]              # location to put the resulting OD matrix
        sgm.functionType = LOGNORMAL          # use the Lognormal distribution function
        sgm.functionSpec = [[2,-0.5]]         # parameter values of the distribution function.
        sgm.balance = PRODUCTIONS             # balance based on production/departures
        sgm.iterations = 10                   # number of iterations to perform
        sgm.execute                           # compute the trip distribution
    end
end
```

Route Assignment

```
assign = OtTraffic.new
assign.assignMethod = AON

for j in [1,2,3,4,5,6] #Modes
    for i in [1,2] # for work trips & educational trips
        assign.load = [i,j,1,1,1,1]
        assign.execute
    end
end
```

Annex 7: Population Projection

For logistic growth population projection, the formula is

$$P = \frac{K}{1 + Ae^{-bt}}$$

Where,

K is the upper asymptote, i.e. the carrying capacity

A and b, are the parameters that determine the shape of the logistic curve

t is the time period

Calculation of 'K'

Agricultural Land = 25,064.6 Ha

Population of KTM Valley (P_0) = 1,645,901

Average Residential Population Density = 212.8 Inh / Ha

Population of KTM Valley, 2011 (P_n) = 2,422,988

Maximum additional Population = 5,338,763

Maximum Total Population (K) = 2,422,988+ 5,338,763 = 7,761,751 (approx. 7,800,000)

Calculation of 'A'

$$A = \frac{K - P_0}{P_0} = \frac{7{,}800{,}000 - 1{,}645{,}901}{1{,}645{,}901} = 3.74$$

Calculation of 'b'

For 2001 to 2011,

$$b = -\ln\left(\frac{K - P_n}{P_n A}\right) \times \frac{1}{t} = -\ln\left(\frac{7{,}800{,}000 - 2{,}422{,}988}{2{,}422{,}988 \times 3.74}\right) \times \frac{1}{10} = 0.049$$

Therefore, final equation is as follows:

$$P = \frac{7800000}{1 + 5.079e^{-0.049t}}$$

For Year 2050,

$$P = \frac{7{,}800{,}000}{1 + 3.74e^{-0.049 \times 49}} = 5{,}809{,}375$$

For other years, the values are given in the table below

Population Projections

Year	Time Period	Projected Population
2001	0	1,645,091
2006	5	1,983,955
2011	10	2,365,791
2018	17	2,962,978
2020	19	3,144,238
2025	24	3,610,747
2030	29	4,085,731
2035	34	4,555,255
2040	39	5,006,015
2045	44	5,426,779
2050	49	5,809,375
2060	54	6,149,055
2070	59	6,444,299

Population of TAZ in 2050

TAZ_ID	AreaHa	Pop 2011	Builtup	Agri	Pden	ResDen	NetDen	Pmax (agri)	PopMax	Additional Population 2050	Total 2050	HH Size	HH 2050
1	147.006	3159	11.0	129.3	21.49	286.9	22.5	27548.2	30707.2	17767	20926	4.7	4452
2	480.18	3779	9.6	286.1	7.87	391.7	12.8	60938.8	64717.8	39303	43082	4.6	9366
3	263.473	3576	11.5	195.3	13.57	311.6	17.3	41605.2	45181.2	26834	30410	4.5	6758
4	523.751	4333	20.0	374.5	8.27	217.2	11.0	79759.9	84092.9	51442	55775	4.7	11867
5	211.808	7323	38.5	166.1	34.57	190.2	35.8	35386.6	42709.6	22823	30146	4.2	7178
6	283.952	15881	112.3	163.5	55.93	141.5	57.6	34830.8	50711.8	22464	38345	4	9586
