DEVELOPING A RESIDENTIAL LOCATION CHOICE MODEL TO CAPTURE THE HETEROGENEITY IN COMMUTE VEHICLE MILES TRAVELLED (VMT)

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

August, 2011 _____

Sayeeda Bint Ayaz

Dedicated

To

My Father

Muhammad Ayaz

Who is now in the kind hand of Almighty Allah

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ABSTRACT

Residential location choice plays a prime role regarding all types of travel decisions and has a direct influence on average trip lengths, frequencies and modes of all household members. Total Vehicle Miles Travelled (VMT) increases with the increase in trip lengths and modes as well as with the frequency of trips. Modeling choice of home location is a direct indicator of VMT and an important issue in modeling transport demand. In this research, residential location choice models have been developed to capture the heterogeneity in commute vehicle miles travelled. The models have been specified using detailed survey data collected from faculty members of two public universities (Dhaka University of Engineering and Technology, Gazipur and Shahjalal University of Science and Technology, Sylhet) of Bangladesh. Both of the universities have residential facilities for their faculty members but many of them are not currently using these. It is observed that many faculty members are living in Dhaka (and/or Sylhet in case of SUST) and commuting long distances to go to universities. In some cases, faculty members are living at or, near their workplaces and the rest of their family are staying in the major cities resulting in a 'split' family. Therefore, it is necessary to identify the potential variables that attract them to the capital and the major cities and thereby lead to increase in their commute VMT. The survey includes the current Revealed Preference (RP) data regarding choice of residential locations, as well as Stated Preference (SP) data where the faculty members are given some hypothetical future scenarios which include some improved facilities at or near university campus and are asked to choose a location among alternative residential locations. The SP scenarios include multiple levels of five attributes (better school facilities, reduced rent of university residence, spouse's job opportunity, professional work scope and some additional facilities including better health care, big shopping mall etc.).

Data analysis shows that in the presented SP scenarios, 61 percent commute trips are likely to be reduced in case of DUET and 78 percent commute trips are likely to be reduced in case of SUST. The analysis also shows that 68 percent commute VMT are likely to be reduced with a reduction of two-way daily commute VMT of 690 for DUET and 78 percent commute VMT are likely to be reduced with a reduction of two-way daily commute VMT of 891 for SUST in the presented SP scenarios.

Discrete choice models have been developed using the SP data and the coefficients of the utility functions have been estimated using the maximum likelihood technique. The observed taste heterogeneity of the respondents has been taken into account by the introduction of socio-economic variables like age, gender, income, car ownership etc. into the model. Survey reveals significant distinction in the choice process of residential location between the two universities and therefore separate models have been developed for them. A Nested Logit Model (NL) and a Multinomial Logit Model (MNL) have been found as the best models for DUET and SUST respectively.

Estimation results show that better school facilities with Bengali as well as English medium, reduced house rent, professional work scope and spouse's job opportunity are the potential variables of choosing on-campus housing facility for DUET faculty members. Faculty members of average age 45 years have less likelihood of choosing on-campus facility whereas female faculty members are more likely to choose on-campus housing facility in DUET. On the other hand, higher standard Bengali medium schools and reduced rent are the most influential variables in the choice of residential location for SUST faculty members. Female faculty members of SUST have higher likelihood of choosing off-campus housing facility which is quite a different scenario from DUET. The faculty members who own car are more likely to choose off-campus housing facility. The unmarried faculty members of SUST have higher likelihood of living split from their family.

The estimated equations can be used to predict the probabilities of shifting to on-campus facilities and calculating the corresponding change in VMT in response to a certain policy change. Therefore, the findings of this research work can help transport policy makers and university authorities in formulating policy guidelines to promote on-campus housing. Further, the methodology used in this research work can be used in future researches on residential location choice modeling of other segments of population.

