RELATIONSHIP BETWEEN URBAN FORM AND TRAVEL BEHAVIOUR, KATHMANDU, NEPAL.

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March, 2014

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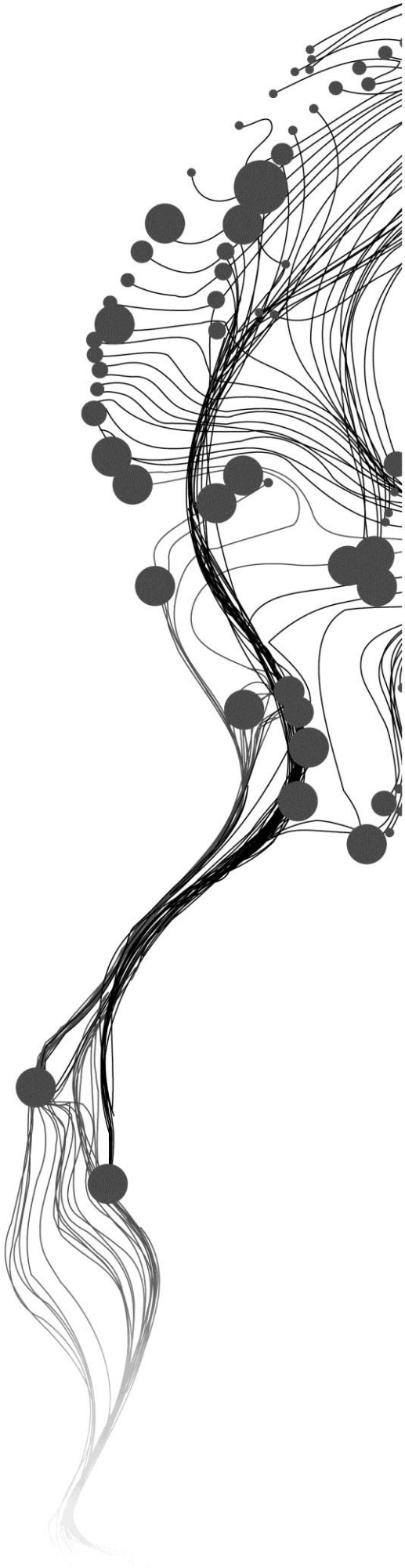

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Enschede, The Netherlands, March, 2014

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

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ABSTRACT

Transportation system is the foundation of development of any city or country especially a developing country like the study area. The issue of development cannot be discussed devoid of the sustainability in terms of physical (environmental), social and economic. The sustainability of every development is necessary for long term benefit of that infrastructure or plan, therefore transport and sustainability has been studied in context of each other to come up with solution for long term development and environmental protection. LCD is a concept that has been researched for deriving development through sustainable means and it has been specially focused on the transport sector. So to aid in the understanding of sustainable transport this research studies the relation between urban form and travel behaviour.

Urban form in terms of principle 3D's i.e. density, design, diversity and its derivatives and travel behaviour indicators i.e. travel mode is studied in context of KMC. The results of the analysis show that KMC has walk as the largest mode share followed by motorbike and last is the public transport mode. Even though it's the second largest mode share it creates the most traffic issues in the city. The study does not show clear relationship between the urban form and travel behaviour as it has multidimensional effect on each other. A general conclusion can be that further in depth research is required to quantify the relationship between urban form and travel behaviour.

Key words: Transportation, urban form, travel behaviour, LCD, 3D's.

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ABBREVIATIONS

LCD	Low Carbon Development
KMC	Kathmandu Metropolitan City
CBD	Central Business District
ZID	Zone Identity
JICA	Japan International Cooperation Agency
KSUTP	Kathmandu Sustainable Urban Transport Project
LPG	Liquefied Petroleum Gas
GHG	Green House Gases

1. INTRODUCTION

1.1. General Introduction

Climate change and its causes and effects have become a major point of focus globally. The level of greenhouse gases (GHG) and mainly CO_2 concentration in the atmosphere is significantly rising. The effects of climate change, though felt by both developed and developing countries, are mostly being ignored in the developing countries whose main focus is on development activities (Halsnæs & Verhagen, 2007).

The United Nations Framework Convention on Climate Change (UNFCCC), 1992 was established as a framework for policy making to mitigate climate change. In 1997, Kyoto protocol became the international climate change document(UNFCCC, 1997)which set an internationally binding emission reduction targets for its members. With these frameworks the developed countries are required to assist the developing countries in adapting and mitigation action to the global climate change.

One of the mitigation measure adopted is the Low carbon development. There are various concept/interpretation of Low carbon development (LCD), Yuan et al. (2011) summarize it as the reduction of CO_2 emission, intensive use of low carbon energy and ensuing economic growth. The importance of LCD can be deduced from the statement of Clapp et al. (2010) that LCD strategy not only helps the developing countries to prioritize and coordinate their development and climate change policies but also helps the international communities to prioritize their assistance to these countries through LCD.

LCD is applied in broad spectrum of development strategies for different sectors like industries, agriculture, tourism, transportation, household etc. Transportation system is the backbone of development, hence important for people's general welfare. However it is also cause of major environmental and health problems like air and noise pollution, destruction and degradation of the natural habitats etc. According to Chapman (2007), 26% of the global CO_2 emission is due to transportation and it was one of the main sectors highlighted in the 1997 Kyoto protocol. The demand for transport is ever increasing as a result the CO_2 emission will also increase unless some major measures are put into place whether it is policy implementation or innovative technology. Technology alone cannot mitigate the threat of GHG emission so it is suggested that the focus of the policy makers should be towards more sustainable modes of transport (Cools et al., 2009).

In the recent years studies have been conducted to halt the increased transportation demand also through promotion of sustainable urban development in which the design and layout of urban areas assist in reducing travel(Stead & Marshall, 2001). The urban form can be defined as the spatial pattern or arrangement of the individual urban elements such as buildings, road networks, and land use (Bourne, 1982). The urban forms also effects the travel behaviour thus changing the natural environment of the space we live in (Cervero, 1998). Therefore another major impact source on the environment is perceived to be the form of the growing urban areas around the world (Alberti et al., 2007).

1.2. Background and Justification

Kathmandu Metropolitan city is the capital city of Nepal in South-east Asia. With the estimated population of over 1 million and annual growth rate of 6.6%, it is facing rapid and unchecked urbanization
(Thapa & Murayama, 2010). Though the national rate of urbanization of Nepal is very low, the urbanization rate of 60% for KMC in the year 2001 is very high. KMC hosts 50% of the total urban population of the country. This phenomena has led to massive changes in land-use patterns as well as put increasing pressure on urban planning, infrastructures and environmental services (Dhakal, 2006).

The urban form of the city has changed considerably from the agrarian based economy to urban economy. According to Thapa and Murayama (2008) a polycentric development pattern can be observed in KMC with most expansion confined to the existing built-up periphery. With the increase in migration and natural population growth, KMC is also experiencing an uncontrolled sprawl towards the transportation corridor (Dhakal, 2006). This haphazard development has serious consequences like environmental pollution, unemployment, inadequate infrastructure and health problems (Haack & Rafter, 2006).

Transportation being the base network for urbanization is also an issue of concern for its impact on the urban environment. The major contributor to the increasing air pollution in KMC is transportation (Shrestha & Malla, 1996). The modes of transport in KMC are bus, microbus, minibus, electric and gas tempo, motorcycles, cars. Among these 71% of the total vehicle population is made up of private cars and motorcycles and only 1.4% constitutes of the high occupancy buses and minibuses (Dhakal, 2006). This demand for transportation has increased 7-8 folds from 1989 and will keep on increasing simultaneously increasing the CO_2 emission. This problem is compounded by the lack of realization from the policy makers of the benefits of GHG mitigation measures on development activities (Dhakal, 2003) which is aided by the lack of the scientific studies on the impact of these mitigation measures.

Transport can be defined in terms of travel behaviour of residents and measured as the distances travelled by individuals in a day and the modes they prefer. Travel can be defined as a means for overcoming the spatial barrier to participate in socio-economic activities and can therefore be modified using land use planning (Cervero, 1989; Newman & Kenworthy, 1999).

In recent times some studies and research have been conducted with Nepal as case study site. These researches involve the need of LCD, the effect of reduction of emission CO_2 in development scenarios Shrestha and Shakya (2012). The urban growth and land use of the KMC has also been studied in various researches (Thapa & Murayama, 2008, 2010, 2011).There have been previous researches on low carbon development in transport (Shrestha, 2012; Shrestha, 2013) and on the urban growth modelling of KMC(Duwal, 2013). These researches dealt with the evaluation of proposed transport plans for KMC and preferences of user for proposed sustainable public transport as well as scenario development of the possible urban growth and land use changes. They have yet to relate the relationship between the urban form and travel and their consequent effect on the environmental issues. This research aims to create an understanding of how the urban form and travel behaviour interact and if urban form can be structured to benefit the environment through changes in the travel behaviour.

1.3. Research Problem

The world is growing at a rapid pace and with this the pace of urbanization of the cities and places we live are inevitable. The cities grow and change their form. This change in our cities is multidimensional and

has varying effects in the way we live. The urban form can be described as the spatial pattern of distribution of its elements. Transportation is also major part of the urbanization process and also has impact on the environment.

The transportation system of any city is defined by the travel behaviour of its inhabitant and is measured as distances travelled by individuals in a day and the modes they prefer. These behaviours are in turn affected by the urban form of the cities. The travel distances, modes, modal splits are directed by the density, distribution of built form.

With transport and rapid urbanization the environmental quality is degrading. The problems of GHGs and CO_2 emission have become a global concern. Low carbon development is a policy measure that every city wants to incorporate in their development plans especially in the transport sector. Therefore studying the urban form and travel behaviour, and its relationship with CO_2 emissions in transport is important and relevant.

There are researches conducted on integrating land use and transportation and have come up with various land use-transport models (Boarnet & Sarmiento, 1998; Ewing et al., 1996; Newman & Kenworthy, 1996). These researches only focus on the land use and transportation aspects. Other dimensions of the urban form are also significant in their relation to the transportation. In context of the KMC, the rapid urbanization with the haphazard developments is creating chaos in the city. The transportation system has not improved in the past decade, aggravating the environmental and sustainability problems. These researches conducted in KMC are limited to the urban growth, transport demand and emissions. There is need to connect each of these issues to see how they affect each other. This research is a bridge between these concepts and studies how related these problems are and if they can contribute to development of a sustainable transport development in KMC.

This research focuses on the relationship between urban form and travel behaviour and its impact on the low carbon transport development. What are the possible impacts of urban form on travel and is there a potential in adapting the dimensions of the urban form to affect travel behaviour?

1.4. Research Objectives

The main objective is to understand the impact of urban form on travel behaviour to evaluate their potential of low carbon development on transport in KMC.

1.4.1. Sub-objectives

- To understand the urban form of the KMC
- To study the travel behaviour of the individual in KMC
- To study the impact of urban form on travel behaviour and its potential of LCD in transport

1.4.2. Research Questions

To understand the urban form of the KMC

- What type of urban form is prevalent in KMC?
- What are suitable indicators to measure these urban forms?
- How can the urban forms be quantified?

To study the travel behaviour of the individual in KMC

- What are the measures of travel behaviour in KMC?

To study the impact of urban form on travel behaviour

- What is the relationship between urban form and travel behaviour?

1.5. Conceptual Framework

The figure 1 illustrates the conceptual diagram of the research. The diagram represents the relation between the key concepts of the research. The urban form of the cities is often shaped by the formal and informal activities that demand and result in infrastructures and land use development and planning policies to regulate them. The urban form and the travel behaviour of individuals have mutual impact on each other and which in turn has impact on the environment. The research only looks into the impact of urban form on travel behaviour.

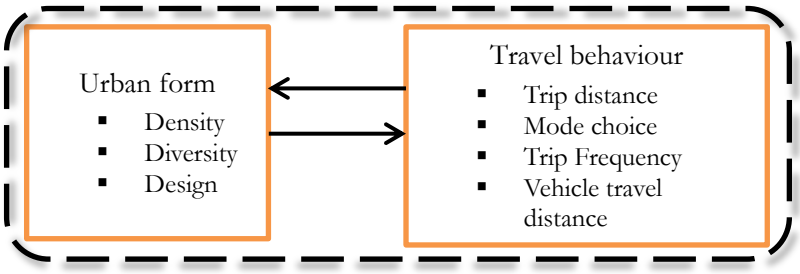

Figure 1: Conceptual Framework

1.6. Thesis Structure

Chapter 1- Introduction: This chapter includes general introduction with background and justification, research problem, research objectives and conceptual framework.

Chapter 2- Literature Review: This chapter includes the review of the concept of urban form, travel behaviour and previous studies to create information base for the research.

Chapter 3- Study Area: This chapter gives the overview of the study area with its land use and transport plans and policies.

Chapter 4- Research Methodology: this chapter includes the research design with the description of different phases of research. It also includes the description of methods used for data collection and data analysis.

Chapter 5- Travel Behaviour and Urban Form of Kathmandu: This chapter is the presentation of the results after analysing the urban form and travel behaviour data for the study area.

Chapter 6- Urban form and Travel Behaviour Relationship for Kathmandu: This chapter presents the discussion of the results presented in the previous chapter and the analysis of the relationship of the urban form and travel behaviour.

Chapter 7- Conclusion: this chapter includes the conclusion derived from the result and discussion of the analysis with the limitation of the research conducted. It also provides the recommendations based on the results and conclusion for possible implementation of the research and further research direction.

2. LITERATURE REVIEW

2.1. Urban form and travel behaviour

According to Anderson et al. (1996) urban form can be described as the spatial configuration of fixed elements with a metropolitan region which includes spatial pattern of land uses, their densities and the spatial design of transport and communication infrastructure. The urban form can also be referred to as the spatial imprint of an urban transport system as well as the adjacent physical infrastructure. According to Rice (1978), urban form is often understood as simple archetypal forms that could be expected to emerge under different circumstances for example: the concentric form, the radial form and the poly-centric form. The concentric form has very dense transport network where the straight line distance can be measured as the travel impedance. The radial form has the transport network extending out from the CBD which has corresponding intense land use sector along it. The poly-centric form has complex transport network where not all the routes are oriented to the CBD and has overall higher connectivity.

In the recent years there have been many urban development philosophies like new urbanism, transit oriented development, traditional town planning and low carbon development to shape the travel demand.

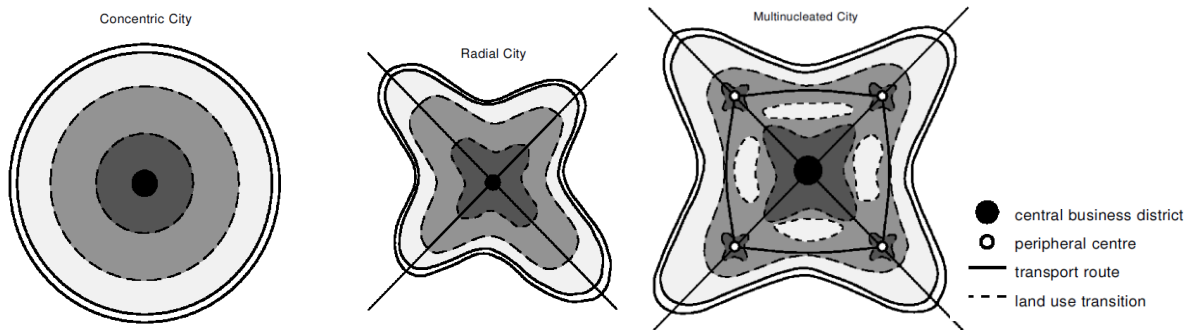

Figure 2: Archetypal Urban Forms (Source: Anderson et al. (1996))

Trip degeneration, non-motorized transport, reduced travel distances and increased vehicle occupancy level are the common objectives of these philosophies (Cervero & Kockelman, 1997). All these developments aim to use land use policy and urban design to advocate more sustainable patterns of travel.

According to Boarnet and Crane (2001),travel is a derived demand and the demand for activities and goods that require travel determine the demand for trips. The activities like living, working, shopping and recreating are spatially separated activities which require travel for people to participate in them (Van Acker et al., 2010). The travel patterns and activities are influenced by the distribution, location and form of activity sites and transportation systems (Fried et al., 1977).

There has been an on-going debate whether the relationship between the urban form and travel behaviour is significant as to warrant their integration in various policy demands. In US, UK, Netherlands, Hong kong, Taiwan empirical research have been conducted to study the impacts of urban form on travel behaviour/demand (Bagley & Mokhtarian, 2002; Boarnet & Sarmiento, 1998; Cervero & Kockelman, 1997; Crane & Crepeau, 1998; Stead, 2001; Zhang, 2004). These studies mostly concluded that dense development, mixed land use and pedestrian friendly design reduced vehicle trip generation and travel distances and encouraged use of public transport, cycling and walking (Lin & Yang, 2009). Some other research include Newman and Kenworthy's research which found an inverse relation between urban density and fuel consumption per capita i.e. higher the density less would be the consumption of fuel

(Newman & Kenworthy, 1999; Newman & Kenworthy, 1989). Whereas Stead (2001) stated that the travel demand is more influenced by socioeconomic characteristics than by the urban form characteristics. There was also no significant relationship between land use and trip generation seen in the research by (Ewing et al., 1996). Most of these researches use statistical analysis to establish the link between urban form and travel behaviour. For example: Bagley and Mokhtarian (2002) and Lin and Yang (2009) used Structured Equation model (SEM), Boarnet and Sarmiento (1998) used regression model, Cervero and Kockelman (1997) used multiple regression, binomial logit analysis, factor analysis and Zhang (2004) used logistic regression.

