LOW CARBON DEVELOPMENT IN TRANSPORT: USERS' PREFERENCES FOR PROPOSED SUSTAINABLE PUBLIC TRANSPORT OPTION IN KATHMANDU METROPOLITAN CITY, NEPAL.

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March, 2013

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EXECUTIVE SUMMARY

Anthropogenic climate change has become one of the most challenging issues all across the world and the global atmospheric concentrations of carbon dioxide (CO_2) have increased significantly. To address such issues, one of the emerging concepts in search of new development paths to reduce CO_2 emissions while keeping the economic growth, is Low carbon development (LCD). One of the significant sectors, where LCD can be followed, is transport since though it is an important component for people's welfare; it is responsible for severe environmental problems and contributes considerably to the climate change. To overcome this increased ecological threat, the policy makers have to focus towards more sustainable transport modes. However, only technological innovations and relevant policies are not the only solutions for LCD in transport; behavioural change will also be required. For the behaviour change, the preference of the users should be known to analyse the impact of the interventions otherwise such interventions may not be appropriate to be implemented. Although the transition to sustainable transport systems is considered as the preferred solution for LCD, the preference of the users and the factors determining their preference have to be researched to find out its actual performance and its impacts.

Despite such serious impacts, the issue of GHG emissions is being overshadowed especially in developing cities like in case of Kathmandu Metropolitan City (KMC), the capital of Nepal, which has been facing rapid urbanization and population growth over the decades and hence the demand for energy has been increasing at rapid rate resulting in air pollution as a major problem in recent years. There is an urgent need to understand "what works" in policy terms in KMC to encourage behaviour shifts for transport energy reduction in both shorter and longer terms. To understand any kind of behaviour is to know how the decision maker values and reacts to the information that is available. Therefore, a stated preference (SP) survey was conducted for work trips of 520 samples among five different major travel mode users with three attributes and three attribute levels to analyze the preference of the users and modal shift potential.

In case of KMC, public transportation (PT) services should be improved according to the coverage, frequency and hours of operation by assigning the appropriate vehicles to appropriate routes since people of KMC have been more inclined towards private modes than public ones. There should be rationalization of the vehicle fleet for the convenience and comfort of the users. Reintroduction of a Trolley Bus (TB) service has been recommended by the transport professionals in current scenario in KMC. While comparing the current modes the users are using and proposed public bus system (PPBS) through SP survey, from utility modelling, it was found that with the increase in comfort level, the relative attractiveness of the proposed mode can be increased. Similarly, travel time was found more valuable for private mode users while travel cost for public mode users. Therefore, the proposed public bus system was found to be more attractive than the current modes except for car.

Moreover, there is considerable willingness to shift from existing public modes to proposed mode PPBS. However, 90% of the car users are not willing to shift while about 78% of the motorbike users are willing to shift to proposed public bus. With the use of ASIF modal from the mode shift approach, it has been found that if PPBS will be implemented in KMC; there will be 48% of decrease in CO_2 emissions per working day which is a significant decrease. If more car users will shift to the new system, it will contribute most to the reduction in CO_2 emissions, then bike and then public transportation modes – tempo, then bus and microbus. In case only the motorbike users will shift, it will contribute significantly for the reduction in CO_2 emissions since the number of motorbike users is increasing rapidly in context of KMC. Therefore, the implementation of such low emission public transport should be encouraged, promoted and implemented in the study area to contribute to LCD. In addition to the reduction of CO_2 emissions, the modal shift to new public transport system will contribute towards the development of the transport system contributing to the lifestyle of the residents and enriching the environment of the study area.

In summary, this research has focussed only on emissions of CO_2 but other GHG have not been included and the result is based only on the sample population to whom the SP survey was conducted. In addition, the result is the outcome of the way choice sets were presented as there may be small variations if they would have been presented differently. Moreover, though the study is limited on a relatively small population and working class only as a proportion of the whole city, the results suggest that any new improved public transport system like trolley bus will be successful in encouraging modal shift which will have significant reduction in CO_2 emission contributing to LCD in the study area.

Keywords: *Low Carbon Development, Stated Preference, Utility Model, Choice sets, Travel Behaviour, Public transportation, Trolley Bus, Modal shift.*

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Reshma Shrestha
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LIST OF ACRONYMS

ADB	Asian Development Bank
ASC	Alternative Specific Constant
ASI	Avoid-Shift-Improve
ASIF	Activity Structure Intensity Fuel
Avg	Average
BRT	Bus Rapid Transit
CBS	Central Bureau of Statistics
CO_2	Carbon dioxide gas
DOR	Department of Road
DOTM	Department of Transport Management
EV	Electric Vehicle
GHG	Greenhouse gas
JICA	Japan International Cooperation Agency
KMC	Kathmandu Metropolitan City
KSUTP	Kathmandu Sustainable Urban Transport Project
LCD	Low Carbon Development
LDV	Light Duty Vehicles
LR	Likelihood ratio test
Min	Minutes
MNL	Multinomial Logit Model
Pkm	Passenger Kilometre
PPBS	Proposed Public Bus System
PT	Public transportation
ϱ^2	rho-squared
RP	Revealed Preference
SP	Stated Preference
STI	Sustainable Transport Initiative
TB	Trolley Bus
TC	Travel Cost
TT	Travel Time
Veh km	Vehicle kilometre

1 INTRODUCTION

This chapter discusses the contextual scenario of the research with its general introduction and its background with relevant justification. It includes the necessity behind this research with its main objective and sub-objectives with their respective research questions. This chapter also includes the overall concept, the methodology and research design used in this research along with the whole structure of this research.

1.1 General Introduction

The changes in the atmospheric abundance of greenhouse gases and aerosols which lead to change in energy balance of the climate system is climate change (IPCC, 2007). Climate change can occur due to various reasons, one of which is human induced, called Anthropogenic Climate Change, such as air pollution, which has become one of the most challenging issues all across the world. The global atmospheric concentrations of carbon dioxide (CO_2), methane and nitrous oxide have increased significantly due to the accumulation of continual combustion of fossil fuels and land use changes over the years (Chapman, 2007).

To address the climate change, one of the emerging concepts developed in search of new development paths to reduce CO_2 emissions while keeping the economic growth, is Low carbon development (LCD) (Yuan *et al.*, 2011). In report of "China's Low-carbon Development path to 2050", the Energy Research Institute of China National Development and Reform Commission defines LCD as the development of social - economic system which can realize low-carbon emissions (Yuan *et al.*, 2011). Hence, the main concept of LCD is to reduce CO_2 emissions as much as possible along with the economic development at the same time.

There are many sectors such as industry, agriculture, household, socio-economic system, where LCD can be followed, one of which is transport. Even though transport is an important component for people's welfare as it facilitates physical movement of goods and individuals for certain purpose, it is responsible for severe environmental problems like air pollution and contributes considerably to the climate change. According to Chapman (2007), transport contributes 26% of global CO_2 emissions with road transport consuming 81% of total energy used in transport sector which are expected to be higher and unlikely to keep pace with the increasing travel demand.

More frequent and longer use of vehicles are being generated (Hickman *et al.*, 2011), which will increase greenhouse gas (GHG) emissions remarkably over the next decades in the world. Against this continuous increase, it will be very difficult to reduce CO_2 emissions even with significant improvements in vehicle technologies since those improved vehicles will ultimately increase the travel distance. Hence, to overcome this increased ecological threat, Cools *et al.* (2009) suggest that the policy makers have to focus towards more sustainable transport modes. Therefore, sustainable transport modes can play a significant role for the reduction of GHG emissions and increment of the economical condition of a country.

Though the issue of GHG emissions requires immediate actions, it is being overshadowed especially in developing countries since economic development, poverty reduction; living standard improvements and social welfare are their first and immediate priorities. For instance, Kathmandu, the capital of Nepal, has been facing rapid urbanization and population growth over the decades and hence the demand for energy has been increasing at rapid rate (Shrestha & Rajbhandari, 2010) resulting in air pollution as a major problem in Kathmandu in recent years.

Even though formulation of sustainable transport policy is the significant measure for reduction in CO_2 emissions, the measures related to individual daily mobility are not being implemented despite of their likely contribution towards lower GHG emissions (Prillwitz & Barr, 2011). More fundamental behavioural changes are required which can change attitudes, perceptions, motivations, aspirations and ultimately their travel and lifestyle choices (Anable *et al.*, 2006). According to Anable *et al.* (2006), there is an urgent need to understand and deliver "*what works*" in policy terms to encourage behaviour shifts for transport energy reduction in both shorter and longer term. To achieve this, there should be specific understanding and ability to monitor how attitudes translate into actual travel choices. According to Gaker *et al.* (2011), to understand any kind of behaviour is to know how the decision maker values and reacts to the information that is available.

In this context, Hickman *et al.* (2012), while examining the potential for lower CO_2 emissions in transport in Oxfordshire, UK and assembling policy measures, packages, scenarios and frameworks for wider sustainability and lower CO_2 transport impacts, raised important question of preferences. Despite of all the studies done so far, there are still major difficulties in analysing preferences of the users to contribute meaningfully to transport sustainability.

Consequently, technological innovations and relevant policies are not the only solutions for LCD in transport; behavioural change will also be required. For the behaviour change, the preference of the users should be known to analyse the impact of any interventions otherwise such interventions may not be appropriate to be implemented. Although the transition to sustainable transport systems is considered as the preferred solution for LCD, different aspects have to be researched to find out its actual performance and its impacts. In summary, intensive research is still needed for the analysis of the preferences of the users for the sustainable transport options.

1.2 Background and Justification

Kathmandu Metropolitan City (KMC), the capital city of Nepal, is the most important commercial and administrative hub in the country. According to national census 2011 (CBS, 2011), the total population of KMC is nearly half of the total population of whole country. Since last decade, KMC is undergoing rapid urbanization, high population growth, urban sprawl and increased motorization which has led to the problems of congestion, pedestrian/vehicular conflict, environmental degradation, road accidents and poor public transport operation and services. The number of cars have reached 450,000 in 2009, a 13% increase since 2008 and if this trend continues, the air quality will deteriorate and the volume of GHGs, estimated 386,000 metric tons per annum, is likely to exceed 1 million tons in 10 years (ADB & MoPPW, 2010).

Because of their low cost and high mobility on congested and narrow roads, the two wheeler population is dominant in KMC whose share gradually increased from 51% in 1988 to 69% in 2000 (Dhakal, 2003). The next highest growth rate is of Light-duty vehicles (LDVs) like cars, vans and jeeps, minivans and micro vans with the highest share of 30% in total demand of 2000. The majority of travel demand, 57%, is met by Public Transport (PT) modes but it comprises only 19% of the total share (Dhakal, 2006). However, the existing PT modes are not serving well, not sufficient, inefficient, overcrowded (ADB & MoPPW, 2010) and users feel discomfort, unsafe, tiring and time consuming while travelling in PT. Currently, PT facilities are being operated through numerous individual private operators that are often poorly assigned to routes (ADB & MoPPW, 2010). Therefore, people are more opting for private vehicles than mass transit public buses producing majority of the emissions.

To eradicate such problems and to address the urban mobility requirements of KMC, a project for sustainable urban transport in Kathmandu valley called Kathmandu Sustainable Urban Transport (KSUT) has been proposed addresses many transport sectors, one of the subsectors being the Public Transport (MoPPW & ADB, 2010a). According to KSUT, for the improvement of public sector, one major vision can be the reintroduction of more ambitious infrastructure project of trolley-bus (TB) services to ensure the upgrading and future sustainability of PT in KMC. Shrestha (2012) also showed that even 5% shift from private to PT with combined package of penetrating TB system with PT improvement plans will decrease the emissions by 27% and with only TB renewal plans by 42%.

However, there are many factors that influence the mode choice of people such as their socio-economic characteristics, travel time, travel fare, comfort, safety, reliability, convenience, etc. For the better understanding of people's choices on modal split, there is a need of user preference study. In case of KMC, though TB system is viewed as preferred solution to address LCD and urban mobility problems, its implementation cannot be guaranteed as a success. Many aspects have to be taken into consideration from socio-economic perspective, its actual performance and potential impacts especially in developing country like Nepal, where other factors like poverty alleviation, education, developing infrastructures, *etc* are considered more urgent. Hence, the potential shift of the proposed sustainable option needs a research focussing on the preferences of its potential users in KMC evaluating its impact on LCD.

1.3 Research Problem

Promoting LCD in transport, especially in developing cities like KMC, helps to prioritize the development paths and investments by minimizing global climate impacts. On the other hand, the quest of greening the system through mega projects is bound to create employment, improve infrastructure, reduce congestion, maintain social equality and hence reduce carbon emissions (Mulugetta & Urban, 2010). However, the probable impact on LCD due to such projects needs to be researched before implementing any kind of interventions.

Few researches have evaluated CO_2 impacts of urban transport future scenarios (Dhakal, 2006; Pradhan *et al.*, 2006; Schipper *et al.*, 2007; Cuenot *et al.*, 2012) and investigated the role of transport interventions and prospects for modal shifts in transport for mitigating CO_2 emissions. However, the behavioural and lifestyle aspects are not researched much compared to the technological aspects in case of KMC, which is necessary for reasonable balance of study of any intervention (Dhakal, 2006).

Pradhan *et al.* (2006) estimated the effects in fuel consumption and GHG emissions from possible intervention of the TB system up to the year 2025 in Kathmandu Valley by analysing the energy and emission scenarios based on travel demand as a function of population and income and future projection of the vehicle activity but not based on users' preference. Similarly, Shrestha (2012) evaluated LCD Plans for KMC and verified the potential towards LCD from the combined package of penetration of TB renewal with PT improvement plans from supply perspective not from demand aspects.

Though TB system has been successful in many cities (Rafter, 1995), people with different socio-economic conditions can have different behavioural characteristics which may affect the willingness of the people to use this system in KMC. Therefore, the willingness to shift of different groups of a society to the proposed TB system needs to be analysed before implementing it since the final choice of mode depends on people's preference, attitudes and behaviour.

Despite of increasing recommendations on implementing TB in KMC, the impact of TB implementation on LCD due to the potential modal shift based on user preferences has not been researched so far which is major analysis part if such system is being implemented. Hence, this research will address the query of how much people are willing to shift to any proposed sustainable transport system and how this will affect LCD in KMC in terms of modal shift situations.

1.4 Research Objectives and Questions

1.4.1 Main Objective

The main objective of the research is to analyse the possible effect on low-carbon development by analysing the potential shift to the proposed trolley bus system based on user preference in KMC.

1.4.2 Sub Objectives and Questions

Table 1-1 below shows the sub-objectives and corresponding research questions to be answered.

Table 1-1: Research Sub-Objectives and Questions

Sub-Objective	Research Questions
To identify the demand for the public transport and travel behaviour of the people in the study area.	What is the condition and demand of current public transport system in the study area? How does the travel behaviour of the people vary as per socio-economic situation?
To examine users' preferences towards transition to the proposed public transport system.	What are the main attributes that define the choice of a particular transport mode in context of the study area? How do the different socio-economic groups value the proposed public transport system characteristics based on their preferences?
To assess the possible modal shift based on the performance of proposed public transport system attributes.	What will be the likeliness for users to shift from the existing transport modes to the proposed public transport system? How effective is the proposed public transport system in relation to users' preference?
To evaluate the impact of proposed public transport system on LCD.	How to evaluate the impact on LCD from proposed public transport system? What will be the impact of proposed public transport implementation on LCD due to potential modal shift based on user preferences?

1.5 Conceptual Framework

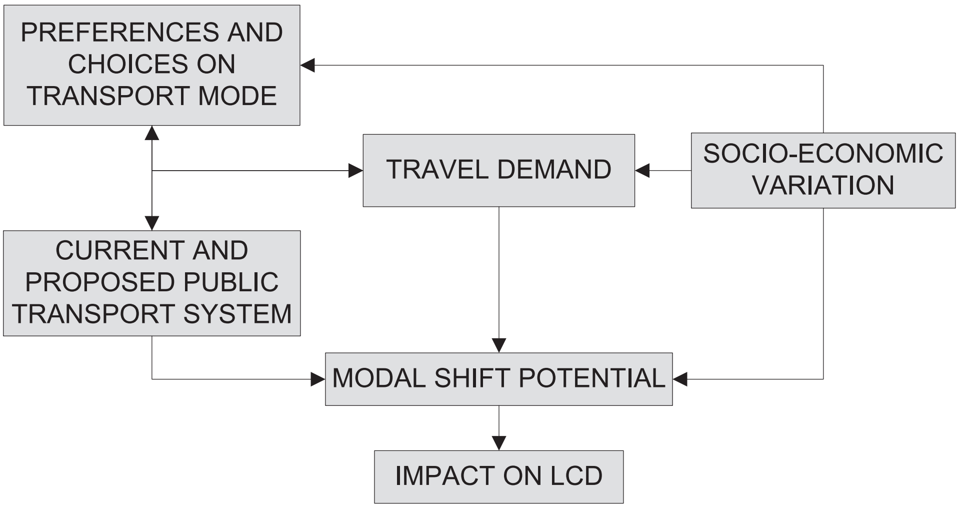

Figure 1-1: Conceptual Framework

Figure 1-1 above shows the conceptual model of the major components and their interaction for the research. The idea of this research is based on the effect of preference of different socio-economic groups for choice of transport modes and its impact on LCD, put forwarded as gap in research on evaluation of LCD plans in KMC by Shrestha (2012). In this regard, the choice of users depends on their characteristics and preferences of the travel attributes (Hensher *et al.*, 2007; Nkurunziza, 2008) and the travel demand varies according to the socio-economic variation (Dhakal, 2003, 2006; Bajracharya, 2008). Based on the demand for high quality service with affordable price, a sustainable public transport system called Trolley Bus (TB) has been proposed in KMC considering the environmental threat due to the increased emissions in the city (MoPPW & ADB, 2010a). However, the proposed system should be able to fulfil the travel demand and preferences of different socio-economic groups to achieve its objective and simultaneously contribute to LCD. Thus, if the proposed TB or any improvised proposed public bus system (PPBS) is found both considerably effective to the users' preferences and also to LCD, then it is recommended for implementation otherwise improvements of the system are proposed and reasons behind the result are discussed. The methodology is elaborated in research design methods section (See section 1.6).

1.6 Research Design and Methods

The research approach is the case study in KMC since the research is about the preference of people of that particular city.

1.6.1 Research Design Operational Plan

The Figure 1-2 below outlines the operational plan adopted for the research which is divided into five phases according to the sub-objectives and answers to the research questions to be achieved.

Phase I (Conceptualization): The first phase comprises of the theoretical concept development on user preference and LCD analysing the available data in KMC which relies largely on literature review. Such analysis helps in identifying the scope and availability of data which determines the general overview of the research.

Phase II (Pre-Field Work): The second phase covers the pre-field work preparation. Choice sets and socio-economic survey questionnaire are prepared and the sources of required data are sorted out in this phase.

The attributes for the choice sets are determined from the context of study area and literature review. Sampling strategy, sample size, survey location and survey design are also determined during this phase.

Phase III (Data Collection): The third phase is the data collection and stated preference survey (Refer to section 2.5.1) to examine the user's attitude towards transition to proposed transport system. The relevant data are collected from concerned departments of KMC - Kathmandu Sustainable Urban Transport Project Office, Central Bureau of Statistics, Department of Transport Management, Kathmandu Metropolitan City Office, *etc*.

Phase IV (Data Analysis): The fourth phase basically is the analysis and processing of the collected data. There are four steps corresponding to each sub-objective.

The first step (*sub-objective 1*) is the qualitative analysis of both existing and proposed PT system in KMC which relies largely on literature review and analysis of available data. It identifies the condition of existing transport system, PT system and demand of the PT system in KMC. The documental analysis of proposed Kathmandu Sustainable Urban Transport Report and other secondary data are summarized. The socio-economic and travel characteristics of the sample population from the result of socio-economic questionnaire are analyzed statistically.

The second step (*sub-objective 2*) examines the users' attitude towards transition to proposed transport system. It includes data processing for modelling, utility modelling and analysis of the model outputs. The utility function of proposed public transport system attributes are derived and utility model is estimated to get the utility parameter values. The attributes defining the choice of a mode are determined from the stated preference data and utility modelling. In addition, the attributes that affect the choice of the mode per socio-economic aggregation level are determined. Then, the likeliness of using the proposed public transport system is assessed.

The third step (*sub-objective 3*) is the assessment of the possible modal shift based on the performance of the proposed public transport system attributes. Thus, the potential modal shift towards proposed transport system is known and the effectiveness of the proposed public transport system is discussed.

The fourth step (*sub-objective 4*) is the evaluation of the impact of the potential modal shift based on user preference on LCD. From the data collected, modelling outputs and literature review, the required data are processed for the impact evaluation for analyzing the impact of proposed public transport system and modal shifts on CO_2 emission levels. Finally, the extent to which the travel pattern will change from users' preference and its impact on CO_2 emissions are known.

Phase V (Result and Discussion): The fifth phase is the qualitative analysis of their potential to LCD by analysing the potential modal shift from the users' preference. Finally, conclusions, policy implications and recommendations are drawn for further research.

1.6.2 Research Matrix

The research matrix consists of the detail data required, their source, methods to be applied to answer the research questions posed and their expected output which is further explained in Table 8-1 in the appendices section.

1.7 Thesis Structure

The thesis comprises of following chapters in following sequence:

Chapter 1: Introduction: This includes general introduction including background and justification, research problem, research objectives, research questions, research design and general overview of how the research aims to achieve its objectives.

Chapter 2: Literature Review: This includes theoretical background for the study, concepts of travel pattern and behaviour, sustainable transportation, LCD, consumer travel and choice behaviour, choice analysis and CO_2 emission estimation.

Chapter 3: Data Collection and Analysis: Approach and Methodology: This presents the data collection methods used, pre-field work stage with the detail of preparation of choice sets, field work stage, data collected and post field work stage with overall data analysis procedure followed. This briefly also includes the general description of the study area, its land use and road network.

Chapter 4: Document Analysis: Current Situation and Demand of Public Transportation in KMC: This includes the background of the transport system in KMC, its existing situation and its public transport system situation with its demand. It also briefly explains about the KSUT Project in which the research is based and TB system being recommended in KMC.

Chapter 5: Socio-economic and Travel Characteristics of Sample Population: This includes the socio-economic characteristics and travel behaviour of the sample population with some discussion in comfort issues.

Chapter 6: User Preference and Impact of Modal Shift on LCD: Results and Discussions: This includes outputs of the utility modelling; model estimation based on sample population, based on socio-economic differences and between different modes and proposed mode. Thus, this explores the attributes defining the choice of mode for the whole sample and for different socio-economic groups. This further includes the analysis of user preference based on socio-economic characteristics towards the proposed transport system. In addition, this comprises of the analysis of the potential modal shift towards proposed transport system. Finally, this chapter provides the impact of the potential modal shift based on users' preferences on LCD by estimating the CO_2 emissions from potential modal shift.

Chapter 7: Conclusion and Recommendations: This includes the conclusion of the results of the research, its limitations and recommendations for further research directions and policy implications.

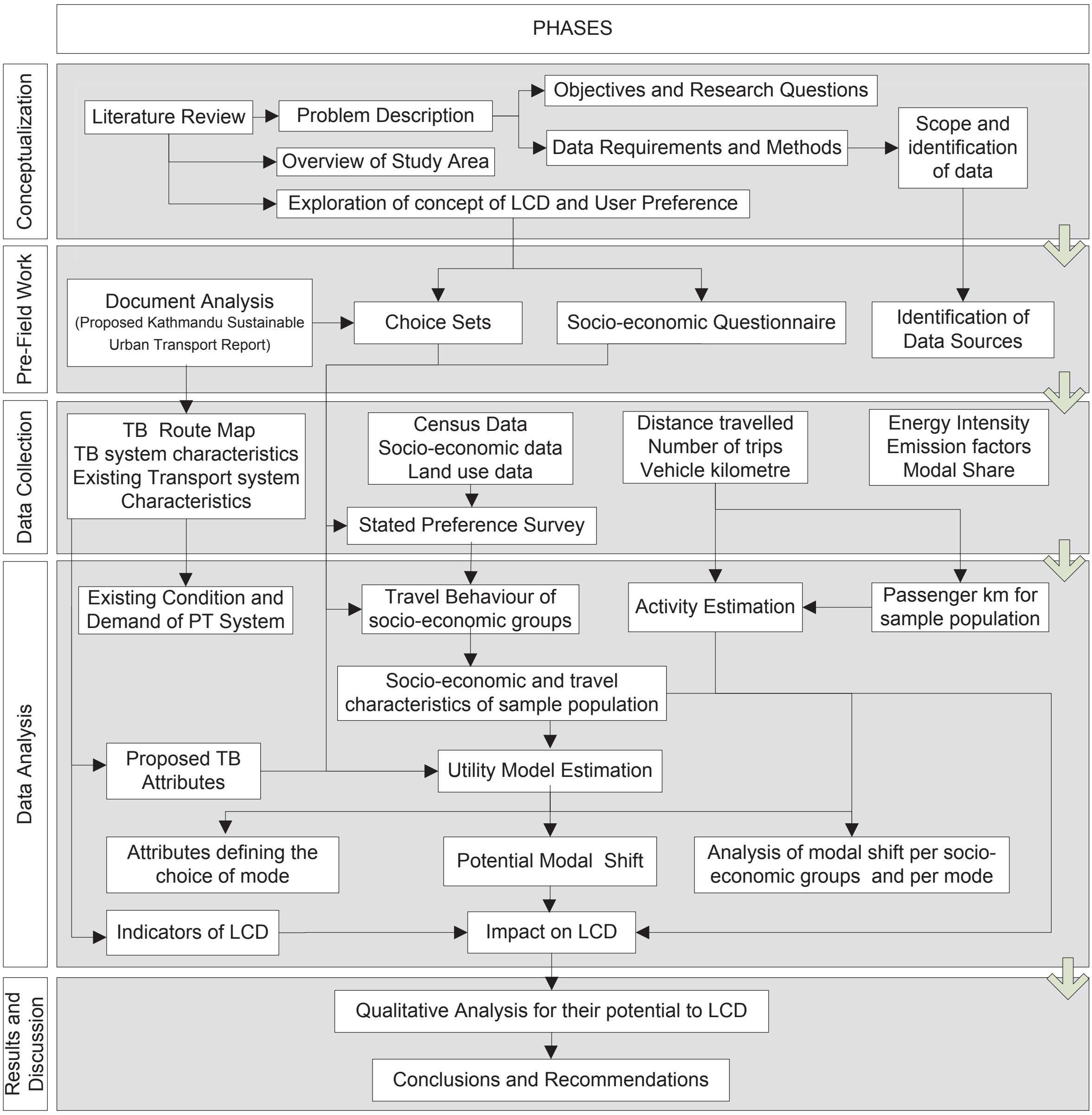

Figure 1-2: Research Design Operational Plan

2 LITERATURE REVIEW

This chapter discusses the different topics relevant to the research - travel patterns and modes, sustainable transport, low carbon development, consumer's travel and choice behaviour, choice analysis and emission estimation with relevant previous studies. The choice analysis includes the tactics of the stated preference survey and choice modelling.

2.1 Travel Patterns and Travel Modes

Transport is the major social and environmental issue throughout the world (Kingham *et al.*, 2001), which is considered as fundamental for the urban development. Its availability and accessibility guides the way of travel. The common elements that affect travel behaviour are distance travelled, travel mode choice, trip frequency and use of transit. Similarly, socio-economic condition of an individual can greatly influence the transport mode chosen. Among great variety of modes, according to Schiller *et al.* (2010), there are two important concepts about modes which are :

i) Multi-modal: The ability to choose among several modes for a trip which can be by foot, bicycle, transit, public transportation (PT), car, motorbike, or any combination of these.
ii) Intermodal: The ability to make connection between modes, such as mounting a bicycle in a bus or transferring between the bus and rail which can be quite convenient for public mode users.

Most trips are trips to work, shopping, services, education, recreation, family, friendship purposes, etc. Though most trips can be easily made by walking or cycling or PT, people are increasingly using the private counterparts. Among variety of modes, PT can be a promising and energy efficient transport mode which facilitates compact development and reduces the need of private mode due to its main advantages such as its capacity to accommodate mass, functionality, trip types serving large number of people to variety of destinations or with appropriate transits with the long term investment (Schiller *et al.*, 2010). In addition, the new generation PT buses such as hybrid of electric and diesel motors, electrified transits, Trolley Buses (TB), Bus Rapid Transits (BRT) have emission-reducing features which largely contribute to environment, health and safety considerations.