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LIST OF NOTATIONS AND ABBREVIATIONS

AHP	Analytic Hierarchy Process
ASC	Alternative Specific Constant
AUST	Ahsanullah University of Science and Technology
BIOGEME	Blerlaire Optimization Toolbox for GEV Model Estimation
BUET	Bangladesh University of Engineering and Technology
CBD	Central Business District
CE	Choice Experiment
DCV	Direct Contingent Valuation
DHUTS	Dhaka Urban Transport Network Development Study
DUET	Dhaka University of Engineering and Technology, Gazipur
GCSE	Generalized Certificate of Secondary Education
GEV	Generalized Extreme Value
GIS	Geographical Information System
HRA	Hypothetical Referendum Approach
HSC	Higher Secondary Certificate
HWM	Home, Workplace and Mode
IIA	Independence of Irrelevant Alternatives
MLE	Maximum Likelihood Estimation
MNL	Multinomial Logit
NDC	Notre Dame College
NL	Nested Logit
NSU	North South University
Off-Dhaka	Living off-campus in Dhaka
Off-family	Off-campus family housing
Off-split	Off-campus split housing
On-family	On-campus family housing
On-split	On-campus split housing
Off-other	Off-campus family housing other than Dhaka
RE	Ranking Exercise

RP	Revealed Preference
SP	Stated Preference
SSC	Secondary School Certificate
SVT	Subjective Value of Time
SUST	Shahjalal University of Science and Technology
VMD	Vehicle Miles Driven
VMT	Vehicle Miles Travelled
VNS	Viqarunnisa Noon School
VNC	Viqarunnisa Noon College

CHAPTER ONE

INTRODUCTION

1.1 Background and Motivation

The major cities of Bangladesh have been developed mostly in unplanned ways leading to a huge mismatch of land use and transportation infrastructure. The result is severe traffic congestion, lost productivity and environmental degradation. Traffic congestion is more severe in areas with rapidly growing populations, particularly in the capital cities like Dhaka where the urban structure is undergoing a transformation towards unbalanced co-ordination of infrastructure and services. A recent study by Roads and Highways Department (RHD) has estimated that, the traffic congestion in Dhaka causes a loss of Taka 19,555 cr a year (Enam, 2010).

Capitals in developing countries attract people for better employment facilities as well as high standard of living. Therefore, centralization is the common phenomenon of these cities. According to the Census 2011, the present population of Bangladesh is about 142.319 million and 11.875 million of these populations live in Dhaka. It is the city with the highest population share (8.3 %) among all the cities of the country with only 1% share of total country area. The population density is the highest with 8,111 persons per square kilometer among all the cities (BBS, 2011). The current housing and employment trend shows that many people live in Dhaka for better quality of life and commute longer distances to go to job place and thus impose a huge pressure on the transport sector. For example, many people travel daily to suburban areas like Narayangonj, Gazipur, Savar etc. and live at residential areas like Dhanmondi, Gulshan, Rampura etc. for enjoying better life standard which includes closeness to lucrative shopping malls, modernized health care, quality education for children and variety of recreational facilities etc. It is also observed that in some cases, the earning member stays near his/her workplace and the rest of the family stays in the major cities resulting in a ‘split’ family. All these are leading to increase in commute distances and favoring use of motorized

transport, ultimately leading to increase in vehicle miles travelled (VMT). Residential location determines the trip lengths, frequencies and modes of all household members, and has a direct impact on household VMT. One's place of residence serves as a spatial anchor, impacting the spatial and temporal attributes of one's movements.

Many studies show that mixed land use settings have a significant impact on the travel choices of individuals. The intermingling of residences, jobs, shops, and recreational facilities in a compact urban environment induces people to carry out their daily activities within a much smaller geographical area, thus reduces VMT to a significant extent. A study in Portland by 1000 Friends of Oregon estimates that an increase in 20,000 jobs within a 20-minute commuting distance by car will reduce daily household vehicle miles travelled (VMT) by half a mile while increasing the number of daily auto trips by one-tenth of a trip. The same increase in jobs within a 30-minute commuting distance by transit was estimated to reduce daily VMT a bit more, to six-tenths of a mile, and the number of daily car trips by one-tenth of a trip (1000 Friends of Oregon 1993). A study by Cervero (1996), which examined the impact of mixed land use on travel choices at a more aggregated level (i.e., the 44 largest U.S. metropolitan areas), finds that having grocery stores and other consumer services within 300 feet of one's residence tends to encourage commuting by mass transit, walking and bicycling, while controlling for such factors as residential density and vehicle ownership.