According to Crane (2000) the urban form and land use measures that might influence travel behaviours are population and employment density, land use mix, street pattern and local balancing of jobs and housing. These elements are commonly studied using simulation method, descriptions and multivariate statistical analysis. Simulations compare the alternative scenarios on given behavioural assumptions whereas descriptive method provides concrete data on the real behaviour in different scenario. The multivariate statistical analysis mostly uses regression analysis to study travel behaviour and urban form. These studies are either at aggregate level i.e. zone, tract, neighbourhood, city or metropolitan level, or at disaggregate level which is individual or household level.

The studies with urban form and travel at an aggregate level provide evidence of significant relationships between various measures of urban form and trip frequency, average trip length or mode split (Handy, 1996). However these studies have limited variance in dependent and independent variables to explain their relationship (Ewing & Cervero, 2010). The use of aggregate data obscures detail of individual behaviour (Boarnet & Sarmiento, 1998) as well as how and why the urban form is linked to travel. The studies at disaggregate level analyse the urban form and travel behaviour at individual or household level representing the within zone variation (Handy, 1996).

2.2. Urban form Indicators and Measures

Many researches on the potential impact of change in urban form to control travel demand have been conducted(Aditjandra et al., 2013; Babalik-Sutcliffe, 2013; Bagley & Mokhtarian, 2002; Buliung & Kanaroglou, 2006; Lin & Hsiao, 2006; Lin & Yang, 2009). These researches have used the concept of the three D's i.e. Density, Diversity and Design first seen in the study by Cervero and Kockelman (1997). There are few more D's added in the subsequent year as destination accessibility, distance to transit (Ewing & Cervero, 2001; Ewing et al., 2009) and demand management.

The main parameter that describes urban form is its **density** which has significant effects on travel distances and modal split (Pushkarev and Zupan 1977). Density is measured as the variable of interest per unit area where the area can be net(density of total developed area) or gross(density of total area)(Munshi et al., 2013). The variables of the interest are population, housing units, retail units, employment, building floor area etc. (Cervero & Kockelman, 1997).

Diversity is related to the number of different land use in a given area and the degree to which they are represented in land use, floor area, or employment (Cervero & Kockelman, 1997). The land use diversity measure indicates the degree to which type of land use are located in close proximity of each other. The entropy measures of diversity is widely used in the researches where higher values indicate mixed land uses and lower values indicate single use.

Design can be the street networks characteristics of an area which varies from dense urban grid to straight street to sparse suburban network (Cervero & Kockelman, 1997). Possible indicators of design

include average block size, proportion of four way intersections, no. of intersection per sq. mile, sidewalk coverage, building setback, street widths etc.

Destination accessibility is the measure of the ease of access of trip attractions which could be local or regional (Handy, 1993) . It could be distance to the CBD or number of jobs or attraction reached within a given time. The gravity model of trip attraction measures destination accessibility.

The average shortest route from residences or workplace in an area to the nearest transit stop is a possible measure for **distance to transit**. It can also be measured by the transit route density, distance between transit stops or the number of stations per unit area.

Demand management is focused on inducing a change or reduction on the demand of vehicular transport specially car use (Kitamura et al., 1997). The measure of demand management mostly applied is the parking supply and cost (Ewing & Cervero, 2010).

Among these six dimensions this research will focus on the density, diversity, design, destination accessibility and distance to transit.
The urban form measures for the original three D's are illustrated in the table 1(the dark to light grey shows the frequency of use of indicators, darkest as the most used and light as least used) :

Density	Diversity	Design
Population or household or residential density	Landuse mix (entropy index)	Intersection density/proportion
Job density	Job-housing/population imbalance	Sidewalk characteristics
Retail floor area ratio	Distance to the closest commercial or grocery stores	Plaza or Block characteristics
Population and employment density	Land use dissimilarity	Street connectivity/density
Employment within walking distance	Business types in neighbourhood	Path directness
Parcel density	Proportion of vertical mix	Pedestrain environment factor
Population per road mile or walking distance	Distance to the nearest park	Proportion front and side parking
Commercial or business density	Non retail job housing balance	Bicycle lane density
Number of parcels	Retail job housing balance	Space syntax Parameters
	Retail store count	
*Source: (Ewing and Cervero,2010)		

Table 1: Measures of 3D's (Adapted fromMunshi et al. (2013))

2.3. Travel behaviour Indicator and Measure

According to Ewing and Cervero (2010), the trip frequency, trip length, mode choice and vehicle distance travelled are the most common outcome of travel modelling with the urban form. Vehicle distance travelled is most commonly measured as the vehicles miles travelled (VMT) or vehicles kilometre travelled (VKT) which is either for household or per person per day. These distances can further be disaggregated for the purpose of travel or by mode choice i.e. distance travelled for work or distance travelled by car etc. The mode choice can also be measured at household or individual level. Walk or cycle trip rate are also used as measure.
The measures for travel behaviour are illustrated in table 2:

Vehicle Mile/Kilometer	Transit Mode Choice	Walk Mode choice
VHT/VMT per household/person	Transit mode choice per trip purpose	Walk trips per household/person
Non work VMT per person	Transit mode choice /(household or person)	Walk Mode choice/trip purpose
VMT per trip purpose	Proportion of transit trips	Walk/bike trips per household/person
VMT per Mode use	Weekday boardings per station	Walk trips per purpose per household/person
		Non-private vehicle choice for non work trips
		Walk/bike mode choice
		Walk/bike mode choice for trip purpose
		Weekday travel distance by walk/bike
		Fraction walk/bike trips
		Pedestrains per hour

*Source: (Ewing and Cervero,2010) Table 2: Measures of Travel behaviour (Adapted from Munshi et al. (2013))

Trip frequency is mostly due to socio economic characteristics of travellers whereas trip length can be attributed to the built form(Ewing & Cervero, 2001). The mode choice is dependent on both built form and socio-economic characteristics. Destination accessibility influences the trip distance as well as mode choice.

3. STUDY AREA

3.1. General Description of Study Area

The study area is Kathmandu metropolitan city. The area of KMC is 50.6 km² and has population density of 19,250 per km². The ward is the smallest unit of administrative boundary. There are 35 wards in KMC. The size and population density of these wards vary considerably. Due to the limitation of the time and resources it was not possible to conduct a survey for the whole metropolitan city therefore only five wards were selected. KMC does not have officially delineated neighbourhood boundaries or TAZ to use and the ward sizes are incomparable to each other. These neighbourhoods were chosen according to their urban form characteristics (density, land use) and their distance from the city core. The chosen neighbourhood do not have an official or administrative boundary. These just represent an area of homogeneous characteristics in the ward for the purpose of this study.

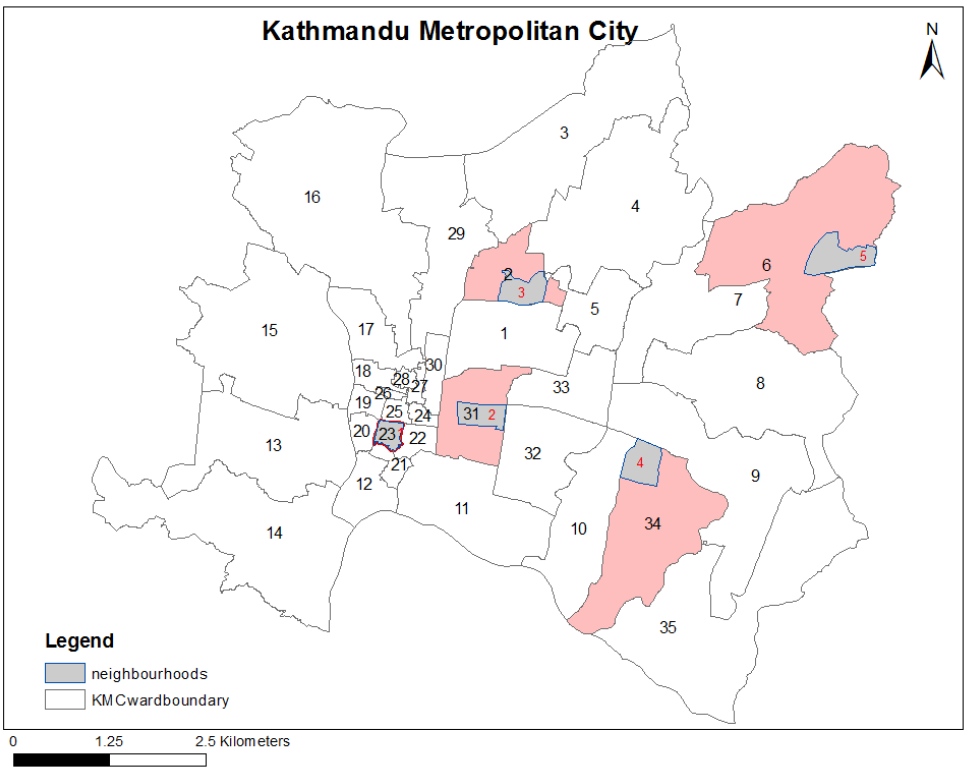

Figure 3: Five selected neighbourhoods with their ward boundaries in KMC

Figure 3 illustrates the selected neighbourhoods in their wards boundaries with other non-selected wards in KMC. The wards with the pink area are the sites chosen for neighbourhood selections. The wards are chosen with different population densities in consideration. The prevalent land use of the study area is given in the Table 3. 69% of the land use fall under the built up land class. The built up area of KMC is broadly divided into three categories; namely i) Historic city core ii) Residential Zone and iii) Conservation Zone. These land use zones are further subdivided into sub zone and provide building guidelines. The building guidelines restrict the use of the land in the allocated area to build according to the land use allocated to them.

The road network in the study area exists of highway, primary feeder road, secondary feeder road and strategic urban road. The main arterial road namely "Ring road" serves to connect the study area with the neighbouring districts through the radial patterned roads. The current modes of transportation in the study area are public motorised vehicles (Bus, Minibus, Microbus, and Electric & LPG Tempo), private motorized vehicles (Car, Van, Jeep and Motorcycle) and non-motorized modes (Bicycle, Walking).

Kathmandu Metropolitan City Land Use

Sno	Land use type	Land class	Area(hectare)	% of Total
1	Mixed	Built up	2592.7	48.89
2	Cultivation	Cultivation	891.18	16.80
3	Open area	Built up	571.17	10.77
4	Road	Road	386.52	7.29
5	Institutional	Built up	385.89	7.28
6	Plantation	Plantation	190.72	3.60
7	Heritage	Built up	63.57	1.20
8	River	River	60.61	1.14
9	Waste land	Waste land	53.72	1.01
10	Airport runway	Airport runway	33.07	0.62
11	Industrial	Built up	32.25	0.61
12	Playground	Playground	17.05	0.32
13	Park	Park	7.04	0.13
14	Pond	Pond	6.5	0.12
15	Parking	Built up	6.22	0.12
16	Road median	Road median	4.4	0.08
17	Others	Built up	0.48	0.01
18	Sandy area	Sandy area	0.21	0.00
19	Total calculated area		5303.3	100.00

Table 3: KMC Land use table ((Pant & Dongol, 2009)

3.2. Transport Plans and policies

There are various plans and policies being formulated and implemented at either national or district level. The focus of these plans and policies is to improve the transport infrastructure thus creating a stronger political and administrative linkages as well as developing and utilization of socio-economic potential. The various plans and policies are briefly mentioned below:

3.2.1. Latest Policy of Road Development

1. Twenty-Year Road Plan: the 20 year road plan was published by Department of road in 2001 with aim to develop the Strategic Road Network. The four major objective of this plan are i) strengthening of political and administrative linkages, ii) alleviation of poverty, iii) develop and utilize socio economic and cultural potentials, and iv) reduction of transportation cost and environmental hazards. The plan aims to extend the SRN to 9,206 km in the entire country.

2. Sector-wide Road Programme and Priority Investment: this study was conducted with the aid of World Bank/ International Development Association Loan in 2005 to maintain and develop the SRN with the preparation of a 10 year Priority Investment Plan with recommendations for expansion and upgrading.

3. Business Plan: This plan was published in 2010 with the aim to present the vision of DOR for road sector. The main objective of this plan is to provide sustainable and efficient road network through development the SRN. This development would aid in managing the main arterial routes which would provide link to rural areas, areas with natural resources and tourism potential as well as the international trade routes.

3.2.2. Ongoing Major Road Improvement Project

1. Kathmandu Sustainable Urban Transport Project (KSUTP)
2. Ring Road Improvement Project
3. Grade-Separated Intersections at Five Major Junctions in Kathmandu
4. Kathmandu Valley Road Widening Projects
5. Railway and Metro Development Project

4. RESEARCH METHODOLOGY

4.1. Research Design

The research design of the study is given below in Table 4 which provides the detail of the data required, source of data and the methods to answer the research objectives.

Table 4: Research Matrix

Research objectives	Research questions	Data Required	Data sources	Methods
To understand the urban form of the KMC	▪ What type of urban form is prevalent in KMC?	Socioeconomic data- population, income, gender, education, employment, Land use data, road data etc.	Literature, Secondary data	Reviewing literature, Field observation, GIS Methods
	▪ What are suitable indicators to measure these urban forms?			
	▪ How can the urban forms be quantified?			
To study the travel behaviour of the individual in KMC	▪ What are the measures of travel behaviour in KMC	Trip purpose, trip mode, trip length, ownership etc.	Primary household Survey Secondary household survey	Questionnaire survey, Literature review
To study the impact of urban form on travel behaviour	▪ What is the relationship between urban form and travel behaviour?	Results from sub objective 1 question 3 and sub objective 2 question 1		Descriptive analysis of primary and secondary data

4.2. Pre-Fieldwork

The first stage of the study was **pre-fieldwork** which mostly consists of literature review. In this stage the concept of urban form, travel behaviour and low carbon development in transportation sector were studied. The measures of urban form and measures travel behaviour to be analysed were also decided on the basis of various relevant literature studied. Based on these review the list of the required data was prepared i.e. socio-economic and demographic data, travel data, road network data, trip origin destination data etc.

This stage also included the fieldwork preparation where the methods of primary and secondary data collection were decided. List of various sources that could provide the relevant data was prepared for the secondary data collection and a questionnaire was prepared for the household survey for the travel data collection. The questionnaire for the household interview survey was developed in a simple format with the ease of understanding in mind. The questionnaire as shown annex 8.1 in was developed to generate the data of the movement of a person in a single day.

4.3. Site Selection

The sites for the survey were selected with various factors in consideration. Five different wards in the total of 35 wards in KMC were selected. The wards were selected on the basis of their distance from the core city area which is the old palace square, their population density and their built form diversity. The selected wards are:

i. Ward 2 and Ward 34
ii. Ward 31 and Ward 6
iii. Ward 23

The ward 2 and ward 34 have similar population density but differ from their distance to the core city area. The built up use and composition of these area also vary, where ward 2 has more mixed use built form compared to ward 34 has less diversity. Similarly, ward 31 and ward 6 were selected. The population density of ward 23 is high with traditional settlement.

VDC/Municipality Name	Ward	Total Household	Population	Area	Density	Characteristics
Kathmandu M.N.P.	34	11039	46136	2.35	4697.45	far from city core,lower mix of built form
Kathmandu M.N.P.	2	3195	13655	0.81	3944.44	near to city core, higher mix of built form
Kathmandu M.N.P.	31	3252	14502	1.03	3157.28	near to city core, higher mix of built form
Kathmandu M.N.P.	6	8768	39316	3.6	2435.56	far from city core, recent settlement, lower mix of built form
Kathmandu M.N.P.	23	1709	8289	0.1	17090.00	very near to city core, traditional settlement, very dense built form

Table 5: KMC Ward characteristics (Population and household data of 2001)

These different wards are of varying sizes and population densities. Due to the lack of time and financial constraint it was not possible to conduct the survey over the whole ward so only a part of the ward was selected to conduct the survey. The neighbourhood were selected according to the homogeneous characteristics of its built form and keeping in mind the areas of each neighbourhood would be comparable to each other. The area of ward 23 which is taken as a whole is taken as a base. The boundary of the neighbourhood is defined by the road surrounding it.

4.4. Sampling Strategy

The sampling unit for the primary survey was the household. The sample size i.e. the number of households to be interviewed in each neighbourhood was taken as 85-90 household per neighbourhood size. The population data and household data were only available at the ward level so the population and household numbers to the neighbourhood were assigned as proportional to its area with the ward. These household numbers were then used to determine the size of household samples required in each neighbourhood. The sample size precision level was ±10 where confidence level was 95% and P=0.5(Israel, 1992). The total sample size of the five neighbourhoods for the survey was around 457 households.