Like in developed countries, the use of cars is also increasing in developing countries. According to Schiller *et al.* (2010), the affordability of auto mobility, in terms of ownership, driving and highway construction expanded greatly in the late 1940s and 1950s. Although welcomed by both small and large cities, cars have increased their disadvantages in urban life with more traffic (Schiller *et al.*, 2010) increasing the pollution. However, transportation pollution is often seen as reducing emissions by technological innovation only rather addressing from policy level (Schiller *et al.*, 2010) since the true reduction in energy consumption isn't on an individual vehicle basis, but on the total basis for the entire city. Hence, it is the availability and promotion of sustainable vehicles, walking and cycling provisions that contribute to the overall efficiency of a city and reduces pollution. Therefore, for sustainable transportation, according to Schiller *et al.* (2010), one of the agendas is the need to reform the PT system and implementation of sustainable transportation systems changing the travel pattern and mode of every individual.

2.2 Sustainable Urban Transport

Schiller *et al.* (2010) states that reducing traffic in cities by reducing personal motor vehicles, promoting pedestrians and walking and using public transportation can have many benefits for mobility and environment. In this context, sustainable transportation is one which is affordable, operates efficiently, supports vibrant economy, limits emissions and waste, minimizes consumption of non-renewable resources, the use of land and the production of noise (Schiller *et al.*, 2010). Moreover, Dalkmann & Huizenga (2010) define sustainable low-carbon transport as "*strategy to provide economically viable infrastructure and operation that offers safe and secure access for both persons and goods whilst reducing short and long term impact on the local and global environment.*" It meets basic access and mobility needs in such a way that do not degrade the environment, do not deplete the resources used, serve multiple economic and environmental goals, maximize efficiency, improve or maintain access while shortening trip lengths and reducing the need to travel, enhance the liveability and human qualities of urban regions (Schiller *et al.*, 2010). However, the increased mobility has created serious environmental and social consequences challenging the progress of sustainable transportation (Schiller *et al.*, 2010). Thus, IPCC (2007) has advocated the direct link of transportation planning and policy with sustainable development which includes reducing oil imports, improving air quality, reducing traffic congestion and improving travelling facilities.

The major solution in such situation is more use of effective sustainable transportation. TB is one of such sustainable public transport modes which is defined by Rafter (1995) as "*a hybrid vehicle, a cross between the medium capacity, rubber-tired, diesel bus that runs in mixed traffic, and high capacity, steel-wheeled, electric rail car that runs in its own right-of-way*". TB is an alternative to the poor conditioned public buses because of its environmental benefits and reduced maintenance level. TB service has been considered ideal in San Francisco, USA operating with minimum noise and pollution, where this service was both preserved and expanded by converting several streetcar lines to trolley buses (Rafter, 1995). Similarly, Seattle, Philadelphia, Boston, Dayton, Ohio in USA, all have considered and implemented TB as an alternative to their private counterparts (Rafter, 1995). Hence, transportation policy must pursue strategies that reduce air-pollution and single-occupancy vehicle trips and make transit more efficient which can be fulfilled by sustainable transport options. This approach leads to both the reduction of GHG emissions and increment of the economical condition of a country by developing the infrastructure sector of a city meeting the high mobility needs of its people.

2.3 Low Carbon Development

Low carbon development (LCD) has been widely known as a new pattern of economic development aiming at reducing CO_2 emissions and at the same time achieving the sustainable development of environment, economy and society (Yuan *et al.*, 2011). In other words, LCD ensures economic development of a country or a city while minimizing emissions (Shrestha, 2012). There are many sectors where LCD can be pursued depending on nation's local context, capacities and priorities. As discussed earlier, the worldwide energy demand and CO_2 emissions in transport sector is projected to increase day by day making it one of the major sectors where LCD pathway needs to be ensured.

Many countries, organizations and authors have their own interpretation and own concept on LCD. JICA (2012) defines LCD as substituting fossil fuels by low-carbon energy based on the assurance of economic growth and rising residential welfare. Thus, the common feature of LCD is to utilize less carbon to promote economic growth in future. Hence, despite of the various understandings, the version of LCD that each country follows needs to be emerged from within its own national reality targeted to its development prospects, aspirations and capacities (Mulugetta & Urban, 2010).

Since, growth through economy-wide decarbonisation certainly seems the common feature in all definitions of LCD, Mulugetta & Urban (2010) classified LCD in four categories; low-carbon growth, low-carbon lifestyles, equilibrium economy and co-existence with nature. Low carbon growth focuses on the production side of economy in producing goods and services with low carbon emissions, with the objective of decoupling economic growth from carbon emissions and involving interventions in technological innovations and sectoral changes (Mulugetta & Urban, 2010). While "*Low carbon Lifestyles assumes that the consumer would be in the position to achieve the LCD through lifestyle and behavioural adjustments, but successful outcomes will be based on how well the supportive policies are in place to deliver better public services. While the equilibrium economy focuses on the production side of economy with a view to invest on social development and well being rather than growth*"(Mulugetta & Urban, 2010). People should be encouraged to choose low-carbon transport mode to promote low-carbon life styles and consumption patterns (Yuan *et al.*, 2011). However, the co-existence with the nature category focuses on the consumption side of the economy, according to which, the policy is geared towards low growth trajectory and uses a combination of technological and behavioural change to achieve LCD (Mulugetta & Urban, 2010). Thus, Low carbon lifestyle can be considered more related to user preference for modal shift potential.

Similarly, the idea of mainstreaming climate change in development practice and climate change policies are making LCD policies to address adaptation, though there have been on-going discussions of integrating mitigation and adaptation policies to practice LCD (Mulugetta & Urban, 2010). Emission reduction targets can also be significantly reached when all the factors simultaneously contribute to mitigation (Ben-Akiva & Lerman, 1985). In the mean time, Dalkmann & Huizenga (2010) argues that the main link between climate change and development is through adaptation. Above all, a low carbon transportation system needs improvements in all dimensions- travel demand, mode choice and technology through both mitigation and adaptation.

From variety of researches, a new paradigm shift emerged for strategic action is the main framework of Avoid/Reduce-Shift-Improve approach where infrastructure is provided in such a way that future travel demand is reduced or avoided, travel is shifted to more economic and environmentally-friendly modes and technology measures improve the vehicle fleet and fuels (Ben-Akiva & Lerman, 1985). A range of mitigation options of avoid, shift and reduce the GHG emissions have to be tackled. Changes in passenger travel structure *i.e* modal shift play an important role in achieving such targets. In addition, developing countries often have the opportunity to develop sustainable infrastructure in growing cities, maintain high shares of traditional, low-carbon modes, while at the same time develop environmentally-friendly technologies. In December 2009, more than 180 heads of state met in Copenhagen to negotiate a new climate change agreement and 36 developing countries mirror the wider paradigm shift, namely to avoid unnecessary journeys, shift travel activity to low carbon modes, and improve the energy efficiency of each mode (Ben-Akiva & Lerman, 1985).

Therefore in case of shift strategies, the plan of different countries is to have a gradual transition from oil-based engines to electric engines for vehicles (Mulugetta & Urban, 2010). The wide implementation of BRT systems are being focussed, where cities are growing fast and where private motorized vehicle growth is rapid, especially in developing countries. Modal shifts range from 6% to 21% for former users of car/taxi now travelling on BRT in cities where the system has been implemented (Cuenot *et al.*, 2012). Cuenot *et al.* (2012) achieved about 20% reduction in energy use and CO_2 from transport around the world for 25% reduction in car and air travel in 2050, compared to the Baseline. To achieve and further improve this modal shift scenario, strong policies will be needed at both local and national levels and people should be aware enough.

Hence, modal shifting by implementing alternative clean energy technology for transport sector is definitely a desirable option (Pradhan *et al.*, 2006) in achieving lower CO_2 emissions. In a workshop organized by CEPT University's Centre for Urban Equity (CUE) in 2011, the stakeholders formulated a list of indicators for promoting LCD covering economic, social and environmental aspects of sustainability. The indicators under Mobility and Accessibility were modal shares, travel time, trip length, affordability and emissions(CEPT, 2011) [See detail in **Error! Reference source not found.**; appendices section 2]. Hence, the analysis of developing any new system in general as a tool for aiding modal shift should include an analysis of the resulting impact in CO_2 emissions (Convery *et al.*, 2008) and mode share can act as LCD indicator.

2.4 Consumer travel and choice behaviour

Since behaviour change is of utmost importance in achieving LCD, individual's choice of travel behaviour should be well understood. The basic principle of consumer behaviour is that an individual will select a good over all the affordable bundles if it gives the greatest utility *i.e* satisfaction and the individual's decision making consists of maximizing the utility subject to budget constraint (Zuidgeest & Maarseveen, 2011).

The Figure 2-2 below shows when there are two types of good X_1 and X_2, the indifference curve U gives the combination of X_1 and X_2 corresponding with a given utility level. The income line Y presents the possible combinations of X_1 and X_2 corresponding to given income level. The equilibrium is reached at point E, where the individual's valuation of the goods is the same as the market valuation (Zuidgeest & Maarseveen, 2011). Though generally utility is generated by goods, it is generated by attributes of goods in most cases. Thus, the demand for a good depends on its price, its characteristics and the characteristics of the consumer as well (Nkurunziza, 2008; Zuidgeest & Maarseveen, 2011).

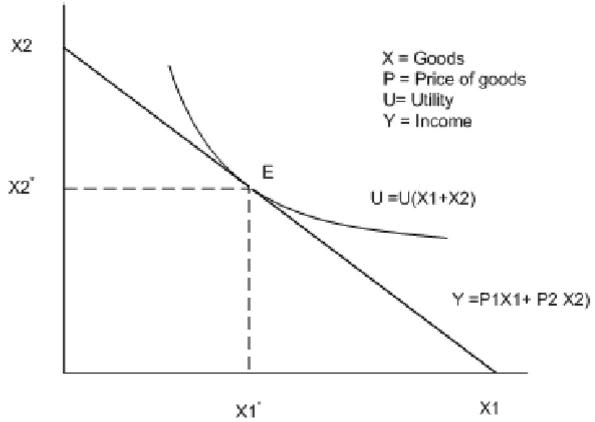

Figure 2-1: Consumer utility maximizing behaviour [Source: (Zuidgeest & Maarseveen, 2011)]

In transport studies, the good represents a certain transport mode or service. The price comprises of all the perceived costs of the traveller which means not only the costs of the trip but also the time spent in travelling. Thus, the utility of a trip and hence its demand depends on the trip to be made, the available modes and the individuals making the trips (Nkurunziza, 2008; Zuidgeest & Maarseveen, 2011). In this regard, the choice of a transport mode is one of the most important models in transport planning that can contribute to LCD since it affects the general efficiency of travelling to the urban areas and help to reduce emissions if private modes are least used. Therefore, it is necessary to develop a choice model which is sensitive to the different attributes of travel that influences individual's choices of mode (Nkurunziza, 2008). In this context, if the travellers are confronted with well informed choice models, then their choices reflect their preference. Then, it will be possible to make improvements in transportation infrastructures following the consumers' preferences with the help of choice models.

2.5 Choice Analysis

When confronted with alternatives, individuals will consciously or subconsciously make decisions by comparing the given alternatives stating their choice. Since the choice varies from person to person, there is huge variability in the reasoning underlying the decisions made by different individuals and therefore, the challenge is to find ways of observing and measuring this variability revealing the choice behaviour of certain population (Hensher *et al.*, 2007). The process of capturing such information through data collection and analysis is choice analysis which can be performed through surveys and certain models.

2.5.1 Stated Preference Survey

Behaviour research provides insights into the reasons of why people behave in certain ways for predicting future behaviour and these studies focus on attitudes, motivation, satisfaction, perception, or simply preferences (Haider, 2002). Transport choices have many attributes that make users to have their preferable choice and involve tradeoffs between several desirable choices. Among various methods for preference research, one is stated preferences (SP), in which survey respondents evaluate hypothetical questions which is stated as the inquiry about future choices or behavioural intentions by Haider (2002).

There are two types of methods in stated preference, compositional and de-compositional methods. In compositional methods, respondents evaluate each aspect of a complex issue separately, and then researcher calculates an overall utility value for an alternative by combining the components of an alternative according to some predefined decision rule (Haider, 2002). In contrast, de-compositional multi-attribute preference models explore the non-existing alternatives in which the respondents can evaluate the hypothetical questions and the non-existing attributes in the non-existing choice sets avoiding multi-co linearity (Haider, 2002). Such alternatives are combinations of a set of attributes, and each set is evaluated as a whole. Thus in a choice experiment, two or more such hypothetical profiles are combined to choice sets, and respondents choose the most preferred alternative (profile) from each set (Haider, 2002).

The main advantage of SP is that the analysis of choice, even though it is only hypothetical, is closer to actual behaviour than rating or ranking task and the respondents evaluate set of attributes as a whole and the statistical analysis derives utility measure for each attribute (Haider, 2002). Similarly, the respondents will think in terms of trade-offs and will be better at expressing relative preferences than absolute ones. Hence, researchers suggest that SP can be reliable indicator of likely travel behaviour. Table 2-1 below shows the brief overview of relevant research approach and outputs.

Table 2-1: Previous relevant studies by Stated Preference Survey

Previous studies	Location	Type of survey	Method applied	Output
(Kingham *et al.*, 2001)	Hertfordshire, England	Journey to work	Combination of revealed and stated preference questions	To identify how willing people are to shift their transport mode and the factors that may encourage people to do so.
(Gaker *et al.*, 2011)	UC Berkeley undergraduates	Auto purchase choice , mode choice and route choice	Stated preference scenarios	To determine whether and to what extent travellers are willing to modify their behaviour to save emissions focusing on time, cost and reliability attributes.
(Nkurunziza	Dar-es-Salaam,	Daily travellers from	Stated choice ,	To analyze commuters' attitudes

, 2008)	Tanzania	residential zones to the city centre within 2 km from BRT lines	Utility models and Spatial analysis	towards the proposed BRT system.
(Bajracharya , 2008)	Ahmadabad, India	Workers or students aged over 14 from different households , colleges and universities that fall within 1 km from the route	Combination of stated and revealed preferences with utility models	To derive the willingness of people to shift from one mode to another.

2.5.1.1 Using Revealed Preference data in SP experiments

Revealed preference (RP) data is the data that is known, representing the data collected on choices that are made in an actual market which are actually occurring (Hensher *et al.*, 2007). This RP data can be included in SP experiment as a switching model in which the choice response is still SP. Across each choice set, the alternative formed from each individual's previous experience remains constant only the attribute levels of the hypothetical alternative will change per choice set. Combining RP with SP will help to know the modal shift better.

2.5.2 Choice modelling

According to Louviere *et al.* (2000), the two elements needed for the development of a basic choice model are the function that relates to the probability of the outcome to the utility associated with each alternative and the function that relates the utility of each alternative to a set of attributes that together with suitable utility parameters, determine the level of utility of each alternative. One of the basic and popular choice models is Multinomial Logit Model (MNL) which provides closed-form choice probability calculations within which choice based questions can be answered (Hensher *et al.*, 2007). Gaker *et al.* (2011) estimated logit and mixed logit models to model the choices of the subjects and infer how they value different attributes relative to each other.

2.5.2.1 Random Utility Maximization

There should be some assumptions to develop a general model. In mixed choice models, it can be assumed that a sample individual q is assumed to consider the full set of provided alternatives in choice situation and choose the alternative with the highest utility and let U_{iq} be the utility of the *i*th alternative for the *q*th individual (Louviere *et al.*, 2000). According to utility theory, utility is satisfaction and travel is disutility. From the literature (Louviere *et al.*, 2000; Hensher *et al.*, 2007; Zuidgeest, 2012), the utility value can be divided into two components: a systematic (observable) portion of utility V_{iq} and a random portion of (non-observable) utility ϵ_{iq}. Then the utility of some option iq can be expressed as:

$$U_{iq} = V_{iq} + \epsilon_{iq} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.1)}$$

Where V_{iq} is assumed to be a function of the attributes of the alternative iq; assumed to be that part of the utility contributed by attributes that can be observed by the analyst whereas ϵ_{iq} is the random component that reflects the individual idiosyncrasies and any errors that may have been occurred; assumed to be that part of the utility contributed by attributes unobserved by the analyst (Louviere *et al.*, 2000; Zuidgeest, 2012). Randomness arises because analyst doesn't know what is going in the respondents' head while they are making choice and they cannot fully observe all the influencing factors and the decision calculus; they can only explain the choice up to probability of event selection (Louviere *et al.*, 2000). In this regard, the two individuals with the same attributes and facing the same choice set may select different options.

The division of the utility function is also for operational reasons when one assumes that one part of utility is common to all individuals whereas the other is individual specific which implies that the existence of a significant element of the full attribute set is associated with homogenous utility across the sample population (Louviere *et al.*, 2000). Therefore, V_{iq} largely depends on the sample population and the ability to segment that population in such a way that each segment satisfies homogeneity of utility and the extent to which one can measure the assumed or known attributes representing the utility (Louviere *et al.*, 2000).

For developing individual choice modal in general, the key assumption is that individual q will choose alternative *j* if and only if (iff):

$$U_{jq} > U_{iq}, \forall\ i \neq j \in A \tag{2.2}$$

where *i* is another alternative. Thus from equation (2.1) and (2.2), the alternative j is chosen iff:

$$\left(V_{jq} + \epsilon_{jq}\right) > \left(V_{iq} + \epsilon_{iq}\right) \tag{2.3}$$

which while rearranging the observables and unobservable yield (Louviere *et al.*, 2000):

$$\left(V_{jq} - V_{iq}\right) > \left(\epsilon_{iq} - \epsilon_{jq}\right) \tag{2.4}$$

Since $\left(\epsilon_{iq} - \epsilon_{jq}\right)$ is not observed by the analyst, if $\left(V_{jq} - V_{iq}\right) > \left(\epsilon_{iq} - \epsilon_{jq}\right)$ cannot be determined exactly, only statements about choice outcomes can be made up to a probability of occurrence (Louviere *et al.*, 2000). For example, a trip will be made if the net-utility V_j is positive. The alternative that maximizes the net-utility: $V_c = max\ (V_{jn})$ is chosen (Zuidgeest, 2012).

2.5.2.2 Generation of Multinomial Logit (MNL) Model

MNL model can be generated by assuming that the random residuals are distributed identically and independent such that (Louviere *et al.*, 2000; Zuidgeest, 2012):

$$P_{iq} = \frac{exp\left(\beta V_{iq}\right)}{\sum_{A_j \in A(q)} exp\left(\beta V_{jq}\right)} \tag{2.5}$$

where for all the individuals q with a given alternative A_j, one of the values of x is defined as equal to one and the coefficient β corresponding to that alternative is interpreted as Alternative Specific Constant (ASC) (Nkurunziza, 2008). Though a constant can be specified for every option, their N parameters are not possible to estimate individually due to the way the model works (Nkurunziza, 2008). Therefore, one is taken as reference by fixing its value to zero without loss of generality and the remaining (N-1) values obtained in the estimation process are interpreted as relative to the reference while the rest of variables may be of two types-generic and specific (Nkurunziza, 2008). If the variables appear in every alternative and their coefficients can be assumed identical, they are called generic while if the assumption of equal coefficients β_k is not sustainable, a typical example occurring, then it is called specific (Louviere *et al.*, 2000; Nkurunziza, 2008).

The *βs* are utility parameters, initially assumed to be constant across individuals *i.e* only *βs* are independent of *q* which are allowed to vary across the sampled observations and can be expressed as a function of contextual influences such as socio-economic characteristics of an individual or the nature of data being analyzed (Louviere *et al.*, 2000).In this regard, when there are only two alternatives, it is called binary logit model which can be expressed as (Nkurunziza, 2008):

$$P_1 = \frac{exp(V_1)}{exp(V_1) + exp(V_2)} = \frac{1}{[1 + exp(V_2 - V_1)]} \tag{2.6}$$

where the observable utilities are postulated as linear functions of two generic variables X_1 and X_2 and two constants (with coefficients β_3 and β_4) which are as follows (Nkurunziza, 2008):

$$V_1 = \beta_1 x_{11} + \beta_2 x_{12} + \beta_3\ ;\ V_2 = \beta_1 x_{21} + \beta_2 x_{22} + \beta_4 \tag{2.7}$$

Only the difference of both β_3 and β_4 are possible to be estimated; hence there is no loss of generality if one taken as 0 and the other estimated relative to it and to any number of alternatives (Nkurunziza, 2008).

If both X_{1j} and X_{2j} have the same value for both options like for the variables representing individual attributes such as income, age, sex or education, a generic coefficient cannot be estimated as it would always multiply a zero value which applies to such variables also which share a common value for two or more options like public transport fares (Nkurunziza, 2008).

2.6 Emission Estimation

In developing world, only few countries have thought and introduced programs to reduce GHG emissions. Moreover, emissions in most countries are not understood and there is very little ability to make accurate future emission estimates (Schipper *et al.*, 2007). Though it is difficult to make accurate future emission estimates, (Dhakal, 2006; Schipper *et al.*, 2007) used the ASIF framework based on a simple decomposition of emissions into pre-defined factors, where emissions are the function of travel (*activity*), transport mode (*structure*), energy (*intensity*) and (*fuel*) quality and choice, *i.e*, $E=F(A,S,I,F)$ to estimate GHG emissions. However, according to Dhakal (2006), there has been limited success in intervening AS in Asian cities but reasonable balance of interventions in both AS and IF are necessary. Dhakal (2006) implemented ASIF framework through a number of spreadsheet models and long-range energy alternative planning (LEAP) software for scenario analysis and studied the nature of CO_2 emissions in Kathmandu Valley. Similarly, Shrestha (2012) calculated emissions for KMC with potential population and distance travelled by the mode derived from accessibility analysis as input in ASIF model. The relationship between the four parameters is represented mathematically by ASIF equation as in Figure 2-3 below:

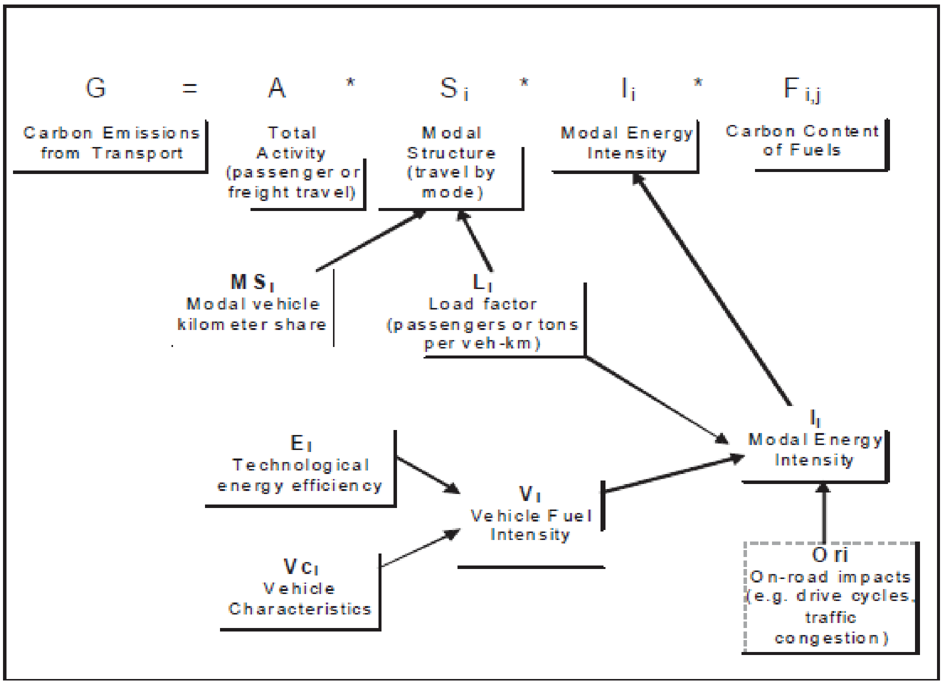

Figure 2-2: ASIF Equation in two dimensions for CO_2 emissions [Source: (Schipper *et al.*, 2009)]

Referring to the past researches, in a Ha Noi study done by the World Resources Centre for Sustainable transport, CO_2 emissions were estimated by ASIF model by using the total vehicle and passenger travel activity by mode as A and S and emissions coefficients and fuel use data as I and F (Schipper *et al.*, 2009). Also according to Schipper *et al.* (2009) in EMBARQ's study in India, an ASIF model was developed to identify and quantify the key variables that give total fuel use and resulting CO_2 emission levels. Therefore, ASIF model can be used to estimate CO_2 emissions but its breakdown depends on the available data and the context.

3 DATA COLLECTION AND ANALYSIS: APPROACH AND METHODOLOGY

Chapter 3 discusses about the approach and methodology used in the research. This chapter comprises of brief description of the study area, pre-field work stage, field work stage and post field work stage.

3.1 Study Area

3.1.1 Introduction

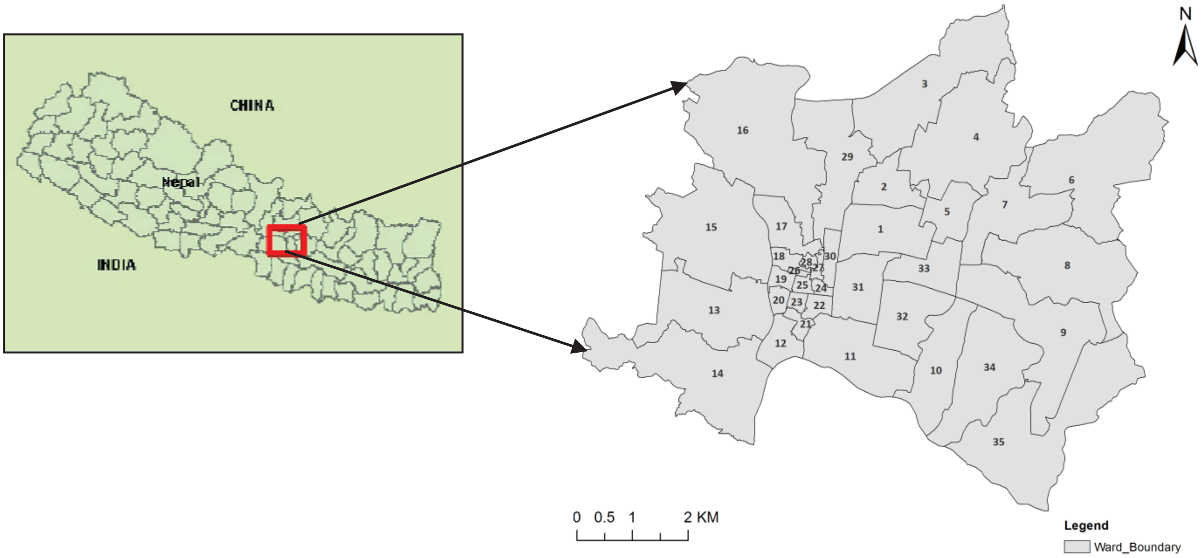

Figure 3-1: Location of study area KMC in Nepal

Located in South Asia, Nepal is a small country with area of 147,181 square kilometers with current population of around 26.6 million with growth rate of 1.4% (CBS, 2011).In Nepal, there are five development regions comprising 14 administrative zones with Central Development Region being located at the central part of the country which consists of three zones namely-Bagmati, Narayani and Janakpur. Kathmandu valley falls in Bagmati zone and surrounded by high mountains. The Valley comprises of three districts-Kathmandu, Lalitpur and Bhaktapur and the capital of Nepal is Kathmandu Metorpolitan City (KMC) in Kathmandu District. KMC is the main city with 35 wards and is also the headquarter of Central Development Region. KMC is the largest urban agglomeration in Nepal with around 20% of urban population in an area of 50.67 square kilometers (Shrestha, 2012). KMC is undergoing rapid societal transformation and modernization (Dhakal, 2006).

According to census of 2001 (CBS, 2011), the total population of KMC was 576,010 with most of the wards in periphery with their population density between 3,233 and 13,983 per square kilometres. Though, the census of 2011 is not finalized yet, it has regulated the preliminary results of total population of KMC as 1,006,656 which is nearly double of the population of 2001. According to JICA (2012), about 501 thousand persons are working in KMC.