7	590.262	5467	19.1	415.3	9.26	286.1	12.6	88449.3	93916.3	57046	62513	4.5	13892
8	167.061	2388	12.1	139.7	14.29	197.1	15.7	29760.7	32148.7	19194	21582	4.7	4592
9	655.507	81748	268.8	351.3	124.71	304.1	131.8	74837.0	156585.0	48267	130015	4.6	28264
10	341.662	4484	11.4	246.9	13.12	394.0	17.4	52582.5	57066.5	33914	38398	4.3	8930
11	507.391	15421	118.7	343.2	30.39	130.0	33.4	73110.5	88531.5	47153	62574	4.1	15262
12	388.764	5966	18.4	333.4	15.35	323.5	17.0	71014.1	76980.1	45801	51767	4.6	11254
13	297.789	4365	19.0	218.5	14.66	229.5	18.4	46535.3	50900.3	30013	34378	4.3	7995
14	678.164	6211	28.5	548.9	9.16	217.7	10.8	116918.2	123129.2	75407	81618	4.5	18137
15	727.254	16420	59.0	475.3	22.58	278.4	30.7	101234.1	117654.1	65292	81712	4.4	18571
16	315.718	10827	49.9	173.7	34.29	217.2	48.4	36992.8	47819.8	23859	34686	4.2	8259
17	960.873	8129	56.7	605.5	8.46	143.3	12.3	128977.3	137106.3	83185	91314	4.5	20292
18	552.244	4753	22.2	419.6	8.61	213.7	10.8	89375.5	94128.5	57643	62396	4.4	14181
19	507.674	5619	33.2	394.0	11.07	169.2	13.2	83911.4	89530.4	54119	59738	4.4	13577
20	359.505	4449	25.5	238.6	12.38	174.6	16.8	50830.9	55279.9	32784	37233	5.2	7160
21	499.319	11246	56.1	386.5	22.52	200.6	25.4	82330.7	93576.7	53100	64346	4.3	14964
22	649.654	11629	96.7	433.0	17.90	120.3	22.0	92218.5	103847.5	59477	71106	4.3	16536
23	489.223	4036	25.2	311.5	8.25	160.2	12.0	66350.6	70386.6	42793	46829	4.7	9964
24	460.232	4755	21.9	302.9	10.33	216.8	14.6	64519.4	69274.4	41612	46367	4.8	9660
25	367.094	12678	72.0	267.1	34.54	176.1	37.4	56892.0	69570.0	36693	49371	4	12343
26	203.752	31406	153.9	36.5	154.14	204.1	165.0	7767.9	39173.9	5010	36416	3.8	9583
27	186.233	6530	44.3	112.4	35.06	147.4	41.7	23945.3	30475.3	15444	21974	4.6	4777
28	490.955	2669	9.5	344.2	5.44	281.2	7.5	73317.4	75986.4	47287	49956	4.8	10407
29	630.43	10461	89.0	504.9	16.59	117.5	17.6	107534.1	117995.1	69355	79816	4.3	18562
30	141.536	4792	22.6	95.7	33.86	211.6	40.5	20393.0	25185.0	13153	17945	4.5	3988
31	834.376	5533	32.4	620.2	6.63	170.9	8.5	132092.4	137625.4	85194	90727	4.7	19304
32	312.51	4914	20.5	224.6	15.72	239.4	20.0	47838.6	52752.6	30854	35768	4.5	7948
33	411.35	7558	34.9	236.9	18.37	216.8	27.8	50456.2	58014.2	32542	40100	4.1	9781
34	469.08	7508	51.8	203.3	16.01	145.0	29.4	43306.2	50814.2	27931	35439	4.2	8438
35	514.707	16174	93.5	365.3	31.42	173.0	35.3	77815.5	93989.5	50188	66362	4.2	15800
36	235.963	54410	177.0	34.5	230.59	307.3	257.2	7348.4	61758.4	4739	59149	3.8	15566
37	461.189	26169	227.4	167.8	56.74	115.1	66.2	35737.1	61906.1	23049	49218	3.9	12620
38	742.837	5689	47.5	369.9	7.66	119.8	13.6	78780.7	84469.7	50810	56499	4.5	12555
39	309.924	10736	47.5	255.8	34.64	225.8	35.4	54483.5	65219.5	35140	45876	3.9	11763
40	407.516	24425	171.6	208.5	59.94	142.3	64.3	44413.6	68838.6	28645	53070	3.9	13608