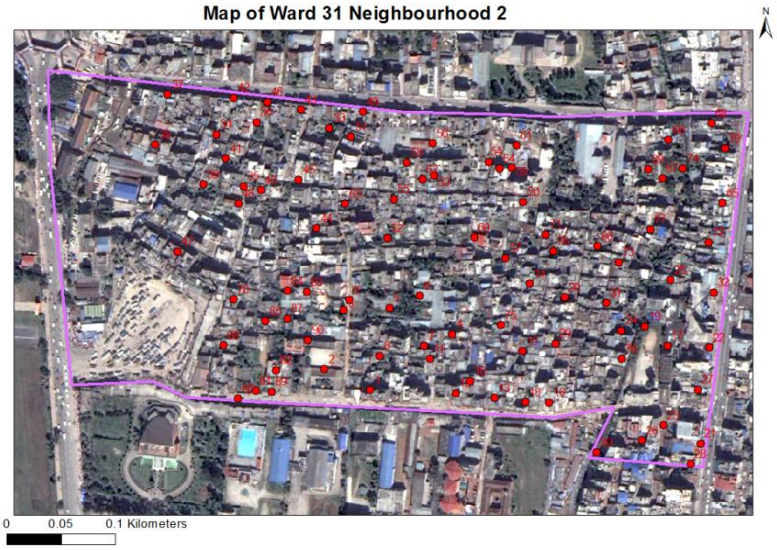

Figure 4: Sample points of household for survey in Ward 31

The simple random sampling was chosen as the method of sampling for this survey. Every household in the defined neighbourhood would have equal chances of being surveyed. The registry for voters or any other registration of the households was not available. The neighbourhood areas were digitized in ArcGIS on the base map with administrative boundary and google base map. The random point tool was used to generate the predetermined number of samples for the survey area. These randomly generated points then served as the location of the household for the survey. Figure 4 shows the sample points generated to locate the households in neighbourhood 2 and figure 20 and 21 in annex show for other four neighbourhoods. Each point is provided with an identification number which was used as the household id of that neighbourhood.

4.5. Fieldwork

The fieldwork consisted of primary and secondary data collection

Primary Data	Secondary Data	Objective fulfilled
Household Interview Travel Survey	KMC ward Boundary	Objective 1
	Census Data- Population per ward	Objective 1
	Road Network O-D for all purpose all modes Household travel survey 2011	Objective 1
	Kathmandu Sustainable Urban transport Project (Report and improvement)	Objective 2
	The study on Kathmandu valley Urban road development	Objective 2
	Data Collection Survey on Traffic improvement in Kathmandu valley 2011	Objective 2

Table 6: Overview of Data Collection

4.5.1. Primary Data

A household interview survey was conducted to generate data for the travel behaviour of the individuals. The survey was conducted with the aid of 5 assistants from 1st Oct 2013 to 8th Oct 2013. The survey was preceded by a pilot survey of 10 households after thorough briefing of the survey assistants. The duration of the survey per person was between 15 -20 minutes. The surveyors were provided with a digital map of the area with the sampling points to locate the household. A copy of the official letter provided by the university was also provided with brief introduction of the purpose of the survey the surveyors. Ideally the questionnaire was aimed to capture the trip information of the entire household but due to the lack of time it was not possible to do so. Therefore the trip information of the person available at that time was recorded.

The questionnaire in annex 8.1 was structured in three sections. The first section of the questionnaire was the household information where the general socio economic information was collected. The number of house hold member, address, type of vehicles owned, monthly income, building type and ownership of home etc. are included in this section. The second section was the household member information. The age, gender, occupation and education of each member were included in this section. The survey was conducted for member of the household above the age of 18. Though the number of total household

members was recorded, the details of only those members above the age 18 were included. The third and final section of the questionnaire was individual trip information.

This section included the detailed travel information of the respondent who was either the household head (preferably) or any member above the age of 18. Though the target of the survey was to interview all the members of the household, due to time limitation only one member of each household was surveyed. The respondent was required to give detailed travel information of a single working preferably the day before the survey was conducted. This section was a series of trip information to make a whole day of travel. In each trip the address and time of starting and arrival was recorded. The destination, purpose of the trip and the mode of travel were recorded.

The total number of survey conducted was 457 households. There were few half-filled questionnaires which were then removed from the data set. After cleaning the data the total number of samples collected was 446 household.

Category	Question Items	Detail
Household information	• Address • Number of household members • Type and number of vehicles owned • Monthly Income • Building Type	
Household Member Information	• Age • Gender • Occupation • Education	
Household Member Trip Information	• Starting place • Place category • Address • Destination • Place category • Address • Trip Purpose • Trip Mode	• Home, School, Work, Store etc. • Home, School, Work, Store etc. • Home, School, Work, Store etc. • Car, Motorcycle, School bus, Public Bus, Micro bus, Tampo, Bicycle, walk

Table 7: Survey Questionnaire Detail

4.5.1.1. Constraints of the primary survey

The primary survey was conducted within three weeks' time i.e 22nd Sep 2013-15th Oct 2013. The survey initially aimed to collect the travel information of every member of the household; during the fieldwork it was not possible due to the limited time available for conducting the survey as well as the reluctance of the household members to answer the question as it was not an official survey. Another constraint was that the survey had to be conducted during weekdays and within the working hours; hence the data for most of the working people could not be collected.

4.5.2. Secondary Data

For the collection of secondary data various organization like Central Bureau of Statistics, Department of Road, Department of urban development and building construction, Kathmandu Sustainable Urban transport project, Full Bright consultancy, JICA Nepal etc. were visited. The reports on the traffic improvement conducted by JICA for Kathmandu in 1993 and 2012 were collected. The household travel

survey for 2012 report was provided by the Full Bright Consultancy. KSUTP provided the report on its project for sustainable urban transport for Kathmandu.

A travel survey of the Kathmandu Valley in the year 2011 was conducted by Full Bright consultancy for JICA Nepal. The survey included 18100 household interviews among which 17,592 were valid household data with total of 70524 household member data. The questionnaire used by the firm was similar in structure with the primary survey questionnaire used in this research. The survey included question for household, information of household member and questions for trips made by each member. The firm only agreed to provide me with the data of Kathmandu Metropolitan City area only. Therefore the number of household samples is 8,670 and the total number of individual trips is about 38,645. The survey area was divided into separate traffic zones which are the wards and village district community (VDC). The total number of traffic zone in KMC is 19 though there are 35 wards. So some wards are grouped together in one traffic zone.

4.6. Post Fieldwork

In the post fieldwork the data collected from questionnaire survey was processed and converted in the digital format. The process was cross checked for entering errors at suitable intervals. A preliminary statistical analysis is done to check the quality and consistency of the data collected.

4.7. Data analysis methodology

Table 8 gives the description of the data collected during the fieldwork and used in analysis of relation of urban form and travel behaviour.

Type of Data	Description	Data Condition	Source
Spatial Data	Administrative Boundary (Wards)	GIS (vector)	KVTDC
	Road (Highway, feeder road, public bus route)	GIS (vector)	KVTDC
	Transit Stop locations	GIS (vector)	Softwel P(ltd) (Shrestha (2012)
Demographic Data	Population Data, Household Data (2011)	Excel	Central Bureau of Statistics, Gov. of Nepal
Primary Household Survey	Socio-economic data, Trip mode, Trip frequency, Trip length, Vehicle Ownership	Excel	Primary survey (Field work)
Secondary Household Survey	Trip mode, Trip frequency, Vehicle Ownership, demographic data	Excel	Full Bright consultancy

Table 8: Dataset used for analysis

4.7.1. Urban Form Quantification

The measures for the urban form are listed in section 2.2 and some of them are selected as per their frequency of use and availability of data for the quantification. The original 3D's (Density, Diversity, and Design) and the two extended D's (Distance to transit, Destination Accessibility) are used in this research. The last D i.e. demand management was not used in this research as it focused on demand of vehicular use mostly car which is not yet a significant factor in transport in KMC.

4.7.1.1. Density

Density is an indication of growth and concentration of activities which can lead to reduction in the travel time and distance. The increased density around specific or strategic activities can encourage people to walk or use public vehicles. The density of an urban form can be measured as population density, job density, residential or household density. Net population and household densities are computed for this research purpose as a measure of intensity of development of urban form. The following equation gives the density values:

Net Population Density: $D_p = P/A$ where D_p= Net population density, P=Population, A=built up area (sq.km)
Net Household: $D_{hh} = HH/A$ where D_{hh}= Net household density, HH=Household, A=built up area (sq.km)

4.7.1.2. Diversity

The spatial distribution of the urban land uses indicates the diversity of the development of the urban form. They are indicative of the various activities that are carried out which then require the means of transport. The arrangement of these various activities in a spatial pattern could decide the need and frequency of travel. Land use mix is the degree to which urban land uses are spatially arranged in a given area. According to Stead and Marshall (2001), the land use mix has an effect on the physical segregation of activities therefore is a determining factor in travel demand. The land use mix is most often used measured for diversity.

The land use mix is measured as Land use entropy and dissimilarity index where
Entropy=$\sum_j \frac{P_j \text{ X } \ln P_j}{\ln J}$; where P_j is the proportion of developed land in the j^{th} use type, J is the number of distinct land use.

Dissimilarity Index= $\sum_j^k \sum_i^8 (X_i/8)/k$; where K= number of actively developed hectares in a zone and Xi= 1 if central active hectares land use type differ from that of neighbouring hectare and Xi=0 otherwise.

The entropy can be used to understand the balance of land use whereas the dissimilarity index provides the information about the degree of interaction or contact of these land uses.

4.7.1.3. Design

Design of the infrastructure provided is one major urban form dimension which accounts for the choices made in terms of travel distance and travel mode. A properly aligned and good road network can influence people to choose non-motorized transport instead. The reduced distance, good connection and provision of other infrastructures can influence this choice. The design of the urban form can be measured in terms of road density, intersection density, sidewalk density and transit stop density etc. the road/street density is measured as the ratio of area of the road to the area of developed land. The grid network or the intersection density can be measured as the ratio of number of four way intersection to the total number of intersection. Kernel density has been used to quantify the measures of design of urban form (Tracy et al., 2011).

4.7.1.4. Destination Accessibility

The destination accessibility can be termed as the ease with which a destination can be reached for carrying out certain activities. The activities could be varied which would require a means of transport to reach the destination. This can be measured in terms of job accessibility through different mode of

transport or it could be measured in terms of the effort expended to reach the central business district. These can be measured in Network distance or Euclidean distance.

4.7.1.5. Distance to Transit

There are various factors that affect the choice of an individual to select public transit as travel mode. Among these one of the most influential is the location of a transit stop. The optimal location of the transit stop encourages people to use the public transit. Lower the distance of the transit higher would be the possibility of an individual to walk to the stop and travel using public transit system. The other measures that can also be used are the population living with in the walking distance of transit stop and transit stop density.

4.7.2. Analysis of Urban form and travel behaviour relationship

The relation of urban form and travel behaviour has been studied in many contexts from which the figure 5 has been derived. The density is related to the trip frequency, trip distance and modal split (Cervero & Kockelman, 1997). The diversity is related to the travel distance and multipurpose trip potential whereas design could aid in mode choice of walking, cycling or public transport. The destination accessibility affects the mode split and vehicle ownership and the transit distance could encourage or discourage the public motorized transport mode.

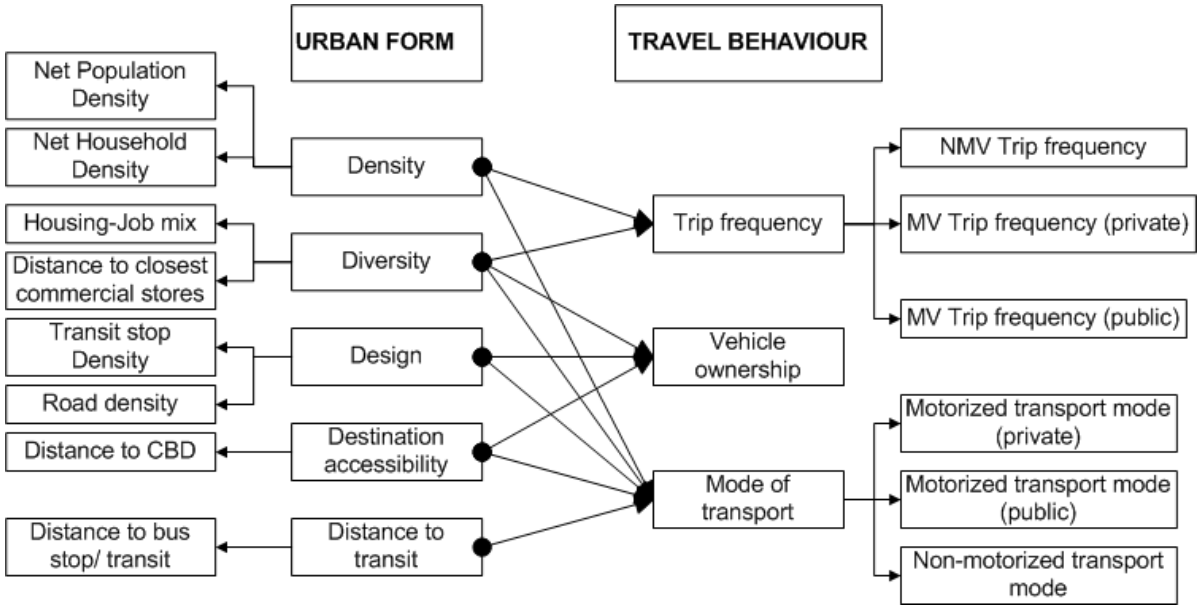

Figure 5: Hypothetical relation of urban form and travel behaviour (Adapted from Lin and Yang (2009)

4.7.2.1. Spearman's Rank Correlation coefficient

Spearman's rank correlation coefficient also known as Spearman's rho is a non- parametric measure of statistical dependence of two variables and can be used when there is non-normally distributed data. This process uses the Pearson's equation after ranking the data(Field, 2009).

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

Using the equation or SPSS's spearman's correlation coefficient in bivariate correlation analysis tool the strength and significance of correlation between the variables can be checked. If the value of ρ is near to either +1 or -1 then there is a strong correlation between the variables.

5. TRAVEL BEHAVIOUR AND URBAN FORM OF KATHMANDU

5.1. Ward Profile

Kathmandu along with Lalitpur, Bhaktapur and Kirtipur form the Kathmandu valley which moreover acts as one city. There is constant flow of traffic through these cities on daily basis. But this research only focuses on the Kathmandu Metropolitan City.

Kathmandu is an old city which developed with the palace square as its core centre. The city developed around the palace with the market place adjoining it, which now functions as the main commercial and institutional sector of the city. So the area surrounding the old palace square is the CBD of the KMC. There are 35 wards in the Kathmandu Metropolitan city. Among these 5 wards namely ward 2, ward 6, ward 23, ward 31 and ward 34 were selected according to their specific characteristics (see section 3.1 figure 3 and section 4.3 table 5).

I) Ward 23

Ward 23 is the part of old city which is closest to the CBD. It has an area of 0.1 km^2 and population of 8,357 in the year 2011. This ward has one of the highest population densities in the KMC and the household number is 1,991. This ward has been chosen for its proximity to the CBD, its high density as well as its unique built up characteristics. Since it is part of the old city the layout and design still adheres to the traditional Nepalese architecture with compact buildings with narrow alley ways to connect it to the main street. Traditionally this was mainly a residential area for the influential court personnel and merchants but now it has evolved into a mixed area used for retail and commercial purpose.

II) Ward 2

Ward 2 has total population of 13,448 and an area of 0.81 km^2. It has the density of 16,436 per km^2 and household number of 3,599. This area is adjacent to the new palace which is now a public museum and is more institutional and residential in nature with existence of foreign embassy and commercial hotels in the vicinity. It has more modern construction with major road adjacent to it. It is within a reasonable distance from the CBD.

III) Ward 31

In an area of 1.03 km^2 ward 31 houses a population of 16,211 with 4,112 household and density of 15,631 per km^2. This area has a high mix of built up use with residential, commercial as well as institutional. This area along with its surrounding is also considered have the business and institutions settled. This area is adjacent one of the busiest roads in the city. It also has one of the two major bus parks of the city.

IV) Ward 34

With a population of 66,121, ward 34 is the highest of the selected areas and has an area of 2.35 km^2. The population density of this ward is 28,099 per km^2 and has 17,772 households. This is one of the largest residential areas with some commercial and institutional use along the road area. It is adjacent to the three of the major road networks in KMC. This is at some distance to the CBD.

V) Ward 6

Among the five selected wards, ward 6 is furthest from the CBD and a considerably new settlement. Ward 6 is at the edge of the city boundary with a population of 60,344 and density of 16,732 per km^2. This is the least dense area among the five selections and has the largest area of 3.6 km^2. The built up here is of mix of residential and commercial.

These wards have been selected to study and compare their urban form and travel behaviour. The Ward 23 has been selected for its unique traditional settlement and proximity to the CBD. Among the other four wards, ward 2, ward 31 and ward 34, ward 6 which are at similar distance from CBD but have different population densities and built form would be studied and their travel behaviour would be compared.

5.2. Travel Behaviour in the five neighbourhood

Travel behaviour for the neighbourhoods have been analysed from the primary data i.e. the household travel survey conducted during the fieldwork. The household travel survey is an interview survey which provides the information about the socio-economic as well as travel choices of the members of the household. It provides with the various travel information like the frequency of the trips made, trip destination, trip purpose, trip mode.

There are five wards selected for this survey based on their various characteristics to study the travel behaviour. Due to the limited amount of time available for field work and the different scale of the wards in terms of area only a section from each wards were used as neighbourhood for the survey. These chosen neighbourhoods are of similar sizes.