3.1.2 Urban Form and Road Network

According to the land use of 2008, mixed land use with residential and mostly commercial activities is abundant in KMC covering nearly 50% of the area with only 27% as open area, cultivation and parks and road network about only 7% of the area (Shrestha, 2012). Similarly, in KMC, the institutional zone, which is mixture of office buildings, educational institutes, commerical buildings, *etc*, where people travel daily to work, is found abundant mainly in the centre of the city. In addition, rapid urbanization has occurred as a result of trips within KMC and Lalitpur Municipality occupying around of 50% of the total trips of Kathmandu Valley (JICA, 2012). The city has sprawled, extending on all sides, but mostly along its transportation corridors (Dhakal, 2006) resulting into increased pressure on infrastructure and environmental services.

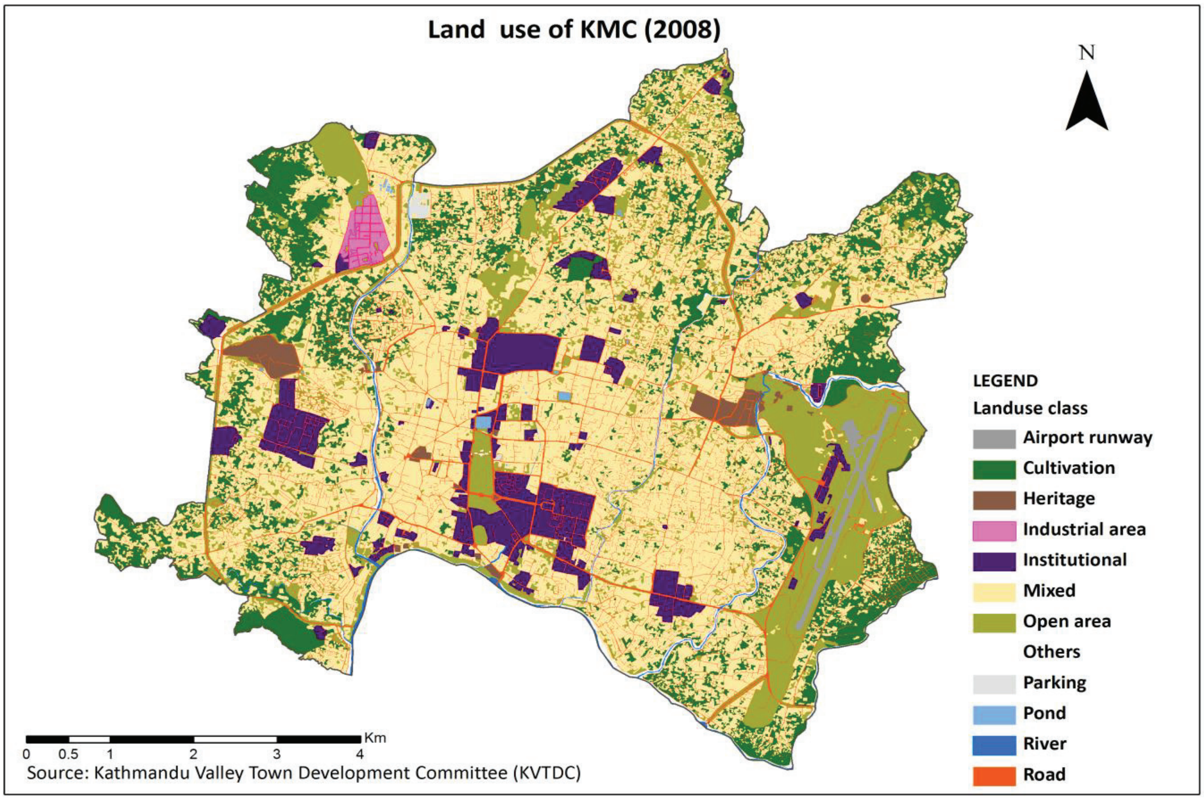

Figure 3-2: Land Use of KMC for 2008 [Source: (Shrestha, 2012)]

3.2 Pre-field Work Stage

3.2.1 Data Collection Technique

Destination based survey was carried out with an objective of finding varieties of people in the same location, study their socio-economic characteristics and daily travel behaviour to work with the help of choice set experiments. Since the survey was targeted to working class, work destinations were chosen for the survey and face to face personal interview method was used to collect information from the sampled population because it was important to observe how respondents reacted to the each hypothetical scenarios presented in front of them and to avoid if there would have any confusions. Each choice set was treated as a separate scenario otherwise respondents may get confused.

3.2.2 Sample Size

In stated choice theory, the sample size depends on the number of attributes and their levels and hence higher number of attributes requires high number of choice sets and thus a big sample is required

(Hensher *et al.*, 2007). However, it is burdensome to answer many questions for the respondent and therefore the number of attributes and their levels were kept small to generate less choice sets. According to Hensher *et al.* (2007), for choice based sampling, the arbitrary number of 50 decision makers per alternative can be an experimental lower limit which provides adequate variation in the variables of attributes and choices. Hence, 100 samples per mode were collected as there were two alternatives in one choice set to meet the minimum sample of choice based sampling. Since there were five different modes, 500 samples were targeted and hence 520 samples were collected in the field since motorbike users were abundantly found in the study area resulting to 120 samples for motorbikes. Moreover, since each mode had 9 choice sets, total of 4680 observations were collected. The sample size also lies within 95 % confidence interval with margin of error between 0.2% and 3.5% with regard to working population of KMC. In addition, 500 to 1000 samples are considered adequate enough to give better estimations (Louviere *et al.*, 2000).

3.2.3 Sampling Strategy

Since the sampling was targeted for working class, as daily trips are mostly working trips, first the main work destinations were identified in ward level, smallest available spatial unit in KMC. The institutional zones were considered the work destinations with socio-economic variations. Among the institutional zone, random major 8 bus stops were chosen falling in all the three TB routes and 500 m buffers from these bus stops were considered as survey locations since 500 m was assumed accessible by walk. The particular survey locations are also considered as major junctions and the junctions with maximum traffic volume in KMC by JICA (2012) in its survey for traffic improvement in KMC. In addition, these locations are wards with most dense institutional zones along the proposed TB system and the highest work trips would be generated in these locations. Therefore, this location was considered appropriate. The personal interviews were conducted randomly in random offices within those survey locations. Those commuters who travelled daily to these locations are considered potential users of the proposed improved bus system. The sampled population were only the city residents not those who were travelling from other cities.

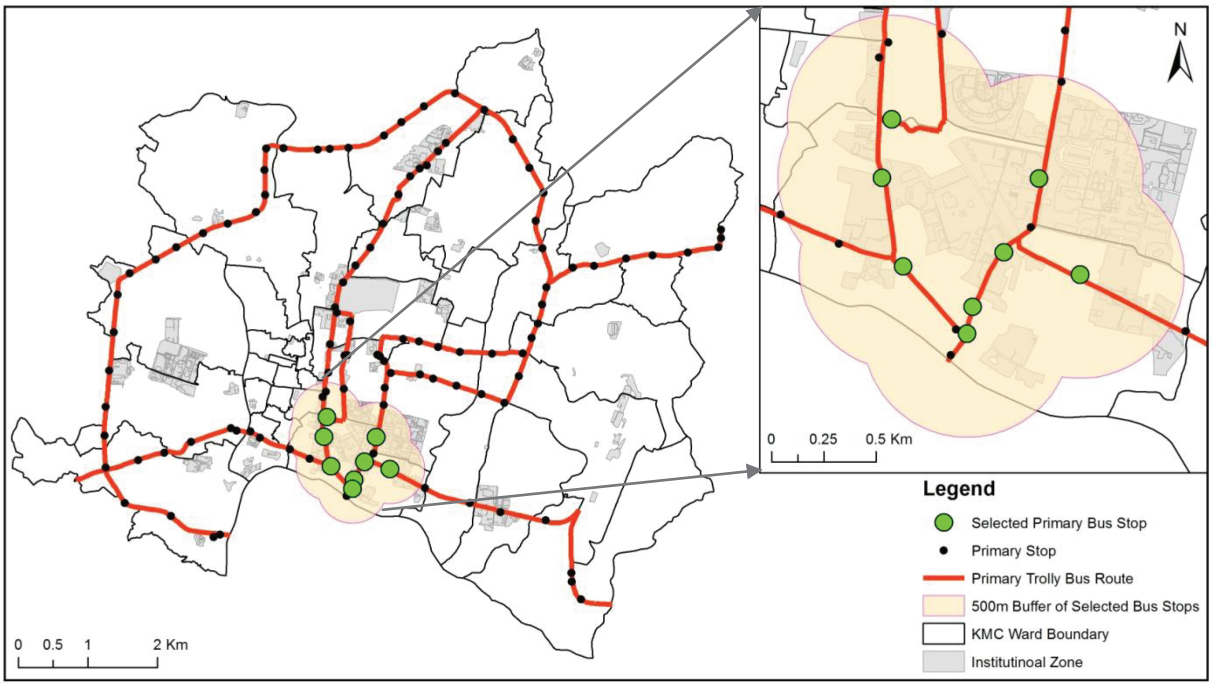

Figure 3-3: Map showing survey location within the buffers

3.2.4 Survey Design and Methodology for Stated Preference Survey

To determine the willingness to shift from existing to proposed mode of transport, a stated preference choice survey technique was selected, in which people were offered hypothetical choices among different alternatives. A stated choice questionnaire contains a number of choice sets which will include two or more alternatives. The alternatives are combination of attributes which differ according to the values assigned to them which are called attribute levels (Nkurunziza, 2008).

3.2.5 Process in Setting up Stated choice survey

3.2.5.1 Experimental Design Set-up: The experimental design set-up had following stages:

i) **Problem Definition Refinement:** The choice experiment was carried out to identify the likelihood for the daily commuters to work to shift from existing mode to proposed bus system in KMC.

ii) **Stimuli Refinement:**

Refining list of Alternatives: Since this study was to identify the shift from one mode to another, there were two alternatives in each choice set. In context of KMC, the current transport modes which are mostly used for work trips are car, bus, two-wheeler - motorbike or motor scooter and three wheelers - microbus and tempo. Hence, the alternatives were any of these comparing with the proposed bus depending on the user whom the survey was conducted.

Refining the list of Attributes and Attribute levels:

Attributes: Though more attributes covered would give better estimation of the systematic utilities, the more number of attributes would create longer questionnaire resulting into fatigue to the respondents (Louviere *et al.*, 2000). Therefore, the numbers of attributes were kept few also considering the complexities of analysis phase. For example, to reduce the number of attributes, the different travel times were combined as one travel time, considering it to be the total travel time including walk time to bus stop, waiting time in bus stop and in vehicle travel time. Nkurunziza (2008) also combined in vehicle travel time and walk time to bus stop in analysis phase.

When identifying the attributes, the analyst must consider the concept of inter-attribute correlation which refers to the cognitive perceptions of decision makers to the attribute provided (Hensher *et al.*, 2007). From the literature and JICA (2012), the most common attributes that affect the choice of mode considered are travel time (one way), travel cost (one way) and comfort. From the LCD indicators, safety and service frequency (CEPT, 2011) were also considered as attributes but they were found to be inter-related with comfort and travel time respectively from the pilot survey among the peers and therefore removed.

Attribute levels: Though more the levels of an attribute, the better utility relationships can be understood, but, three attribute levels has been considered enough for good approximation of underlying utility levels (Hensher *et al.*, 2007). However, the attribute level values *i.e* maximum and minimum values should be realistic and acceptable to the respondents (Nkurunziza, 2008).

Similarly, unbalanced designs should be avoided since they will lead to different statistical power between attributes (Louviere *et al.*, 2000). When attributes have a different number of levels and the levels are not multiple of each other, then it is called unbalanced design (Nkurunziza, 2008). For instance, design with attribute level 3 and 4 are unbalanced but a design with attribute levels 3 and 6 is balanced since 6 is multiple of 3 (Louviere *et al.*, 2000). However, while setting extreme ranges, one of the level values should be higher than the proposed improved bus value and the other value should be lower so that the effects of both an increase and decrease can be seen in the proposed improved bus attribute level value (Nkurunziza, 2008).

3.2.5.2 Experimental Design Considerations

After identifying the attributes and attribute levels and their values, choice sets should be designed. The full factorial design was used in which all the possible treatment combinations were enumerated (Hensher *et al.*, 2007). For convenience, the levels of comfort attribute were designated as low for overcrowded standing, medium for comfortable standing and high for comfortable seating.

Attribute coding: A coding format was created to represent the possible combinations of attribute alternatives which assigned a unique number to each attribute level (Hensher *et al.*, 2007). An orthogonal coding system which uses values for codes which, when summed over any given column equals zero, was used to achieve this effect. Since there were odd numbers of attribute levels, the median value was assigned the value zero and hence the attributes were assigned as -1, 0 and 1 (Hensher *et al.*, 2007).

Factorial design: Since there were three attributes and three levels each and two alternatives for each mode, the full factorial design was given by : $L^{M \times A}$ for labelled choice experiments, where L=number of attribute levels=3, M=number of alternatives=2 and A=number of attributes=3 (Hensher *et al.*, 2007). Hence, there would be $L^{M \times A} = 3^{(2 \times 3)} = 3^6 = 729$ different treatment combinations or choice sets. However, 729 choice sets presenting in front of the respondents is quite a burden and impractical with likely result of a decrease in response rates (Louviere *et al.*, 2000). Therefore, different strategies to reduce the number of choice sets had to be taken like reducing the number of attribute levels or reducing the size of experimental design. But, reducing the number of attribute levels would dramatically reduce the design size and may lose amount of information also and hence, reducing the size of experimental design using a fractional factorial design was adopted (Nkurunziza, 2008).

Fractional factorial design: A fractional factorial design consists of a subset of the choice sets from the full factorial design (Louviere *et al.*, 2000). To produce scientifically efficient fractional factorial design, the scientific method of generating orthogonal design using statistical software SPSS was adopted since random selection was likely to produce statistically inefficient design. An orthogonal design is a design in which all the attributes are required to be statistically independent of one another which means having zero correlations between attributes (Nkurunziza, 2008).

3.2.5.3 Generating Experimental Design

Since the level of one attribute when acting in concert with a second attribute's level affects utility for that alternative, the analyst should not examine the two variables separately, but rather in combination with one another (Hensher *et al.*, 2007) to arrive at optimal solution. Before generating the design, only the main effects were used where the attributes were named such that each design column that will be generated would be assigned to a specific attribute. In this regard, the main effect is the direct independent effect of each attribute upon the response variable (Hensher *et al.*, 2007).

To generate designs in SPSS, the attribute levels were coded using orthogonal codes to allocate the attributes to design columns. Orthogonal coding allows observing the design columns for the interaction effects. To generate the interaction columns, the appropriate main effects columns are simply multiplied together since an interaction effect is an effect upon a response variable or choice obtained by combining two or more attributes which would not have been observed if each of the attributes been estimated separately (Hensher *et al.*, 2007).

From the SPSS, the only main effects design of 64 treatment combinations was generated which was still too many and could be impractical to do the survey. Hence, the choice sets were later adjusted manually where 9 choice sets were obtained which were considered practical to handle ensuring proper tradeoffs between travel time, travel cost and comfort. The sample of the choice set for bus users is shown below in Table 3-1:

Table 3-1: Sample of the choice set for bus users

Choice sets	Travel Cost (Rupees)	Travel time(Minutes)	Comfort level	Trade offs
1	14	15	low	Cost vs Time
	20	5	low	
2	20	30	middle	
	26	15	middle	
3	24	45	high	
	30	30	high	
4	20	15	middle	Time vs comfort
	20	5	low	
5	26	30	Middle	
	26	15	low	
6	30	45	high	
	30	30	middle	
7	14	5	low	Cost vs comfort
	20	5	middle	
8	20	15	middle	
	26	15	high	
9	24	30	low	
	30	30	high	

3.2.5.4 Generating Choice Sets

The relevant attribute level value was assigned to the design using Microsoft Excel. By changing the attribute levels, the experimental design for each treatment combination was converted into 9 individual choice sets. The choice sets were prepared in similar way for all the five modes by only changing the values of attribute travel fare and travel time depending on the type of mode (see detail in appendices section 6).

3.2.5.5 Presentation of Choice Sets

Following the statement of ‘A picture is worth a thousand words’, the choice set were prepared with pictures of KMC to give the feeling of reality to the decision makers as far as possible. Different choice sets were shown to the different mode users according to their mode type and their reported travel time. The travel time and distance travelled was obtained from the socio-economic survey.

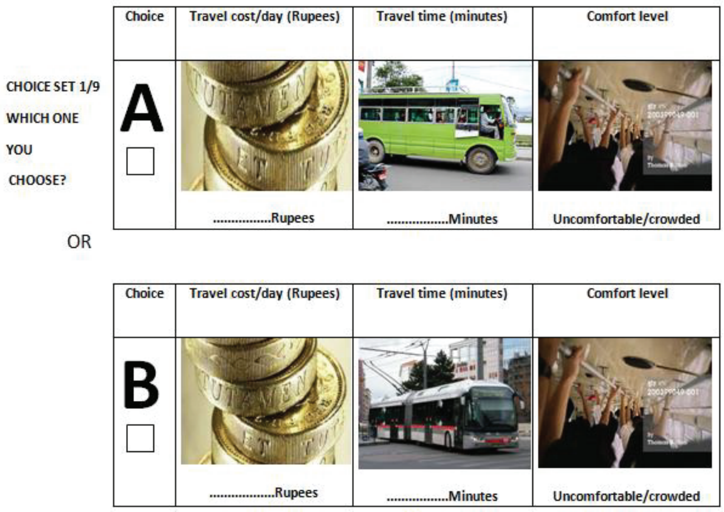

Figure 3-4: Graphical Sample choice set for bus

3.2.5.6 Using revealed data in stated preference experiments

Across each choice set, the alternative formed from each decision maker's current status remains constant *i.e* only the attribute levels vary across choice sets. The attribute levels of the alternatives change from choice set to choice set (Hensher *et al.*, 2007). Hence each decision maker will view different attribute levels for the alternative relating to their prior experiences. In this process, each respondent was asked about the current attribute level travel time experienced for commuting to work when using their current transport mode which was filled in the choice set and then shown to the respondents with their corresponding attribute level for proposed alternative.

The attribute level labels had to be cognitively sensibility predefined as part of experiment which would come from part I survey *i.e* socio-economic questionnaire. The trips only within 60 minutes of travel time were considered for this survey since working trips generally do not exceed 60 minutes in case of KMC. The travel fares for all the public modes were obtained from Department of Transport Management (DOTM) and assumed as fixed attribute levels since these fares are being used in current situation. The travel time depending on the distance travelled as per their corresponding average speed per hour corresponding to attribute levels -1, 0 and 1 per mode was calculated and considered. The travel cost for private modes were also calculated depending on distance travelled and travel time (see detail in the appendices section 5).

3.3 Field Work Stage

A field work was carried out for 3 weeks starting from 26th September, 2012. Both primary and secondary data were to be collected. The primary data was collected by conducting a destination based survey in the areas considered as centre for job locations, where people came to work daily. Various secondary data were also collected from different offices which were mostly the reports about the Kathmandu Sustainable Urban Transport Project (KSUTP), about its implementation phase and earlier studies in transport sector in KMC.

3.3.1 Secondary data Collection

The main objective of the collecting secondary data and visiting relevant offices was to identify the current scenario of PT system in KMC, about the transport related studies done so far, about the implementation phase of KSUT project and about the feasibility of the TB system implementation. During the fieldwork, following data were collected from different offices:

a) **Preliminary Results of National Population Census 2011:** This data is in brochure format and was obtained from Central Bureau of Statistics (CBS). It contains population of KMC in 2011, annual growth rate, sex ratio-males per 100 females and population density.
b) **Travel fare of Micro Bus:** This data is in paper format and was obtained from local Micro Bus Committee, Department of Transport Management (DOTM) for microbus. It contains travel fares of microbus according to distance travelled in kilometre.
c) **Current Travel fares of public vehicles:** This data is in report format and was obtained from Department of Transport Management (DOTM). It contains travel fares of public vehicles including bus, tempo and microbus according to distance travelled in kilometre.
d) **Summary of Kathmandu Sustainable Urban Transport Project (KSUTP):** This data is in report format and obtained from Department of Road (DOR). It contains summary of the main report of the KSUT Project. It includes brief background of the transport system in KMC and its current situation and the project components.
e) **Inception report of KSUTP:** This data is in report format and was obtained from KSUTP Head Office. It contains the final inception report about the current status of proposed work tasks of KSUTP.

f) **Data collection survey slides on Traffic Improvement in Kathmandu Valley:** This is in presentation slides format and was obtained from Japan International Cooperation Agency (JICA), Nepal. It contains brief details about the objectives of the survey done by JICA which includes reviewing of existing information, studies, plans and projects, traffic survey, future travel demand forecast, identification of major traffic related issues and problems in Kathmandu and recommendations for future.
g) **Kathmandu Sustainable Urban Transport Project (KSUTP) Main Report and Annexes:** This is in report form and was obtained from Kathmandu Municipality City Office (KMC). It contains the main report of KSUTP which presents the recommendations from an Asian Development Technical Assistance for Sustainable Urban Transport in KMC. This report is divided into two volumes, first part comprises of the present situation and the visions for sustainable urban transport and the second part includes the annexes on the data containing bus route, bus stops, vehicle traffic counts, vehicle occupancy, vehicle number and types. Hence, the report gives the initial comprehensive framework for sustainable urban transport for KMC.

In addition, brief interviews were carried out to know the current scenario of the PT system in KMC and KSUT project itself mainly about its implementation issues. Some professionals those were interviewed were Mr. Saroj Bhattarai, Department of Road (DOR), Mr. Neeraj Sharma, Kathmandu Sustainable Urban Transport (KSUT) Head Office, Mr Prashant Malla, Director of Abhiyan, Private consultant for transport projects, Mrs. Archana Shrestha, Kathmandu Municipality City Office (KMC), Mr. David J.Ingham, Public Transport Specialist and Mr. Madhab Raj Ghimire of SMEC International Pty. Ltd, Australia, Kathmandu Branch.

3.3.2 Primary data Collection

3.3.2.1 Primary survey preparation

Before the survey, choice sets, socio-economic questionnaire and sampling strategy were revised and amended based on local situation and on the ideas gained after discussion with the local experts of KSUTP and transport professionals. The arrangement of surveyors and training for the surveyors was conducted beforehand the survey. Different transport experts were visited first to have a general idea of transport scenario in KMC before the survey and also simultaneously throughout the field work period aiming for the first objective of identifying the current scenario of PT system in KMC. The prior permissions were also taken for the survey where needed. The travel fares of the public vehicles according to the distance were verified from DOTM and edited in the choice sets before conducting the survey.

3.3.2.2 Recruitment and Training of Surveyors

For the survey, eight surveyors were recruited and trained for one day to make them understand the questionnaire and surveying techniques. The surveyors were the students of Bachelor in Architecture from a local college, who have to study urban planning for six months. Though there were eight surveyors, the survey had to be conducted in team of two and hence four teams were allocated. During the training, first the technique was explained to them, then demo was shown to them and they were also made to interview each other and mistakes were corrected. The surveyors were made aware of the objective of the survey, the concept of SP survey and the difficulties that can be encountered during the survey. The general idea of face to face personal interview was given to them so that the common mistakes could be avoided and the ethics of the interview would be followed by them to achieve the main objective of the survey.

3.3.2.3 Pilot Survey

The objective of the pilot survey was to test the contents of the questionnaire and the choice sets, practicality of the survey and the response from the respondents. It was conducted for two days in the survey locations and a total of 52 samples were collected by 4 teams of surveyors. The pilot survey was done for following reasons:

- To examine whether the socio-economic questionnaire was understandable and practical to the respondents or not.
- To test the interview length and requirement of any addition or subtraction of questions in the survey, appropriate time for conducting survey and the buffer or threshold distance within which survey would be feasible to conduct (Nkurunziza, 2008).
- To examine how respondents made their choice. If a large majority is opting for the same option, it shows that the trade-off is not that well presented. In such case, the most chosen alternative should be made less attractive or vice versa (Nkurunziza, 2008).
- To check the understanding of the surveyors about the survey and as demonstration of the main survey (Nkurunziza, 2008).
- To improve the survey questions and the survey technique if required.

After the pilot survey, the socio-economic questionnaire was revised; few questions were omitted since they were not found feasible for the context. Minor variations were done in the choice sets in proposed travel cost of proposed new system ensuring the better tradeoffs. Some missed questions and some minor mistakes were reminded to the interviewers. In this way, final survey design was finalized and main survey was conducted.

3.3.2.4 Main Survey

The main survey started from 4th Oct, 2012 till 15th Oct, 2012 lasting for 10 days as planned. Every day, short briefing was done to the surveyors before starting the survey to avoid mistakes done in previous days. The survey used to start from 12 pm till 4 pm avoiding rush; first and last hours, since official working time in KMC is from 10 am till 5 pm. The interviews were conducted during lunch time when the working people have some free time so that their work was not disturbed and also depending on the location's situation within the time frame of 12 pm to 4 pm. In some work places, prior permissions were taken which was done 1 day before doing survey. Out of 4 teams, each team was required to collect a minimum of 15 samples per day where the minimum total sample required to be collected was 50 per day to cover 500 samples in 10 days. Finally, 520 samples were collected, majority being on two wheelers.

3.3.2.5 Data Entry

After completion of all the surveys and collection of all the survey forms, the data entry was done on paper simultaneously throughout the field work during evening time. Then, the data was again verified from survey forms and entered in excel data sheet.

3.4 Post Field Work Stage

This includes data entry and data preparation for the analysis to identify the travel behaviour of the travellers in KMC, their willingness to shift to proposed system and to estimate the relative effect in LCD.

3.4.1 Statistical Analysis

The first task was to prepare the data collected for statistical analysis. The questionnaire survey data were converted into statistical environment in excel sheet and then exported to SPSS for statistical analysis of socio-economic factors of the sample population. In SPPS, cross tab and frequencies function from descriptive statistics were used for generating the comparison graphs. In this way, travel behaviour and socio-economic characteristics of the sample population were known.

3.4.2 Utility Modelling

The utility model evaluates the proposed PPBS attributes by examining the preferences of the users based on stated choice data. The primary data was re-entered in excel sheet in format suitable for stated choice modelling. Then, it was converted into notepad format in text file format and then into data file to be accepted for processing in model estimation software called Biogeme. It is a freeware designed for the development of research in discrete choice models (Bierlaire, 2008). The stated choice data was processed and analyzed by using a MNL model which is the most commonly used model for processing data from choice experiments in transportation research (Louviere *et al.*, 2000). According to this model, an individual will choose the alternative that maximizes the individual's utility. The random utility model used (also refer 2.5.2.1) is defined as:

$$U_{PPBSn} = V_{PPBSn} + \epsilon_{PPBSn} \qquad \text{(3.1) following equation (2.1),}$$

where U_{PPBSn}= the utility of the PPBS by an individual n

V_{PPBSn} = the systematic utility component of the PPBS

ϵ_{PPBSn} = the non-observable utility component of the PPBS

n= Individual n

In addition, V_{PPBSn} depends on the attributes considered in the research given by following equation:

$$V_{PPBSn} = \sum \beta_{PPBSn} X_{PPBSkn} \qquad \text{(3.2) following equation (2.7),}$$

Where β_{PPBSn} = the utility coefficient associated with attribute X_{PPBSkn} of the PPBS

X_{PPBSkn} = the attribute of PPBS

k = the kth attribute of PPBS

From equation (3.1) and (3.2), the utility of PPBS against each of the other surveyed modes was estimated to get the probable modal shift. The preference of the whole sample as well as per mode was also estimated. In this way, the effectiveness of the PPBS based on users' preferences was assessed.

3.4.2.1 Model Input Variables

The input variables in the model were the attributes of PPBS used in SP survey which are travel time (TT), travel cost (TC) and comfort (CM). These variables were assumed as the only factors influencing mode choice. The total travel time for public vehicles was derived as:

[*Travel time = the total time of travelling = travel time from home to bus stop + waiting time + in vehicle travel time + travel time from bus stop to destination*]

The variables dependent on the alternative modes such as TT, TC and CM appeared in both equations for two alternatives. ASC (refer to section 2.5.2.2) was estimated for only one option since it was not possible to have it for every option (Nkurunziza, 2008). Continuous variables like TT, TC and CM were multiplied by their respective coefficients which reflected the disutility per unit of that variable.