Residential location choices are affected by various factors. Examples include property rents or prices, distance from work place, presence of good educational institutes, transport connectivity, security etc. Residential location choice models are used to quantify the relative impacts of these factors in the choice process and generally differ depending on the socio-economic patterns of a country.

In the context of Bangladesh, few research works have been conducted so far that focused on the residential location choice. All of these models have however, used Revealed Preference (RP) data only and have not involved rigorous mathematical

modeling. This motivates the current research where rigorous mathematical models are developed to capture the trade-off of different factors that affect the residential location choices in the context of Bangladesh.

1.2 Research Scope and Objective

The scope of this study is to develop a framework for residential location choice model and associated VMT for commute trips and estimate it using data collected from faculty members of two public universities of Bangladesh: Dhaka University of Engineering and Technology (DUET), Gazipur and Shahjalal University of Science and Technology (SUST), Sylhet. In both of the universities, there are on-campus residential facilities for their resource personnel. But many of the faculty members are living in nearby major cities and commuting long distances. In some cases, faculty members are maintaining 'split' families. Therefore, it is necessary to identify the potential variables that attract them to the city center and thereby increase their commute VMT. Moreover, there is scope to provide these facilities which are key parameters to reduce work trip distance. If it is possible to provide them on-campus living provision with facilities which are currently attracting them to live in major cities (e.g. easy access to school facilities, spouse's job location, shopping, health care etc.) then it is likely to increase the percentage of faculty members using on-campus housing facilities and thereby reducing the commute trip length. Thus VMT for commute trips are likely to be reduced to a great extent.

The overall objective of this research work is to develop a residential location choice model structure for Bangladesh and capture the heterogeneity in VMT for commute trips. The model parameters will be estimated using data from faculty members of DUET and SUST in order to identify the critical factors which can attract them to live closer to their workplaces and thus lead to reduction of VMT of commute trips. Data include Revealed Preference (RP) and Stated Preferences (SP) of the respondents. The specific objectives are as follows:

- Conducting an initial survey to identify the potential variables affecting residential location choice and commute VMT.

- ❒ Developing a comprehensive survey to collect data regarding residential location choice and commute VMT.
- ❒ Conducting the survey among faculty members of the selected university.
- ❒ Developing a discrete choice model to quantify the effects of different factors for residential location choice and commute VMT.
- ❒ Analyzing the model results and formulating policy guideline.

The developed model can be used to quantify VMT which can ultimately contribute to reduce the traffic congestion to a significant extent.

1.3 Outline of Methodology

Initial survey

At first an initial survey is conducted in order to identify the variables that are playing major role in the choice of residential location. The survey is conducted by personal interview with the respondents. The respondents are asked questions about their current residential location and the reasons behind choosing that location, their current travel pattern and also socio-economic status (e.g. age, household income, total family member, marital status, number of children etc.) of them.

Selection of the variables based on preliminary data

On the basis of the initial survey, the key variables that affect the preferences of living on-campus are identified. From these, potential variables are chosen for conducting the main survey.

SP Survey Design

The attributes and their levels are identified and the profiles of the on-campus housing are generated with the statistical software SPSS using fractional factorial design.

Main data collection and discrete choice model development

Data are collected from the faculty members by questionnaire survey which includes the SP scenarios along with the questions on the socioeconomic status of the respondents. Discrete choice models are developed with the significant attributes using the software BIOGEME using maximum likelihood estimation (MLE) technique.