5.2.1. Descriptive analysis of the socio-economic characteristics of the five neighbourhoods

The primary household survey was designed to obtain the socio-economic and trip information of the household. The table 9 illustrates the socio-economic and general description of the five selected neighbourhoods. The number of valid household samples in each neighbourhood is shown with ward 34 with lowest sample number of 78 and ward 2 and 6 with 90 samples.

Ward No	No of samples per ward	Avg. family size per ward	Avg. Years of Occupancy	House/ Building Ownership		Gender		No of samples in							
				Owned (%)	Rented (%)	Male (%)	Female (%)	Low income		Middle income		Upper middle income		Higher income	
								No	(%)	No	(%)	No	(%)	No	(%)
23	88	3.86	22.5	64.8	35.2	77.3	22.7	22	25	44	50	18	20.4	4	4.5
31	85	3.58	11.3	34.8	65.2	74.2	23.6	20	24	41	48	22	26	2	2
2	90	3.56	12.1	45.1	54.9	69.2	30.8	16	18	47	52	22	24	5	6
34	78	3.58	11.2	44.3	55.7	73.9	26.1	12	15	39	50	22	28	5	6
6	90	3.84	9.72	40.4	59.6	53.9	46.1	15	17	64	71	11	12		

Table 9: Descriptive statistics of socio-economic characteristics of neighbourhood

The average family size in each neighbourhood ranges from 3.5 to 3.8 with ward 23 highest at 3.86 and 6 following it at 3.84. The lowest family size is of ward 2 at 3.56. The ward 23 is a traditional settlement and ward 6 is mostly residential with new settlements whereas the other wards are mixed and older settlements. The years of occupancy and ownership of the building also is highest for ward 23 and show the relative time of settlement. Ward 6 is relatively new settlement and has less ownership. The lowest

ownership is shown by ward 31 where 65.2% household rent their home as it mostly a residential retail mix area.

The male to female respondent ratio in most of the neighbourhood is 2:1 with the exception of ward 6. The reason for this bias may be due to the reluctance of the female members of the household to talk to the strangers and male members mostly taking the lead in the interviews. The other reason is that even if the female member is a respondent is providing information on behalf of the working household head which was mostly male. This case is not seen in the ward 6 as most people interviewed were working near their home so were available to be interviewed and easily accessed.

These neighbourhoods are categorized into four income groups according to their monthly household income i.e. i) low income <15,000 ii) middle income 15,000 – 30,000 iii) upper middle income 30,000 – 60,000 and iv) higher income >60,000. Most of the neighbourhoods have highest number of households in the middle income group with ward 2 and 34 have each 6% of higher income group. Ward 6 does not have a higher income group but highest share of middle income group at 71%. Ward 34 has the lowest share of low income group and highest share of upper middle income group. Ward 23 has the highest share of low income group at 25%.

5.2.2. Descriptive analysis of the travel behaviour form the household survey

The five neighbourhoods are analysed and compared for their travel behaviour as well as their socio-economic characteristics. The trip purpose, trip mode, trip destination, vehicle ownership, household income and building type are used to analyse the wards. Each trip from start point to a destination is counted as one trip in this analysis so the to and fro trip would be counted as two trips.

Ward No	Avg. trip frequency	trip length		Avg. Nearest bus stop distance (min)	Parking Condition	
		Avg. (m)	Max. (m)		Adequate (%)	Inadequate (%)
23	2.2	2445.5	6904.5	10.9	63.6	36.4
31	2.0	2595.8	6095.6	5.37	40.4	51.7
2	2.0	2759.4	8218.2	7.6	63.7	30.8
34	2.2	1072.6	5895.7	8.3	79.5	18.2
6	2.3	644.6	5483.9	7.1	64	36

Table 10: Descriptive statistics of individual trip information

The research analysis mainly focuses on the trip mode and the trip purpose and their relationship with the urban behaviour though there are other travel behaviour indicators such as trip frequency, trip length which have been used in other researches (Ewing & Cervero, 2010; Ewing et al., 2009). The information on the trip frequency, trip length, parking condition and average distance to the nearest transit stop used are also collected from the household survey conducted during the fieldwork.

Table 10 illustrates the descriptive analysis of the indicators that are not used to derive the relationship between urban form and travel behaviour. The average trip frequency of the five neighbourhoods ranged from 2.0 to 2.3 which may be caused by the limitation of the survey conducted as each household survey on consisted with the trip information of only one person which is generally two trips to a destination and back to the starting place.

Even though the maximum trip length of 8218.2m is in ward 2 but it still has the mean trip length of 2759.4m which is not that greater from ward 31 which has average trip length of 2595.8 and maximum

trip length of 6095.6m. The lowest average trip length is shown by ward 6 at 644.6 m and has maximum trip length of 5483.9 which is also lowest among the neighbourhood. The trip distance for the wards are calculated between the centroids of the wards that the trips origin and destination. This does not represent the true distance as the point location of the destination could not be obtained due to time limitations. The trip distance of the inter ward travels are noted as 0 distance. Hence this cannot truly represent the lengths of the trips so is not used in further analysis.

The average nearest transit stop distance is expressed in terms of time take to travel from the household location to the transit stop location. The lowest time average is of ward 31 at 5.3 minutes followed by ward 6 at 7.1 minutes. The largest time average is of ward 23 at 10.9 minutes. Ward 34 also has relatively longer time average at 8.3 minutes to reach a transit stop.

The adequacy of the parking facility is also queried in the survey. The results in table 10 show that ward 34 has the most availability of the parking spaces as 79.5% respondents answered the parking to be adequate. The least adequate parking facility is in the ward 31 with only 40.4% respondent answering that the parking was adequate. Other three neighbourhoods ie ward 23, 2 and 6 showed an average of 63% adequacy.

These are the general description of the trip information that is not focused upon further in the research. The research now analyses the travel indicators that are used to study the relation between the travel behaviour and the urban form. These are mainly trip mode and trip purpose. Vehicle ownership is also analysed with the income level and the built-up type is also analysed for the five neighbourhoods.

5.2.2.1. Ward 23 Neighbourhood 1

The analysis of the survey illustrates that most of the trips generated are homeward trips with 48% whereas the work based trips are about 24% work (from home to work) and 2% work related trips(work place to other places for work purpose). Among the non-work based trips shopping is the highest with 11%. The survey shows that there is high rate of non-motorized transport i.e. walking is the preferred mode choice with 59% and 30% private motorized transport. The public motorised transport mode choice is fairly low at 10 %. This neighbourhood mainly falls into middle income group with 50% falling under this income class. The ownership of motorbike is highest in every income group whereas cars are owned by middle, upper middle and high income group. The ownership of bicycle is negligible with upper and middle income group owning a few. This neighbourhood's building type is mainly a residential retail mix.

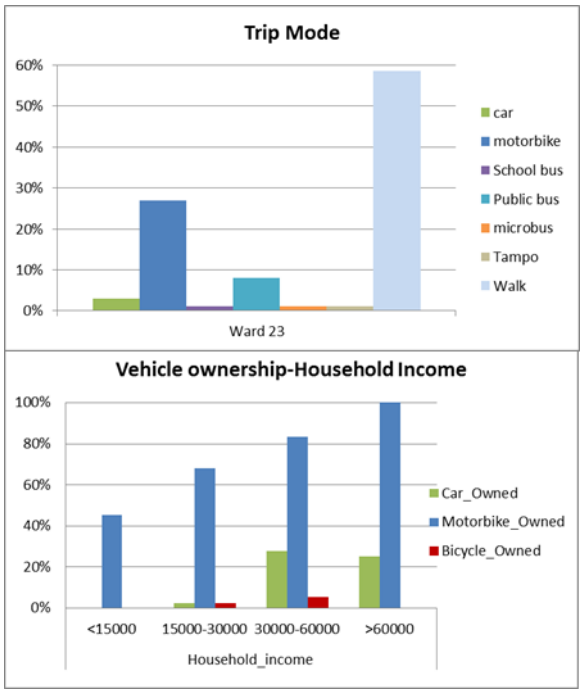

Figure 6: Trip Mode and Vehicle ownership-Household Income of neighbourhood 1

5.2.2.2. Ward 31 Neighbourhood 2

The neighbourhood 2 shows work purpose trip with 24% and in the non-work based trips are largely made by school, shopping and others and highest 48% for the home bound trip. The highest mode choice for this neighbourhood is walking (NMT) with 50%. In the use of private motorized transport motorbike at 30% and 2% use of car is seen. There is minimal use of public transport at 13%. The household income shows that it has high number of middle income household with 48% and about same number of low income and upper middle income household. This area has a distinct residential retail mix built up with over 69% falling under this class. The vehicle ownership shows higher number of motorbikes and fairly high number of car ownership in high income group. Bicycles are owned by only lower and middle income groups.

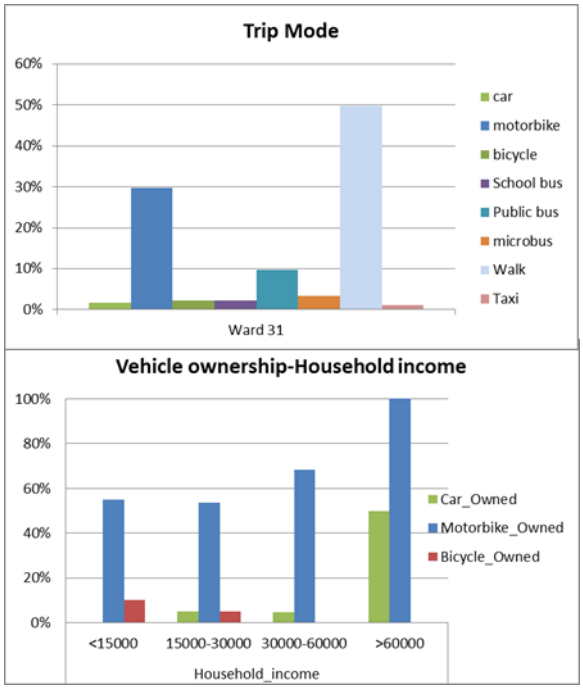

Figure 7: Trip Mode and Vehicle ownership-Household Income of neighbourhood 2

5.2.2.3. Ward 2 Neighbourhood 3

This neighbourhood has higher non-work based trips with only 18% of work based trips. The largest non-work based trips were for shopping at 11% and 10% for other. The preferred mode choice for this neighbourhood was private motorized transport with 48% motorbike and 4% car. The NMT i.e. walk was only 25%. The public transport mode amounted to 22% with greater use of public bus. The household income of most of the respondent fell under middle income at 52 % and only 6% were at high income group. The high income group has greater ownership for all modes i.e. car, motorbike and bicycle with motorbike being the mostly owned in every income group with few bicycle in each group. This area has a higher mix of only residential (41%) and 57% of residential retail mix built up use.

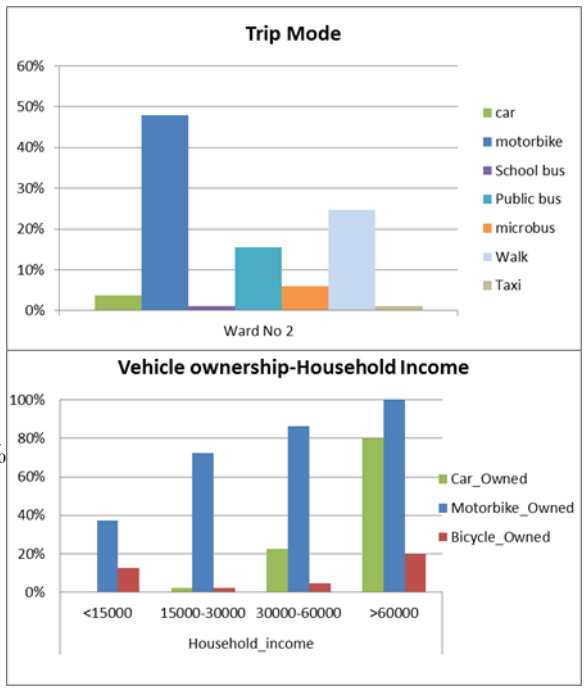

Figure 8: Trip Mode and Vehicle ownership-Household Income of neighbourhood 3

5.2.2.4. Ward 34 Neighbourhood 4

The work based trip for neighbourhood 4 is 29% and 1% for work related trips. The non-work based trip has school at 11% and shopping following it at 7%. Walking is the most preferred mode choice at 43% which is followed by 33% motorbike and 3% of car. The public transport is 19%. 50% of the household falls under middle income, 28% under upper middle class and 6% higher income group. The lower income group has equal number of motorbike and bicycle ownership whereas motorbike ownership is higher for every other income groups. The ownership of car is highest in the higher income group with 60% followed at 18% and 10% by upper and middle income group respectively. The area is mostly residential at 61% and has 36% of residential retail mix.

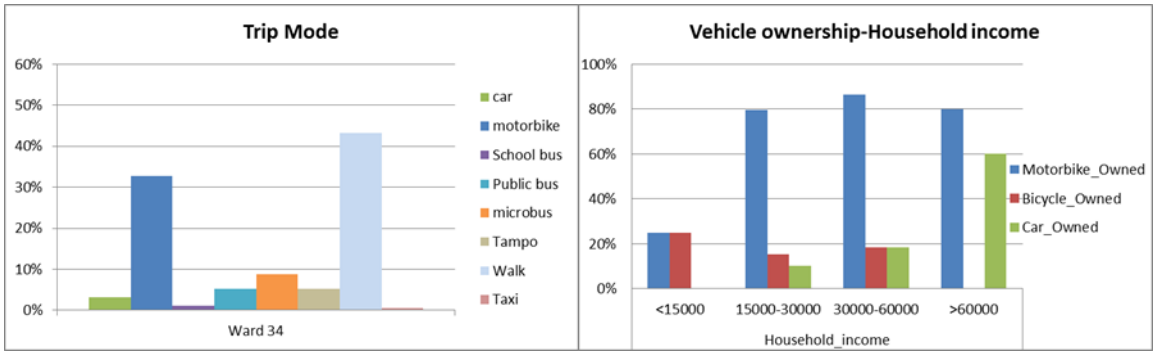

Figure 9: Trip Mode and Vehicle ownership-Household Income of neighbourhood 4

5.2.2.5. Ward 6 Neighbourhood 5

Neighbourhood 5 has higher work based trips at 27% work trip and 1% work based trip followed by 9% school trips and 6% shopping trips for non-work based trips. This neighbourhood also has walk as the highest mode choice at 48% with motorbike at 28% and car at 2%. This area has slightly higher public transport choice at 15% public bus and 7% microbus. This area mostly falls under middle income household at 71% with no higher income household. The car ownership in the upper and middle income group is same at 9% with motorbike as the highest owned for all income group. Residential retail mix is the leading built up use for this area at 74.44% of the households.

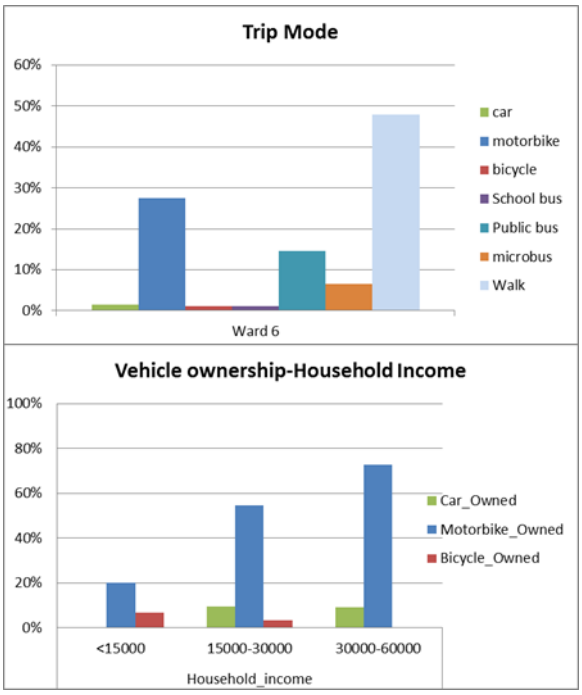

Figure 10: Trip Mode and Vehicle ownership-Household Income of neighbourhood 5

According to this analysis purpose of the trips is home trips as the analysis includes the to and fro trips which generally end with a home based trip. Other important trip purposes highlighted are work based trips in most of the neighbourhoods which is closely followed by shopping and school trips. This is as expected as these are the common and most frequent purpose of travel everywhere. In the mode choice the non-motorized transports i.e. walk was the highest with over 40% in almost every neighbourhood. Neighbourhood 3 showed higher use of private vehicles than its counterpart neighbourhood 2 though they have similar distance to CBD. This may be due to the lack of more mixed built up use as it has higher

quotient of only residential use than the other and a higher rate of vehicle ownership also. The neighbourhood 5 has higher rate of public transport mode choice than neighbourhood 4. This could be due to their different socio-economic level where neighbourhood 4 is well off than neighbourhood 5 and as neighbourhood 5 has higher number of school trips as well as higher residential mix.

The dominant mode choice in every neighbourhood was walking following by the use of motor cycle. The use of cars is limited probably due to the road and traffic condition, parking adequacy and economic reasons. There is distinct lack of ownership and use of bicycle due to the lack of infrastructure and traffic safety required.