41	402.15	27327	192.8	194.1	67.95	141.7	70.6	41339.7	68666.7	26662	53989	4	13497
42	276.542	3361	19.4	233.7	12.15	173.6	13.3	49786.5	53147.5	32110	35471	4.7	7547
43	381.148	4286	19.1	319.0	11.24	224.2	12.7	67955.6	72241.6	43829	48115	4.6	10460
44	522.25	7721	43.0	464.5	14.78	179.6	15.2	98943.5	106664.5	63814	71535	4.7	15220
45	320.087	4103	18.2	271.8	12.82	226.1	14.2	57883.4	61986.4	37332	41435	4.7	8816
46	812.464	5135	40.3	636.1	6.32	127.3	7.6	135485.9	140620.9	87383	92518	4.7	19685
47	481.789	84567	349.2	90.3	175.53	242.2	192.4	19239.0	103806.0	12408	96975	3.9	24865
48	557.781	4774	64.1	410.1	8.56	74.5	10.1	87354.2	92128.2	56340	61114	4.7	13003
49	465.535	48463	231.7	168.1	104.10	209.2	121.2	35810.8	84273.8	23096	71559	3.9	18349
50	137.488	8008	126.9	0.4	58.25	63.1	62.9	78.3	8086.3	50	8058	4.2	1919
51	157.42	39820	138.2	4.7	252.95	288.1	278.6	1004.9	40824.9	648	40468	3.8	10650
52	173.59	17765	138.7	1.3	102.34	128.1	126.9	271.4	18036.4	175	17940	4	4485
53	132.514	80256	120.4	1.5	605.64	666.4	658.3	315.2	80571.2	203	80459	4.1	19624
54	213.531	40456	182.0	19.2	189.46	222.3	201.0	4099.9	44555.9	2644	43100	4	10775
55	319.691	58495	210.2	84.6	182.97	278.3	198.4	18024.9	76519.9	11625	70120	3.8	18453
56	291.534	54476	202.9	45.7	186.86	268.5	219.2	9724.5	64200.5	6272	60748	3.9	15576
57	84.1495	13448	77.3	1.4	159.81	173.9	170.8	306.2	13754.2	197	13645	3.7	3688
58	193.6	45052	144.2	16.0	232.71	312.5	281.2	3416.6	48468.6	2204	47256	3.7	12772
59	320.424	34866	259.3	24.7	108.81	134.5	122.8	5256.7	40122.7	3390	38256	3.8	10067
60	94.1316	16211	54.5	0.0	172.22	297.4	297.3	2.1	16213.1	1	16212	3.9	4157
61	130.135	33316	122.4	0.1	256.01	272.2	272.0	24.5	33340.5	16	33332	3.6	9259
62	91.8664	25694	84.6	0.6	279.69	303.6	301.5	128.3	25822.3	83	25777	3.7	6967
63	233.285	66121	209.5	4.9	283.43	315.6	308.4	1041.8	67162.8	672	66793	3.7	18052
64	434.237	76299	258.8	42.7	175.71	294.8	253.0	9104.3	85403.3	5872	82171	3.7	22208
65	285.879	47362	245.0	16.1	165.67	193.3	181.4	3421.5	50783.5	2207	49569	3.9	12710
66	71.1263	18320	60.8	4.4	257.57	301.4	281.1	932.9	19252.9	602	18922	3.8	4979
67	339.441	60344	278.7	40.8	177.77	216.5	188.9	8679.9	69023.9	5598	65942	3.9	16908
68	154.474	51581	139.3	1.5	333.91	370.3	366.4	323.3	51904.3	208	51789	3.8	13629
69	180.738	10738	57.4	9.0	59.41	187.0	161.7	1909.4	12647.4	1231	11969	3.9	3069
70	375.653	40371	168.7	1.1	107.47	239.3	237.9	223.9	40594.9	144	40515	3.9	10389
71	410.997	84441	294.0	70.2	205.45	287.2	231.9	14950.5	99391.5	9642	94083	3.7	25428
72	118.343	52013	103.6	1.9	439.51	501.9	492.9	399.8	52412.8	258	52271	4.1	12749

TAZ_ID	AreaHa	Pop 2011	Builtup	Agri	Pden	ResDen	NetDen	Pmax (agri)	PopMax	Additional Population 2050	Total 2050	HH Size	HH 2050
73	432.775	19497	109.6	256.4	45.05	177.8	53.3	54616.1	74113.1	35225	54722	4.2	13029