Analyzing model results

Different model specifications are tested and the best models are selected based on statistical tests and overall goodness-of-fit measure. From the estimated results of the best models, recommendations for future study and also policy guide lines are suggested.

A flow chart of the methodology of the research work is presented in Figure 1.1.

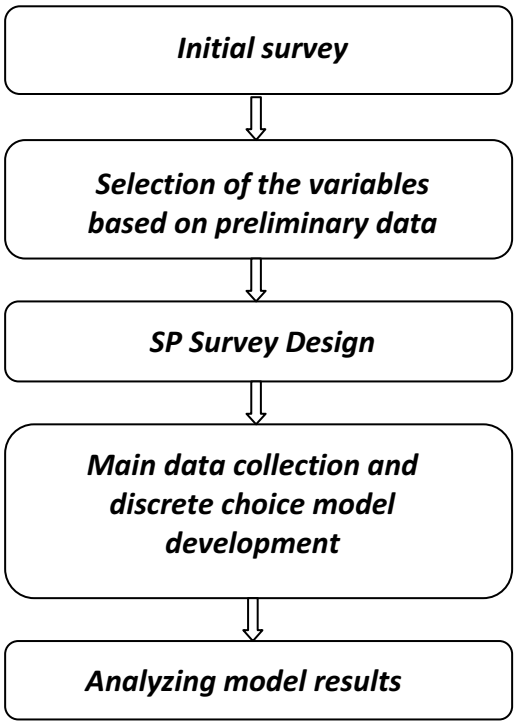


Figure 1.1: Outline of methodology

1.4 Thesis Organization

The remainder of this thesis is organized in four chapters. In Chapter 2, a literature review on state-of-the-art residential location choice models is presented. Descriptions of the survey methods for collecting data for disaggregate model development are also presented in this chapter with special focus on SP survey techniques. Finally, state-of-the-art approaches of discrete choice modeling techniques are highlighted.

Chapter 3 describes the SP survey design procedure which is followed by collection of data for the main survey. The statistical analysis of the collected data is presented at the end of this chapter.

In Chapter 4, the modeling framework is discussed followed by the development of model structure. The estimation results are presented at the end.

Chapter 5 describes the summary of the research work and points out major research contributions. Finally directions for future research are suggested in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter presents a review of literature on state-of-the-art residential location choice models and also focuses on the relevant studies done in the context of Bangladesh. This is followed by review of survey methods and issues associated with development of disaggregate models.

2.2 Residential Location Choice Models

2.2.1 State-of-the-art models

For transportation planning, residential location choice models are important tools in evaluating how households are likely to alter the location of their residences in response to changes in regional demographics and, transportation service and policy. Residential location is a prime determinant of almost all of the travel decisions made by households. In addition to short term transportation decisions such as those on daily trip chains, long term travel decisions such as decisions on automobile ownership are generally centered on the residential location.

Various factors have been found to have an influence on people's residential location choices such as cost and size of dwelling unit, household size, income, life cycle, neighborhood environment, proximity to activity centers, travel time and travel cost to workplace, schools, shopping malls etc. According to the random utility approach, a decision maker chooses an alternative which has the maximum utility. The utility of an alternative housing location is expressed as a function of the attributes of the alternative and characteristics of all possible factors that may influence the choice of that location.

Most residential location models in urban economic-related studies are originated from Alonso's land use and location theory (Alonso 1964). He proposed a

deterministic equilibrium model based on a micro-economic model where utility depends on the consumption of a generalized good, property size and distance to the centre, subject to an income restriction. This model assumed that all workplaces are concentrated in a highly compact central business district (CBD) on the side of city configurations. Commuters home are continuously dispersed over the residential area surrounding the central business district.