3.4.2.2 Utility Model Expression

Since there were only two alternatives, the MNL model was developed as a binary logit model between the current mode – motorbike, car, tempo, microbus, bus and PPBS. To derive the utility, the β values were estimated by maximum likelihood method for MNL model (Louviere *et al.*, 2000). The utility function was expressed as:

$$U_{PPBS} = \text{ASC2} \times \text{one} + \beta_{travel\ time} \times \text{P\_TT} + \beta_{travel\ cost} \times \text{P\_TC} + \beta_{comfort} \times \text{P\_CM} \qquad \text{(3.3),}$$

Where U_{PPBS} = Utility of PPBS

P_TT = Total travel time of PPBS

P_TC= Total travel cost of PPBS

P_CM = Comfort level in PPBS

$\beta_{travel\ time}$= weight or coefficient associated with Travel time

$\beta_{travel\ cost}$= weight or coefficient associated with Travel cost

$\beta_{comfort}$ = weight or coefficient associated with comfort

The above utility equation (3.3) was used to derive the total utility of the PPBS. The higher the utility value, the more the PPBS is preferred by the sample population otherwise visa-versa. The contribution of each attribute to a utility of an alternative is also indicated by the sign of its coefficients which means a positive value indicates the positive impact on the utility while negative value indicates the negative impact (Louviere *et al.*, 2000). Thus, the utility functions were derived from the values of attributes of the particular mode whose utility was to be known and the parameter values of the respective attributes.

3.4.2.3 Processing data in the Biogeme software

The estimation of parameters of the utility equations was done by using Biogeme software, Michel Bierlaire BIOGEME Version 1.6. All the choice set data was processed in this software separately for each mode. According to Bierlaire (2008), when estimating a MNL model with two alternatives, the utility function associated with alternative *i* will be,

$$V_1 = ASC_i + \beta_1 x_{i1} + \beta_2 x_{i2} \tag{3.4}$$

where, β_1 and β_2 are coefficients to be estimated [see section 2.5.2.2]. To estimate the coefficients, following data were coded as:

Table 3-2: Classification of data

Parameter	Category	Code
Choice	Current mode	0
	Proposed PPBS	1
Comfort	Low	-1
	Middle	0
	High	1

There are two types of input files in biogeme- data file with extension .dat and model specification file with extension .mod. The .dat file indicates that file that has arbitrary data. Other attributes like travel time and travel cost were maintained authentic. All these data were first entered in excel sheet, then converted into text file and then to dat file. Since binary logit model was used, there were two variables added in excel file which were denoted by av1 and av2 having the value 1 if the associated value was available for the current observation and 0 if not (Bierlaire, 2008). Data file contains a list of labels of available data and that subsequent line contains the exact same number of numerical data, each row corresponding to an observation. According to Hensher *et al.* (2007), data collected using ratings or ranking data create problems at the time of estimation. Thus, authentic real world data on real attribute levels were used since they often produces cleaner data which is preferable for modelling purposes. However, comfort was entered as classified data according to Table 3-2. Delimiters can be tabs or spaces (Bierlaire, 2008). Some part of dat file and the model specification of the mod file is shown in appendices section 3.

3.4.2.4 Model Outputs

1. Estimation of utility parameters:

An estimate of *Viq* can be calculated by taking the *βs* and the *Xs* for the individual *q* and alternative *i* by using equation below following equation (2.7):

$$V_{iq} = \left(\sum_{k-1}^{k} \beta_{jk} x_{jkq}\right) \tag{3.5}$$

Where, the resulting Viq can be interpreted as an estimate of the relative utility Uiq of alternative i to individual q. The generic and alternative specific specifications for an attribute existing in more than one utility expression across the choice sets can be evaluated from above equation (Louviere *et al.*, 2000).

2. Statistical Significance of Utility Model Parameters:

Most of the applications require the ability to statistically test whether a particular parameter is significantly different from zero or some hypothesised value. Thus, the type of statistical tests performed on ordinary least squares regression weights like t-tests are required in a choice model (Louviere *et al.*, 2000). The maximum likelihood method permits to calculate the asymptotic standard errors for the βs in the MNL model and use these to test the statistical significance of individual βs using asymptotic t-tests (Louviere *et al.*, 2000). Generally, the mean utility parameters which have sufficiently small standard errors or variations are required so that the mean estimation is a good representation of the influence of the particular attribute in explaining the level of relative utility associated with each alternative (Louviere *et al.*, 2000).

The results were evaluated on basis of the model coefficients with their associated t-ratios and p-values which indicate the significance of an individual parameter associated with an attribute. For 95 % confidence interval, p-value should be less than 0.05 (Louviere *et al.*, 2000). Further, model summary statistics including the number of observations and rho-square value gives the indication of overall goodness-of-fit whose value varies between 0 (no fit) and 1 (perfect fit). Normally, the values between 0.2 and 0.4 are considered as good fit models but it should not be expected to be obtained so high (Louviere *et al.*, 2000; Bajracharya, 2008; Nkurunziza, 2008).

Similarly, the ratio of the mean parameter to its standard error is the t-value, desirably 1.96 or higher (positive or negative both) so that one can have 95% or greater confidence and that the mean is statistically significantly different from zero. However, according to Louviere *et al.* (2000), t -values as low as 1.6 are also often accepted. The possible reasons why an attribute may not be statistically significant can be presence of outliers on some observations, missing or erroneous data (often 0, blank, 999 or -999), not normal attributes distribution and in some cases, the attribute may be simply not important influence of the choice under study (Louviere *et al.*, 2000).

The other informal tests can be the examination of the sign of the estimated coefficient since the rejection of the variable with a proper sign mainly depends on its importance (Louviere *et al.*, 2000). However, a relevant variable with a correct sign should be included even if it fails any significance test since the estimated coefficient is the best approximation available for its real value (Louviere *et al.*, 2000; Bajracharya, 2008). Moreover, re-estimation or fixing the values to one already obtained in similar study can be tried as much as possible to make it significant (Louviere *et al.*, 2000).

3. Overall goodness-of-fit tests:

According to Louviere *et al.* (2000), the predicted dependent variable should be compared with the observed dependent variable relative to some useful criterion to find out how well the basic MNL model fits a given set of data. This test allows evaluating predicted probabilities against a vector of observed discrete - choices. It can be used to evaluate the output of sample fit of any MNL model by taking repeated samples of data, one of which is the likelihood–ratio index (L), which is used to measure the goodness-of-fit of the MNL model (Louviere *et al.*, 2000) which must lie between 0 and 1. The smaller this ratio, the better the statistical fit of the model and hence larger the quantity 1 minus this ratio (Louviere *et al.*, 2000). Therefore, ϱ^2 (rho-squared) is used as a type of pseudo–R^2 to measure the goodness-of-fit of the MNL model. (Louviere *et al.*, 2000; Nkurunziza, 2008).

3.4.2.5 Behavioural Outputs

The random utility MNL model provides a very powerful way to access the effects of a wide range of policies. Policies have greater impact in individuals and thus it is very significant to determine individual-specific effects prior to the market share effects and the model should be a very flexible and policy-sensitive tool (Louviere *et al.*, 2000). The outputs of the models can be used to estimate the responsiveness of a population group to changes in levels of particular attributes, to marginal rates of substitution between attributes and to obtain individual and group estimates of the likelihood of choosing a particular activity according to the given levels of attributes (Louviere *et al.*, 2000; Nkurunziza, 2008).

3.4.3 Modal Shift Calculation

To shift from one mode to another is regarded as modal shift. After getting the utilities, using binary logit model, the probability of the proposed alternative, PPBS being chosen was determined by (Bajracharya, 2008; Zuidgeest, 2012):

$$P_{PPBS} = \frac{exp(U_{PPBS})}{[exp(U_{PPBS})+exp(U_{Current\ mode})]}$$ (3.6) following equation (2.6)

This probability is expressed in percentage. If P_{PPBS} = x%, then the probability of choosing proposed mode is x% and probability of choosing current mode would be $P_{Current\ mode}$=1 - P_{PPBS} % (Bajracharya, 2008).

For current bus users, using equation (2.6), the probability of the proposed alternative, PPBS being chosen was determined by:

$$P_{PPBS} = \frac{exp(U_{PPBS})}{[exp(U_{PPBS})+exp(U_{Current\ bus})]} \tag{3.7}$$

In this way, the probabilities of choosing PPBS against each of the surveyed mode were determined per mode following equation (3.6).

3.4.4 Link to LCD and Emission Estimation

Mainly there are three concepts regarding LCD in transport which are avoid, shift and improve (Schipper *et al.*, 2009) as already discussed in chapter 2. Out of ASI, avoiding is not possible at the current stage since there are no land use plans developed yet in KMC (Shrestha, 2012). But, shifting has high potential since TB identified as zero emission vehicles has been recommended for implementation in KMC. Improving is also possible but SP survey was not done in that context since it would take time and huge investments to implement this strategy for technological advancement. In some literature, it is also overlapped with shifting since the shifting to new vehicles means shift to advance technology (Schipper et al., 2009). Since only shift concept was used in SP survey, this concept was pursued to study the impact on LCD. Under LCD concept, measuring carbon consists of three levels (Schipper *et al.*, 2009) which are as follows:

i) Analyzing and monitoring present transport activity, pollutant emissions, fuel use and CO_2 emissions.
ii) Projecting future transport activity and CO_2 emission levels
iii) Evaluating impact on policies aimed at transport activities and CO2 emissions.

But in this study, the analysis was limited to analysing and monitoring present transport activity, pollutant emissions, fuel use and CO_2 emissions. Since different kind of vehicles use different fuels, there is no simple formula to relate aggregate fuel use. So, measuring both fuel consumption and distance for each kind of vehicle-fuel combination was quite significant to measure the impacts. However, according to Schipper *et al.* (2009), the number of vehicle may grow over time and the distance each vehicle travels may decrease or increase and the fuel used per km may change. Therefore, Schipper *et al.* (2009) define the understanding of how these components change as the bottom up approach of measuring fuel use and carbon in transportation.

Hence, the bottom up approach of measuring carbon in transport means linking vehicles and vehicle activity and personal and good mobility by mode to fuel used by vehicle and mode, from which CO_2 emissions are calculated (Schipper *et al.*, 2009) which is also applied to estimate how specific investments in new transport systems like BRT or TB would effect emissions. In this regard, emissions (G) in transport depend on ASIF and how ASIF is defined since ASIF is a whole package to address LCD (already discussed in chapter 2). But in this study, for linking SP survey, which focuses on modal shift and share, structure aspect was taken into consideration. Since ASIF has two major components behavioural and technological (Dhakal, 2006), technological aspects were derived from secondary sources while behaviour aspects were derived from the primary survey carried out. In this context, the breakdown for ASIF model was adapted as in the following Table 3-3 below:

Table 3-3: ASIF Model and its components [Source: Adapted from (Schipper *et al.*, 2009)]

Behavioural Aspects		Technological aspects	
A(Activity)	S (Structure)	I (Energy/ Intensity)	F (Fuel)
Passenger travel or vehicle km. Number of passenger km= (number of trips X distance per trip)	Share of travel in each mode - shifts from one mode to another	(Fuel intensity of each mode in litres per passenger km)/ (Energy use per passenger kilometre) = Modal fuel intensity	Carbon content of the fuel or emission factor in grams of carbon or pollutant per litre of fuel consumed

Therefore, the ASIF approach uses the total emissions as the product of total activity (A), the share of each mode (S), the fuel used per passenger–km by mode (I), and the emissions per unit of fuel for each fuel and mode combination(F) (Dhakal, 2006; Schipper *et al.*, 2009). Further, the approach used for emission calculation following ASIF model is shown from Figure 3-5 below.

i) Activity (A): From Figure 3-5, first from the time reported by the sample population, the average actual travel time was estimated for each mode within the sample. In case of public travel modes, walking time to bus stop and waiting time was deducted from the time reported to get the actual travel time. Then, average distance travelled per trip by each mode was derived by multiplying the average speed per mode by the actual travel time. Then the average vehicle kilometre was calculated by multiplying the calculated average distance by the number of trips per day.

ii) Structure(S): Structure is simply the mode share which is the number of people using a particular mode. In current situation, the mode share used was the current sample population for each mode while the mode share for modal shift situation was the number of people not willing to shift from the sample since they would still contribute to CO_2 emissions.

iii) Energy Intensity (I): By dividing the average vehicle kilometre travelled by the fuel efficiency per mode from secondary source, the fuel use per mode was calculated. Then by dividing the fuel use per mode by the occupancy factor for each mode, fuel use per passenger was estimated. The fuel used per passenger was calculated since the ASIF modal in this study is passenger based. Finally, the total mode wise fuel use was calculated by multiplying the fuel use per passenger by mode share from the sample mode wise population for current situation and from the not willing to shift sample for modal shift situation.

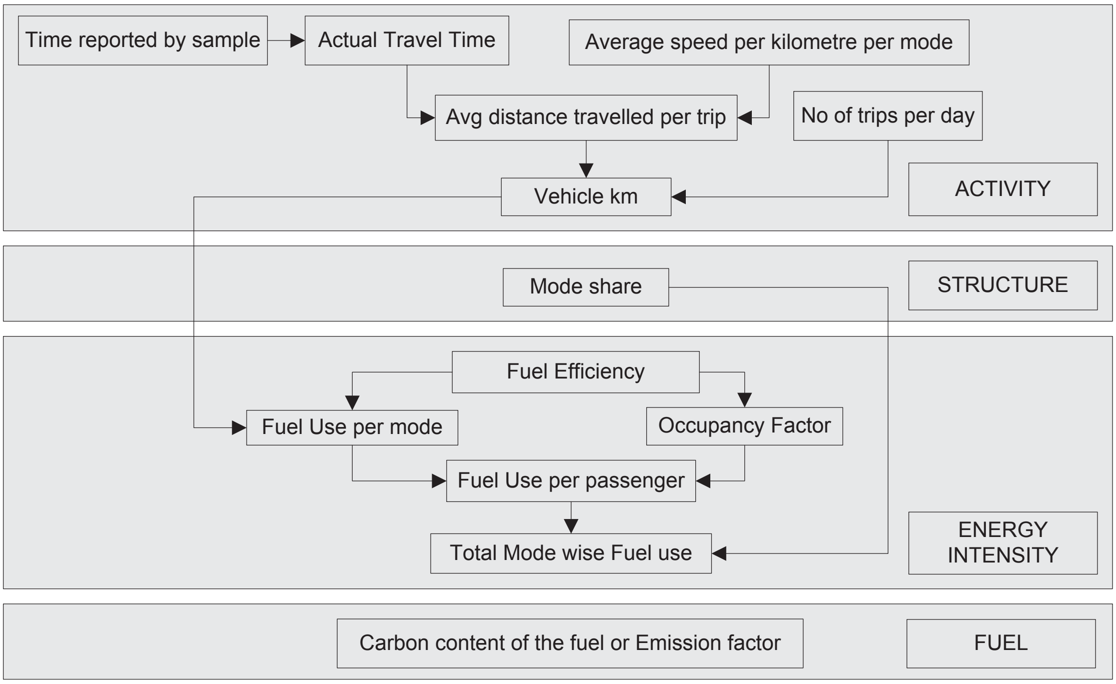

Figure 3-5: Steps for calculating emissions by adapting ASIF modal

iv) **Fuel (F):** Fuel is simply the carbon content of the fuel per mode type or the emission factor of each mode which was obtained from secondary source and directly used in the calculation.

Hence, using mode shift population, transport characteristics and vehicle operating data, CO_2 emissions was estimated for the sample and its impact on LCD was known.

4 DOCUMENT ANALYSIS: CURRENT SITUATION AND DEMAND OF PUBLIC TRANSPORTATION IN KMC

This chapter basically deals with the document analysis of the available documents from the fieldwork and the literature available for the current situation of the public transportation in KMC and its demand.

4.1 Background

KMC is increasingly becoming constrained in developing urban infrastructure, mainly its urban transport system (SMEC, 2012). Due to population growth, urban sprawl and increasing motorization, congestion, road accidents, pedestrian and vehicular conflict, environmental degradation and poor PT are becoming the major issues in transport sector in KMC. If no clear policy for managing urban transport is formulated, the situation will be more worse (SMEC, 2012). The increasing dependence on private transport modes and consumption of imported fossil fuels will have adverse impacts on air quality resulting in rapid increase in GHG gas emissions. The transport sector was the biggest contributor of CO_2 emissions in 1994/95 accounting for 31% of the total CO_2 emissions in Nepal (SMEC, 2012).

4.2 Existing Situation of Transport System

Road transportation is the only means of travel in Nepal until now. The transportation system in KMC is characterized by inadequate road length, narrow and congested roads, unmanaged traffic, an inadequate traffic management infrastructure, a combination of old and new vehicles and a multimodal PT system (from three wheelers to buses) in which the role of high occupancy PT is becoming marginalized (Dhakal, 2006). Moreover, there have been very less improvements in traffic management, emission control, PT promotion with the declination of high occupancy PT, rapid increment of the transportation activities and the growth in number of private cars and motorcycles (Dhakal, 2006).

Main roads are narrow, occupied with parked vehicles and the public buses waiting to fill the passengers. In this context, the cost of acquiring land to widen the narrow sections of the main road network is estimated to approximately US$ 190 million (MoPPW & ADB, 2010b). However, the advantage of such huge investment is questionable especially in a developing city like KMC and is also likely to be short lived. Moreover, if the vehicle ownership continues to increase at the current rates, the capacity of widened roads will soon be exceeded (MoPPW & ADB, 2010b).

According to MoPPW & ADB (2010b), traffic congestion has been a serious problem in KMC as roads have become saturated. If the rate of population growth of Kathmandu Valley continues in the same pace at 3.83% annum, it may get double in 10 years to 4 million (MoPPW & ADB, 2010b). In addition, vehicle ownership is increasing with approximately 444,000 vehicles being registered in Bagmati zone, most of which runs in the areas of KMC with 74% of two wheeler - motorbikes. According to JICA (2012), in near future, road traffic would exceed the road capacity, bus share would decrease while motorbike and car share would increase, land use pattern and population distribution would not change; hence modal shift would be unavoidable with all type of flow shifting to cars more in the long run due to the increase in car ownership.

4.3 Existing Situation and Demand of Public Transport System

Public transport was used to be operated by the government bodies in KMC but now it is exclusively offered by the private sectors by numerous individual operators, owning a variety of different vehicles which are often poorly assigned to the routes (MoPPW & ADB, 2010a). The public transport is not well managed and considered as the poor replacement of the private vehicles. The services need to improved and accessible to the poor people as well as the physically impaired people(MoPPW & ADB, 2010b) .

Moreover, another major concern is the poor air quality due to increased emissions from vehicles. Many of the PT vehicles are old and need to be replaced. According to MoPPW & ADB (2010a), the quality of fuel is adulterated, the vehicles engines are not tested properly and the vehicles which has low or zero emissions is less than 1 percentage. Thus, the environmental quality of KMC has seriously declined.

"*Complexity of the route network, the mix of vehicle types used and the pattern in which service are operated make the public transport of KMC inefficient. There is a basic network of approximately 25 routes, with most routes having several variations - almost 20 in one case*" (MoPPW & ADB, 2010a). Neither there is authority which has up to date information regarding the routes operated nor there is any agency authorized for planning routes. According to MoPPW & ADB (2010a), the next main concern of the PT route network of KMC is that numerous routes terminate at numerous stops and since there are no sufficient main terminal points, delays and traffic congestion are being caused with exposing passengers to danger. Moreover, all the micro buses, another PT options, are parked in the bus terminals for their turn to depart and wait for the passengers adding more congestion (MoPPW & ADB, 2010a)."*In KMC, there are mix types of vehicle service operated like 26-56 seat buses, 15-25 seat mini buses, 6-14 seat microbuses and 11 seated 3 wheeler tempos. In addition to that, taxi services are available all around the Kathmandu valley and the rickshaw services in the core places or tourist places*" (MoPPW & ADB, 2010a).

In this regard, the overall conclusion of the discussion from short interviews with transport professionals can be summarized as:

i) The stakeholders are trying to get a good model of PT suitable in case of KMC; it has been decided that they will be either low carbon or electric or may be just improvement of the existing public vehicles.
ii) The reintroduction of the TB has been recommended but one of the objectives of the KSUT project is limited to study of TB Renewal Feasibility only.
iii) The identification of which road sections should comprise which type of PT to know the hierarchy of the routes and modes of transport is another target of the project. Any form of mass public transport system like BRT or TB can be implemented.
iv) There has been a plan to analyze the shift from poorly maintained buses to high capacity modern buses and the modal shifts from low occupancy public vehicles to high ones.
v) The stakeholders are working stepwise. The project is in its very initial stage. The project will be more discussed in next section 4.4.

4.4 Kathmandu Sustainable Urban Transport Project

Following the degrading situation of Urban Transport in KMC, a subsequent Review and Fact Finding Mission of Asian Development Bank (ADB) forwarded the recommendations in preparation of a 4-year long project called Kathmandu Sustainable Urban Transport (KSUT) to commence in early 2011(MoPPW & ADB, 2010b). The assistance in this project is part of ADB's Sustainable Transport Initiative (STI) launched in 2006 to enhance ADB's transport sector interventions by incorporating energy efficiency, inclusive transport infrastructure and services to reduce GHG emissions in transport sector (MoPPW & ADB, 2010a). STI examined sustainable urban transport in five pilot cities, one of which is Kathmandu. The project has aim to serve the city with improved PT service. In this regard, the project has a vision for sustainable transport with following immediate measures (MoPPW & ADB, 2010b):

i) Improve operations of public transport
ii) Implement a traffic management plan for the central area of Kathmandu
iii) Introduce pedestrian areas within the old town of Kathmandu with links to transport facilities, and
iv) Improve the air quality within the city.

According to KSUT, for the urban PT system, the routes can be classified into three different routes (MoPPW & ADB, 2010a) which are Primary, Secondary and Tertiary routes. The appropriate choice of the vehicles on each route will contribute in preventing the congestion and the exhaust emissions. In addition, the use of small electric vehicles in the city core area and the large TB on the primary routes like city outskirts will be beneficial for economic development and will be environment friendly as well. Moreover other than land pooling, there is little that can be done to control urbanization in KMC in today's context (MoPPW & ADB, 2010b), so improvement in transport system has to be encouraged.

4.4.1 Urban Transport Vision

Asian Development Bank (ABD) will assist the government of Nepal to achieve the following visions of KSUT initially with the central area of KMC and later extending to other areas (MoPPW & ADB, 2010a):

i) Encourage people to travel by public transport or foot.
ii) Discourage private motorized vehicles from entering the central area of Kathmandu.
iii) Improve the movement of all modes, including pedestrians within the central area.
iv) Improve air quality and reduce carbon emissions and
v) Improve transport equity

These visions are regarded as the building blocks to the socio-economic well being of KMC for achieving LCD in transport sector in KMC.

4.4.2 Project Components

To implement the visions, KSUTP comprises four inter-related components: A)Public transportation, B)Traffic Management, C)Pedesterisation and D)Air Quality (MoPPW & ADB, 2010a). Out of these, only two of them which are relevant to this study are discussed below:

A) Public Transportation:

Existing routes will be rationalized and operated by appropriate vehicles such that larger buses; the big length buses approximately 12 metres in length are suitable for the primary routes or wider main roads picking and dropping up passengers at appropriately located bus stops. Medium sized bus; mini buses of approximately 9-10 meters in length or similar electric should operate in the secondary type of route or narrower main roads in similar manner. The tertiary routes are suitable for the central core area to avoid congestion. Thus, smaller sized buses or small electric vehicles which have capacity up to 14-15 people are useful for the tertiary routes. These routes will carry passengers to interchange bus stops on main roads. These vehicles will not operate in main

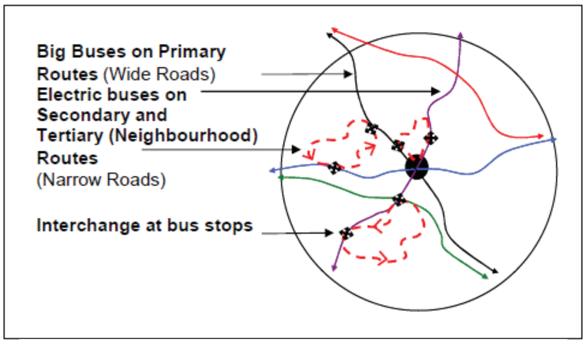

Figure 4-1: Assignment of vehicles to routes [Source: (MoPPW & ADB, 2010b)]

roads as far as possible (MoPPW & ADB, 2010a).

Reorganization of existing PT vehicle owners into a much smaller number of cooperatives will be done. Improved bus interchanges will be provided in the central area for passengers to safely and easily enter, exit or change buses without creating obstruction to the traffic flow. The existing fleet of PT vehicles will be rationalised to increase the proportion of larger, more cost effective buses, with a corresponding reduction in proportion of medium sized and small (mini and micro) buses. The level of comfort and safety to passengers will be improved as a result of fleet renewal and replacement and the proportion of zero-emission vehicles will be increased. Rules and regulations related to operation of PT will be reviewed and amended accordingly. Technical support will be given to ensure the efficiency, acceptability and affordability of PT to all sections of society, including the poor and physically impaired (MoPPW & ADB, 2010a).

B) Air Quality:

To maintain the air quality, KSUT has proposed reintroduction and extension of the TB Service and improvement of Emission and Mechanical Testing (MoPPW & ADB, 2010a). All fuel in near future is expected to be Euro III standard. The number of vehicles should be reduced by discouraging the vehicle ownership by proper tax regulations. Similarly, people should be made aware about the risks associated with vehicle emissions and air quality monitoring stations should be established for air quality monitoring.

4.4.3 Proposed Public Bus System (PPBS)

Considering section 4.4.1 and 4.4.2, KSUTP has proposed that the TB system should be reintroduced using existing infrastructure but with new vehicles with the provision of extended network of two or three primary routes. MoPPW & ADB (2010a) have stated that the fund for the project will be used to purchase more buses and for the study of re-introduction and extension of TB service since replacement of existing fossil fuel vehicles with electric buses for minor routes and TBs for the main routes will be a major contribution for improvement of poor air quality increasing in KMC. This study will assess the feasibility of reintroducing and extending the TB service which offers the potential for mass transit with zero emission. In this regard, the existing overhead cables could be repaired and extended along the routes (MoPPW & ADB, 2010a). If the government is willing to finance the overhead cables, 80 or more vehicles could be purchased and operated from existing depots by the private sector. However, buses should be new and existing buses should be scrapped. Hence, proposed TB has huge potential for environmental benefits (MoPPW & ADB, 2010a).

However, the stakeholders and transport professionals are arguing on the model of new public transport bus system. They are also stating that it can be any other sustainable public transport system other than TB. Therefore, the term used for further analysis is proposed public bus system (PPBS). Moreover, the proposal is in its very early stage; hence the attribute values like travel time and travel cost have not been defined yet. Therefore such attributes were assumed with the consultation with transport professionals simply keeping in mind that the PPBS should travel faster and should be little expensive than existing PT modes in order to maintain its quality. The routes proposed for allocating TB and the suggested trolley bus model are shown below.