Ward No	Neighbourhood	Mode			Purpose		
		Non motorized Mode	Private Motorized Mode	Public Motorized Mode	Home Bound	To Work	Non- Work
23	1	**59%**	30%	10%	48%	26%	25%
31	2	50%	31%	13%	48%	24%	**28%**
2	3	25%	**52%**	**22%**	50%	**30%**	20%
34	4	43%	**36%**	**19%**	46%	**29%**	25%
6	5	48%	29%	**21%**	48%	27%	25%

Table 11: Travel behaviour in KMC (From Primary data)

The walking mode choice in most of the neighbourhood is over 40% with the exception of ward 2 neighbourhood 3 which shows distinctly higher motorized transport use. The ward 31 neighbourhood 2 and ward 2 neighbourhood 3 both have high private motorized transport choice though they have distinctly different choice in public transport use and non-motorized transport mode. Both these neighbourhood have higher concentration of residential retail mix built up.

Table 12 shows that most of the walking i.e. about 50% to 60% of the walking trips in wards 31, 2, 34 and 6 are inter zonal. The trips that are within their own neighbourhoods are walking trips. Only ward 23 show larger percentages of intra zone walk trips. This might be due to its proximity with number of other wards or neighbourhoods. The table 12 also shows that in ward 23 and 2 there is greater percentage of inter zonal trips than others. The wards 31 and 34 show similar inter zonal and intra zonal trips. Only ward 6 has almost equal percentage of inter zonal and intra zonal trips.

Zone	Ward 23		Ward 31		Ward 2		Ward 34		Ward 6	
	Total Trip %	Walk %	Total Trip %	Walk %	Total Trip %	Walk %	Total Trip %	Walk %	Total Trip %	Walk %
Intra zone trip	86.8	80.9	65.7	40.2	81.7	43.5	65.1	50.6	44.0	40.2
Inter zone trip	13.2	19.1	34.3	59.8	18.3	56.5	34.9	49.4	56.0	59.8

Table 12: Inter and Intra zone walk trips

The ward 34 neighbourhood 4 has higher private motorized mode choice than the ward 6 neighbourhood 5 with the opposite for public motorized transport mode choice. The neighbourhood 4 has mix of income group but neighbourhood 5 is predominantly middle income group. The built up of neighbourhood 4 is mostly residential whereas for neighbour 5 it is residential retail mix.

The non-motorized mode of transport bicycle is very minimally used in the study area. It might be due to lack of proper design and safety measures for the bicycle riders.

These observations are only based on the descriptive analysis. Detail comparison and analysis will be followed with the analysis of urban form and travel behaviour.

5.3. Travel behaviour of Kathmandu metropolitan city

5.3.1. Analysis Zone Description

For the purpose of traffic improvement in Kathmandu valley JICA prepared a report for which a household survey of travel behaviour was carried out. For this purpose the valley was divided into small zones which were either the existing ward or combination of the existing wards. The KMC which has 35 wards was thus consists of 19 small zones as shown in table 8 for which the survey was conducted. The total number of household surveyed in KMC was 8,670 which generated 38,645 individual trips by 32,966 members.

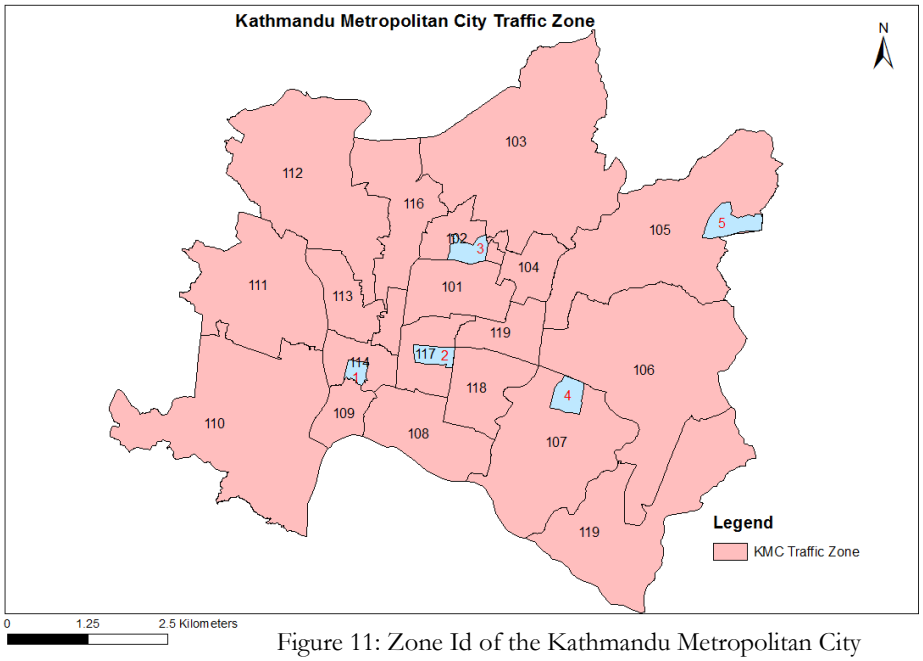

Figure 11: Zone Id of the Kathmandu Metropolitan City

This secondary data has been analyzed to derive the travel behaviour characteristics of the Kathmandu Metropolitan city. This data provides information of the trip purpose, trip mode, vehicles owned.

The blue areas in figure 11 show the neighbourhood selected for the primary survey and the red numbers are their neighbourhood numbers. The table 9 shows the composition of traffic zones with the combined ward numbers.

Small Zone No	Ward No	2011 Zone Population
101	1	13700
102	2	13600
103	3	85900
	4	
104	5	18500
105	6	116700
	7	
106	8	57300
	9	
107	10	110500
	34	
108	11	17700
109	12	26700
	21	
110	13	100300
	14	
111	15	52000
112	16	87000
113	17	46100
	18	
	26	
	28	
114	19	44200
	20	
	22	
	23	
	24	
	25	
115	27	16300
	30	
116	29	44600
117	31	16600
118	32	62200
119	33	76600
	35	

Table 13: Ward No and Zone ID

5.3.2. Descriptive analysis of the travel behaviour from the secondary data of household survey

The travel behaviour of the traffic zones in the secondary data are analysed to check its consistency with the primary survey. The similarities and the dissimilarities due to various factors are also discussed.

5.3.2.1. Trip purpose and Trip mode

The data of the various traffic zone show that the main trip purpose is home bound trip which can be as discussed in section 5.2.2 almost every trip chain ends with home as the destination. The work and school are other two major trip purposes seen from the analysis. For the trip mode non-motorized transport i.e. walks is highest mode share for almost all the zone with private motorized transport as second and public motorized transport as far third. There are some variations in some of the zones in the composition of trip purpose and trip mode. Only the zones with variations (ZID: 108, 109, 110, 111, 118) and the zones corresponding to the neighbourhoods (ZID: 114, 117, 102, 107, 105) selected in the primary data analysis would be discussed in detail.

Zone Id		Mode			Purpose		
		Non motorized Mode	Private Motorized Mode	Public Motorized Mode	Home Bound	To Work	Non- Work
ZID	**102**	51%	**34%**	11%	48%	22%	30%
	105	48%	28%	**21%**	48%	18%	34%
	107	36%	35%	**25%**	45%	19%	**35%**
	108	45%	29%	**23%**	45%	28%	26%
	109	50%	**35%**	11%	28%	28%	**43%**
	110	41%	28%	**27%**	48%	16%	35%
	111	**61%**	29%	5%	31%	28%	**41%**
	114	**59%**	28%	7%	47%	21%	32%
	117	35%	**40%**	**22%**	49%	13%	37%
	118	46%	**34%**	15%	45%	30%	25%

Table 14: Travel behaviour in KMC (From Secondary data)

ZID 102 has work at 22% and school at 19% as the most frequent purpose of the trip after the home bound trip at 48%. The non-motorized transport mode of walk is the highest at 51% followed by private motorized transport mode. The motorbike has 28% mode share whereas car is at 6%. This zone also has low public motorised transport share at 11% in total.

In **ZID 105** the public motorised transport mode show slight improvement with 21% of the mode share. Walk and motorbike at 48% and 24% still have the largest mode share. The trip purpose of school is slightly higher at 19% than 18% of the work purpose trip. Business and shopping are other minor purpose of the trip in this zone.

ZID 107 has large share of motorcycle at 29% and car at 6% making private motorized mode the second after walk at 36%. This zone also has greater public motorized mode share at 25%. The purposes of trips in this zone are home, school and work at 45%, 22% and 19% respectively.

The **ZID 108** has large bus mode at 19% which along with other public motorized mode make up 23% of the mode share. The work purpose of the trip is at 28% followed by school at 17% with minor share of shopping and business.

ZID 109 has a small public motorized mode share at 11% with large share of walk and motorbike at 50% and 32% respectively. This zone has almost equal number of trips for work, school and home followed by minor amount of business and shopping.

In **ZID 110** private motorized mode and public motorized mode of transport have almost equal share at 28% and 27% following walk at 41%. The trip purpose to school at 24% leads followed by work at 16% with home bound trips at 48%.

ZID 111 has almost equal trips for work school and home at 28%, 27% and 31% each. The non-motorized mode of transport i.e. walk has the largest mode share at 61% followed by private motorized mode at 29% and minor share of public motorized mode at 5%.

The trip mode of walk is largest in **ZID 114** at 59% with only 27% of private motorized mode and small share of public motorized mode at 7%. The home trip at 47% is followed by work trip at 21% and school trip at 15%.

ZID 117 has private motorized mode as the largest mode share at 40% followed by walk at 35% and public motorized mode at 22%. The school, work and business trips at 22%, 13% and 12% respectively make the trip purpose after the home bound trips at 49%.

ZID 118 shows work trips at 30% followed by 12% of school trips with 45% of home bound trips. The mode share is led by walk at 46%, private motorized mode at 34% and public motorized mode at 15%.

The secondary data analysis also shows the same trip mode and purpose leading in the most analysis zone as in the primary data analysis. Walk and home being the largest mode and purpose respectively in most of the zones. The motorbike can also been seen as the most preferred mode choice of private means in all of the zones. The public transport mode is the weakest in most of the zones analysed with decent share in only some of the zones.

The **ZID 102** and **ZID 117** represent the same ward as neighbourhood 3 and 2 whereas a neighbourhood 1, 4 and 5 lie on the **ZID 114**, **ZID 107** and **ZID 105** which are combination of ward with the neighbourhood and other adjoining wards.

ZID 102 and ward 2 neighbour 3 show a different composition of trip mode where in the former the non-motorised mode takes largest share and in latter the private motorised mode has largest share**.** It is same case for also **ZID 117** and ward 31 neighbourhood 2 which has where private motorized mode and non-motorised mode respectively are the largest mode share.

ZID 114 and ward 23 neighbourhood 1 has similar mode share and trip purpose. Similarly **ZID 107** and ZID 105 show similar mode characteristics with ward 34 neighbourhood 4 and ward 6 neighbourhood 5.

This similarity and dissimilarity are the result of the sampling characteristic and the built form of the zones. The secondary data has wider spread of the sample collection in the zones where as in the primary data it is concentrated on the selected neighbourhood.

5.4. Urban form Quantification

There are various dimension of urban form however the study uses the concept of the 3D's coined by Cervero and Kockelman (1997) i.e. density, diversity and design. To these a few more D's have been added such as destination accessibility, distance to transit and demand management. These dimensions have their own measures which are used to quantify the urban form. The measures used in this research were bound by the data limitations. The measures used are:

1. Net population density
2. Net household density
3. Land use mix
4. Transit stop density
5. Road network density
6. Distance to CBD
7. Distance to bus stop
8. Distance to transit

5.4.1. Density

The net density of the population expressed in person/km^2 and the net household density expressed in household/km^2 as described in section 4.7.1.1.

These densities in the KMC on the whole are similar to each other with minor variation in some wards with the highest in the core city area i.e. the traditional settlement area. Other than that there seems to be no clear pattern for the concentration of population or the household. In the five selected neighbourhoods the ward 23 neighbourhood 1 has the highest density in both net population and

household as it is in the traditional settlement. It also has a high rate of non-motorized transportation. The ward 2 neighbourhood 3 is the least populated and has lower household density among the five which corresponds with the higher rate of private motorized transportation and low non-motorized transportation choice.

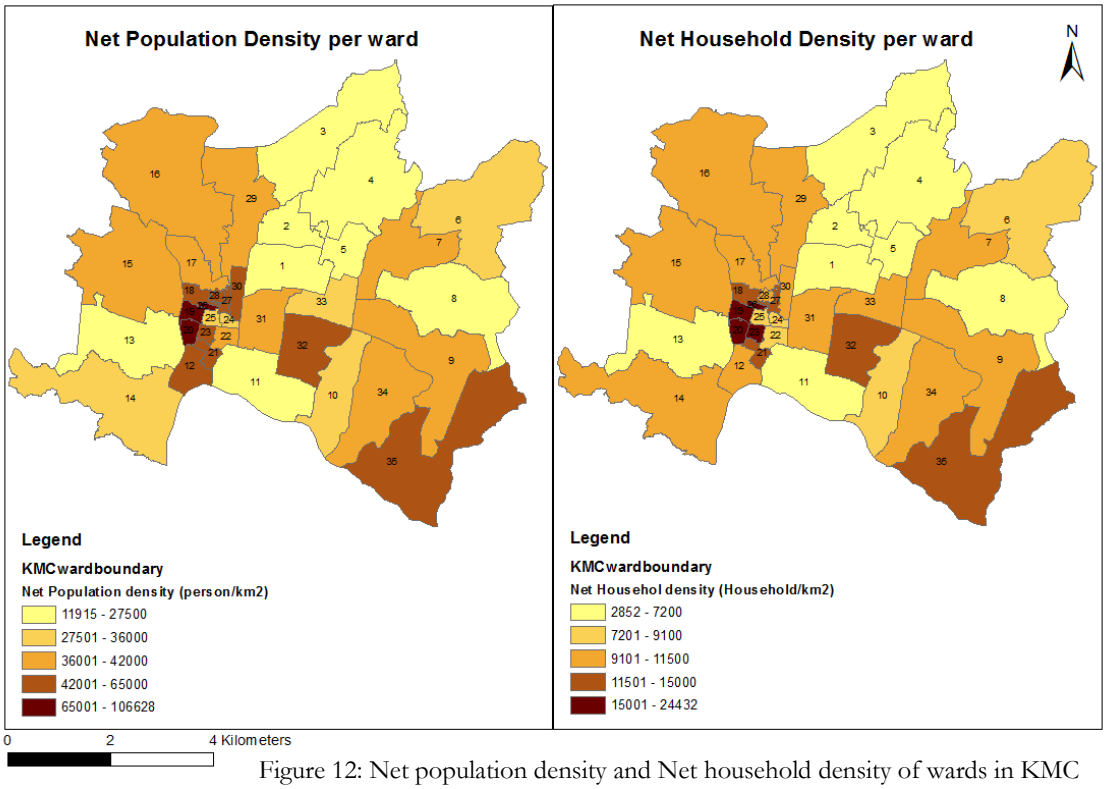

Figure 12: Net population density and Net household density of wards in KMC

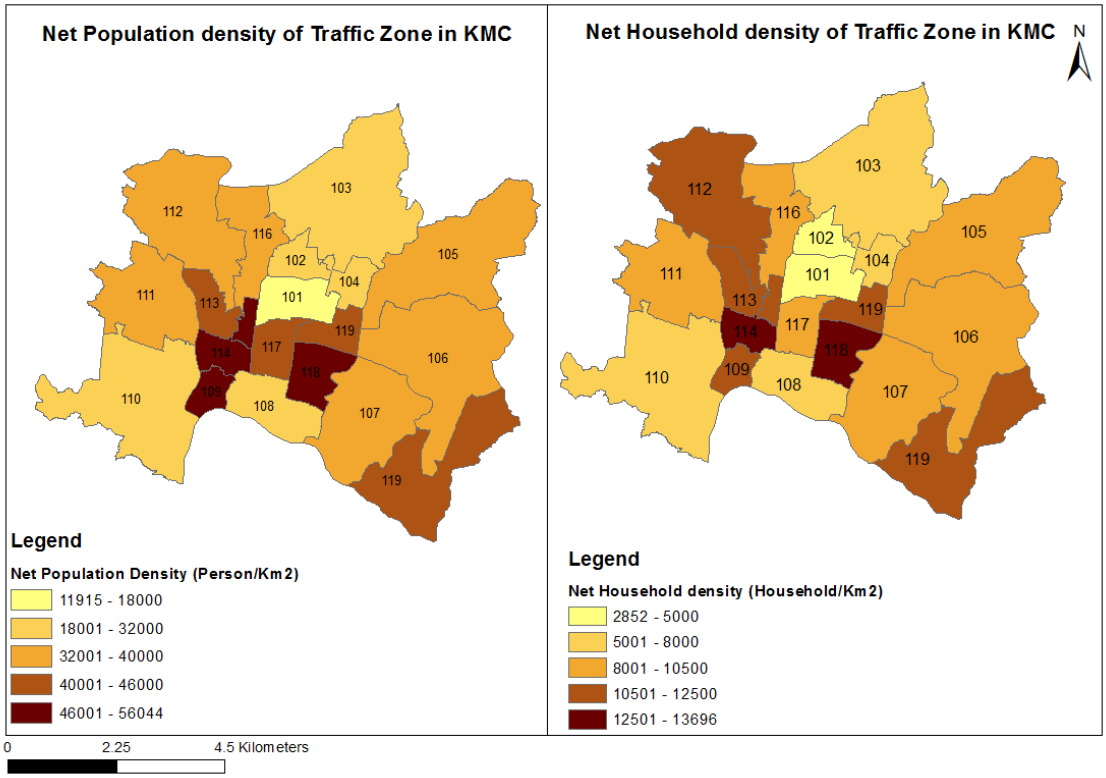

Figure 13: Net population density and Net household density of traffic zones in KMC

Due to different spatial unit for the primary and secondary survey data the population and household density cannot be compared from figure 12 which is at ward level. Therefore figure 13 illustrates the net population density and net household density for the traffic analysis zone.