McFadden (1978) was the pioneer who considered the problem of translating the theory of economic behavior into models suitable for the empirical analysis of housing location. He was concerned particularly with two problems in the modeling of individual or disaggregates choice among residential locations. There might be a structure of perceived similarities between alternatives, which invalidated the commonly used joint multinomial logit model of choice. Individual dwelling units were treated as the elemental alternatives among which choice was made. Each individual dwelling unit would have a list of attributes, observed and unobserved to which the individual was responsive. It was assumed that the space of attributes was sufficiently rich so that each physical dwelling unit was represented by a unique point in attribute space. The individual might perceive two dwellings, which are similar in some attributes as quite similar overall; it is the impact of such perceptions on choice that was modeled.

Rosen (1974) specified the concept of willingness to pay for a piece of land of certain characteristic, employing the theory of hedonic prices. Evans (1973) defined that the plot size, the time devoted to work, the travel time to work and the time devoted to the rest of the activities are the sources of individual utility in choosing residential location. He assumed that the workplace is located in the CBD. Jara-Diaz et al. (1994), continuing the development of Evans, proposed a model in which utility originates in the time devoted to activities, which are described in terms of their frequency, mean time and quality.

The socioeconomic attributes of the household are often included, but travel to work attributes are usually only included for the journey to work of one household

member as Jara-Diaz et al. (1994) did. The influence of the job opportunities available to other household members is rarely taken into account. Hunt et al. (1994) stated that household behavior in the selection of home location and the selection of workplace locations and commuting modes for employed members involve trade-offs among the attributes of the available alternatives for the different household members. They presented a stated preference experiment related to residential location choice conducted in Calgary, Canada. The experiment attempted to determine the influence of various factors on housing preference. A survey was conducted in which a set of hypothetical residential location choice was given to individuals to choose from. The set of observations obtained was used to estimate the coefficients for various utility functions in logit models. The authors concluded that a wide variety of dwelling unit attributes, location attributes and household characteristics influence housing choice behavior. The main interest of the work was that of identifying the influence of transportation systems on housing preference. Transportation related attributes were found to have an effect on the attractiveness and hence on the value of residential locations in Calgary. Various trade-off rates among housing attributes have been identified in the models and all of them seemed plausible. A trade-off between money values and proximity to LRT stations was found, but it seemed to be too high. Kaysi and Abed (2001) conducted a similar Stated Preference survey concerning residential location choice employed in Beirut, Lebanon. The outcome of the experiment was used to estimate the coefficients for various utility functions of logit models to determine which residential location attributes had statistically significant effects on the attractiveness of residential choice behavior and consequently the potential impact of this behavior on patterns and structural transformation of urban growth. Almost all the attributes were found to have statistically significant effects on the attractiveness of residential behavior. Pagliara, Preston and Kim (2003) also conducted a SP survey and represented an exploratory investigation concerning estimates of the tradeoffs that residents made in Oxford shire. They suggested that transport attributes and house price were very important aspects of residential

location decisions. House price was more important for movers and for those who had been living in Oxon for less than 10 years compared to non-movers more than 10 years. Perez, Martinez and Ortuzar (2003) also developed a generic framework capable of integrating each household member's utility considering household members and their activities separately. They incorporated a Stated Preference (SP) experiment in their work. Their objective was to develop a micro-economic model to allow a direct interpretation of the variables and parameters involved in the indirect utility function and to allow inferences be made from these, such as the subjective value of time (SVT). This fact conceptually differentiates a micro-economic model of residential location with the research line based on analysis of activity patterns, for example, with characteristics such as time windows and discrete variables.

de Palma et al. (2005) developed a model of residential location choice with endogenous housing prices and traffic for the Paris region by integrating a dynamic land use model UrbanSim (www.urbansim.org/) and a dynamic traffic model METROPOLIS (http://metropolis-online.dyndns.biz/ devwww/). This was the first attempt of integrating a dynamic land use model and a dynamic traffic model. The result confirmed that housing price was not endogenous with regard to the location choice model. White (1977) developed an urban model composed of both one and two-worker households and considered its implications for men's and women's commuting distances. He restricted the scope of investigation to married women who work, or to households which had two wage earners. He assumed that the household acts according to the rules of economics rationality with respect to both jobs, rather than with respect to just the husband's job. The theory suggested that in a city of mixed two-worker and one worker household's job, the two-worker households choose their residential locations so that the wife's commuting journey is shorter that the husband's. The wife's journey is also shorter than that made by workers in single-job households.