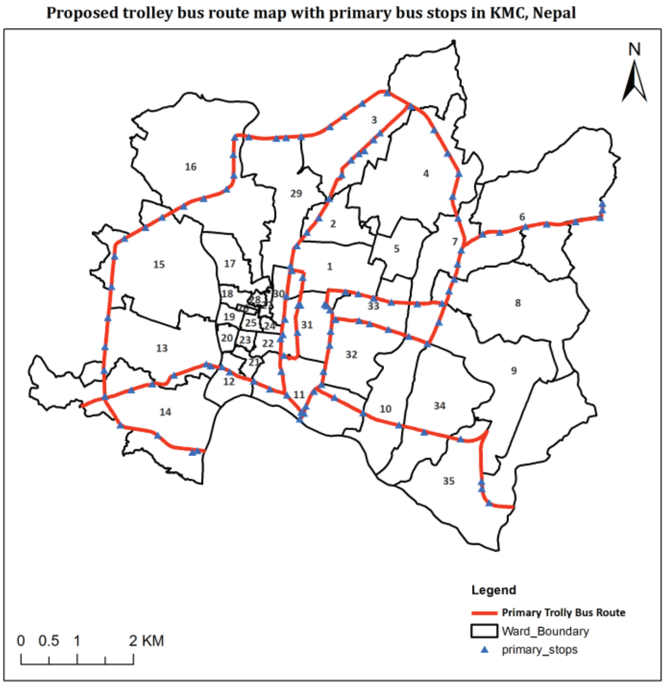

Figure 4-3: Possible routes for trolley bus service

Figure 4-2: Suggested Trolley Bus
[Source: (MoPPW & ADB, 2010b)]

5 SOCIO-ECONOMIC AND TRAVEL CHARACTERISTICS OF SAMPLE POPULATION

Travel behaviour of an individual is directly affected by own socio-economic status which influences the type and frequency of the travel. Moreover, income is the main indicator of socio-economic status of an individual while travel time and travel mode are the indicators of travel behaviour (Bajracharya, 2008). This chapter includes the socio-economic character and travel behaviour of the sample population.

5.1 Socio-economic characteristics

Socio-economic characteristics like gender, age, income level and education level are the important factors that influence the travel behaviour and hence these factors were interviewed during the survey.

5.1.1 Distribution of socio-economic variables

Out of 520 samples, the distribution of the socio-economic variables from the survey is stated as below in Table 5-1:

Table 5-1: Distribution of the socio-economic factors of the sampled population

Socio-economic factor	Category	Percent (%)	% within whole population [Source: (CBS, 2011)]
Gender	Male	55.8	52.26
	Female	44.2	47.74
Age	17-30	58.5	50.78
	31-50	33.5	27.82
	Above 51	8.1	10.49
Income level	Less than Rs12,000/low income group	50.2	Data not available
	Rs 12,000-25,000/lower middle income group	36.3	
	Rs 25,000-60,000/higher middle income group	11.0	
	Above Rs 60,000/high income group	2.5	
Education level	None	1.9	Data not available
	Primary School	2.5	
	Secondary School	12.3	
	Intermediate	19.8	
	Bachelors	41.9	
	Masters	21.5	

(Note: Exchange Rate: 1 US$ = Rs 88.80)

From the above Table 5-1, out of 520 samples, there are only slightly more male than female which shows both male and female are involved about equally in earning their living in the sample. The result shows relatively good representation of male and female respondents in the collected samples with small variations in comparison with the entire population of KMC. The most abundant age group that travel to work is between age group of 17-30 which shows young people travel more for work. The age-group distribution also represented the samples with minor variations to whole population. Most of them have low income and very few have high income which shows that the middle income group travel more to work. Most of the people of sample population are educated up to Bachelors level since Bachelor level is considered as minimum requirement for a fair job in KMC and the sample was targeted to working people; hence it is obvious that most of the people will be fairly educated. However, the data for whole population for socio-economic variables - income level and education level is not available in city level.

5.1.2 Mode wise socio-economic characteristics

Since the sample was distributed among five modes, the mode wise socio economic distribution is discussed as per socio-economic character in following way:

i) Gender:

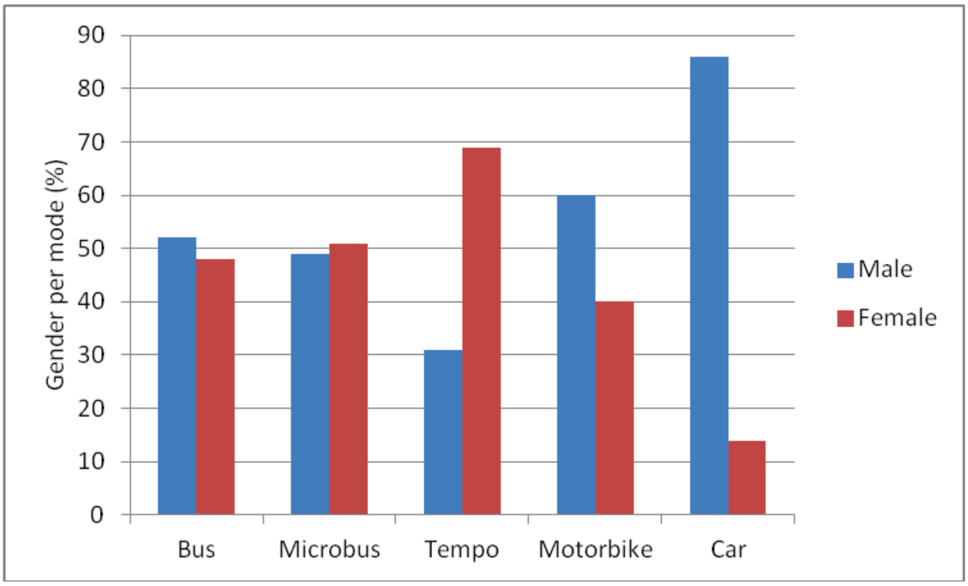

Figure 5-1: Gender distribution (%) per mode

From the above Figure 5-1, comparing all the five modes for the surveyed sample, male users use car the most but tempo the least. There are more male than female users in case of motorbike with car being the most preferable mode by male which shows that they prefer private modes. There are slightly more male in bus. While female are using tempo the most and car the least since tempo is considered the most comfortable among other public modes because of its seating facilities. However, there is nearly equal distribution in case of microbus as it has highest average speed per hour among all public modes (refer to appendices section 8) and cheaper than the private modes.

ii) Age group:

From Figure 5-2 below, the most abundant age group that travel to work is between the age group of 17-30 who are travelling most in microbus since time seems to be very important for this young group as the average speed of microbus is more than other two public modes and affordable. Motorbike comes at second most preferred mode since this mode has become really attractive in context of KMC (Dhakal, 2006) as it is cheaper than car and faster to travel. Tempo stands at third and then bus and at last car since this age group generally cannot afford cars. To the contrary, the abundance of age group of 31-50 fall under car who travel least in microbus since most of them seem to able to afford car and seek for more comfort because of their age. The age group above 51 rarely travel and even rarely travel in public vehicles as generally people are retired or work very less after age of 60 in context of KMC. Gradually, with the age, they seek for comfort and opt for more comfortable mode like car. Since the sample was targeted to working class, hence the abundance of age group was found below 51.

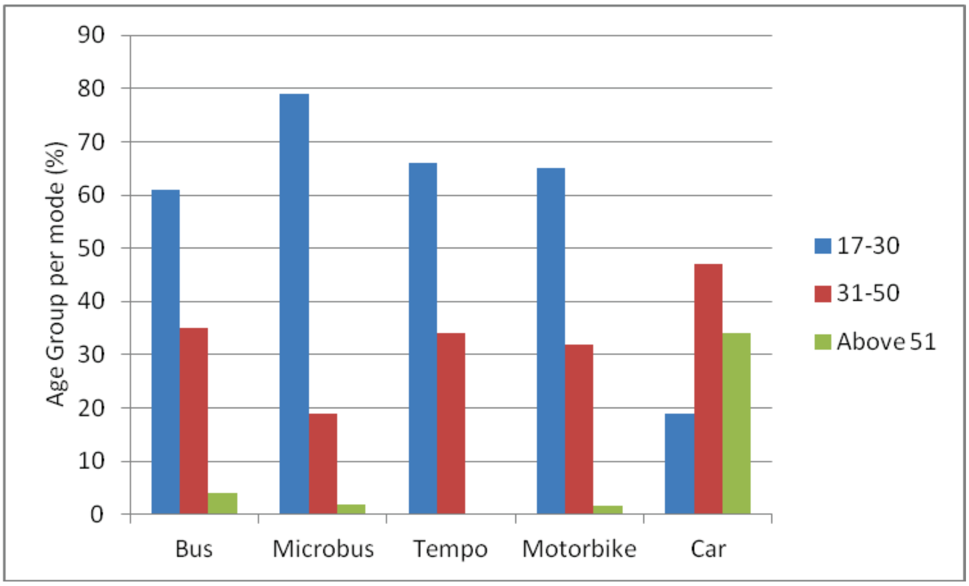

Figure 5-2: Age group distribution (%) per mode

iii) **Income level:**

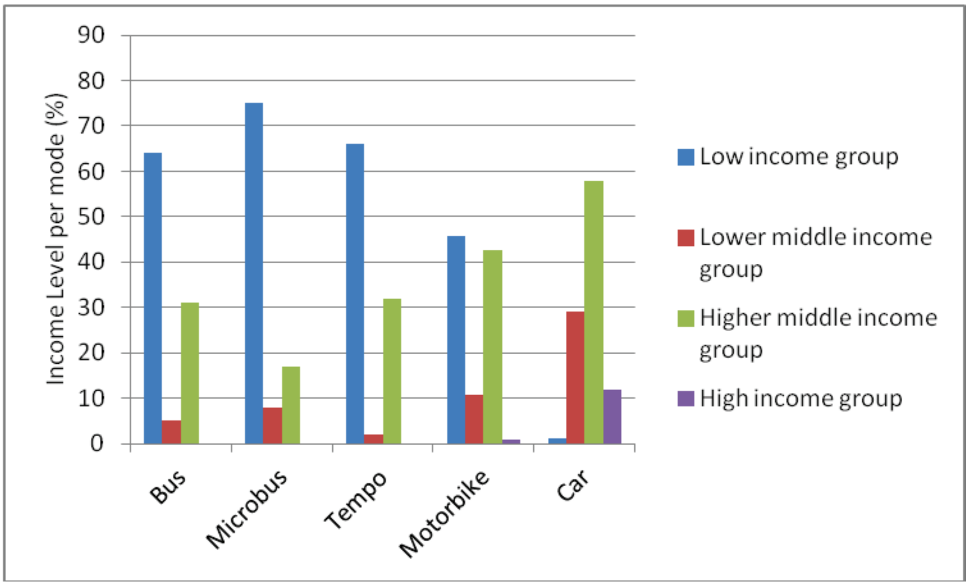

Figure 5-3: Income level distribution (%) per mode

From above Figure 5-3, low income group uses public vehicles the most with microbus as the highest in use since it is affordable while car the least since it is expensive. Also, fair amount of low income group use motorbikes since it is convenient than other public modes and cheaper than cars. Both higher and lower middle income group are using cars more and microbus and tempo less with motorbike as the second most used mode. The reason for this is higher middle income group can afford car and prefer to use it considering its comfort. Some people of this group still use motorbike since using car is still more expensive for those people. Similarly due to the same reason of valuing comfort, minimum people of this income group use public vehicles. About high income group, only few of them travel to work because most of them might have already set up their business and may have started working from home; with the highest number observed in car and almost nil in other modes due to comfort reasons.

iv) Education level:

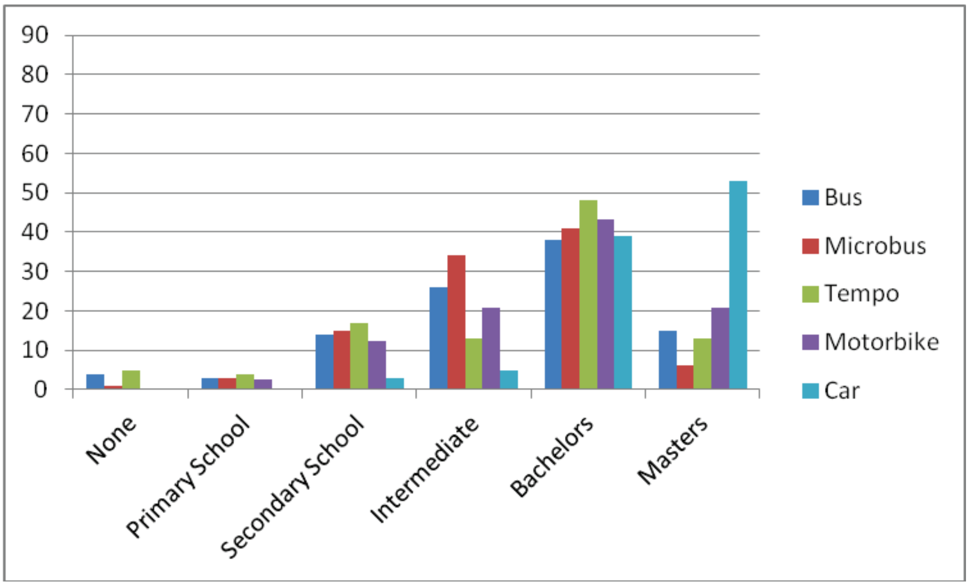

Figure 5-4: Education level distribution (%) per mode

From Figure 5-4, the most prominent group, except car with the prominence in Masters level, is the group who have studied up to bachelor level since this level is considered adequate for getting a fair job in KMC. The second prominent group is of intermediate level in all the modes except car with second prominence in Bachelors level. Then the majority comes from Masters level and then of secondary school level and then primary school level respectively again with exception in car. Since the sample was working class, only few people were of primary school level and who were illiterate. The hierarchy is similar in all modes. None of the private mode users were illiterate. Thus, the more their level of education, they are more inclined to private mode as they seek for more comfort.

5.2 Travel behaviour

5.2.1 Travel mode

The modal split of KMC can be generalized according to the modal split of Kathmandu valley since the modal split of only whole valley is available. From Figure 5-5, it is observed that there is abundance of PT which is likely since it is combination of different types of high-occupancy- bus and low occupancy- micro bus and tempo. Among private modes, motorbikes are more used than car. Since bicycle and pedestrian do not contribute to CO_2 emissions, public modes - only bus, microbus and tempo and private mode-car and motorbike were taken as sample from field observation and from the discussion with transport professionals. Hence, even if only PT can be replaced by sustainable mode, it can contribute largely for CO_2 reduction. Moreover, the choice of travel mode depends on various factors; some of them are travel time, travel distance and comfort level which are described in following sections.

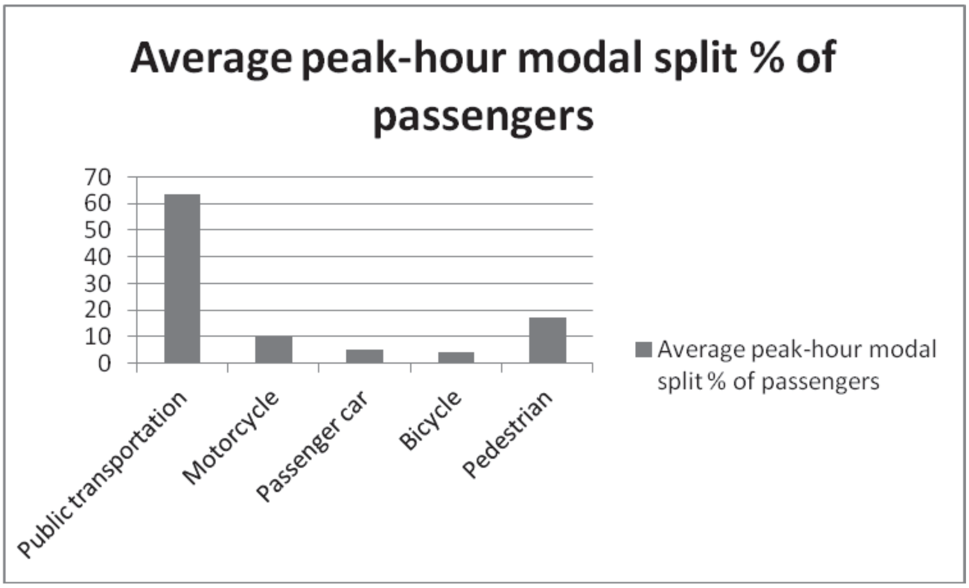

Figure 5-5: Average peak-hour modal split % of passengers in whole Kathmandu Valley [Source: (Dhakal, 2006)]

5.2.2 Travel time

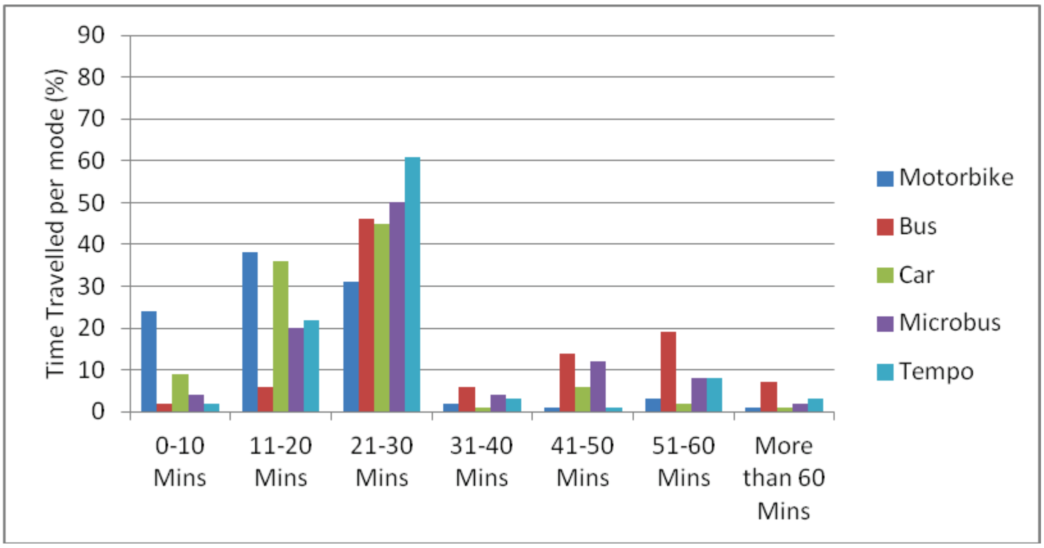

Figure 5-6: Travel time spent for travelling per mode by the sample

Considering travel time spent, it is observed from Figure 5-6 that people from the sample generally travel 21-30 minutes the most which is mostly travelled by tempo and microbus which shows that they don't prefer to travel more than half-hour to reach their job-locations. However, the sample population travel 0-10 minutes and more than 60 minutes the least which shows they don't want to travel more than 1 hour for their work and travel mostly more than 11 minutes for work. Hence to reduce the time in travelling, more tempo users and microbus users should shift their mode to sustainable modes for low emissions.

5.2.3 Travel distance

Considering the distance travelled, from Figure 5-7 below, the people from the sample mostly travel more than 5 km and that by microbus since its average speed is more than other two public modes. More than 7 km and 10 km are mostly travelled by motorbike since they want to cover more distance in short time. Motorbike is being used abundantly also for even shorter distance like more than 2 km. Motorbike is least used for more than 15 km while car the most as they want to travel longer distance in comfortable way.

Therefore, to reduce travel distance, motorbike users and car users have to shift their mode to sustainable modes for low emissions.

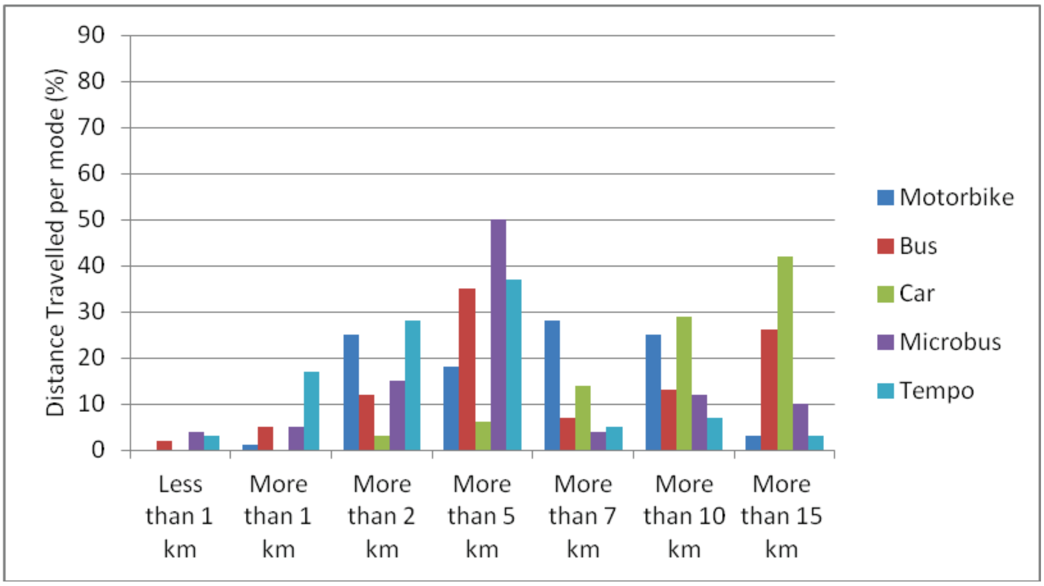

Figure 5-7: Travel distance spent for travelling per mode by the sample

5.2.4 Comfort level

Since comfort was one of the main attributes in the choice set to state their preference, it was decided to verify the actual comfort level they are going through in their current travel mode so that there will be general idea of the comfort level of the sample. From Figure 5-8 below, it can be seen that most of the motorbike users feel highly comfortable with their mode due to its guarantee seat and feasibility in the narrow roads of KMC. However, majority of public mode users are stating their comfort level as middle with highest percentage of microbus users feeling moderately comfortable with their mode. While in case of car, nearly half of the samples are stating their comfort level as high and other half as middle with only 1% saying its low. The reason for this is the comfortable seat in cars which is rare in public modes. Minimum amount of sample are stating their comfort level as low with the majority of bus users feeling their comfort level low. Hence, it seems that only if the comfort level is slightly improved, there are much more chances of modal shift from private vehicles to public vehicles. The results are also affected by the particular sample selection as the case may be different for another sample location or for the whole city.

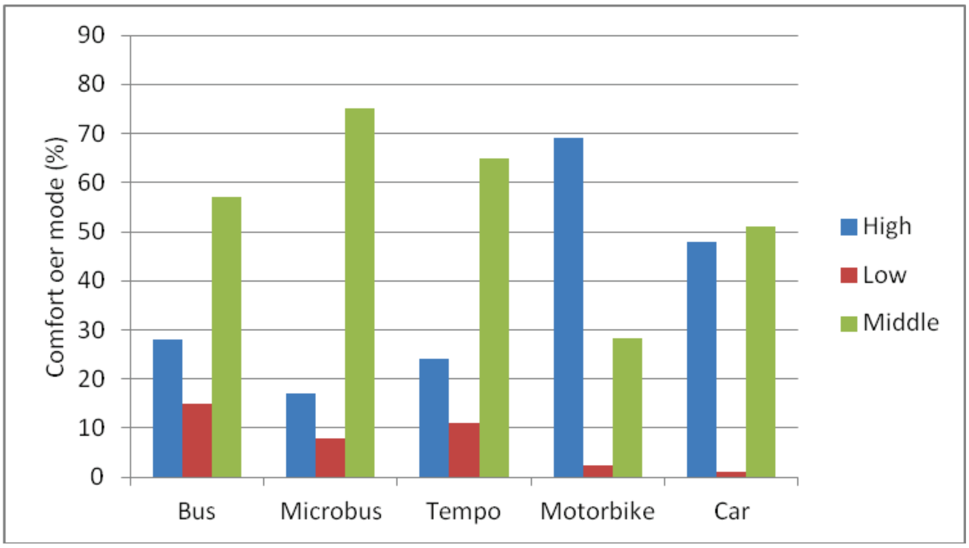

Figure 5-8: Comfort level (%) per mode

5.2.4.1 Comfort factors per mode

Though in the SP survey, the comfort attribute was considered as high for seat guaranteed, middle for comfortable standing and low for uncomfortable seating and standing, during the survey, it was found users were confused about the real meaning of comfort. Since the comfort level perceived by the users of different modes may be confusing, it was decided to survey the comfort reasons which mean actually what factors the users are considering as comfort. From the survey, following factors in Table 5-2 are considered as major factors for feeling uncomfortable according to the sample:

Table 5-2: Comfort factors per mode as stated by respective users

Comfort factors	Mode type (%)				
	Bus	Microbus	Tempo	Motorbike	Car
Crowded	44	54	22	35	49
Crowded, pick pocketing, uncomfortable seat, not hygienic	11	0	2	2	0
Crowded, time	0	0	6	5	0
Crowded, uncomfortable seat	11	12	7	1	0
Crowded, uncomfortable seat, not hygienic	5	2	11	0	0
None	13	12	31	39	33
Not hygienic	5	1	6	18	15
Others, time, not hygienic, no route	0	0	0	4	0
Others	0	4	0	7	0
Pick pocketing, uncomfortable seat, no route, not hygienic, time	8	11	11	7	2
Risky and Pollution	0	0	0	2	0
Uncomfortable seat	0	0	2	0	0

From above Table 5-2, the greatest factor regarding comfort is crowded since majority of the people from the sample feel that when there will be less crowd, it will be comfortable. In this regard, the users who feel uncomfortable most due to the crowd inside the vehicle are microbus users and then bus users then only tempo users. However, the car and motorbike users are feeling more uncomfortable because of the more crowds in the road referring to the vehicular crowd. Tempo users are the least complaining group about their comfort level due to their comfortable seats. However, some of all mode users stated that there is no issue of comfort in their mode of travel mainly the motorbike and car users being the majority group in saying so. The reason behind this may be those were still not clear what they mean by their comfort level. Therefore, the private mode users feel fairly comfortable with their mode than public mode users. The next main reason of discomfort is hygiene as most of the motorbike and car users care about hygiene a lot. Other factors that matter for not feeling comfortable are crowded together with pick pocketing, uncomfortable seat and not hygienic. But the factors like uncomfortable seat, no route, not hygienic and not in time together matter for only few people in the sample population while risk and pollution matter for motorbike users.

5.3 Conclusion

This study has helped to create the relationship between socio-economic characteristics and mode choice. From socio-economic analysis, it is known that if the preference of male groups, the age group of 17-30, the middle and high income group and master level people is known, the new system can be developed according to their priorities as they are more likely to shift their modes. The policies should address these groups more to contribute more in CO_2 emission reduction. Similarly those groups who travel nearly half and hour and those who travel more than 5 km need to be addressed more for lowering CO_2 emissions.

6 USER PREFERENCE AND IMPACT OF MODAL SHIFT IN LCD: RESULTS AND DISCUSSIONS

This chapter deals with the results and discussions of the whole analysis of this research which includes stated choice modelling, user preference based on socio-economic characteristics, modal shift analysis and its potential impact on LCD.

6.1 Stated Choice Modelling

MNL model (refer to section 2.5.2 for detail) was used to model the preferences of the commuters, to derive polynomial linear utility functions and to estimate the relative importance of the attributes used. Modelling of the choice data was done on basis of whole sampled population, socio-economic differences of the individual commuters and between different modes and PPBS.

6.1.1 Model Estimation based on total sampled population of the city

This model was developed to analyse the preference of the whole sampled population *i.e* individual commuters at the city level. The samples from the different modes were aggregated together. The result of the estimation of the model is summarized as below in Table 6-1:

Table 6-1: Utility parameters

Attribute	Parameter	Value	Units	t-test	p-value
Travel Time	β_{TT}	-0.0330	Minutes	-9.07	0.00
Travel Cost	β_{TC}	-0.00305	Rupees	-3.71	0.00
Comfort	β_{C}	0.222		4.26	0.00
Error term	ASC1	0.172		3.21	0.00
Rho-square	ϱ^2	0.028			

Utility parameter values:

The signs of all the utility parameters are correct as seen in Table 6-1. Travel time and travel cost have negative coefficients which means that the utility of an alternative decreases as their values increase and vice-versa. However, positive sign is associated with comfort attribute since individual's relative utility increases when the level of comfort increases and vice-versa.

From Table 6-1, it is observed that all the attributes have t-statistics greater than 1.96 and p-values lower than 0.00 which show that they are significant enough to have impact on transport mode choice. In addition, this generalized model for the total sampled population has the model fit with a rho-square of 0.028 which lies closer to the acceptable minimum and maximum range of 0.2 and 0.4 for the best modal fit indicating this model as a good one (Louviere *et al.*, 2000).

The error term in the model represents the non-observable part of utility together with any observational errors made by modeller. In this study, only three attributes were used in choice experiments, thus, the error term was included in this model to capture the mean effect of the other factors unobserved by the analyst which might have influenced the choice decision. From the result, it is known that all the parameters are statistically significant. The reason for this result could be the large data sample used in the model estimation and the variations within the individual responses.