5.4.2. Diversity

Diversity is measured in either the land use entropy or dissimilarity or the job-housing mix etc. as stated in section 4.7.1.2. Due to the lack of data on the job and the housing in the city the latter could not be used to measure the diversity of the city. The land use of the city is broadly classified with all the residential and commercial built up areas grouped into a single unit. The growth of the city has not allowed for the separation of the residential and commercial areas so it would be difficult to see the land use mix in the city. It is also possible to separate different built up uses through visual inspection as there is not much distinctive characteristics of these built up areas. Using the land use mix in this situation would not be very helpful to the research. Hence the research would not focus on the diversity of the urban form and would try to analyze the relation between other built form indicators and the travel behaviour.

5.4.3. Design

Design is the measure of the infrastructure provided in the city to aid in travel. The density of the transit stops and the density of the road network can give the overview of the design of the urban form.
From figure 14 illustrates the transit stop density which can be clearly seen to concentrate around the inner city area with fairly less concentration around the periphery areas. The transit stops include all the public vehicle stops around the city. The density of the transit stops seems to concentrate at certain location in the inner city area with the least around the outlying areas according to figure 14.

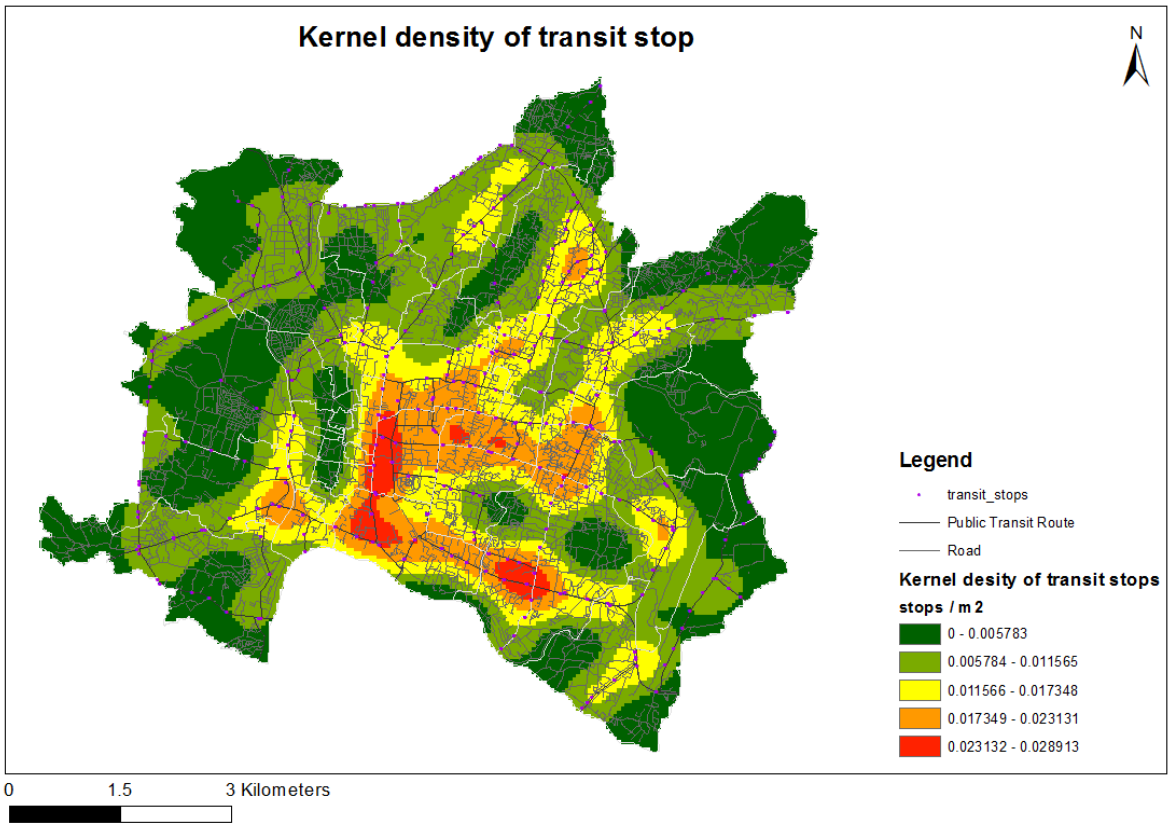

Figure 14: Kernel density of transit stops

The ward 23 neighbourhood 1 falls under the low transit density area which might be corresponding to its high private motorization choice as mode choice. This also is the case for the ward 2 neighbourhood 3 and ward 6 neighbourhood 5. The ward 34 neighbourhood 4 falls under partially high density and partially under low density. Though the ward 31 neighbourhoods 2 falls under the high density transit stop area it does not show an increase in public transport.

The road densities for the neighbourhoods are fairly similar with most of them falling under high density road network. The parts of neighbourhood 4 and 5 have the highest road density which might account for their fairly high non-motorized transport use.

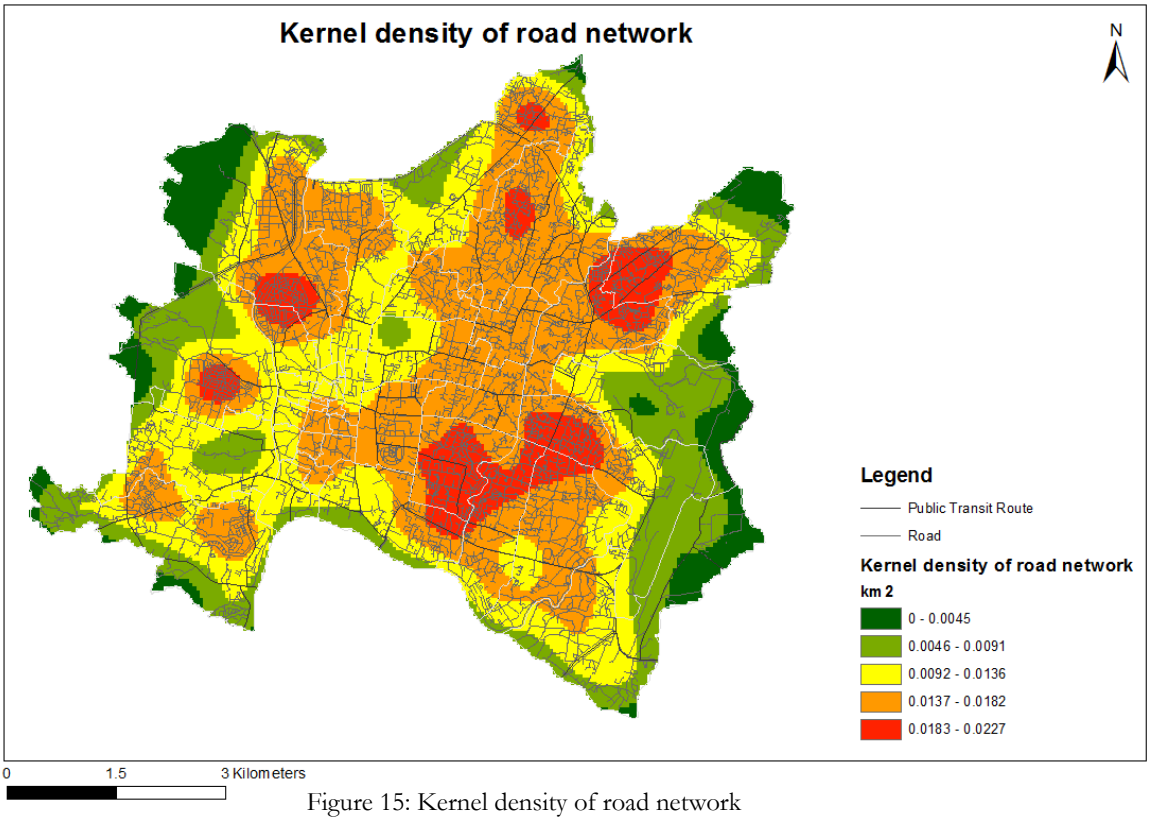

Figure 15: Kernel density of road network

5.4.4. Destination Accessibility

To illustrate the destination accessibility, the area has been divided into continuous buffer zones of distance ranging up to 6km with a center point as CBD. The distance of the center point of the CBD from each of these grid points give the accessibility of the destination. The Euclidean distance has been used to show the accessibility as though using network distance would have given more realistic result, the lack of road network data it could not be possible. Figure 16 illustrates the distance of the each zone to the CBD.

The ward 2 neighbourhood 1 being the closest and ward 6 neighbourhood 5 being the furthest the neighbourhood 1 shows the high rate of non-motorized transport mode choice and the neighbourhood 5 shows high rate of public motorized transport. Though ward 2 neighbourhood 3 is fairly good accessibility it has a higher rate of motorized transport mode choice this might be explained with other urban form measures.

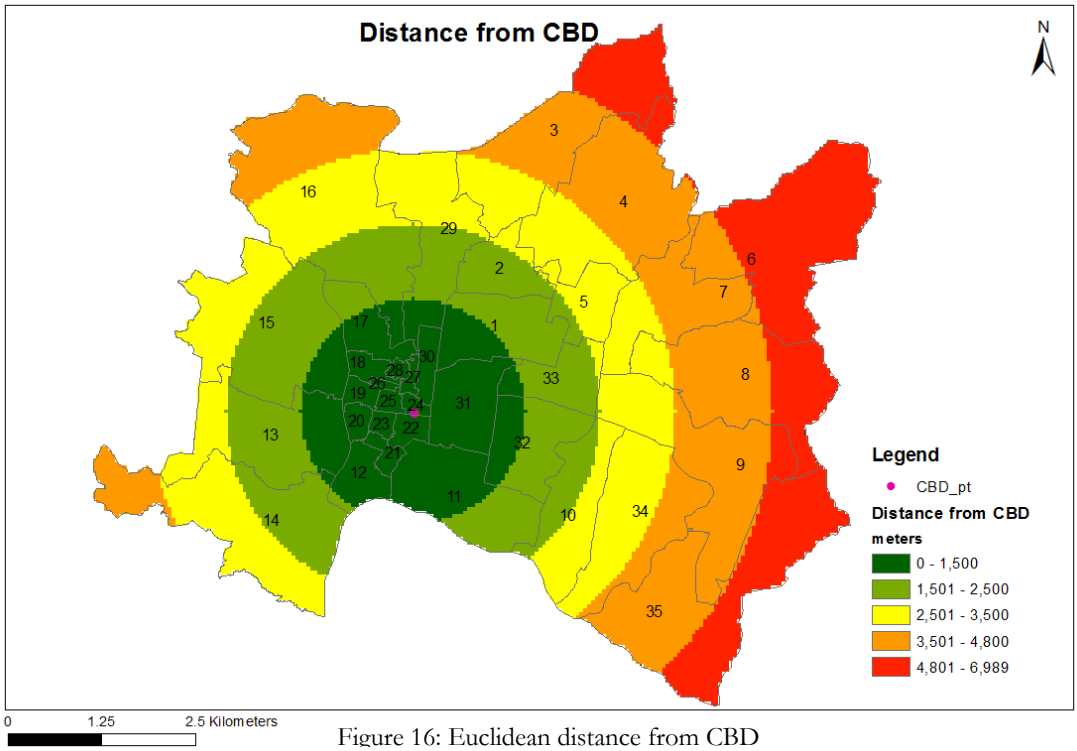

Figure 16: Euclidean distance from CBD

5.4.5. Distance to Transit

The figure 17 illustrates the Euclidian distance of the transit stops. From this figure it can be seen that the most of the inner city area is within the 500 m of the transit stops. There are few areas in the inner city which do not seem to be accessible to the transit.

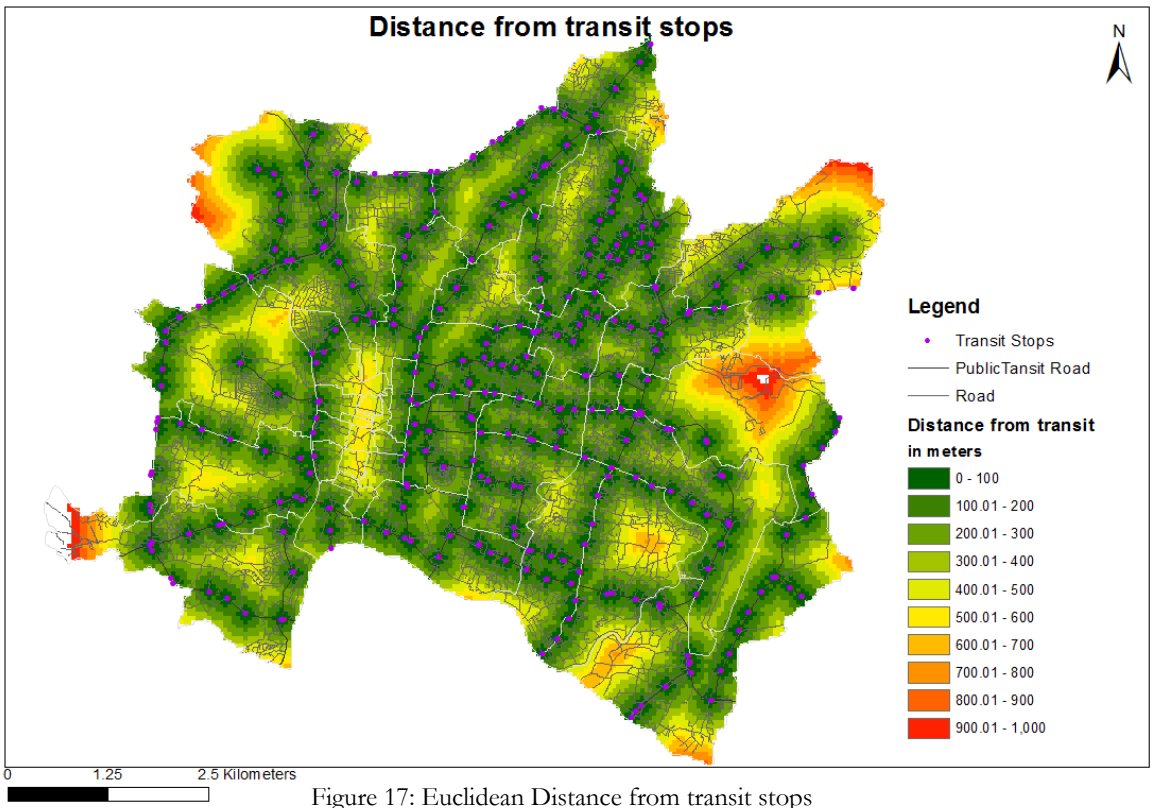

Figure 17: Euclidean Distance from transit stops

The ward 23 neighbourhood 1, parts of ward 2 neighbourhood 3 and ward 34 neighbourhood 4 are over the distance of 500 meters from the transit. Though the public transport choice in neighbourhood 3 is high but compared to its private transport mode choice it's still low and in neighbourhood 4 is low. The lowest public transport use is in the ward 23 neighbourhood 1.

5.5. Description of the Urban form

The urban form of the both the selected neighbourhood and the traffic zones of KMC are described below from quantification of the urban form in section 5.4.

5.5.1. Urban form of the five selected neighbourhood

According to the table 15 the five selected neighbourhood are ranked according to their urban form measure. The first neighbourhood 1 has high net population and household density with closest distance to the CBD. The neighbourhood has fairly good road density but has low transit stop density as well as lowest access to the transit stop.

Ward	Neighbour hood	Net Population density	Net household density	Transit stop density	Road network density	Distance from CBD	Distance from transit
		Person/km2	household/km2	m2	Km2	meters	meters
23	1	80,738	15,162	0.0377	0.0149	456	465
31	2	15,631	10,203	0.2155	0.0152	805	147
2	3	16,463	4,830	0.0809	0.0139	2,269	225
34	4	28,099	10,833	0.1048	0.0147	3,355	280
6	5	16,732	8,541	0.0416	0.0110	5,561	377

Table 15: Urban form matrix of selected neighbourhood

The neighbourhood 2 shows lower net population density with slightly higher net household density. This neighbourhood has the highest transit stop density as well as access to the transit. It is closer to the CBD with fairly good road network density.
The lowest net population density and net household density is in the neighbourhood 3 with low access to transit and low transit stop density. It has close proximity to the CBD with low road network density.

Neighbourhood 4 has the second largest net population and household density in the selection. It has good transit stop density but the access to the transit is limited in some of its parts. It has high road network density but is a fair distance from the CBD.

The neighbourhood 5 has fairly low net household and population density and is furthest from the CBD. Though it has high road network density, the transit stop density is low. The accessibility of transit is high in area.

5.5.2. Urban Form of the traffic analysis zone of KMC

The table 16 illustrates the urban form of different traffic zone of the secondary data in form of ranking. These zones are chosen for their different travel behaviour characteristic for which the changes in urban form would be discussed in the next chapter. The net population and household densities of the ZID 102 is the lowest with the medium road network density. The distance from transit and transit stop density is also comparatively low. It is closer to the CBD.