Traditional urban economic theory and the vast majority of empirical work in urban modeling treat the residential location choice as conditional on an exogenous

choice of workplace. Some empirical work, on the other hand, including the workplace destination choice models embedded in metropolitan transportation models, assume that residence location is predetermined when predicting the workplace location choice. For long term prediction of household locational patterns it is important to examine both workplace-location choice and home-location choice (Giuliano, 1993). There are some previous works in modeling the choice of home and workplace in a joint-choice model. Waddell (1993) calibrated a single model of the simultaneous choice of both home and workplace location and investigated whether the home-location or workplace-location choices have larger dispersion terms in the nested-logit formulation. He found that the dispersion terms were of similar size. This suggests that the accessibility to homes in job location choice is as important as the accessibility to jobs in home location choice. One way to represent this mathematically is to consider both choices in one model. Waddell, et al. (2006) also developed a joint model of residence location and workplace using an activity-based travel survey collected in the Puget Sound region of Washington in 1999, incorporating latent market segmentation within discrete choice models. Abraham and Hunt (1997) also explored that each household must choose a home location along with a workplace and commuting mode for each employed household member. They considered that these decisions were interrelated, and could be considered together as one joint household decision. This joint decision was termed HWM (Home, Workplace and Mode) choice. HWM choice was defined as a complex choice process because trade-offs were made between the individual members of the household as well as among the various attributes of home, workplace, and travel mode. A modified form of nested logit model representing this behavior had been developed and estimated using disaggregate revealed preference observations collected in Calgary, Alberta, Canada. Three categories of choice—choice of home location for the household, choice of workplace location for each worker in the household, and choice of mode for the trip to work for each worker in the household—were treated as a joint choice made by the household, allowing for differing numbers of workers in different

households. They explored the nature of this household choice process and the role of transport conditions within it.

Rivera and Tiglao (2005) also investigated how the household trade off location attributes as well as the effect of transportation in their choice behavior in a disaggregate manner. Special attention was given to two-worker households to give them an insight on how workers in the household assess each worker's disutility when relocating. They used multinomial and nested logit models to examine the nature of household choices of residential location, workplace location and mode choice to work in Metro Manila. Results confirmed the existing pattern of suburbanization in the metropolis as more households were willing to tradeoff longer distances and hence commuting time in their residential location choices.

Levinson (1998) worked on the suggestion that achieving a balance between jobs and housing in an area (equal numbers of jobs and workers residing in that area) could lead to relatively short commuting distances and times. On the basis of a household survey in the Washington DC area, he concluded that residences in job-rich areas and workplaces in housing-rich areas are associated with shorter commutes.

From another point of view and in order to advance in the comprehension of the location choice process, it is interesting to note the work of Morigushi and Yoshida (1986). They treated the case of house owners explicitly. Although in strict terms they did not pay rent, because they faced an alternative cost for their dwelling that eventually could allow them to lease it and change location. Their main conclusions go in the direction of defining that the time employed in the different activities is the principal source of utility. The assignment of these times is held to time and income restrictions and defines the individual state of equilibrium.

Weisbrod, Ben-Akiva. and Lerman (1980) analyzed consumers' tradeoffs in the decision to move and the selection among alternative residential locations. They focused on the role of transportation level-of-service changes relative to various aspects of neighborhood quality, including crime, taxes, school quality, and

demographic factors. The empirical results suggested that households make significant tradeoffs between transportation services and other public service factors in evaluating potential residences, but that the role of both in determining where people choose to live is small compared with socioeconomic and demographic factors. This suggested that the potential of most available public policies for altering residential location demand may be limited, and that the coordination of policies to achieve desired changes in residential patterns may prove useful.