In general, commuters prefer shorter travel time to longer travel time and cheap travel cost since both the travel time parameter and travel cost parameter are negative and their magnitudes are also less than of comfort parameter. However, comfort is positive with fair significance value which means that commuters prefer more comfort. Thus, according to the magnitude and the significance level associated with each attribute, it is found that the sample population prefer comfort the most, then travel time and then only travel cost. Since the sample population was targeted to working class, travel time seems to be more important than travel cost and comfort seems to be of utmost importance. When comparing to previous study of (Nkurunziza, 2008) in Dar es Salaam, also a developing city in Tanzania, he also observed that commuters prefer comfort the most in commuting their journey, then travel time and then only travel cost. Hence, it can be concluded that less travel cost is not always the attraction factor for the modal shift of the users. Therefore, comfortable environment has to be created and maintained in the new public transport systems in order to change user's behaviour to use public transport.

6.1.2 Model Estimation based on socio-economic differences

Table 6-2: Utility parameters for different income groups

Income group	Attribute	Parameter	Value	Units	t-test	p-value
Low Income	Travel Time	β_{TT}	-0.0409	Minutes	-6.87	0.00
	Travel Cost	β_{TC}	-0.0151	Rupees	-3.10	0.00
	Comfort	β_{C}	0.222		5.40	0.00
	Error term	ASC1	0.240		2.87	0.00
Lower middle income	Travel Time	β_{TT}	-0.0257	Minutes	-4.38	0.00
	Travel Cost	β_{TC}	-0.00205	Rupees	-1.76 ^	0.08 *
	Comfort	β_{C}	0.134		1.54 *	0.12 *
	Error term	ASC1	0.122		1.41 *	0.16 *
Upper middle income	Travel Time	β_{TT}	-0.0283	Minutes	-2.11	0.03
	Travel Cost	β_{TC}	-0.00346	Rupees	-1.83 ^	0.07 *
	Comfort	β_{C}	0.0330		-0.20 *	0.84 *
	Error term	ASC1	0.244		1.47 *	0.14
High income	Travel Time	β_{TT}	-0.0108	Minutes	-0.30 *	0.76 *
	Travel Cost	β_{TC}	0.000496 *	Rupees	0.09 *	0.93 *
	Comfort	β_{C}	0.220		0.50 *	0.62 *
	Error term	ASC1	1.03		1.94 ^	0.05 ^

(Note: * = not significant and ^ = can be assumed significant)

Regarding parameter signs, from Table 6-2, it is observed that comfort has positive value while travel cost and travel time have negative value indicating that all the income groups prefer more comfort but less travel time and travel cost except high income groups. These results show that more the comfort, more the utility while less the travel time and travel cost, more the utility. For high income group, travel cost is observed as positive which could have generally been negative. The reason behind this is that the travel cost does not matter as much as travel time and comfort for this group as they can afford it.

Considering significance values, most of the parameters have not reached the desired significance level of confidence interval of 95% except few. Only the parameters of the low income group have reached the desired significance level which shows that these values are significant to them and have impact on them which may make them shift to PPBS. Comfort has the highest impact on this group and then travel cost while travel time has the least impact on them which shows that if the travel time is increased, then there is the least chances of shifting. Adversely, comfort and travel cost have to be taken care of to make this income group shift. Except travel times in lower and higher middle income groups, all the other parameters have not much significance which shows that travel time have more impact on this group. However, travel cost in both middle income groups can be considered significant enough (see section 3.4.2.4) as travel cost matters to them since they have moderate income. But, the more insignificant values on most of the parameters and in the error terms show that the income variable is not the responsible factor for the sampled population of KMC for not using public vehicles since they don't have much impact on them regardless of their parameter values.

Regarding parameter values, from Table 6-2, it is known that all the income groups value comfort the most which shows that they are willing to pay more to get more comfort. After comfort, low income group value travel cost and then only travel time since they cannot afford more on travelling. While middle income groups value travel time more than travel cost since these are the income groups of middle and they seem to prefer to reach their destinations in time. However, high income group prefer travel cost after comfort and then only travel time.

6.1.3 Model Estimation between different modes and PPBS

The modelling approach was to analyze the stated preferences of the sampled population between their current travel mode and proposed mode. Since there were five major different modes being mostly used to travel to work in KMC, five models were developed and the results of their respective model estimation are summarized in Table 6-3 below:

Table 6-3: Utility parameters for different modes

Travel modes	Attribute	Parameter	Value	Units	t-test	p-value
Bus	Travel Time	β TT	-0.0507	Minutes	-1.54 *	0.12 *
	Travel Cost*	β TC	0.0307	Rupees	0.45 *	0.65 *
	Comfort	β C	0.781		2.24	0.02
	Error term	ASC1	0.518		1.83 ^	0.07 *
	Rho-square	ϱ^2	0.061			
Microbus	Travel Time	β TT	-0.0663	Minutes	-2.7	0.01
	Travel Cost*	β TC	0.0678	Rupees	1.32 *	0.19*
	Comfort	β C	0.64		3.17	0.00
	Error term	ASC1	0.521		2.06	0.04
	Rho-square	ϱ^2	0.066			
Tempo	Travel Time	β TT	-0.0544	Minutes	-5.37	0.00
	Travel Cost*	β TC	-0.0412	Rupees	-0.69 *	0.49 *
	Comfort	β C	0.744		2.64	0.01
	Error term	ASC1	0.695		2.21	0.03
	Rho-square	ϱ^2	0.086			
Motorbike	Travel Time	β TT	0.0284	Minutes	1.73 ^	0.08 *
	Travel Cost	β TC	-0.0115	Rupees	-2.12	0.03
	Comfort	β C	0.567		2.25	0.02
	Error term	ASC1	-1.83		-3.65	0.00
	Rho-square	ϱ^2	0.130			
Car	Travel Time	β TT	0.0272	Minutes	2.24	0.02
	Travel Cost*	β TC	0.000441	Rupees	0.7*	0.48*
	Comfort	β C	2.62		9.86	0.00
	Error term	ASC1	0.676		0.347*	5.21*
	Rho-square	ϱ^2	0.459			

(Note: * = not significant and ^ = can be assumed significant)

Since the value of likelihood ratio-index ϱ^2 (Rho-square) between 0.2 and 0.4 is considered to be indication of extremely good model fits, the models above only indicates fair levels since their value range from 0.061 to 0.459 when comparing the log-likelihood at 0 and the log-likelihood at convergence. However, model of car can be considered better model than other modes due to its greater ϱ^2 value. The individual utility parameters are discussed below:

i) Travel time:

A negative sign was expected to be associated with travel time since an individual's utility increases when travel time decreases and vice versa. From Table 6-3, among five different modes, all the modes except motorbike and car, negative sign for travel time was obtained since people didn't seem to prefer spending more time in travelling. However, in case of motorbike and car, the sampled population seemed to be willing to spend more time in travelling with the positive sign associated with it since more distance can be covered with motorbike in less time and travelling by car is much more comfortable despite of the time spent in travelling.

Regarding the significance levels, travel time for all the modes is in general significant at 95% confidence level and nearly significant in case of motorbike (see section 3.4.2.4) except for bus. This shows that less travel time has not much impact on bus users in compared to comfort and travel cost in their travel behaviour to make them shift to PPBS. In context of preference of the sampled population for travel, travel time is at the highest priority among motorbike users and then car users. This shows that the travel time is quite important for the private mode users while compared to their public counterparts.

ii) Travel cost:

Similar to travel time, negative sign was expected from travel cost since an individual's utility increases when travel cost decreases and vice versa as people are usually not willing to spend more money in travelling. However from Table 6-3, its sign is observed positive in case of current bus, microbus and car while negative in case of tempo and motorbike. In case of car, travel cost is not the important factor for the car users to choose their travel mode as they are usually from high income group. But in case of public vehicles - bus and microbus, in general, travel cost should be observed as negative. This may be due to the limitation of the sample area selection and choice of sample population, for whom, travel time would matter the most.

Regarding significance levels, travel cost for all the modes is not so significant at 95% confidence level in general except for motorbike. This shows that travel cost have not much impact on changing sampled population's behaviour to shift to PPBS irrespective of their travel mode. However, it has impact on motorbike users since most of them fall into low income group with few on lower middle income group and hence value travel cost than travel time. This may be due to the limitations such as improper trade offs in the choice sets and even may be dependent on the sample used. Considering the preference of the sampled population for travel cost, travel cost is most preferred by microbus users and then current bus users while least preferred by tempo users and the private mode users. This shows that the travel cost is quite important for the public mode users except tempo users while compared to their private counterparts.

iii) Comfort:

Similarly positive sign was expected with comfort as individual's utility increases with the increase in the comfort level. As expected from Table 6-3, positive signs of comfort parameter values are obtained for all the modes. Hence, sample population from all modes value comfort the most while choosing their travel mode. Regarding significance levels, comfort for all the modes is highly significant at 95% confidence level which shows comfort has definitely strong impact on all the mode users in order to make them shift to PPBS. Considering the preference, comfort is the most significant attribute in case of car, then tempo and current bus, then microbus and then only motorbike since public mode users value the travel cost more except tempo users and motorbike users value the travel time the most.

iv) Error term:

From Table 6-3, it is observed that the error terms for all the travel modes expect cars are statistically significant in all models. According to Hensher et al. (2007), the inclusion of error term has been regarded as best estimate available where other parameters are not significant which is applicable in this case since one of the attribute travel cost was observed not significant in most of the cases in the analysis.

Compared to the model estimation of the whole sample, it is observed that the likelihood ratio-index ϱ2 is lower but closer to the acceptable range showing fairly good model fits for the estimated models of all the five modes with models for motorbike and car being the better model than other modes. The reason behind this may be the small data samples used in the modelling, 100 samples for each of the mode since to collect more than 100 samples for each mode was not possible during 3 weeks of field work.

In previous researches, Ahern & Tapley (2008) first checked the choice set responses for non-trading behaviour which occurs when the respondent selects the same response option in all choice sets and removed such responses from the analysis. Secondly, he also examined for lexicographic behaviour which occurs when the individual uses only one attribute to determine their choice and hence removed them from the analysis. Similarly, Lancsar et al. (2006) stated that the choice responses have been deleted from choice experiments where they were found to be irrational and lexicographic responses. Therefore, in this experiment, the choice responses were checked for the non-trading behaviour. But when removing such responses, the significance level of parameter values decreased. Secondly, the responses were checked for lexicographic behaviour and such responses were not found. Though irrational choice responses from the data were thought to be the reason for statistically inefficient results and deleting them could be one solution, Lancsar & Louviere (2006) criticizes that deleting such responses from choice experiments may result in the removal of valid preferences, induction of the sample selection bias and reduction of statistical efficiency and power of the estimated models since it is not necessary that all the choices considered irrational are irrational in real. Therefore, the choice data was entered as it is from the field into the Biogeme software and the results were obtained as in Table 6-3.

6.1.4 Utility function derivation

From equation (3.3), replacing the estimated parameter values related to current mode and PPBS attributes, the utility of the two alternatives can be derived as following equations:

For current mode,

$$U_C = \text{ASC1} \times \text{one} + \beta_{TT} \times \text{C\_TT} + \beta_{TC} \times \text{C\_TC} + \beta_C \times \text{C\_CM} \tag{6.1}$$

For proposed mode,

$$U_{PPBS} = \text{ASC2} \times \text{one} + \beta_{TT} \times \text{P\_TT} + \beta_{TC} \times \text{P\_TC} + \beta_C \times \text{P\_CM} \tag{6.2}$$

Where U_C = Utility of the current mode

U_{PPBS} = Utility of the proposed mode PPBS

ASC1= Error term

ASC2= Alternative specific constant for proposed mode = 0

β_{TT} = weight or coefficient associated with travel time

β_{TC} = weight or coefficient associated with travel cost

β_C = weight or coefficient associated with comfort

Since there were four different values according to different time slots during the survey, the utility equations were derived four times for each time slot with respective attribute values in the choice sets. The average of the all the four utility equations were taken into consideration. The parameter (β) values from Table 6-3 were entered in equation 6.1 and 6.2 and the utilities for both current mode and PPBS were calculated separately for each mode. More utility means better the mode for the potential traveller (Zuidgeest & Maarseveen, 2011). According to Ben-Akiva & Lerman (1985), an individual is always assumed to select the alternative with the highest utility. As survey and biogeme analysis was done for five travel modes, five models have been developed which are as follows:

Model 1: Bus and PPBS

Following equation 6.1 and 6.2, the utility equations of model for current bus and PPBS are as follows:

For bus,

For bus,

$$U_{Bus} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{Bus} + \beta_{TC} \times Travel\ Cost_{Bus} + \beta_C \times Comfort_{Bus} \quad (6.3)$$

Where U_{Bus} = Utility of bus

For PPBS,

$$U_{PPBS} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{PPBS} + \beta_{TC} \times Travel\ Cost_{PPBS} + \beta_C \times Comfort_{PPBS} \quad (6.4)$$

Where U_{PPBS} = Utility of PPBS

The utilities of bus and PPBS for each time slot are as follows:

Table 6-4: Utility values for bus and PPBS

Time Slot	Utility for bus	Average utility for bus	Utility for PPBS	Average utility for PPBS
0-15	0.1873	-0.74623	1.1415	0.3981
16-30	-0.389		0.8187	
31-45	-1.0267		0.181	
46-60	-1.7565		-0.5488	

From Table 6-4, it is observed that the utilities for both bus and PPBS are decreasing for all the four time slots as the travel time is increasing. Lesser time has more utility in both cases which means bus users from sample do not prefer to travel more. But while comparing bus and PPBS, it is observed that the average utility for PPBS is more compared to bus due to its more magnitude and positive sign. Therefore, PPBS will be more attractive alternative for making a trip to work than bus for the sample in the study area if they will be implemented. Thus, the more utility of PPBS proves it to be a better mode for bus users assuring that when there will be two choices of PPBS and bus, current bus users will choose PPBS more.

Model 2: Micro bus and PPBS

Following equation 6.1 and 6.2, the utility equations of model for micro bus and PPBS are as follows:

For Micro bus,

$$U_{Micro\ Bus} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{Micro\ Bus} + \beta_{TC} \times Travel\ Cost_{Micro\ Bus} + \beta_C \times Comfort_{Micro\ Bus} \quad (6.5)$$

Where $U_{Micro\ Bus}$ = Utility of Micro bus

For PPBS,

$$U_{PPBS} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{PPBS} + \beta_{TC} \times Travel\ Cost_{PPBS} + \beta_C \times Comfort_{PPBS} \quad (6.6)$$

Where U_{PPBS} = Utility of PPBS

The utilities of the microbus and PPBS for each time slot are as follows:

Table 6-5: Utility values for micro bus and PPBS

Time Slot	Utility for micro bus	Average utility for micro bus	Utility for PPBS	Average utility for PPBS
0-17	0.3431	-0.40923	1.6645	0.879025
18-27	0.0869		1.4083	
28-42	-0.6364		0.685	
43-55	-1.4305		-0.2417	

From Table 6-5, it is known that the utilities for both microbus and PPBS are decreasing like in case of model 1 for bus as the travel time is increasing. In this case also, less time has more utility which means less time is more attractive to the micro bus users. But while comparing micro bus and PPBS, it is observed that the average utility for PPBS is more compared to the micro bus like in model 1 due to its more magnitude and positive sign. Hence, PPBS will be more attractive alternative for making a trip to work than micro bus in the study area if they will be implemented. Like in model 1, the more utility of PPBS proves it to be a better mode for the microbus users which means when there will be two choices of PPBS and microbus, they will choose PPBS more.

Model 3: Tempo and PPBS

Following equation 6.1 and 6.2, the utility equations of model for tempo and PPBS are as follows:

For Tempo,

$$U_{Tempo} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{Tempo} + \beta_{TC} \times Travel\ Cost_{Tempo} + \beta_C \times Comfort_{Tempo} \quad (6.7)$$

Where U_{Tempo} = Utility of Tempo

For PPBS,

$$U_{PPBS} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{PPBS} + \beta_{TC} \times Travel\ Cost_{PPBS} + \beta_C \times Comfort_{PPBS} \quad (6.8)$$

Where U_{PPBS} = Utility of PPBS

The utilities of tempo and PPBS for each time slot are as follows:

Table 6-6: Utility values for tempo and PPBS

Time Slot	Utility for tempo	Average utility for tempo	Utility for PPBS	Average utility for PPBS
0-15	-0.6978	-2.3903	-0.352	-1.6501
16-33	-1.9242		-1.1432	
34-51	-3.0682		-2.124	
52-65	-3.871		-2.9812	

From Table 6-6, it is known that the utilities for both tempo and PPBS are decreasing like in case of model 1 for bus and model 2 for micro bus as the travel time is increasing. In this case also, less time has more utility which means less time is more attractive to the tempo users also. But while comparing tempo and PPBS, it is observed that the average utility for PPBS is more compared to tempo like in model 1 and model 2 due to its more magnitude though they are of negative signs. Hence, PPBS will be more attractive alternative for making a trip to work than tempo in the study area if they will be implemented. Like in model 1 and 2, the more utility of PPBS proves it to be a better mode for the tempo users which means when there will be two choices of PPBS and tempo, they will choose PPBS more.

Therefore, the public mode users from the sample are found to be more attracted towards PPBS which will be their choice if it will be implemented. They do not prefer less travel time as well. While designing PPBS, it should have less travel time than current public modes to be chosen by the public mode users.

Model 4: Motorbike and PPBS

Following equation 6.1 and 6.2, the utility equations of model for motorbike and PPBS are as follows:

For Motorbike,

$$U_{Motorbike} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{Motorbike} + \beta_{TC} \times Travel\ Cost_{Motorbike} + \beta_C \times Comfort_{Motorbike} \quad (6.9)$$

Where $U_{Motorbike}$ = Utility of Motorbike

For PPBS,

$$U_{PPBS} = \text{ASC1} \times \text{one} + \beta_{TT} \times Travel\ Time_{PPBS} + \beta_{TC} \times Travel\ Cost_{PPBS} + \beta_C \times Comfort_{PPBS} \quad (6.10)$$

Where U_{PPBS} = Utility of PPBS

The utilities of motorbike and PPBS for each time slot are as follows:

Table 6-7: Utility values for motorbike and PPBS

Time Slot	Utility for motorbike	Average utility for motorbike	Utility for PPBS	Average utility for PPBS
0-15	-1.1245	-0.88695	-1.17913	0.650875
16-27	-0.9562		-1.4335	
28-42	-0.8177		-0.896	
43-54	-0.6494		-0.6425	

From Table 6-7, it is known that the utilities for both motorbike and PPBS are increasing contrary to the case of previous model 1, 2 and 3 as the travel time is increasing. Hence, adversary to public mode users, more time has more utility which means more time is more attractive to the motorbike users. But while comparing motorbike and PPBS, it is observed that the average utility for PPBS is more compared to motorbike like in model 1, 2 and 3 due to its more magnitude and positive sign as utility for motorbike is of lesser magnitude and negative sign. Hence, PPBS will be more attractive alternative for making a trip to work than motorbike in the study area if they will be implemented. Like in model 1, 2 and 3, the more utility of PPBS proves it to be a better mode for motorbike users which means when there will be two choices of PPBS and motorbike, they will choose PPBS more.

Model 5: Car and PPBS

Following equation 6.1 and 6.2, the utility equations of model for car and PPBS are as follows:

For Car,

U_{Car} = ASC1 $\times$ one + $\beta_{TT} \times Travel\ Time_{Car}$+ $\beta_{TC} \times Travel\ Cost_{Car}$ + $\beta_C\ \times Comfort_{\ Car}$ (6.11)

Where U_{Car} = Utility of Car

For PPBS,

U_{PPBS}=ASC1 $\times$ one + $\beta_{TT} \times Travel\ Time_{PPBS}$+ $\beta_{TC} \times Travel\ Cost_{PPBS}$ + $\beta_C\ \times$
$Comfort_{\ PPBS}$ (6.12)

Where U_{PPBS} = Utility of PPBS

The utilities of car and PPBS for each time slot are as follows:

Table 6-8: Utility values for car and PPBS

Time Slot	Utility for car	Average utility for car	Utility for PPBS	Average utility for PPBS
0-17	4.925475	5.543716	2.76482	3.380348
18-30	5.309945		3.04123	
31-46	5.7694		3.857671	
47-60	6.170045		3.857671	

From Table 6-8, it is known that the utilities for both car and PPBS are increasing as in model 4 for motorbike but contrary to the previous models 1, 2 and 3 since the travel time is increasing. Hence, adversary to the public mode users, more time has more utility which means more time is more attractive to car users similar to the motorbike users. But while comparing car and PPBS, it is observed that the average utility for PPBS is less compared to car contrary to all the previous models due to its more magnitude though both the utilities are of positive sign since utility for PPBS is of lesser magnitude than of car. Hence, car still will be more attractive alternative for making a trip to work than PPBS in the study area even when it will be implemented. Adversary to the previous models, the more utility of car proves it to be a better mode for car users which means when there will be two choices of PPBS and car, they will still go for cars not for PPBS.

Therefore, PBBS has more utility value and hence more attractive to users from the sample except car users.

6.1.5 Limitation in mode choice analysis

Though the model has resulted into some reasonable results, some limitations have been observed. Not all the utility parameters reached the significance level of 90% confidence interval in all models; travel cost didn't reach the expected significance level in all models. In addition, rho-square values for all the models didn't fall in the optimal range of 0.2 - 0.4 except for the model between car and PPBS. Therefore, there is need of better combinations for choice sets and more number of observations to have a better representation of the utility functions in terms of parameter significance and attribute interaction. The attributes values for PPBS were assumed and used in the choice sets since they were not defined till date the survey. The exact values for the attributes for PPBS from the policy makers may lead to better model in future.

6.2 Preference of users based on their socio-economic characteristics

To know the preference of different individual socio-economic groups, five different socio-economic characteristics were considered for the samples which were gender, age, income level and education level. By knowing the preference of such socio-economic groups, it will be easy for the stakeholders to address those specific groups and focus on them accordingly. This means if a certain group is not willing to shift, then more awareness has to be put forwarded for that particular group. Similarly, those groups who are more willing to shift will be the potential users who will contribute to CO_2 reductions and hence will be targeted accordingly by the policy makers. The preferences of different users on basis of their socio-economic characteristics are described below:

6.2.1 Gender and Age Group wise preference of users

From Figure 6-1, slighly more male are willing to shift than female from the sample survyed. Female are observed to be neutral since the willingness to shift and not willingness to shift are nearly equal. While with the increment in age, people are not so willing to change and so not so willing to shift. The age-group of 17-30 are the most willing to shift group since they are young and they are more open to the changes. However, the case may be different for whole population of KMC. Moreover, the willingness to shift seems to be not affected much from both gender and age perspective since nearly uniform variation is found among these socio-economic variables. This shows gender and age group are not the major factors behind their change of travel behaviour.

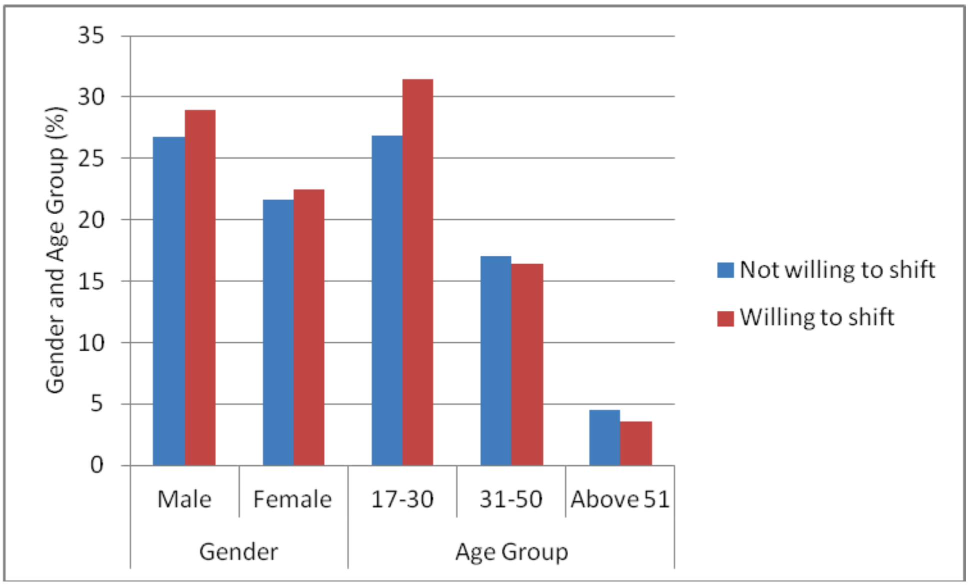

Figure 6-1: Gender and Age Group (%) wise preference of the users of sample population

6.2.2 Income Level and Education Level wise preference of users

From Figure 6-2 below, the high income group are more willing to shift from the sample since they consider co-benefits of travelling except travel cost. Another willing to shift group is income group of lower middle income since they also do not consider the importance of travel cost that much since they are more concerned about travel time. On contrary, half of the samples of low income group are willing to shift. Though they prefer less travel cost, sometime travel time and comfort also matter to them. But, all these results depend on the attribute levels of the choice sets also. In case of education level, more the sample is educated, more they are willing to shift since they value other factors also rather than travel cost and travel time only. Though there is not much variation, most of the secondary level and primary level are willing to shift as they are educated enough to understand the importance of the new systems and their benefits. Moreover, the willingness to shift seems to be not affected much from both income and education level perspective since nearly uniform variation is found among these socio-economic variables. This shows income and education are not the major factors behind their change of travel behaviour.

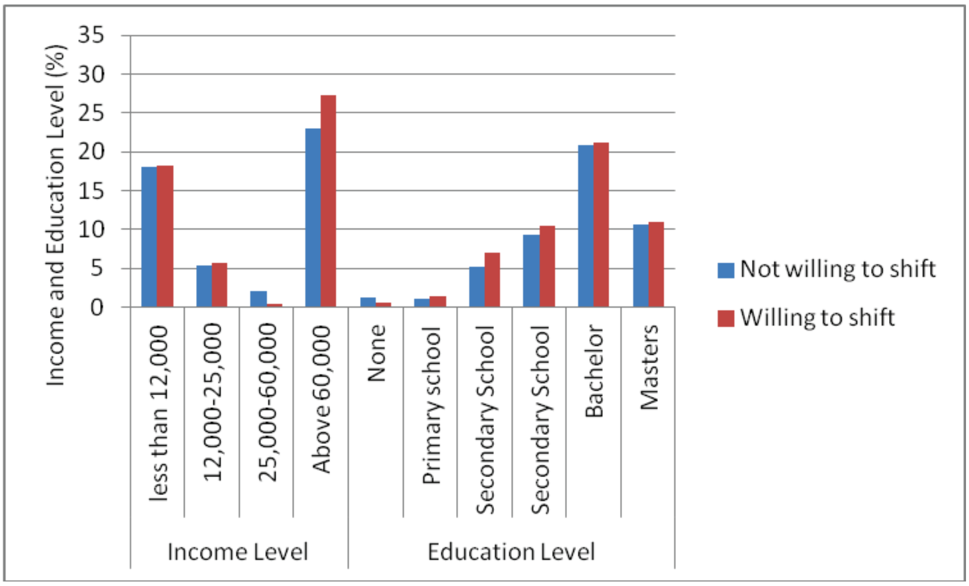

Figure 6-2: Income Level and Education Level (%) wise preference of sample population

6.3 Modal shift analysis

The probability of choosing the proposed alternative PPBS was calculated for all modes for average utilities of all the modes following equations 3.6 and 3.7. Considering the average utility values, the average probabilities of willingness to shift were calculated. From Figure 6-3 below, out of five different modes, it is observed that most of the public transport users- microbus, current bus and then tempo are likely to shift to PPBS. From public mode users, the highest percentages of people who are willing to shift are microbus users, about 78%. Therefore, if provided moderate travel fare with adequate travel time with comfortable environment in public buses, there is huge tendency to shift from their current mode to sustainable transport mode. While in case of private modes, most of the motorbike users, about 78% are willing to shift on contrary to other private mode - car. More motorbike users are willing to shift since nearly half of the sample of motorbike users is not considering their mode as comfortable and they would shift to PPBS if there will be adequate comfort with moderate travel fare and desired travel time. As already discussed in section 5.2.4.1, comfort doesn't always necessarily means comfortable seating inside the vehicle, there are other factors also which affect comfort level of the users.