74	239.027	10761	84.3	127.8	45.02	127.6	50.7	27229.6	37990.6	17562	28323	4.2	6744
75	316.886	4927	11.6	283.1	15.55	423.1	16.7	60300.2	65227.2	38891	43818	4.7	9323
76	129.221	18556	51.2	67.5	143.60	362.7	156.3	14385.3	32941.3	9278	27834	3.6	7732
77	150.926	10964	38.8	111.0	72.64	282.3	73.2	23649.7	34613.7	15253	26217	3.2	8193
78	236.102	8176	39.0	138.3	34.63	209.8	46.1	29453.5	37629.5	18996	27172	3.2	8491
79	285.241	3767	26.8	250.0	13.21	140.4	13.6	53256.9	57023.9	34349	38116	4.4	8663
80	97.5793	2510	26.4	70.3	25.72	95.0	26.0	14966.9	17476.9	9653	12163	3.2	3801
81	83.4839	8128	36.9	44.1	97.36	220.3	100.4	9387.0	17515.0	6054	14182	3	4727
82	83.976	985	4.9	78.3	11.73	200.2	11.8	16673.5	17658.5	10754	11739	4.4	2668
83	151.788	7343	72.6	41.8	48.38	101.2	64.2	8911.4	16254.4	5747	13090	2.9	4514
84	145.089	5173	25.7	98.5	35.65	201.6	41.7	20985.1	26158.1	13535	18708	4.3	4351
85	124.262	14988	100.5	5.4	120.62	149.1	141.5	1150.5	16138.5	742	15730	3.8	4139
86	155.57	37615	109.5	34.3	241.79	343.5	261.6	7305.6	44920.6	4712	42327	4.1	10324
87	97.1533	23315	77.6	15.1	239.98	300.3	251.4	3215.9	26530.9	2074	25389	4.2	6045
88	75.1149	14867	51.8	18.5	197.92	287.1	211.6	3936.0	18803.0	2539	17406	3.9	4463
89	172.005	21232	122.3	32.0	123.44	173.6	137.6	6812.6	28044.6	4394	25626	3.9	6571
90	228.018	13858	180.9	39.5	60.78	76.6	62.9	8420.0	22278.0	5431	19289	4	4822
91	137.635	36308	129.9	0.5	263.80	279.5	278.5	102.2	36410.2	66	36374	4.3	8459
92	111.128	19061	90.3	11.9	171.52	211.0	186.5	2530.5	21591.5	1632	20693	3.9	5306
93	45.1138	10109	32.9	7.5	224.08	307.3	250.5	1590.0	11699.0	1026	11135	4.1	2716
94	165.196	14082	138.7	11.8	85.24	101.5	93.6	2523.9	16605.9	1628	15710	4	3927
95	203.816	15367	146.9	30.3	75.40	104.6	86.7	6450.2	21817.2	4160	19527	3.9	5007
96	228.449	6909	26.8	170.6	30.24	257.9	35.0	36327.3	43236.3	23430	30339	4.7	6455
97	390.779	5823	16.3	265.4	14.90	356.9	20.7	56523.0	62346.0	36455	42278	4.4	9609
98	249.453	4551	46.8	199.4	18.24	97.3	18.5	42469.2	47020.2	27391	31942	4.4	7260
99	179.01	3849	22.0	147.3	21.50	174.6	22.7	31385.0	35234.0	20242	24091	4.4	5475
100	478.366	42476	255.4	186.0	88.79	166.3	96.2	39619.9	82095.9	25553	68029	3.8	17902
101	632.56	40560	188.1	390.1	64.12	215.6	70.1	83092.4	123652.4	53591	94151	4.5	20922
102	304.088	15514	80.2	211.4	51.02	193.5	53.2	45032.4	60546.4	29044	44558	4.2	10609
103	410.485	17997	191.3	203.5	43.84	94.1	45.6	43351.8	61348.8	27960	45957	4.1	11209
104	305.005	40416	148.5	122.5	132.51	272.2	149.2	26090.4	66506.4	16827	57243	3.7	15471
105	238.463	5982	37.2	192.5	25.09	160.8	26.0	41004.7	46986.7	26446	32428	4.2	7721
106	386.326	11742	80.4	267.9	30.39	146.1	33.7	57056.0	68798.0	36799	48541	4.4	11032
107	125.161	7944	37.7	85.2	63.47	210.9	64.7	18140.6	26084.6	11700	19644	4	4911
108	173.955	4546	34.3	127.8	26.13	132.4	28.0	27220.3	31766.3	17556	22102	4.3	5140