Many transportation and land use policies are based on the implicit or explicit assumption that accessibility considerations play an important role in people's residential choice decisions. Land use and transportation can be considered as two sides of the same coin. It is generally believed, both in planning and transportation, that spatial land use patterns influence trip generation and trip distribution. Vice versa, it is commonly believed that accessibility and other transportation-service level variables significantly influence location decisions of firms and households. Molin and Timmermans (2003) summarized and re-interpreted six case studies on housing choice over the last decade to put the assumption to an empirical test, using stated preference data. These case studies involved different cities and study areas that used different SP designs and applied various model specifications. The results of these studies suggested that regardless of the study area and the model specification accessibility considerations are significantly less important than housing attributes and attributes related to the neighborhood. It seems that as long as people have the opportunity to afford flexible means of transport, the impact of accessibility on their residential choice behavior is relatively limited. This may be different for people who necessarily rely on public transport. However, they may not constitute a sufficiently sizeable group to have a substantial policy impact. It suggested that the direct living environment generates as much utility to people, on average, than the disutility of necessary travel. Zondag and Pieters (2005) also analyzed the importance of accessibility in explaining residential location choices. They illustrated on the basis of the research findings for the Netherlands that the

transport system influences residential moves at three stages: in move–stay choice, estimation results showed that households were less likely to move away from a more accessible location; travel time variables were significant for all household types, and therefore changes in the transport system would affect the size of the housing market and search area of the households; the model estimation results suggested that accessibility of a specific location for many household types was not a significant variable in their location choice. Overall, the empirical results suggested that the role of accessibility is significant but small compared with the effect of demographic factors, neighborhood amenities, and dwelling attributes in explaining residential location choices.

Households value their neighborhood or their immediate environment. On a study done by Gayda (1998), she discovered that residents in Brussels were attracted to urban residential neighborhoods which were quiet, safe and have very low traffic volume. Children being able to play in the street were also considered important by the residents.

Sermons and Koppelman (1998) investigated the issue of multicollinearity among measures of socio-economic status in developing residential location choice models. The authors tested alternative methods of representing these attributes with a smaller number of summary or representative measures. In particular, they performed factor analysis on the census tract-level family status and socioeconomic status variables to produce factor scores that are used in residential location choice models. The authors concluded that the factor analysis approach provided a clearer interpretation of the influence of socioeconomic status and family status than inclusion of multiple variables, which obtains may non significant and counterintuitive parameters. Basic conclusions emphasized the sensitivity of households to housing costs and to travel time to work.

The study of Sun, Wilmot and Kasturi (1998) qualitatively revealed that land use makes a big difference in household VMT, whereas its impact on the number of daily trips is rather limited. The household lifestyle appears to be more relevant to

the residence location. And the land use development of the residence location imposes the greatest impact on the household daily VMT. Cao, Xu and Fan (2009) applied propensity score matching to explore the effects of the regional location of residences on vehicle miles driven in Raleigh, North Carolina. They found that residential location plays a much more important role in affecting driving behavior than residential self-selection and that individual who lived farther away from Downtown Raleigh tended to drive more than those living closer. Therefore, they remarked that outward expansion in the urban periphery is likely to increase vehicle miles travelled. This result highlighted the importance of urban growth management strategies in reducing auto dependence. Naess (2009) also explored that residential location choice has significant impact on vehicle miles driven (VMD). They found that importance of residential location's influence on VMD increased as the distance of the location from the city center increased. After controlling for residential self-selection, the farther people live from the city center, the more miles they drive. For all pairs of locations but one, self-selection plays a less important role in affecting VMD than the location of residences within a metropolitan area.

Ozturk and Irwin (2003) estimated a spatial model to test the influence of a better residential location choice. According to them, housing is a special kind of commodity for several reasons. First, housing is spatially immobile; its location is an intrinsic attribute of a dwelling. So, one component of the housing bundle is the residential location. Housing units differ in structural characteristics, lot features, the neighborhood, local public services and in accessibility to desired destination. Difference in all these features affect the location choice of household and make for a wide spectrum of degrees of substitutability among dwelling.