The ZID 105 has medium density of net population, net household with fairly high road network density. This zone is furthest from the CBD with low transit stop density and access to transit in some parts of this zone.

ZID	Net Population density	Net household density	Transit stop density	Road network density	Distance from CBD	Distance from transit
	Person/km2	household/km2	m2	Km2	meters	meters
102	18,048	4,830	0.008	0.014	2269	225
105	36,220	9,382	0.006	0.013	4962	323
107	37,488	10,029	0.012	0.015	3039	253
108	27,452	7,062	0.018	0.013	1380	193
109	51,218	12,453	0.014	0.011	1061	214
110	30,784	7,989	0.006	0.010	2496	263
111	37,949	9,818	0.004	0.010	2278	262
114	56,044	13,446	0.010	0.014	482	299
117	40,226	10,203	0.022	0.015	805	147
118	49,076	13,696	0.015	0.019	1670	177

Table 16: Urban form matrix of traffic analysis zone of KMC

With medium net population density and net household density the ZID 107 has fairly high road network density. It is at some distance from the CBD with medium transit stop density and low transit accessibility in some area.

The net population density and net household density of ZID 108 is low. It has the highest transit stop density as well as accessibility to the transit. It has medium road network density and is near to the CBD.

ZID 109 has highest net population density with fairly high net household density. It is close to the CBD with medium transit stop density and high accessibility to the transit. The road network density is also medium.

The net population density, net household density and transit density of ZID 110 are all low. The accesses to the transit and road network density both are medium though it is fairly close to CBD.

ZID 111 has medium net population density and net household density. The transit stop density is lowest with less access to the transit in some inner areas. The road network density at inner area is high but at the periphery is very low. The distance to the CBD is fairly high at the periphery of this zone.

The ZID 114 has both highest net population as well as net household density. It is also closest to the CBD but has low transit stop density and access to transit. The density of the road network is medium.

The net population density and net household density for ZID 117 are both medium. It has highest transit stop density and access to transit. The road network density is also fairly high and is close to the CBD.

This zone with ZID 118 has high net population density and highest net household density. It also has highly accessible transit with high transit stop density. The road network density is also high with close distance to CBD.

6. URBAN FORM AND TRAVEL BEHAVIOUR RELATIONSHIP FOR KATHMANDU

This chapter discusses the relationship between the urban form and travel behaviour based on the literature review and the results presented in the section 5. This will discuss the expected and the actual outcome of the analysis and attempt to form the link between the urban form and travel behaviour. This will also discuss the potential for changes in the urban form in KMC to aid the low carbon development in the transport sector.

6.1. Urban form and travel behaviour of the five selected neighbourhoods and traffic analysis zones

The travel behaviour indicator discussed in this chapter is mode of travel and purpose of travel. Other indicators such as trip distance and trip frequency are not discussed here since the trip distance across the city is not high enough to influence the travel behaviour and trip frequency is more dependent on socio economic characteristics as stated in section 2.3.

6.1.1. Non-motorized transport mode choice

The non-motorized transport i.e. walk is seen in both the primary data analysis and secondary data analysis as the major mode choice. From the five neighbourhoods, it can be seen that neighbourhood 1 has the highest walk percentage with neighbourhood 3 with the lowest. The neighbourhood 1 has high density of population as well as household providing area with high density of development. It is close to the CBD and has good road network density. The neighbourhood 3 has low density of development (net population and net household) as well as low road network density. The other neighbourhoods also have walk as the highest mode share.

Comparing the neighbourhood 2 and 3 it can be deduced that though they both have close proximity to the CBD the significant difference in the walk mode share could be explained by their difference in net population and household density as well as their road network density. The neighbourhood 4 and 5 have similar share of walk mode share as they both have similar density as well as road network density despite being further from CBD. This could be explained by the built up mix explained in section 5.2.2.4 and 5.2.2.5 as both have high residential retail mix leading most to have jobs locally with in the ward or neighbourhood.

In the secondary data analysis the ZID 109, ZID 114 and ZID 118 show high mode share of walk with high density measure, medium road network density and closer proximity to the CBD. There are some zones with low density of development but closer proximity to the CBD which have high walk mode share.

As stated in section 4.7.2 we can say that density measure has some influence on the use non-motorized transport in this case walk mode as well as the design measure (road network density indicator). But the most influencing dimension of urban form on walk mode is the destination accessibility measured by the indicator distance to CBD.

6.1.2. Private motorized transport mode choice

It is the second largest mode share in most of the neighbourhood and traffic analysis zone. The private motorized mode share in the two of the neighbourhoods i.e. 3 and 4 are high with highest in the

neighbourhood 3. The other neighbourhoods have similar share. Comparing and analyzing the urban forms of these neighbourhoods the distance show that the distance from transit of both neighbourhood is higher along with the distance to the CBD. Both the neighbourhood 3 with the highest mode share exhibits low density value. Both neighbourhoods have high rate of vehicle ownership.

In the neighbourhood 2 and 3, neighbourhood 2 has higher access to transit than neighbourhood 3 as well as is closer to the CBD. Hence it has lower mode share of private motorized transport. This case can be seen between neighbourhood 4 and 5 where though neighbourhood 5 is further from CBD it has higher access to transit. Therefore neighbourhood 4 has higher mode share of private motorized transport.

From the secondary data analysis, ZID 109 and 117 show higher mode share for private motorized transport despite having closer proximity to CBD and transit. ZID 117 has highest rate of vehicle ownership among the traffic zones and ZID 109 also has high vehicle ownership. On the other hand ZID 107 corresponds with results from primary data analysis as it has low accessibility to CBD and transit and high mode share of private motorized transport. This can be due to the socio economic characteristic of that zone which could not be determined through the secondary data analysis.

The private motorized transport can be influenced by the distance to CBD and transit i.e. higher the distance great would be the probability of travelers choosing private motorized transport. But this alone cannot explain the mode choice. It can be affected by the socio economic characteristics and vehicle ownership of the traveler.

6.1.3. Public motorized transport mode choice

The neighbourhood 3, 4 and 5 have improved mode share of public motorized transport mode as the other two neighbourhoods have very low public mode share. Comparing the two neighbourhood 2 and 3, though neighbourhood 2 has greater accessibility to transit as well as higher transit density, it has low mode share of public motorized transport mode. This may be explained by its great proximity to the CBD. Whereas neighbourhood 3 though does not have greater accessibility and density of transit, is further from CBD than neighbourhood 2. Similar is the case of neighbourhood 4 and 5 with neighbourhood 5 being furthest from CBD and better accessibility to transit than neighbourhood 4.

ZID 108 and ZID 117 are adjacent traffic analysis zones with greater accessibility to transit as well as greater proximity to CBD. Since the proximity of the CBD is expressed as Euclidean distance, the network distance of these zones will vary in reality. The density of the transit is also high hence the increased mode share of public motorized transport mode. The ZID 107 has high public motorized transport mode share even though it has medium transit stop density and low access to transit. This could be explained by the low proximity of the zone with CBD.

ZID 111 and 114 have very low public motorized vehicle mode share and they have correspondingly low transit stop density, low access to transit and high proximity to CBD.

The indicator transit stop density of design dimension and distance from transit are two of the most important factor affecting the choice of public motorized transport mode. But it is also affected by the distance to CBD as stated in section 4.7.2.

6.1.4. Trip Purpose and Trip mode

Trip purpose according to section 4.7.2 is the function diversity which could not be studied in this research. The trip purpose can also influence the trip mode. From the section 5.2.2and 5.3.2 it can be seen

that the most frequent trip purpose to be home bound trip. From the table 12 it can be seen that the increase in work purpose in neighbourhood 4 and 5 corresponded with increase in mode share of private and public motorized mode share. The same can be seen in table 14 with ZID 108 and 118 has increased work purpose as well as either increase in public or private motorized transport.

The selected neighbourhoods and traffic zones were analyzed using spearman's rank coefficient to verify if they show strong relationship between the indicators of urban form and travel behaviour. From the table 17, a significant relationship cannot be seen in most of the indicators though public motorized mode has strong negative correlation with net household density and non-motorized mode ($r=-.900$, $p< 0.01$). The increase in the household density decreases the use of public vehicles. It could be attributed to the decrease in the need to travel due to dense development. The increase in the public mode of transport decreases the need for non-motorized transport or walking decreases the need of public transport.

Correlations

			Net Population density	Net household density	Transit stop density	Road network density	Distance from transit	Distance from CBD	Non motorized Mode	Private Motorized Mode	Public Motorized Mode
Spearman's rho	Net Population density	Correlation Coefficient	1.000								
		Sig. (2-tailed)									
		N	5								
	Net household density	Correlation Coefficient	.700	1.000							
		Sig. (2-tailed)	.188								
		N	5	5							
	Transit stop density	Correlation Coefficient	-.700	-.200	1.000						
		Sig. (2-tailed)	.188	.747							
		N	5	5	5						
	Road network density	Correlation Coefficient	-.100	.600	.400	1.000					
		Sig. (2-tailed)	.873	.285	.505						
		N	5	5	5	5					
	Distance from transit	Correlation Coefficient	**-.900***	-.500	**.900***	.300	1.000				
		Sig. (2-tailed)	**.037**	.391	**.037**	.624					
		N	5	5	5	5	5				
	Distance from CBD	Correlation Coefficient	.100	.500	-.100	.800	0.000	1.000			
		Sig. (2-tailed)	.873	.391	.873	.104	1.000				
		N	5	5	5	5	5	5			
	Non motorized Mode	Correlation Coefficient	.300	.700	-.300	.600	-.400	.600	1.000		
		Sig. (2-tailed)	.624	.188	.624	.285	.505	.285			
		N	5	5	5	5	5	5	5		
	Private Motorized Mode	Correlation Coefficient	-.300	-.300	.500	.100	.600	.100	-.700	1.000	
		Sig. (2-tailed)	.624	.624	.391	.873	.285	.873	.188		
		N	5	5	5	5	5	5	5	5	
	Public Motorized Mode	Correlation Coefficient	-.400	**-.900***	.100	-.800	.300	-.700	**-.900***	.400	1.000
		Sig. (2-tailed)	.505	**.037**	.873	.104	.624	.188	**.037**	.505	
		N	5	5	5	5	5	5	5	5	5

Table 17: Correlation table of five neighbourhoods

The table 18 obtained from correlating urban form and travel behaviour of the traffic zones also do not show high correlation between many of the indicators, though the strong negative correlation between public motorized mode and non-motorized mode is the same. This table also shows private motorized mode and transit stop density have significant moderate positive correlation ($r=0.634$, $p<0.05$). This illustrates that the areas with higher transit stop density have higher use of private motorized mode though according to the hypothesis public motorized mode should have had this relationship with the transit stop density. The private motorized mode also has significant negative strong correlation ($r= -0.780$, $p < 0.01$)

with distance of transit (which is ranked lower the better). So with the increase in distance to transit the use of private motorized mode also increases.

Correlations

			Net Population density	Net household density	Transit stop density	Road network density	Distance from CBD	Distance from transit	Non motorized Mode	Private Motorized Mode	Public Motorized Mode
Spearman's rho	Net Population density	Correlation Coefficient	1.000								
		Sig. (2-tailed)									
		N	10								
	Net household density	Correlation Coefficient	**.952****	1.000							
		Sig. (2-tailed)	**.000**								
		N	10	10							
	Transit stop density	Correlation Coefficient	.243	.353	1.000						
		Sig. (2-tailed)	.498	.318							
		N	10	10	10						
	Road network density	Correlation Coefficient	.227	.442	.615	1.000					
		Sig. (2-tailed)	.528	.201	.058						
		N	10	10	10	10					
	Distance from CBD	Correlation Coefficient	-.564	-.467	-.614	-.233	1.000				
		Sig. (2-tailed)	.090	.174	.059	.517					
		N	10	10	10	10	10				
	Distance from transit	Correlation Coefficient	-.079	-.200	**-.833****	-.479	.479	1.000			
		Sig. (2-tailed)	.829	.580	**.003**	.162	.162				
		N	10	10	10	10	10	10			
	Non motorized Mode	Correlation Coefficient	.200	.030	-.559	-.380	-.115	.430	1.000		
		Sig. (2-tailed)	.580	.934	.093	.278	.751	.214			
		N	10	10	10	10	10	10	10		
	Private Motorized Mode	Correlation Coefficient	.186	.266	**.634***	.495	-.266	**-.780****	-.403	1.000	
		Sig. (2-tailed)	.607	.457	**.049**	.145	.457	**.008**	.249		
		N	10	10	10	10	10	10	10	10	
	Public Motorized Mode	Correlation Coefficient	-.456	-.304	.280	.114	.365	-.134	**-.900****	.068	1.000
		Sig. (2-tailed)	.185	.393	.432	.754	.300	.713	**.000**	.851	
		N	10	10	10	10	10	10	10	10	10

Table 18: Correlation table of selected traffic zones

In both instances the distance to CBD does not show any significant relation with travel behaviour indicators. This might be due to the assumption of CBD as a single district or zone. Formation of multiple centres of business and service centres around the city could also be taken in consideration.

7. CONCLUSION

This chapter is the summary of the research conducted and highlights its principal findings. It also discusses the limitation of the research and the recommendation for further research.

7.1. Summary of the findings

The concept of relating the urban form with the travel behaviour of an area to further the sustainable development of transport in that area is the main focus of this research. As explained in the section 1.5, the urban form of an area has an impact on the travel behaviour of the inhabitant of that area which can then be influenced to create a sustainable transport development.

Though the research could not prove conclusively the significant relationship between many of the urban form and travel behaviour measures, still it cannot be said that there is no relation between these measures. This research only studied the one to one relationship between the indicators but as said by Lin and Yang (2009), the complex relationship among the measures cannot be represented so. The relationships are multidimensional with each urban form indicator affecting other and then the travel behaviour. These are yet again constrained by the socio-economic factors of the studied population.

In general consensus results of the analysis of urban form and travel behaviour in section 5 can be interpreted to show that there is relation between the various urban form dimension and travel behaviour measure. The different mode choices i.e. non-motorized transport, private motorized transport and public motorized transport were seen to be dependent not only on one urban form dimensions but various interrelated dimensions. The private and public mode choice were seen to be affected by the design as in density of transit stop, access to transit as well as the access to the destination (CBD). High density of transit stops, easier access to the transit and larger distance to CBD encourages the use of public motorized transport mode. The larger distance to CBD but lower access to transit and low density of transit stops make private motorized mode share increase. The ownership of vehicles also has influence in choosing the private motorized transport.

The non-motorized transport for this research is walk mode is seen to be the largest share which is related to the road network density (design), distance to CBD (destination accessibility) as well as the density of development (density of population and household). With higher road network density, closer proximity to the CBD and high development density the probability of a traveller choosing walk mode is higher in KMC.

7.2. Limitation of the study

This research was conducted with the aim to understand the relationship between the urban form and travel behaviour. But there have been certain limitation which could not be overcome during the research. The first limitation is the different spatial unit of analysis of the primary and secondary data used. The primary data has been analysed on the neighbourhood level were as the secondary data has been analysed on traffic zone level. The primary data due to time constraint could only include trip information of the single individual of the household whereas the secondary data has trip information of every member of the household.

For urban form quantification the lack of proper data has only provided few indicators which could be used for the analysis. The lack of land use data, job distribution data and road network data made it necessary to simplify the quantification.

7.3. Recommendations

The research has shown that the non-motorized mode is the largest mode share but this only includes the walk mode whereas bicycle mode has insignificant share in it. The provision of bicycle tract in KMC could increase this mode share even more. The increase in accessibility of public motorized transport through increased bus and tempo routes in the areas with decreased transit stop density could provide shift in mode share especially on longer travel distance.

Though this research could not analyse the land use dynamics in relation to travel behaviour, it could not be wholly ignored. The land use or the diversity measure has been researched by many authors (Bertolini et al., 2005; Boarnet & Crane, 2001; Boarnet & Sarmiento, 1998) and is deemed as one of the major influencing factor. The land use should be planned with special focus on high density of development as well as transit oriented development. In case of the study area diversifying and regulating the land use to promote decentralized activities developing multiple commercial and employment hubs would decrease the need of travel. A centralized commercial and employment hub or CDB is not conducive for reducing travel or use of motorized travel mode.

7.4. Further research

This research has focused on understanding the relation between the urban form and travel behaviour in the Kathmandu Metropolitan city. This research had limited scope due to the lack of necessary data, therefore could only come up with a general relationship between the urban form and travel behaviour. This study has made a base to compare these two concepts and only briefly touch the low carbon development concept.

For further research, in depth analysis of the travel behaviour with smaller and uniform unit of measurement is recommended.

The quantification of the urban form dimensions that could not be dealt with in this research could give more perspective in the relation.

This research has only glanced upon the effect of socio-economic constraints upon the travel behaviour; further research could shed more light on the significance of this for development of sustainable transportation.

Further scenarios could be developed to check whether there are actual changes in travel behaviour with the change in urban form.