109	363.266	5509	34.7	274.4	15.17	158.8	17.8	58453.1	63962.1	37700	43209	4.5	9602
110	509.406	7257	45.5	406.0	14.25	159.5	16.1	86473.1	93730.1	55772	63029	4.2	15007
111	138.31	2676	11.7	97.5	19.35	229.7	24.5	20760.9	23436.9	13390	16066	4.5	3570
112	578.797	8759	43.9	369.1	15.13	199.7	21.2	78607.7	87366.7	50699	59458	4.5	13213
113	411.784	19721	138.4	251.1	47.89	142.5	50.6	53494.0	73215.0	34501	54222	3.9	13903
114	388.791	3622	29.0	314.7	9.32	125.1	10.5	67041.1	70663.1	43239	46861	4.5	10413
115	233.263	10452	60.8	168.1	44.81	171.8	45.6	35815.5	46267.5	23100	33552	3.8	8829
116	461.868	4248	18.0	355.9	9.20	235.9	11.4	75798.7	80046.7	48887	53135	4.1	12960
117	274.043	13412	68.2	157.7	48.94	196.6	59.4	33579.9	46991.9	21658	35070	4	8767
118	296.984	3855	17.6	137.3	12.98	218.7	24.9	29238.3	33093.3	18857	22712	4.6	4937
119	200.933	6147	24.5	175.2	30.59	250.9	30.8	37326.5	43473.5	24074	30221	4.1	7371
120	810.837	9876	70.1	479.6	12.18	140.8	18.0	102153.4	112029.4	65885	75761	4.3	17619
121	136.662	4790	30.4	102.2	35.05	157.7	36.1	21775.9	26565.9	14045	18835	4.6	4094
122	350.825	17909	109.8	210.3	51.05	163.1	55.9	44790.4	62699.4	28888	46797	4	11699
123	301.68	10092	43.8	244.5	33.45	230.1	35.0	52079.1	62171.1	33589	43681	4.2	10400
124	869.886	5698	33.6	726.8	6.55	169.6	7.5	154810.9	160508.9	99847	105545	4.5	23454
125	234.123	8261	48.4	174.8	35.28	170.7	37.0	37241.0	45502.0	24019	32280	4.2	7686
126	300.891	12047	49.4	240.7	40.04	244.0	41.5	51261.8	63308.8	33062	45109	4.3	10490
127	325.433	10086	52.1	249.4	30.99	193.4	33.4	53120.7	63206.7	34261	44347	4.3	10313
128	301.06	10136	71.9	220.4	33.67	140.9	34.7	46955.5	57091.5	30284	40420	4.2	9624
129	128.836	9726	46.4	78.5	75.49	209.8	77.9	16710.5	26436.5	10778	20504	3.9	5257
130	441.337	3961	42.9	281.3	8.98	92.3	12.2	59911.5	63872.5	38640	42601	4.7	9064
131	193.449	5152	55.4	125.0	26.63	93.1	28.6	26617.6	31769.6	17167	22319	4.3	5191

Annex 8: Transport Energy Calculation – Scenario Analysis

Transport Energy for 50 x 50 OD trips (Subset S)

Travel Mode	Total Daily Passenger-km	Average Vehicle	Total Daily Vehicular - km	Energy per KM (MJ/km)	Total Energy (MJ)
Car	623551.4	1.8	346417.5	3.46	1198604.5
Motorcycle	1860099.6	1.5	1240066.4	1.11	1376473.7
Bus	1031704.6	35	29477.3	11.08	326608.2
Micro	295755.6	15	19717.0	5.17	101937.1
Tempo	93957.8	8	11744.7	0.65	7634.1
Total	**3905069.1**		**1647422.9**		**3011257.5**
				GJ	3011.3
				+ Return Home Trips	6022.5
				Annual (GJ)	1686304.2
				TJ	1686.3

Transport Energy for 50 x 50 OD trips (Subset S) – Modal Shift (Willingness)

Travel Mode	Total Daily Passenger-km	Average Vehicle	Total Daily Vehicular - km	Energy per KM (MJ/km)	Total Energy (MJ)
Car	280598.2	1.8	155887.9	3.46	539372.0
Motorcycle	520827.9	1.5	347218.6	1.11	385412.6
Bus	2543575.5	50	50871.5	12.90	656242.5