Not only limited to the attributes of the survey, the motorbikes are more inclined to change due to the reason of its highest accident rate in compare to other modes (Dhakal, 2006). However, in case of car, only 10% are willing to shift. In overall sample, 36.92 % of the commuters are willing to shift to PPBS. Hence, it can be concluded that if the new system is implemented, there are definitely good chances of modal shift from public modes and also high chance of modal shift of motorbike users.

In similar study of the impact of modal shift on transport ecological footprint in Ahmadabad, India by (Bajracharya, 2008), he found out that 34% of the commuters are willing to shift to BRT System which means the results are somehow similar. In another study of using bus rapid transit to mitigate CO_2 emissions from transport by (Convery et al., 2008), they concluded the modal shifts ranging from approximately 15% and 29% when analysing a Quality Bus Corridor implemented in Dublin, Ireland. Therefore, the implementation of new improvised public transport has been predicted successful in encouraging the modal shifts in many cases.

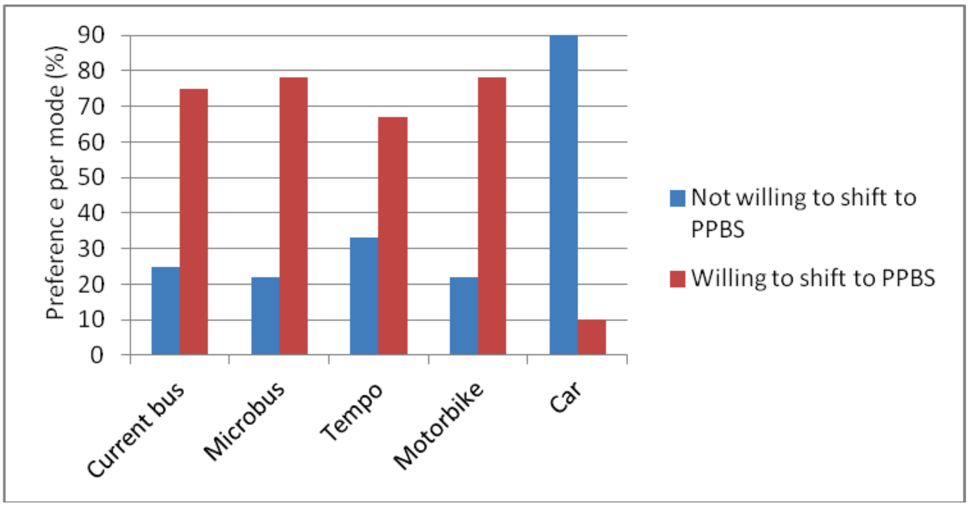

Figure 6-3: Comparison of willingness to shift from different current modes to proposed mode PPBS

Further, for analysing the impact of the modal shift on LCD, two situations were compared; current and modal shift situation and respective CO_2 emissions were calculated which is shown in following sections. The calculation detail is provided in appendices section 8.

6.3.1 Current situation

This situation represents the present situation in the study area where the mode share is same from the sample allocation for each mode when PPBS has not been implemented. By following the ASIF model from Figure 3-5, the carbon emission from each mode was calculated using the latest data available from the secondary source as shown in Figure 6-4 below. In current situation, the private travel modes contribute to CO_2 emissions the most; car being the highest contributor while public modes contribute similar amount of CO_2 emissions among themselves but less than their private counterparts. Therefore, it is observed that if this trend continues and from previous studies also (Dhakal, 2006), it has been forecasted that the use of private mode will increase year by year in the study area, thus, there should be the implementation of an environmental friendly travel counterpart with low emissions to reduce the CO_2 emissions and encourage the modal shift.

6.3.2 Modal Shift Situation

This is the situation in which it was assumed that the new proposed public transport system PPBS like trolley bus is implemented in the study area. From the sample population, the population which were not willing to shift and would continue their current mode were considered the mode share from the modal shift analysis. Following the ASIF model from Figure 3-5, the carbon emission from each mode was calculated. Other data available from the secondary source was used as similar to the current situation. The Figure 6-4 shows the emission level of different modes in metric tons in KMC in case of the current and modal shift situations. The CO_2 emissions tend to decrease in each mode with higher drops in public transportation modes with the abrupt drop in case of motorbikes.

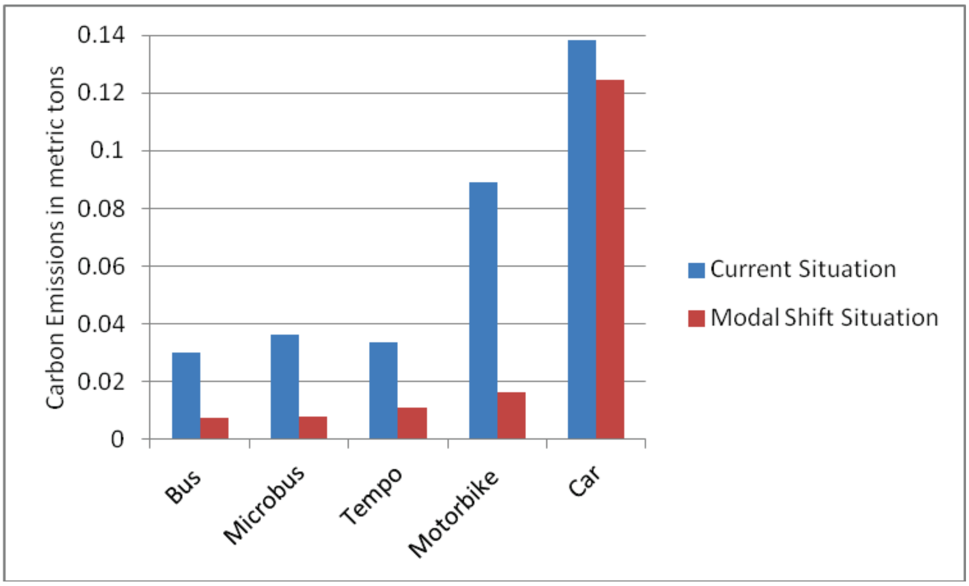

Figure 6-4: Carbon emission levels in metric tons in KMC from different modes in current and modal shift situations

6.4 Potential CO_2 emissions reduction

GHG assessment has been complicated by the large number of diverse sources of emissions and the large number of assumptions that are required for the assessment which can be applied across countries and regions. The better information on GHG benefits will provide opportunities for project developers to identify better low-carbon transport investments (Dalkmann & Huizenga, 2010). In this regard, if the new public transportation PPBS will be implemented, then there will be 48% of decrease in CO_2 emissions per working day (from Figure 6-5) which is a significant decrease. From Figure 6-4, it is observed that if more car users will shift to the new system, it will contribute most to the reduction in CO_2 emissions, then motorbike and then public transportation modes – tempo, bus and microbus respectively from the sample. However, from modal shift analysis (Figure 6-3), only 10% of the car users are willing to shift but in case of motorbike, about 78% are willing to shift to proposed public bus. Therefore, if even only the motorbike users will shift, then it will contribute significantly for the reduction in CO_2 emissions. Therefore, the implementation of such low emission public transport should be encouraged, promoted and implemented in the study area to contribute to LCD. In addition to the reduction of CO_2 emissions, the introduction of new public transport system will contribute towards the development of the transport system due to modal shift contributing to the lifestyle of the residents of the study area.

When comparing the previous studies in the study area, Shrestha (2012) found the decrease of 41% of emissions for public transport with the trolley bus renewal scenarios. Similarly, Convery *et al.* (2008) observed that the implementation of Quality Bus Corridor in Dublin, Ireland had a positive effect on the abatement of CO_2 emissions and there is scope of further reductions.

Figure 6-5: CO_2 emissions reduction after modal shift

6.5 Discussion

From this study, it has been found in general that the sample population prefer comfort the most, then travel time and then only travel cost which is supported by JICA (2012) also stating that the main concern of passengers of KMC are time, fare, safety and comfort which discourage them to not to use bus.

Most of the public transport mode users are willing to shift as they are getting more facilities with the little higher travel fare and desired travel time with the ample comfort. However, only 10% of the car users are willing to shift as most of them still do not want to compromise in several ways. To the contrary, most of the motorbike users are willing to shift. The reason behind this is if they can reach their destinations in desired time through moderate travel fare and ample comfort level, they will prefer to shift since most of them are middle and low income group of people. The ample comfort level doesn't refer to only the comfortable seating inside the vehicle in case of KMC as known from the survey. As already discussed in section 5.2.4.1, there are other factors that differ from person to person in their interpretation of their comfort level. They can refer to crowd in the road, pick pocketing, not hygienic, risk, pollution, no route *etc* for defining your comfort level. Hence, different aspects that can affect the comfort level of a person have to be identified and then taken care for designing new public transport system to make the users shift to it.

Not only limited to the attributes used in the survey, the motorbike users are more inclined to shift because of its highest accident rate also compared to other modes (Dhakal, 2006) in the study area. In addition, the petroleum products are being sold in high price to the consumers of Nepal which is increasing day by day in rapid pace due to the shortage in petrol and diesel since the engine suppliers totally depend on importing the oil from neighbouring countries especially India (Thapa, 2012). Hence due to their high price and scarcity, most of the motorbike users are willing to shift if they get comfortable travel in moderate travel fare which they can afford.

Moreover, the more willingness to shift in motorbike users is due to the majority of them falling into the category of higher middle income group (see Figure 5-3). This income group is supposed to be able to afford the moderate travel fare and is educated enough (see Figure 5-4) to be aware to shift.

6.6 Limitations

Though the decrease of 48% was found in CO_2 emissions for the sample in this study from modal shift, there are some limitations. One is the congestion level which was not considered while accounting the travel time spent by the sample used in ASIF model. Another is though walking time to bus stop, waiting in the bus stop and returning from the bus stop has been generalized and deducted from the actual travel time reported by the sample for ASIF model, it is not necessary that the deducted travel time is same for all the people in the sample. While stating the travel time by the sample, some of them may have considered only in vehicle travel time which was not considered in this study. In addition, there is no reliable statistics available for the average speed of different vehicles in context of KMC which has affected the actual distance covered and eventually the quantification of the impact on emissions. Further, the effect of various maintenance and technological improvements on current travel modes could not be updated due to lack of data which may have affected the calculation in ASIF model.

6.7 Conclusion

With the increase in comfort level, the relative attractiveness of the proposed mode can be increased for the sample except for the car users. Therefore, while designing PPBS, comfort has to be given the utmost importance, then travel time targeting private mode users and then only travel cost addressing public mode users to encourage them for the modal shift. Income level is not main factor behind not using the public transportation in case of sample population from sample. Moreover, there is not much difference in levels of willingness to shift from socio-economic variable perspective among each variable which shows that the preference is also not affected by socio-economic condition of a person from the sample. Therefore, considerable amount of population from the sample are willing to shift causing adequate decrease in CO_2 emission level which strongly recommends following the shift strategy to obtain LCD in case of KMC.

7 CONCLUSION AND RECOMMENDATIONS

This chapter deals with the findings and achievements gained for each objective of the research, includes its limitations, policy implications and highlights the recommendations on the issues that should be considered with future research in this direction.

7.1 Conclusion

In the study area, PT services should be improved according to the coverage, frequency and hours of operation by assigning the appropriate vehicles to particular routes and the route network should be made simpler to make the PT system more efficient and well managed. Many of the PT vehicles need to be replaced, the quality of fuel should be maintained and the vehicles engines should be tested properly. There should be private company or cooperatives to run the PT in particular route and franchise should be issued by the government bodies. There should be improvement in the interchange of bus stops within the central area. There should be rationalization of the vehicle fleet for the convenience and comfort of the users. There should be introduction of the subsidies for the poor people and introduction of the vehicles which are friendly for the physically impaired passengers.

In this regard, the stakeholders are trying to get a good model of PT suitable in case of KMC; it has been decided that they will be either low carbon or electric or may be just improvement of the existing public vehicles. Any form of mass public transport system like BRT or trolley bus can be implemented. The reintroduction of the trolley bus has been recommended. The identification of which road sections should comprise which type of PT to know the hierarchy of the routes and modes of transport has to done. There has also been a plan to analyze the shift from poorly maintained buses to high capacity modern buses and from low occupancy public vehicles to high ones.

The future policies should target the male groups and the age group of 17-30, the middle and high income group and master level people more to contribute more in CO_2 emission reduction as they are more likely to shift their modes from the sample.

While designing any new public transport system, the topmost priority should be given for creating comfortable environment in general and also maintaining it in the new public transport systems in order to change user's behaviour to use public transport in the study area. Then the secondary significant factor that should be focussed is maintaining less travel time than current public modes to be chosen by the public mode users. Then the tertiary factor is the less travel cost that should be considered. To change the travel behaviour of the private mode users, less travel time should be taken care of while to change the travel behaviour of public mode users, less travel cost should be maintained. Since it is observed from the sample that most of the public transport users are likely to shift to PPBS, there should be strategies developed to encourage the private mode users especially car users to change their travel behaviour.

If the PPBS will be implemented, then there will be reduction of 0.15 metric tons of CO_2 emissions per working day which is a significant decrease for sample of population 520. Similarly, the reduction will be 0.00030 metric tons per head resulting into 154.08 metric tons reduction in case of working class only and 309.37 metric tons per day for the whole population of KMC.

Though the shift of the car users will contribute most to the reduction in CO_2 emissions, in case of the study area, only few of them are willing to shift. Hence, even the shift of the motorbike users will contribute significantly for the reduction in CO_2 emissions since they are more in number. The greater the modal shift from motorbike to low carbon modes, better is for reduction of CO_2 emissions which support the shift strategy for achieving LCD in KMC since the growth rate of motorbikes is particularly high over 17% and rising very rapidly due to their low cost and high mobility on congested and narrow roads in KMC (Dhakal, 2006). Further, the dramatic rise in new registrations of motorbikes is due to various financial options offered by local financial options institutions and motorbike distributors as assumed by Dhakal (2006).

In the study area, the private modes meet less travel demand consuming more energy while public modes fulfil more demand by consuming less energy. In addition, the rates of ownership of cars and motorbikes are both expected to double and the number of vehicles per km of road trip length to triple by 2025 (Dhakal, 2006) and trip generation of owner of motorbike or car per person is higher than non-owner by 1-18% (JICA, 2012). Therefore, the large-scale introduction of a bus system is supposed to reduce large numbers of cars, motorbikes, and low occupancy public transport modes, reduce trip generations and thus help to reduce the congestion level and energy usage if implemented.

Comparing with the other indicators of LCD, the modal shift may have counter effects. For instance, the trip length of the public transportation due to modal shift may increase resulting into more congestion on the streets of KMC and users may be exposed to risk of accidents due to increased speed of PPBS. To solve this, another indicator of LCD, *i.e*, land use has to be planned properly allocating activities at proper locations to manage the trip generations and trip distributions, for example, job-housing balance, equality in social cohesion and proper public transport networks assuring desired accessibility (CEPT, 2011). In addition, the quality of footpath should be maintained and proper street lights should be provided at proper junctions to avoid accidents. Walking lanes and cycle lanes should be designed. Not only emission from transport, proper measures should be incorporated to reduce emission level from other energy sectors also. The health impacts should also be monitored and considered, for instance, users exposing to the excessive noise levels. Apart from these issues, economic balance should also be maintained from different investments, fare prices, petrol prices and different types of taxes ensuring affordability to the users (CEPT, 2011).

7.2 Limitations

Apart from the findings from this study, there are some limitations which are as follows:

i) This study has focussed only on emissions of CO_2 while the analyses of other GHGs have not been included.
ii) The result is based on the sample population only to whom the SP survey was conducted. Though the study is limited on a relatively small population and working class only as a proportion of the whole city, the results suggest that any new improved public transport system like trolley bus will be successful in encouraging modal shift which will have significant reduction in CO_2 emission contributing to LCD in the study area.
iii) The evaluation of the impact on LCD is limited to the present transport activity, pollutant emissions, fuel use and CO_2 emissions.
iv) The emissions in transport depend on ASIF and how ASIF is defined, so the result may vary from approach to approach. But in this study, for linking SP survey, which focused on the modal shift and

share in the field, only structure aspect was taken into consideration. The technological aspects were derived from secondary sources which need to be updated.

v) The study was limited to a specific cluster at central hub of KMC not for the whole city which has assigned the shift of the sampled population of that location only resulting into high reduction in CO_2 emissions. But the travel behaviour of users may vary from place to the place.

vi) The identified comfort factors were not included in SP survey since more attributes would result into more choice sets which would create fatigue to the respondent being practically impossible in a survey.

However, the analysis was done in relative terms comparing the current and modal shift situation; therefore, it can be argued that the results on impact on LCD would be still reasonable.

7.3 Policy Implications

In developing cities like KMC, the capacity and authority of local policy-makers are weak, resources are scarce, institutions for urban environmental management are undeveloped, policy enforcement mechanisms are feeble, the involvement of stakeholders is minimal and the problems are often intricately interwoven with poverty issues (Dhakal, 2006). Thus, any infrastructure development like sustainable transport like TB or any other improved public bus system with reasonable travel fares can highly contribute to better environment with lower emissions. Moreover, though urban planning related issues like land pooling, containment and mixed–land use have long been advocated in KMC, the measures related to transport have not been implemented and considered seriously. Therefore, the sustainable public vehicles should be promoted more.

Further, there are distinct gaps in the measures currently being implemented in KMC. The focus of air pollution measures revolves around only vehicle tail-pipes and doesn't recognize the activities and structure (AS) part of the solution (Dhakal, 2006). Therefore, AS should be considered seriously from planning perspective in order to reduce CO_2 emissions to reform the public bus system and improve its reliability and quality concentrating on A and S.

In this regard, from urban and transportation planning and management approach, the short term actions can be improvement of the performance, reliability and quality of PT with more comfort, less travel time and less travel cost. Similarly, the long term vision can be to make the transport system safe, affordable, organized, non-polluting and service-oriented through qualitative increase in vehicle and transport services, thereby making contribution towards the overall development and prosperity of the country (Pandey, 2009) with institutional improvement. Hence, the new paradigm for urban transport should be to provide accessibility with proper management of demand to the road capacity keeping public transport as central with people-cantered approach. This study also shows that apart from the technical experts and stakeholders, users also need to participate in the policy-making process to ensure that plans and projects reflect the actual needs.

To control the use of private vehicles further in KMC, strict parking policies, vehicle ownership cost, registration charge, vehicle tax and congestion charges should be practised. Similarly, charges with vehicle license that reflect vehicle's impact on air pollution and other externalities can also be incorporated (Dhakal, 2006). People should be made aware about the need of sustainable development strategies through travel awareness campaigns and quality information to motivate their shift towards sustainable transport options. There should be always proper planning and appropriate implementation tactics for any new plan or system to be successful. Therefore, studies like this would give decision-makers the better feedback on their proposed polices and help them to evaluate existing and proposed policies more effectively, judge what works to implement them and make appropriate and beneficial revisions. Hence, the paradigm for sustainable urban transport offers the potential of a much more effective management of the cities with the main challenge to place cities on a more sustainable trajectory by accomplishing what everyone is looking for with the commitment and appropriate resources (Dhakal, 2006).

7.4 Recommendations

Several studies have demonstrated that electric vehicles (EV) like trolley buses are feasible in context of KMC (Dhakal, 2006; Shrestha, 2012). "*Since electricity is generated by run–of–river hydropower plants, the use of EVs can reduce air pollution as well as reduce oil imports and mitigate CO_2 emissions*"(Dhakal, 2006). In addition, EV use can help to improve the load factor of power generation reducing the average cost of electricity by making the possible use of otherwise wasted off-peak hour energy. An EV based approach if integrated well with policies to restrain private cars, promote high–occupancy PT and improve energy efficiency, can make a big improvement (Dhakal, 2006) due to increasing scarcity and higher price of petroleum products to solve this long term issue in KMC.

Though as stated in earlier chapters, the large-scale introduction of a bus system will reduce large numbers of less energy efficient modes but only making users to shift to low carbon modes will not be sufficient for obtaining the LCD. Proper land use plans, spatial organization and route organization would also be essential. As argued by many (Dhakal, 2006; Shrestha, 2012), the overall effectiveness will be gained only through the package of policies such as reducing travel demand, technological improvement, efficient PT system, tightening emission standards along with the modal shift to low carbon modes.

7.5 Further research

The research was able to link the SP survey with one of the indicator of LCD which is mode share by analysing the potential modal shift to sustainable transport option in case of KMC. However, the approach has been limited with the unavailability of different transport related data. Other possible research topics that can be associated with this study are as follows:

i) Better graphical representation of the choice sets can be experimented. The design of SP survey could be further upgraded with all the available modes including PPBS as a stated choice and a multinomial logit model could be constructed. Moreover, the attribute levels and values could be worked out in more detail with more study in the experimental design phase before generating choice sets.
ii) This study doesn't cover many other issues and possible options such as travel demand management, fuel quality improvement, role of alternative fuels, supply side issues. Also with better data, more accurate CO_2 emission estimates would have been obtained. The attribute level values of the PPBS were assumed since the proposal of KSUT Project is in its very initial stage and there was no reliable statistics on average speed of the vehicles. The unavailable data was acquired from secondary sources, some of which were not updated, especially for emission factors and fuel efficiency. Thus, more reliable data sources are required in this research and to fill the gap, further transport related studies should be done to have a better vision in analysis and result phase.
iii) Similar performance assessment for any new system can be assessed using similar process of this research. Similar studies can be conducted for other type of trips like shopping trips, entertainment trips, education trips and difference in reduction of CO_2 emission can be compared with each other. Further, modal shift from low occupancy to high occupancy or vice versa can be studied as more shifts to high occupancy contribute more to CO_2 reduction. Similarly, the trend of modal shift from motorbikes to cars can also be researched since many studies have also predicted that there will be more shift from motorbike to cars in KMC.
iv) JICA (2012) has predicted that BRT between the centre of Kathmandu and Bhaktapur, another city in Kathmandu Valley, would be introduced and similar study can be applied for this case.

v) For spatial explicit analysis, evenly distributed survey clusters can be identified and such SP surveys can be conducted there to study the user preference according to the spatial variation in KMC.
vi) Alternative scenarios could be developed with contextual assumptions and respective CO_2 emission could be estimated for further discussion and comparisons.
vii) In this study, the only variation was in mode share while activity, energy intensity and fuel being considered the same which may vary in reality since they are affected by travel pattern, transportation system and different parts of the city experience different travel pattern.

Therefore, with the above recommendations, further studies are emphasized in these directions.

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8 APPENDICES

8.1 RESEARCH METHODOLGY MATRIX

The following research methodology matrix from Table 8-1 shows the data required and their source, methods to be applied to answer the research questions posed and their expected output.

Table 8-1: Research Matrix

Research Questions	Data required	Data Sources	Methods	Expected output
What is the condition and demand of current public transport system in the study area?	Issues related to current transport system, Land use data, Related reports and studies	Secondary- Kathmandu Metropolitan Office, Kathmandu Sustainable Urban Transport Project Office, Central Bureau of Statistics	Literature review, Field observation, Document Analysis	Condition of existing public transport system and its demand.
How does the travel behaviour of the people vary as per socio-economic situation?	Socio-economic data –population, age, gender, income, education, modal share, trip length, travel time, mode used	Primary-Survey, Secondary- Central Bureau of Statistics, (Dhakal, 2006)	Questionnaire survey, Literature review, Statistical Analysis in SPSS and Excel	Travel Behaviour of different socio-economic groups
What are the main attributes that define the choice of a particular transport mode in the study area?	Choice Sets, Current and Proposed PT system characteristics	Primary- Survey, Secondary- 1st sub-objective	Stated preference survey, Utility modelling-Biogeme	Preference attributes defining the choice of a mode
How do the different socio-economic groups value the proposed public transport system characteristics based on their preferences?	PPBS characteristics, Stated preference data per income level	Primary- Survey	SP survey, Utility modelling-Biogeme software	Analysis of attributes per socio-economic aggregation level
What will be the likeliness for users to use the proposed public transport system?	Utility model outputs per mode	Secondary-Utility equations per mode	Utility modelling, Binary logit model, Calculation in Excel	Probable modal shift per mode and willingness to shift.

How effective is the proposed public transport system in relation to users' preference?	Proposed PPBS Attributes, Modal Shift per socio-economic aggregation level, Stated Preference data	Secondary-Output from 2nd sub-objective	Utility modelling, Statistical Analysis in SPSS, Calculation in Excel, Qualitative Analysis	Effectiveness of the proposed PPBS system with respect to user preference
How to evaluate the impact on LCD from proposed PPBS system?	Distance travelled, Number of trips, modal share, vehicle km, fuel efficiency, fuel use, occupancy factor, mode wise emission factor	Primary- Survey Secondary- (Dhakal, 2006), Output from 3rd sub-objective, Other literature	ASIF model , Spreadsheet calculation in Excel, Literature Review	Estimation of the impact of the modal shift on CO_2 emissions
What will be the impact of PPBS implementation on LCD due to potential modal shift based on user preferences?	CO_2 emissions per scenario, Potential modal shift	Secondary- Stated Preference Output, Output from 2nd question of 4th sub-objective, Scenario outputs	Statistical analysis in SPSS, Spreadsheet calculation in Excel	Impact of potential modal shift on LCD

8.2 POTENTIAL LCD INDICATORS

The definition of indicators must be developed to evaluate the current situation and measure progress towards more low-carbon activities (Kojima & Lovei, 2001). The number of indicators can be formulated for working on LCD. Recently, in a workshop organized by CEPT University's Centre for Urban Equity (CUE) on 2011, the concerned stakeholders formulated the list of indicators for promoting LCD covering economic, social and environmental aspects of sustainability under mobility and accessibility to address the sustainable transport which are as follows:

Table 8-2: List of potential indicators for LCDs

Indicator name	Description	Data source	Relevance	Method*
Mobility and Accessibility				
Modal shares	Modal shares by trip purpose	Household surveys and modal split data from Department of transport management (DOTM)	To identify the preferable modes for various trip purposes and to understand the movement towards or away from goal of low carbon transport.	Stated Preference survey and Socio-economic survey
Travel time	Average travel time by trip purpose	Household surveys	To understand the properties of mode to reach specific destinations	Stated Preference survey and

			and accordingly plan strategies to achieve the low carbon goal.	Socio-economic survey
Affordability	Affordability of transport fare by social group	Measured by percentage of household income likely to be spent for transport and household survey	To determine the affordability for different modes by different social groups.	Socio-economic survey, Secondary data

[Source: Adapted from: (CEPT, 2011)]

From above indicators, mode share has been adopted as LCD indicator in this research according to the context and survey undertaken.