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8. ANNEXES

8.1. Questionnaire

House ID:	Sheet No:	

Name of the Interviewer:…… Date……

Ward No: …….. Street Name & House No:……

1. Name of Household head:…… Name of Respondent:……
2. How many people are there in the household? ……(Include the information of people over 18yrs old only)

Member ID	Age	Sex	Education	Marital status	Occupation	(S=SLC; I= Intermediate/+two; B= Bachelor; MA= Masters; L= Literate; IL= Illiterate)
1		M/F	S /I /B / MA/ L / IL	Married / UM		
2		M/F	S /I /B / MA/ L / IL	Married / UM		
3		M/F	S /I /B / MA/ L / IL	Married / UM		
4		M/F	S /I /B / MA/ L / IL	Married / UM		
5		M/F	S /I /B / MA/ L / IL	Married / UM		
6		M/F	S /I /B / MA/ L / IL	Married / UM		
7		M/F	S /I /B / MA/ L / IL	Married / UM		
8		M/F	S /I /B / MA/ L / IL	Married / UM		

(S=SLC; I= Intermediate/+two; B= Bachelor; MA= Masters; L= Literate; IL= Illiterate)

3. Is the house the respondent living in : Owned / Rented ?
4. How many year have they occupied the house they are currently living in?.....yrs
5. What is the approximate household income (Monthly Nrs):

Less than 15,000	15,000-30,000	30,000-60,000	More than 60,000

6. How many vehicles are owned in the household?

Car:		Motorbike:		Bicycle:	

7. What is the condition of parking space: Adequate \ Not Adequate?
8. How many stories are there in the house the respondent are living in? ……..
9. Built up use of the each floor of house:

Type of Building	Type I	Type II	Type III	Type IV
Use	Only Residential	Residential-Retail mix	Residential-Institutional mix	Residential-Retail- Institutional mix

10. Nearest distance to bus stop: ……..mins of walking distance (Please indicate the location of the bus stop: …….)

House ID:	Sheet No:	

Trip Information: (Of a single working day preferably one day before the interview)

Name : ……. Date: ……

Member ID:…….

Trip No:	Trip Start Information		Trip End Information		Travel characteristics			
	Start time	From	Arrival time	To	Purpose	Destination	Travel means	Travel made as
Trip1		Address: Ward No:		Address: Ward No:	▪ Work ▪ Work related ▪ Shopping ▪ School ▪ Home ▪ Recreational ▪ Medical ▪ Other ……. ….	▪ Home ▪ Work ▪ School ▪ Store ▪ Recreational Place ▪ Other …… …… ……	▪ Car ▪ Motorbike ▪ Bicycle ▪ School bus ▪ Public bus ▪ Micro bus ▪ Tampo ▪ Walk	▪ Driver ▪ Passenger ▪ No of person in vehicle:…….. ▪ If public transport Specify bus stop name…… …… ……
Trip2		Address: Ward No:		Address: Ward No:	▪ Work ▪ Work related ▪ Shopping ▪ School ▪ Home ▪ Recreational ▪ Medical ▪ Other ……. ….	▪ Home ▪ Work ▪ School ▪ Store ▪ Recreational Place ▪ Other…… ……	▪ Car ▪ Motorbike ▪ Bicycle ▪ School bus ▪ Public bus ▪ Micro bus ▪ Tampo ▪ Walk	▪ Driver ▪ Passenger ▪ No of person in vehicle:…… ▪ If public transport Specify bus stop name…… …… ……
Trip3		Address:		Address:	▪ Work ▪ Work related ▪ Shopping ▪ School ▪ Home ▪ Recreational ▪ Medical	▪ Home ▪ Work ▪ School ▪ Store ▪ Recreational Place ▪ Other	▪ Car ▪ Motorbike ▪ Bicycle ▪ School bus ▪ Public bus ▪ Micro bus ▪ Tampo	▪ Driver ▪ Passenger ▪ No of person in vehicle:…… ▪ If public transport Specify bus stop name……

		Ward No:		Ward No:	▪ Other	.....	▪ Walk	....
Trip4		Address: Ward No:		Address: Ward No:	▪ Work ▪ Work related ▪ Shopping ▪ School ▪ Home ▪ Recreational ▪ Medical ▪ Other	▪ Home ▪ Work ▪ School ▪ Store ▪ Recreational Place ▪ Other	▪ Car ▪ Motorbike ▪ Bicycle ▪ School bus ▪ Public bus ▪ Micro bus ▪ Tampo ▪ Walk	▪ Driver ▪ Passenger ▪ No of person in vehicle:..... ▪ If public transport Specify bus stop name..... ....
Trip5		Address: Ward No:		Address: Ward No:	▪ Work ▪ Work related ▪ Shopping ▪ School ▪ Home ▪ Recreational ▪ Medical ▪ Other	▪ Home ▪ Work ▪ School ▪ Store ▪ Recreational Place ▪ Other	▪ Car ▪ Motorbike ▪ Bicycle ▪ School bus ▪ Public bus ▪ Micro bus ▪ Tampo ▪ Walk	▪ Driver ▪ Passenger ▪ No of person in vehicle:..... ▪ If public transport Specify bus stop name..... ....

11. Would the respondent be willing to change the mode of travel from private vehicle to public or walking if:

i. work place was closer ii. market place was closer iii. roads were better iv. side walk were available

12. Would the respondent prefer to live in an area with more mixed use to decrease their travelling time? Yes / No

8.2. Research methodology

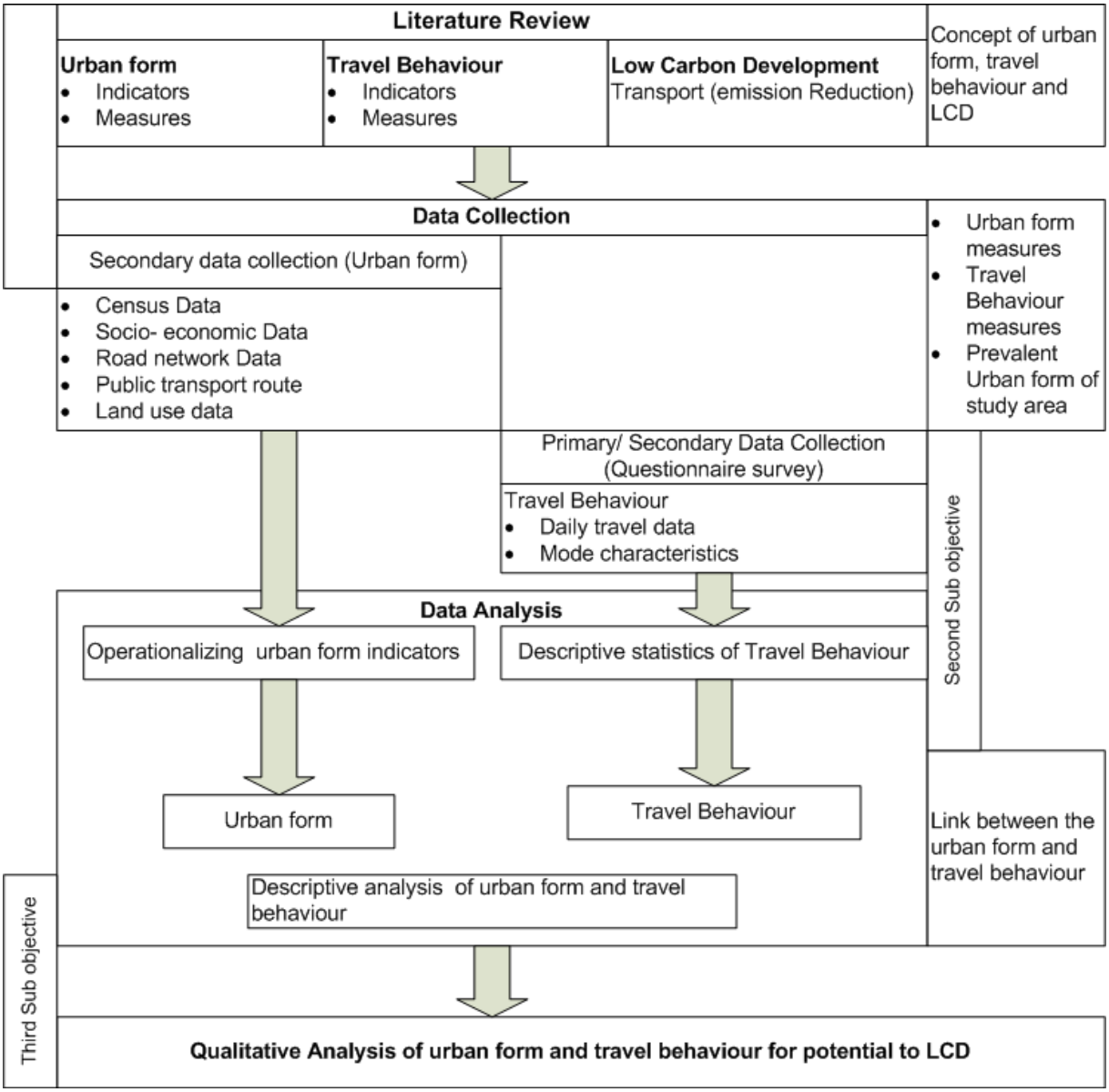

Figure 18: Research Methodology

8.3. Builtup (Zoning) Map of Kathmandu Metropolitan City

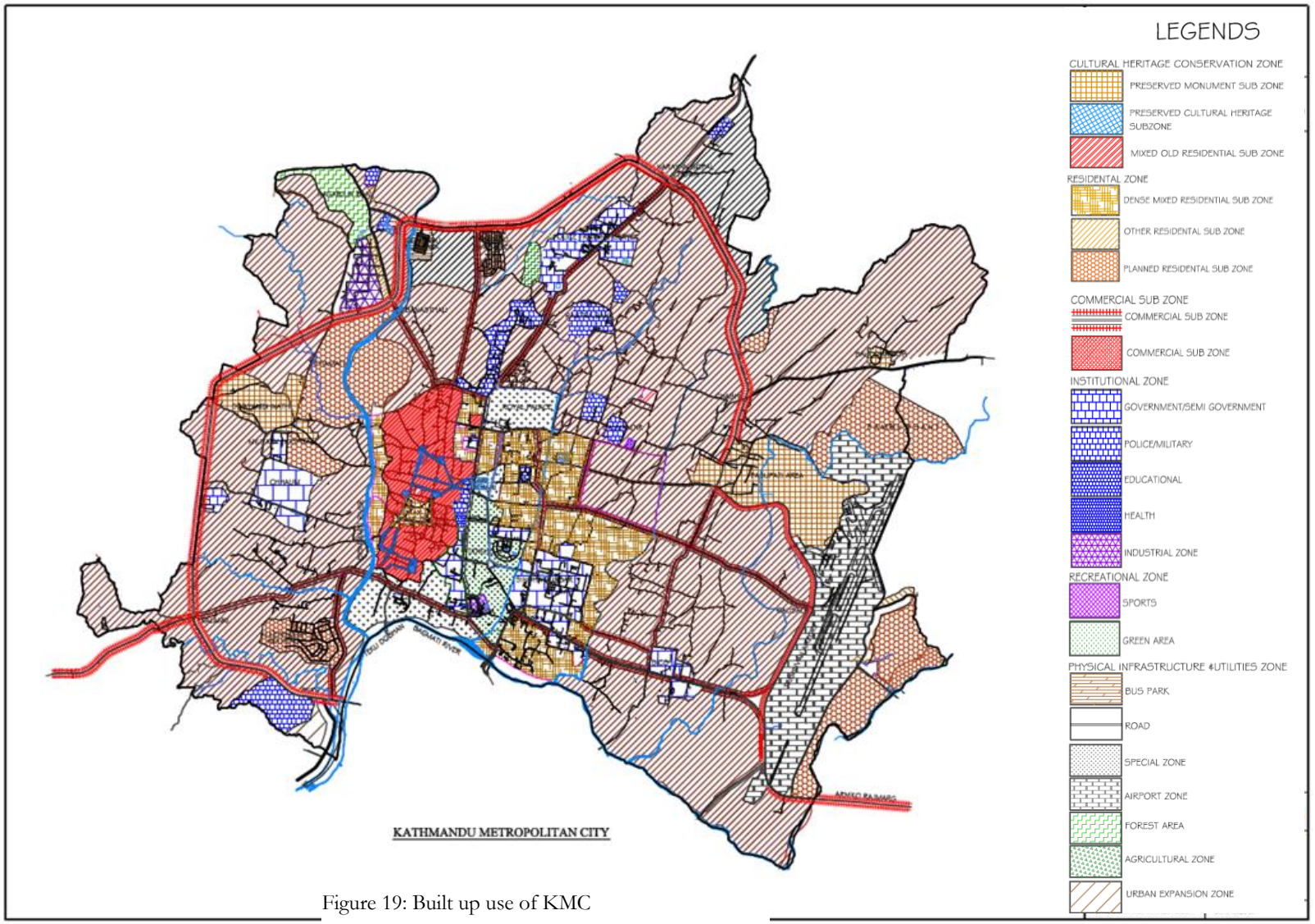

Figure 19: Built up use of KMC

8.4. Sampling of household for survey

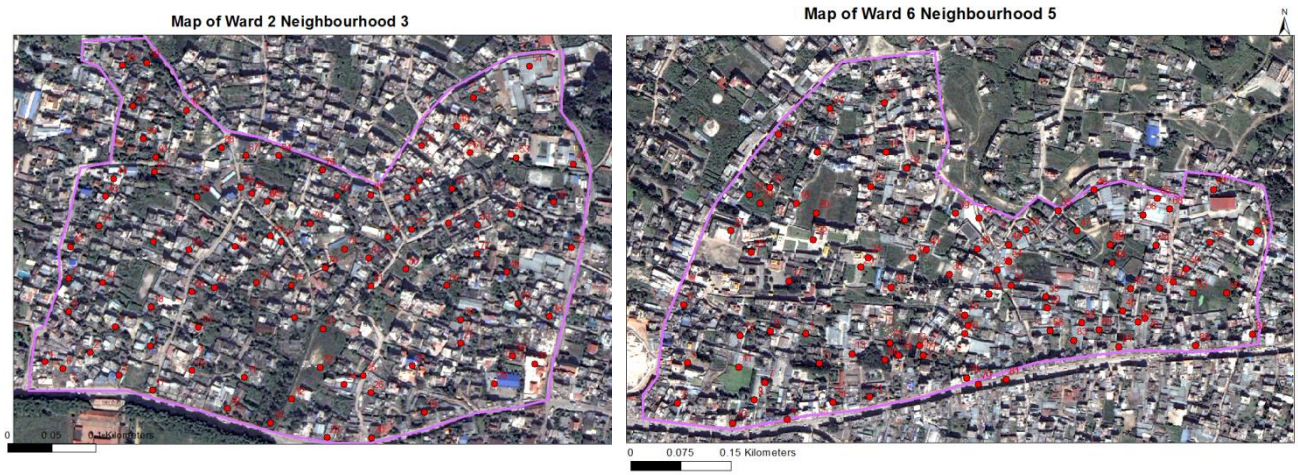

Figure 20: Sample points of households for survey in ward 2 and ward 6

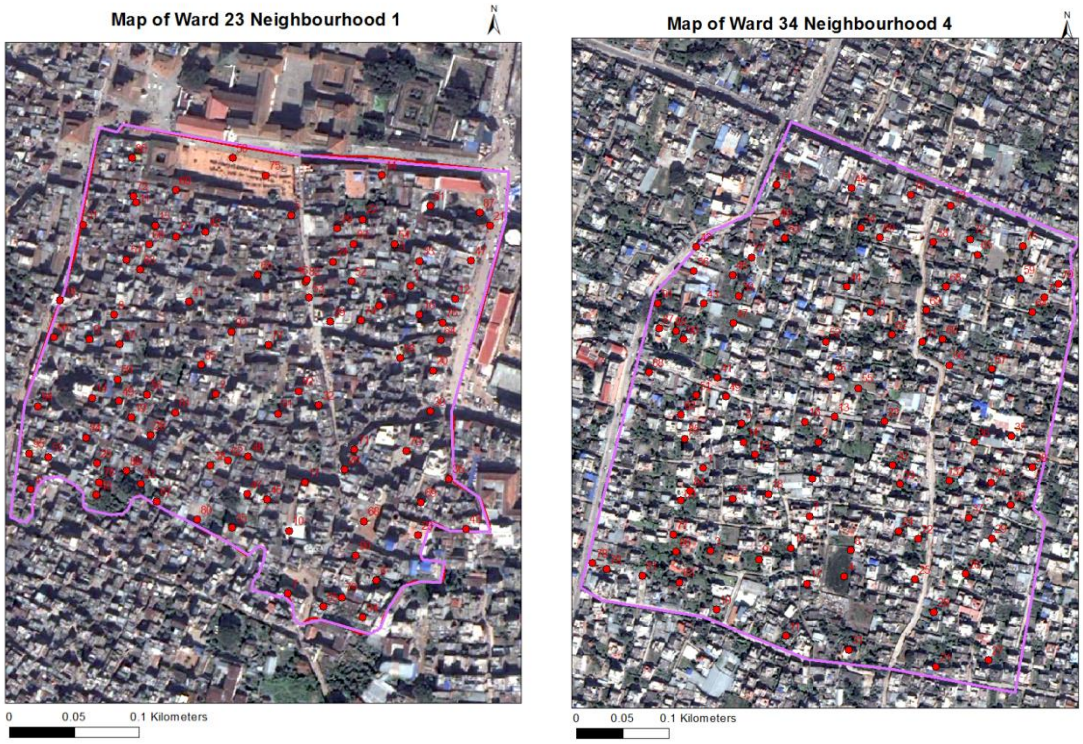

Figure 21: Sample points of households for survey in ward 23 and ward 34