Micro	295755.6	15	19717.0	5.17	101937.1
Tempo	93957.8	8	11744.7	0.65	7634.1
Total	**3734715.0**		**585439.7**		**1690598.3**
				GJ	1690.6
				+ Return Home Trips	3381.2
				Annual	946735.1
				TJ	946.7

Transport Energy for 50 x 50 OD trips (Subset S) – Modal Shift (90 %)

Travel Mode	Total Daily Passenger-km	Average Vehicle	Total Daily Vehicular - km	Energy per KM (MJ/km)	Total Energy (MJ)
Car	62355.1	1.8	34641.7	3.46	119860.4
Motorcycle	186010.0	1.5	124006.6	1.11	137647.4
Bus	3040610.3	50	60812.2	12.90	784477.5
Micro	295755.6	15	19717.0	5.17	101937.1
Tempo	93957.8	8	11744.7	0.65	7634.1
Total	**3678688.9**		**250922.4**		**1151556.5**
				GJ	1151.6
				+ Return Home Trips	2303.1
				Annual (GJ)	644871.6
				TJ	644.9

Transport Energy – Equal Production and Attraction

Travel Mode	Total Daily Passenger-km	Average Vehicle	Total Daily Vehicular - km	Energy per KM (MJ/km)	Total Energy (MJ)
Car	1207301.4	1.8	670723.0	3.46	2320701.6
Motorcycle	3799097.2	1.5	2532731.5	1.11	2811331.9
Bus	2540233.0	35	72578.1	11.08	804165.2
Micro	570667.7	15	38044.5	5.17	196690.1
Tempo	96064.0	8	12008.0	0.65	7805.2
Total	**8213363.2**		**3326085.1**		**6140694.0**
				GJ	6140.7
				+ Return Home Trips	12281.4
				Annual (GJ)	3438788.7
				TJ	3438.8

Annex 9: List of Publications

Article Publications

- Bajracharya, A. R, Shrestha, S. (2019). Assessing the role of Modal Shift in minimizing Transport Energy Consumption, A Case Study of Kathmandu Valley. *Journal of Institute of Engineering, October, 2019, Volume 15 (No. 3)*. ISSN 1810-3383. Proceedings of 4th International Conference on Renewable Energy Technology for Rural and Urban Development (RETRUD-18)

- Bajracharya, A. R., Shrestha, S., Skotte, H. (2020). Linking Travel Behavior and Urban form with Travel Energy Consumption, for Kathmandu Valley, Nepal; *Journal of Urban Planning and Development (ASCE), 2020, 146(3): 05020008*; ISSN: 1943-5444; DOI: 10.1061/(ASCE)UP.1943-5444.

Conference Paper Presentations

- Bajracharya, A. R., Shrestha, S. (2017). *Gender Differences in Travel Behavior, for Daily Trips in Kathmandu Valley*. Paper presented at International Symposium on Gender for Sustainable Development 2017, Lalitpur, Nepal

- Bajracharya, A. R., Shrestha, S. (2018). *Assessing the role of Modal Shift in minimizing Transport Energy Consumption, A Case Study of Kathmandu Valley*. Paper presented at 4th International Conference on Renewable Energy Technology for Rural and Urban Development (RETRUD-18, October 29-31, 2018), Kathmandu, Nepal

- Shrestha, S. Bajracharya, A. R. (2019). Issues and Challenges in Land Pooling Projects of Nepal. Paper presented at International Workshop on 'Land Pooling Policy: Paradigm for Sustainable Development, Organized by The Energy and Resources Institute (TERI) at India Habitat Centre, Lodhi Road, New Delhi