8.3 UTILITY MODEL INPUTS

8.3.1 Input file-.dat file

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File Edit Format View Help

Rdents	csets	C_TC	C_TT	C_CM	P_TC	P_TT	P_CM	CHOICE	av1	av2
1	1	25	10	-1	20	15	-1	0	1	1
1	2	40	18	0	26	30	0	1	1	1
1	3	65	28	1	31	45	1	1	1	1
1	4	20	10	0	20	5	-1	1	1	1
1	5	26	18	-1	26	30	0	0	1	1
1	6	30	28	0	30	45	1	1	1	1
1	7	25	5	0	20	5	-1	1	1	1
1	8	40	15	1	26	15	0	1	1	1
1	9	65	30	1	31	30	-1	1	1	1
2	1	25	10	-1	20	15	-1	1	1	1
2	2	40	18	0	26	30	0	0	1	1
2	3	65	28	1	31	45	1	0	1	1
2	4	20	10	0	20	5	-1	1	1	1
2	5	26	18	-1	26	30	0	0	1	1
2	6	30	28	0	30	45	1	0	1	1
2	7	25	5	0	20	5	-1	0	1	1
2	8	40	15	1	26	15	0	1	1	1
2	9	65	30	1	31	30	-1	1	1	1
3	1	25	10	-1	20	15	-1	0	1	1
3	2	40	18	0	26	30	0	1	1	1
3	3	65	28	1	31	45	1	1	1	1
3	4	20	10	0	20	5	-1	0	1	1

Figure 8-1: Snapshot of part of dat file for overall sample

8.3.2 Input file-.mod file

The model specification is described in mod file. From equation 3.1, the mod file is created as:

```
[Model Description]
"Binary Logit Model between Current & Proposed"
[Choice]
CHOICE
[Beta]
ASC1   0   -10000  10000   0
ASC2   0   -10000  10000   1
BETA1  0   -10000  10000   0
BETA2  0   -10000  10000   0
BETA3  0   -10000  10000   0
 [Utilities]
0   Alt1   av1   ASC1 * one + BETA1 * C_TT + BETA2 * C_TC + BETA3 * C_CM
1   Alt2   av2   ASC2 * one + BETA1 * P_TT + BETA2 * P_TC + BETA3 * P_CM
```

```
[Expressions]
One = 1
 [Model]
$MNL
```

Model specification file:
This is a file where model specification is described which is divided into many sections which are as follows:
Section Choice: It simply describes to the software where the dependent variable can be found in file with syntax: [Choice]
Section Beta: It describes to the software the list of coefficients that must be estimated with syntax: [Beta]. Every line starting by // are not considered by biogeme which is for the understanding to the modeller only used to include comments in the file. There are columns, first column containing the name of the coefficients and second column containing the default value usually 0 (Bierlaire, 2008). The third and fourth columns contain upper and lower bounds on the value of coefficients. Using -1000 and 10000 by default is appropriate in the vast majority of practical cases. The last column tells biogeme that the coefficient must be estimated 0, or maintained at its default value 1. In this model, since not all ASC are identified, thus, ASC2 is fixed to its default value 0 by putting value 0 and by putting a 1 in the last column.
Section Utilities: The specification of the utility functions is described in this section. Four entries are specified for each of the alternative which is the identifier of the alternative, 0 or 1, the name of the alternative Alt 1, the availability condition and the linear parameter utility function. The utility function is composed of a list of terms, each term comprising name of a parameter and the name of an attribute.
Section Expressions: This explains how to compute attributes not directly available in the data file.
Section Model: It tells biogeme which assumptions must be used regarding the error term that is which type of model must be estimated. In this case, it is MNL model.

8.4 SURVEY FORMS

INTERVIEWER'S ID/NAME:
To be filled by the interviewer:
Location of the survey: .... (For example: Address of the survey location: Ward No=11/31/32 and Babarmahal / Tripureshwor)
Date: .... (mm/dd/yy)
Respondent's Serial number / ID: .... (Initials of each type of office and sequential number, Government Office: GO1 and Name of Office, Private Office: PO1, Others: O1, etc , For example GO.1, For ID, ID Numbers or position held)
Objective: The objective of the survey is to collect the information about the travel pattern used by the daily travellers to work. It starts with general questions followed by 9 choice sets. The choice sets presents the two options, the existing mode used and proposed mode. The respondent has to choose between the two options based on their preference in each choice sets for their work daily trips.

PART 1: SOCIO-ECONOMIC QUESTIONNAIRE

1) Where do you come to work from? ....Ward ....Tole / Street..........................(Address of home)

2) Which transport mode do you use mostly to work?
    a. Motorbike/Scooter [ ] Car [ ] Bus [ ] Micro bus [ ] Tempo [ ] others, specify.................
    b. (If they use only one of the above modes, then only continue the survey and show the choice sets accordingly, for example, if they use motorbike, show them the choice sets of motorbike)
3) Do you share your mode of transport with others? (Not for public vehicle users – bus, microbus/tempo users)
    a. Yes [ ] If yes, with how many people? ....No [ ]
4) How long does it take to reach your workplace? ....minutes
    a. (According to this answer, use the following Table from annex 1 and fill in the choice sets accordingly and show them the filled choice set)
5) How much comfortable you feel with your transport mode? Low [ ] Middle [ ] High [ ]
6) Why do you feel so? Which of the following reasons make you say feel so?
    i) Crowded
    ii) Pick pocketing
    iii) Sexual harassment
    iv) Uncomfortable seat
    v) Not hygienic
    vi) Others.......................
7) Sex: male [ ] female [ ]
8) Age: ....
9) What is your highest education level?
    a. None [ ] Primary school [ ] Secondary School [ ] Intermediate [ ] Bachelor [ ] Masters [ ]
10) How much is your average monthly income?
    b. Less than 12,000 [ ] 12,000- 25,000 [ ] 25000-60,000 [ ] Above 60,000 [ ]

PART 2: STATED CHOICE QUESTIONNAIRE

In this part, choose the choice set offering the comparison between the option A and option B, which one you prefer to use for daily trip to work. Select the preferred option as per your judgement of the total set of attributes of each choice.

Show the respondents the choice sets one by one and tick the chosen option in the Table below. The blank values should be already filled up before showing the choice sets to the respondents.

Choice Sets	**Preferred choice set**
Choice set 1	A [ ] B [ ]
Choice set 2	A [ ] B [ ]
Choice set 3	A [ ] B [ ]
Choice set 4	A [ ] B [ ]
Choice set 5	A [ ] B [ ]
Choice set 6	A [ ] B [ ]
Choice set 7	A [ ] B [ ]
Choice set 8	A [ ] B [ ]
Choice set 9	A [ ] B [ ]

8.5 REFERENCE TABLE FOR TRAVEL COST AND TRAVEL TIME FOR DIFFERENT MODES GENERATING CHOICE SETS

Distance travelled and travel cost for bus, microbus and tempo are obtained from Department of Transport Management (DOTM), KMC. Since there are no reliable statistics on current average speed, the average speed of 20-30 km per hour has been assumed for private modes (Dhakal, 2006). Travel time from bus is assumed as general travel time to generate travel time for other modes. Based on the general travel time, other travel times are generated in following way:

Table 8-3: Travel time for each public mode for their respective average speed per distance travelled

Distance (km)	Time(min) for bus for average speed of 18.15 km/hr	Time(min) for micro bus for average speed of 19.8 km/hr	Time(min) for tempo for average speed of 16.5 km/hr	Time(min) for PPBS for average speed of 20 km/hr
1	3.3	3.03	3.63	3
5	16.52	16.52	15.15	15
9	29.75	27.27	32.72	30
14	46.28	42.42	50.9	45
18	59.50	54.54	65.45	60

Distance travelled is considered same as in other modes and travel cost for motorbike and car are generated from fuel consumed and maintenance cost which is derived from (Dhakal, 2006) which are as follows:

Table 8-4: Distance travelled, fuel consumed, fuel cost, maintenance cost and travel time for Motorbike

Distance covered(km)	Fuel consumed @53 km/litre	Fuel cost @ Rs 125/ litre	Maintenance cost @Rs 0.85 per km	Total cost(rupees)	Final cost (rupees)	Time (min)
1	0.018	2.35	0.85	3.2	3	3
5	0.144	18.8	6.8	25.6	25	15
9	0.27	35.25	12.75	48	40	27
14	0.414	54.05	19.55	73.60	65	42
18	0.54	70.5	25.5	96	80	54

[Note: *Average speed for motorbikes assumed as 20km/hr* (Dhakal, 2006)]

Table 8-5: Distance travelled, fuel consumed, fuel cost, maintenance cost and travel time for Cars

Distance covered(km)	Fuel consumed @13.6 km/lt	Fuel cost @ Rs 125/ litre	Maintenance cost @Rs 1.1 per km	Total cost (rupees)	Final cost (rupees)	Time (min)
1	0.073	9.19	1.10	10.29	10	3.3
5	0.584	73.52	8.80	82.32	75	16.52
9	1.095	137.85	16.5	154.35	145	29.75
14	1.679	211.37	25.3	236.67	200	46.28
18	2.19	275.70	33	308.7	245	59.50

[Note: *Average speed for cars assumed as 18.15 km/hr since it is assumed to be equal to current bus's average speed due to declining speed of the vehicles in KMC* (Dhakal, 2006).]

The above Table 8-5 were used as reference for the survey. For example, if the user uses motorbike as current transport mode and he travels only 0-15 minutes per day to his work, his travel cost will be 25 rupees, which will be compared with corresponding travel time and travel cost of proposed improved bus, PPBS. The Tables were verified from the secondary data as well.

8.6 CHOICE SET GENERATION

A) FOR BUS USERS:

Table 8-6: Reference Table for Bus users

Current Bus		Improved Bus System	
Total Travel time(walk time to bus stop + in vehicle travel time+ walk time from bus stop to destination)(minutes)	Travel fare(rupees)	Total Travel time(walk time to bus stop + in vehicle travel time+ walk time from bus stop to destination)(minutes)	Travel fare(rupees)
0 - 15	14	0-5	20
16 - 30	20	6-15	26
31 - 45	24	16-30	30
46 - 60	25	31-45	31

(Note: *Corresponding Travel time has to be referred from Part I questionnaire and equivalent fares are to be filled in the choice sets and travel fares derived from DOTM, Nepal*)

For travel time 0-15 minutes,

Cost	Time	Comfort
14	15	low
20	5	low
20	30	middle
26	15	middle
24	45	high
30	30	high

Cost	Time	Comfort
20	15	middle
20	5	low
26	30	middle
26	15	low
30	45	high
30	30	middle

Cost	Time	Comfort
14	5	low
20	5	middle
20	15	middle
26	15	high
24	30	low
30	30	high

For travel time 16-30 minutes,

Cost	Time	Comfort
20	30	low
26	15	low
24	45	middle
30	30	middle
25	60	high
31	45	high

Cost	Time	Comfort
26	30	middle
26	15	low
30	45	middle
30	30	low
31	60	high
31	45	middle

Cost	Time	Comfort
20	15	low
26	15	middle
24	30	middle
30	30	high
25	45	low
31	45	high

For travel time 31-45 minutes,

Cost	Time	Comfort
24	30	low
30	15	low
25	45	middle
31	30	middle

Cost	Time	Comfort
30	30	middle
30	15	low
31	45	middle
31	30	low

Cost	Time	Comfort
24	30	low
30	30	middle
25	45	middle
31	45	high

25	60	high
31	45	high

31	60	high
31	45	middle

25	60	low
31	60	high

For travel time 46-60 minutes,

Cost	Time	Comfort
25	30	low
31	15	low
25	45	middle
31	30	middle
25	60	high
31	45	high

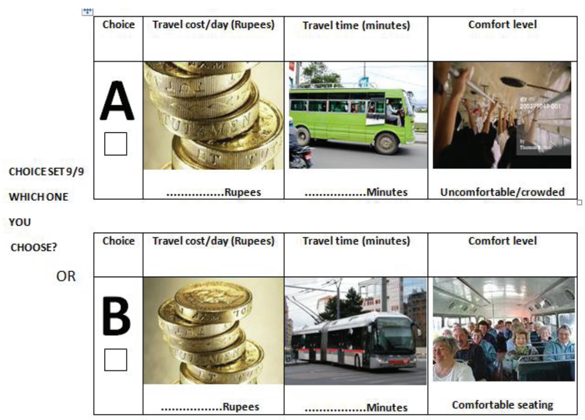
Cost	Time	Comfort
31	30	middle
31	15	low
31	45	middle
31	30	low
31	60	high
31	45	middle

Cost	Time	Comfort
25	30	low
31	30	middle
25	45	middle
31	45	high
25	60	low
31	60	high

Graphical representation of choice sets for bus users:

The Figure 8-2 below represents the sample of choice sets used during SP survey for bus users. Similar choice sets were used for other travel mode users.

Figure 8-2 : Choice sets used for SP survey for bus users (a)



In similar way, reference Tables were prepared for other four modes and corresponding graphical choice sets were prepared.

Figure 8-3: Choice sets used for SP survey for bus users (b)

B) FOR MICROBUS USERS:

Table 8-7: Reference Table for microbus users

Microbus		Improved Bus System	
Total Travel time	Travel fare(rupees)	Total Travel time(walk time to bus stop + in vehicle travel time+ walk time from bus stop to destination)(minutes)	Travel fare(rupees)
0 - 17	14	0-5	20
18 - 27	20	6-15	26
28 - 42	24	16-30	30
43 - 55	25	31-45	31

(Note: *Corresponding Travel time has to be referred from Part I questionnaire and equivalent fares are to be filled in the choice sets and travel fares derived from DOTM, Nepal*)

For travel time 0-17 minutes,

Cost	Time	Comfort
14	17	low
20	5	low
20	27	middle
26	15	middle
24	42	high
30	30	high

Cost	Time	Comfort
20	17	middle
20	5	low
26	27	middle
26	15	low
31	42	high
31	30	middle

Cost	Time	Comfort
17	5	low
26	5	middle
20	15	middle
26	15	high
25	42	low
30	30	high

For travel time 18-27 minutes,

Cost	Time	Comfort
20	27	low
26	15	low
24	42	middle
30	30	middle
25	55	high
31	45	high

Cost	Time	Comfort
26	27	middle
26	15	low
30	42	middle
30	30	low
31	55	high
31	45	middle

Cost	Time	Comfort
20	15	low
26	15	middle
24	30	middle
30	30	high
25	45	low
31	45	high

For travel time 28-42 minutes,

Cost	Time	Comfort
24	28	low
30	15	low
25	42	middle
31	30	middle
25	55	high
31	45	high

Cost	Time	Comfort
30	28	middle
30	15	low
31	42	middle
31	15	low
31	55	high
31	45	middle

Cost	Time	Comfort
24	30	low
30	30	middle
25	45	middle
31	45	high
25	60	low
31	60	high

For travel time 43-55 minutes,

Cost	Time	Comfort
25	27	low
31	15	low
25	42	middle
31	30	middle

Cost	Time	Comfort
31	27	middle
31	15	low
31	42	middle
31	30	low

Cost	Time	Comfort
25	30	low
31	30	middle
25	45	middle
31	45	high

25	55	high
31	45	high

31	55	high
31	45	middle

25	60	low
31	60	high

C) FOR TEMPO USERS:

Table 8-8: Reference Table for tempo users

Tempo		Improved Bus System	
Total Travel time	Travel fare(rupees)	Total Travel time(walk time to bus stop + in vehicle travel time+ walk time from bus stop to destination)(minutes)	Travel fare(rupees)
0 - 15	14	0-5	20
16 -33	20	6-15	26
34 - 51	24	16-30	30
52 -65	25	31-45	31

(Note: *Corresponding Travel time has to be referred from Part I questionnaire and equivalent fares are to be filled in the choice sets and travel fares derived from DOTM, Nepal*)

For travel time 0-15 minutes,

Cost	Time	Comfort
14	15	low
20	5	low
20	33	middle
26	15	middle
24	51	high
30	30	high

Cost	Time	Comfort
20	15	middle
20	5	low
26	33	middle
26	15	low
31	51	high
31	30	middle

Cost	Time	Comfort
14	5	low
20	5	middle
20	15	middle
26	15	high
24	30	low
30	30	high

For travel time 16-33 minutes,

Cost	Time	Comfort
20	33	low
26	15	low
24	51	middle
30	30	middle
25	65	high
31	45	high

Cost	Time	Comfort
26	33	middle
26	15	low
30	51	middle
30	30	low
31	65	high
31	45	middle

Cost	Time	Comfort
20	15	low
26	15	middle
24	30	middle
30	30	high
25	45	low
31	45	high

For travel time 34-51minutes,

Cost	Time	Comfort
24	34	low
30	15	low
25	51	middle

Cost	Time	Comfort
30	34	middle
30	15	low
31	51	middle

Cost	Time	Comfort
24	30	low
30	30	middle
25	45	middle

31	30	middle
25	65	high
31	45	high

31	30	low
31	65	high
31	45	middle

31	45	high
25	60	low
31	60	high

D) FOR MOTORBIKE USERS:

Table 8-9: Reference Table for Motorbike users

Motorbike		Improved Bus System	
Total Travel time	Travel fare(rupees)	Total Travel time(walk time to bus stop + in vehicle travel time+ walk time from bus stop to destination)(minutes)	Travel fare(rupees)
0 - 15	25	0-5	20
16 - 27	40	6-15	26
28 - 42	65	16-30	30
43 - 54	80	31-45	31

(Note: *Corresponding Travel time has to be referred from Part I questionnaire and equivalent fares are to be filled in the choice sets and travel fares derived from DOTM, Nepal*)

For travel time 0-15 minutes,

Cost	Time	Comfort
25	10	low
20	15	low

Cost	Time	Comfort
20	10	middle
20	5	low

Cost	Time	Comfort
25	5	middle
20	5	low

40	15	middle
26	30	middle

26	15	low
26	30	middle

40	15	high
26	15	middle

65	27	high
31	45	high

30	27	middle
30	45	high

65	30	high
31	30	low

For travel time 16-27 minutes,

Cost	Time	Comfort
40	15	low
26	30	low

Cost	Time	Comfort
26	15	low
26	30	middle

Cost	Time	Comfort
40	15	middle
26	15	low

65	27	middle
30	45	middle

30	27	low
30	45	middle

65	30	high
30	30	middle

80	42	high
31	45	high

31	42	middle
31	45	high

80	42	high
31	45	low

For travel time 28-42 minutes,

Cost	Time	Comfort
65	28	low
30	45	low

Cost	Time	Comfort
30	28	low
30	45	middle

Cost	Time	Comfort
65	30	middle
30	30	low

80	42	middle
31	45	middle

30	42	middle
30	45	high

80	45	high
31	45	middle

80	54	high
31	45	high

31	54	middle
31	45	high

80	45	high
31	45	low

For travel time 43-54 minutes,

Cost	Time	Comfort
80	28	low
31	45	low
80	43	middle
31	45	middle

Cost	Time	Comfort
30	28	low
30	45	middle
31	43	middle
31	45	high

Cost	Time	Comfort
80	30	middle
31	30	low
80	45	high
31	45	middle

80	54	high
31	45	high

31	54	middle
31	45	high

80	45	high
31	45	low

E) FOR CAR USERS:

Table 8-10: Reference Table for car users

Car		Improved Bus System	
Total Travel time	Travel fare(rupees)	Total Travel time(walk time to bus stop + in vehicle travel time+ walk time from bus stop to destination)(minutes)	Travel fare(rupees)
0 - 17	75	0-5	20
18 - 30	145	6-15	26
31 - 46	200	16-30	30
47 - 60	245	31-45	31

(Note: *Corresponding Travel time has to be referred from Part I questionnaire and equivalent fares are to be filled in the choice sets and travel fares derived from DOTM, Nepal*)

For travel time 0-17 minutes,

Cost	Time	Comfort
75	17	low
20	30	low

Cost	Time	Comfort
20	17	middle
20	5	low

Cost	Time	Comfort
75	5	middle
20	5	low

75	17	middle
20	30	middle

20	17	low
20	5	middle

75	5	high
20	5	middle

145	30	high
26	45	high

26	30	middle
26	45	high

145	15	high
26	15	low

For travel time 18-30 minutes,

Cost	Time	Comfort

Cost	Time	Comfort

Cost	Time	Comfort

75	17	low
20	30	low

20	17	middle
20	5	low

75	5	middle
20	5	low

145	30	middle
26	45	middle

26	30	low
26	45	middle

145	15	high
26	15	middle

200	46	high
30	60	high

30	46	middle
30	60	high

200	30	high
30	30	low

For travel time 31-46 minutes,

Cost	Time	Comfort
145	30	low
26	45	low

Cost	Time	Comfort
26	30	low
26	15	middle

Cost	Time	Comfort
145	15	middle
26	15	low

200	46	middle
30	60	middle

30	46	low
30	60	middle

200	30	high
30	30	middle

245	30	high
31	45	high

31	30	middle
31	30	high

245	45	high
31	45	low

For travel time 47-60 minutes,

Cost	Time	Comfort
200	30	low
30	45	low

Cost	Time	Comfort
30	30	low
30	45	middle

Cost	Time	Comfort
200	30	middle
30	30	low

245	46	middle
31	45	middle

30	46	middle
30	45	high

245	45	high
31	45	middle

245	60	high
31	45	high

31	60	middle
31	45	high

245	45	high
31	45	low

8.7 SUMMARY OF RAW DATA FROM THE SURVEY

Following Table 8-11 is just the statistical summary of the choices as made by users in raw data using SPSS.

Table 8-11: Statistical summary of raw data per choice set

Cost vs Time

C-SET-1

Travel modes	0	1	Total
Bike	47	73	120
Bus	36	64	100

Time vs Comfort

C-SET-4

Travel modes	0	1	Total
Bike	20	100	120
Bus	21	79	100

Cost vs Comfort

C-SET-7

Travel modes	0	1	Total
Bike	29	91	120
Bus	32	68	100

Car	85	15	100
Microbus	29	71	100
Tempo	44	56	100
Total	284	236	520

Car	56	44	100
Microbus	15	85	100
Tempo	51	49	100
Total	331	189	520

Car	86	14	100
Microbus	22	78	100
Tempo	45	55	100
Total	213	307	520

C_SET_2

Travel modes	0	1	Total
Bike	36	84	120
Bus	28	72	100
Car	98	2	100
Microbus	32	68	100
Tempo	20	80	100
Total	212	308	520

C_SET_5

Travel modes	0	1	Total
Bike	23	97	120
Bus	26	74	100
Car	91	9	100
Microbus	19	81	100
Tempo	37	63	100
Total	320	200	520

C-SET_8

Travel modes	0	1	Total
Bike	25	95	120
Bus	17	83	100
Car	87	13	100
Microbus	23	77	100
Tempo	59	41	100
Total	259	261	520

C-SET_3

Travel modes	0	1	Total
Bike	41	79	120
Bus	22	78	100
Car	96	4	100
Microbus	35	65	100
Tempo	26	74	100
Total	219	301	520

C-SET_6

Travel modes	0	1	Total
Bike	42	78	120
Bus	40	60	100
Car	89	11	100
Microbus	7	93	100
Tempo	24	76	100
Total	267	253	520

C-SET_9

Travel modes	0	1	Total
Bike	22	98	120
Bus	12	88	100
Car	73	27	100
Microbus	18	82	100
Tempo	35	65	100
Total	163	357	520

8.8 CALCULATION DETAIL OF CO_2 EMISSIONS FROM ASIF MODAL

From ASIF model, the results of base line scenario and modal shift from SP survey are as follows:

Table 8-12: Calculation detail of emission estimation for current and modal shift situations

Current Situation

	Activity			Structure	Energy Intensity					Fuel	Emissions	
Mode	Avg dist	No of trips	Veh km	Mode share	Fuel efficiency	Fuel use	Occupancy factor	Fuel use per pkm	Total fuel use mode wise	Carbon content(g/l)	Grams	Metric tons
Motorbike	6.5	1.5	9.9	120	41	0.2	1.3	0.18	22.3	3984.8	88932.3	0.08
Car	7.5	1.5	11.5	100	11.5	1.0	2.5	0.40	40.1	3440	138181.1	0.13
Tempo	4.8	1.5	7.4	100	11.65	0.6	7.6	0.08	8.4	3984.8	33508.03	0.03
Bus	9.1	1.5	13.9	100	6	2.3	26.4	0.08	8.7	3440	30218.3	0.03
Microbus	6.8	1.5	10.3	100	8	1.2	12.3	0.10	10.5	3440	36218.6	0.03
				520							**Total**	**0.32**

Modal shift situation

	Activity			Structure	Energy Intensity					Fuel	Emissions	
Mode	Avg dist	No of trips	Veh km	Mode share	Fuel efficiency	Fuel use	Occupancy factor	Fuel use per pkm km	Total fuel use mode wise	Carbon content(g/l)	Grams	Metric tons
Motorbike	6.5	1.5	9.9	22	41	0.2	1.3	0.18	4.09	3984.8	16304.2	0.01
Car	7.5	1.5	11.5	90	11.5	1.0	2.5	0.40	36.1	3440	124363.07	0.12
Tempo	4.8	1.5	7.4	33	11.65	0.6	7.6	0.08	2.7	3984.8	11057.6	0.01
Bus	9.1	1.5	13.9	25	6	2.3	26.4	0.08	2.1	3440	7554.5	0.007
Microbus	6.8	1.5	10.3	22	8	1.2	12.3	0.10	2.3	3440	7968.1	0.007
				192							**Total**	**0.16**

Abbreviations:

Avg dist = Average distance

Veh km = Vehicle Kilometre

Pkm = Passenger Kilometre

a) **Secondary data for ASIF modal and their source:**

i) **Average speed per mode:**

a) Average speed for car = 18.5 km /hr assumed as from (Dhakal, 2006)

b) Average speed for motorbike = 20 km/hr [(Dhakal, 2006)]

c) Average speed for public transport modes:

Vehicle type	Speed(Km/hr)		
	Peak	Off peak	Average
Public Transportation	16.5	19.8	18.15

Source: Broersma, K and N Pradhan, Mission Report, Kathmandu Valley Mapping Program, Kathmandu Metropolitan City/European Commission, Kathmandu, 2001.

In case of public transport modes, the average speed of 16.5 km/ hr is assumed for tempo, 19.8 for microbus and 18.15 for current bus users.

ii) **Number of working trips per day:** 1.521 (JICA, 2012)

iii) **Fuel efficiency per mode:**

Fuel efficiency, km/l, (km/Kw-h for electric)

	Vehicle Type	**Categories**	**Fuel**	**2000[4]**	**2001[5]**	**2010[6]**
LDV	Private car/jeep					
	Gasoline vehicle	PC	Gasoline	11.34		**11.5**
	Diesel vehicle	PC	Diesel	8		**11.5**
	Commercial					
	Taxi	PC		10.6		11.6
	Diesel microbus	MUV	Diesel	8	10	**8**
	LPG microbus	MUV	LPG	8	250/cyl	**8**
	Gasoline car	PC	Gasoline	11.14		
	Diesel jeep	PC	Diesel	8.9		
Bus	Diesel	Bus	Diesel	3.9	3.5	3.14
	Trolley bus	Bus	Electric	0.75		
Minibus		BUS	Diesel and Gasoline	5.4	7	**6**
3-wheeler	Battery	3W	Electric	5.83		
	Petrol	3W	Gasoline	**11.65**		
	Diesel	3W	Diesel	12.5		
	LPG	3W	LPG	14.7	250/cyl	201/cyl
Motorcycle	Four-stroke	2W	Gasoline and Diesel	53.8		**41**

Source:

[4] Dhakal, 2006, Transportation and the Environment in Kathamandu valley, Nepal. Institute for Global Environmental Strategies (IGES), Japan
[5] Broersma, K and N Pradhan, Mission Report, Kathmandu Valley Mapping Program, Kathmandu Metropolitan City/European Commission, Kathmandu, 2001.
[6] Kathmandu Sustainable Urban Transportation Project, 2010

b) Occupancy factor:

Passenger Occupancy

			Year		
Vehicle Type	**Categories**	**Fuel Type**	**2000[4]**	**2001[5]**	**2010[6]**
Motorcycle	2W	Gasoline	1.60	1.30	1.3
Car	PC	Gasoline and Diesel	2.60	1.80	2.5
Mini bus	Bus	Gasoline and Diesel	30.00	20.00	26.4
Micro bus	MUV	Gasoline and Diesel	18.00	12.00	12.3
Safa tempos(electric three wheeler)	3W	Electric	10.00	8.80	7.6

Source:

[4] Dhakal, 2006, Transportation and the Environment in Kathamandu valley, Nepal. Institute for Global Environmental Strategies (IGES), Japan
[5] Broersma, K and N Pradhan, Mission Report, Kathmandu Valley Mapping Program, Kathmandu Metropolitan City/European Commission, Kathmandu, 2001.
[6] Ministry of Physical Planning and Works, ADB, 2010, *Kathmandu Sustainable Urban Transportation Project*

c) Emission factor:

LDV		Categories	Fuel type	**CO2(g/ltr)**
	Private			
	Gasoline	PC	Gasoline	3984.8
	Diesel	PC	Diesel	3440
	Commercial			
	Diesel microbus	MUV	Diesel	**3440**
	LPG microbus	MUV	LPG	1620
	Government/semi			
	Gasoline cars	PC	PC	3984.8
	Diesel car/jeep	PC	PC	**3440**
Bus	Diesel	Bus	Diesel	**3440**
	Trolley	Bus	Electric	0
Minibus	Diesel	Bus	Diesel	**3440**
Three-wheeler	Battery	3W	Electric	0
	Gasoline	3W	Gasoline	**3984.8**
	Diesel	3W	Diesel	3440
	LPG	3W	LPG	1620
Motorcycle	4-stroke	2W	Gasoline and diesel	**3984.8**

Source: Dhakal, 2006, *Transportation and the Environment in Kathmandu valley, Nepal.* Institute for Global Environmental Strategies (IGES), Japan