Habib and Kockelman (2008) investigated a critical element of residential mobility decisions: relationships between home type choice and residential location choice which are normally evaluated in isolation. They developed a series of Nested Logit (NL) models using a survey of recent home buyers in Austin, Texas. They explored that homes of similar type tend to share more unobserved qualities than distinctly

styled homes in similar locations. With a particular home type in mind, location choice may become constrained by home availability across locations of the urban area. They suggested that location choice decisions can best be nested within the choice of home type.

2.2.2 Residential location choice models for Bangladesh

High urbanization rate and the resulting problem in housing and transport sectors are the common scenarios in major cities of Bangladesh; particularly the divisional ones are facing serious challenges. There have been few research works that focused on transportation and land use interactions in the context of Bangladesh. Modeling residential location choice in particular, has been found to be a relatively less researched area. Previous researches in this topic include Nabi and Habib, 2003, Nabi and Kamruzzaman, 2003, Nabi, 2003, Habib, 2004, Mitra, 2004, and Nahrin, 2009. All of these works used only revealed preference (RP) survey.

Habib (2004) developed a hedonic price model for Rajshahi city using RP survey to explore the impacts of transportation attributes on residential property values. Geographical Information System (GIS) was used as a tool for the determination of hedonic models based on residential asking rental price. Structural attributes of rental house (e.g. usable living area, number of bedrooms etc.), neighborhood attributes and network access distance from the rental house to various utility sources (e.g. CBD, markets, schools etc.) were used to measure the value of rent. Number of bedrooms and, accessibility to CBD and major arterials were found as the most important parameters in affecting the rental asking price. However, the study did not use any socioeconomic characteristics (e.g. employment, income, age etc.) in the model which was a major limitation of the work.

Nahrin (2009) determined the relative weight of selected variables in rental house locations and rental apartment's choice by the middle-income dwellers of Dhaka city using Analytic Hierarchy Process (AHP). The study group was divided on the basis of having school going children. She considered some spatial attributes (e.g. distance to workplace, school, market, bus stop), physical attributes (e.g.

neighborhood, municipal services etc.), social and environmental attributes in determining preferences on housing location choice , and affordability, number of bedrooms, availability of air, sunlight etc. as factors of house choice. The study explored that proximity to workplace, school, market and bus stop holds higher weight for house location selection and affordability is the most important factor in house selection. It was evaluated that the middle-income tenants were not satisfied with the locational attributes of the residential areas as well as the apartment standards. They actually did trade-off among different determinants of residential areas as well as the house selection. As a continuation of Nahrin's work, Nabi (2010) focused on the influence of bus service on the choice of residential location and also identified the influential factors in residential location choice for low, medium and high rent areas of Dhaka city. Multinomial Logistic Regression was applied to determine the influence of bus service in choosing residential location and AHP was used to determine the pair-wise importance of transport related aspects. She explored house rent as the most significant factor followed by housing characteristics, bus services and so on in the choice of residential location. Findings revealed that people of low and medium rent give the highest priority to house rent and bus service compared to the people of high rent area. A model was developed to indicate housing location choice patterns categorizing the Dhaka City into low, medium and high rent areas and results show that the people of low and medium rent give highest priority to house rent and bus service with compared to the people of high rent area. The study also indicated that people who give significant importance to bus service give more importance to frequency of service whereas people, who do not give significant importance to bus service, give highest importance to transport fare in choosing residential location.

2.3 Survey Methods

Two methods of survey are widely used in the development of models in transportation which are described below:

- ❒ Revealed Preference survey (RP survey)
- ❒ Stated Preference survey (SP survey)

2.3.1 Revealed preference survey

Revealed preference survey represents data collected on choices that are made in an actual market. As such, RP data represents events that have been observed to have actually occurred. Several possibilities exist as to how such data may be collected. Firstly the analyst may elect to observe a market and note the alternatives as chosen and non-chosen. Alternatively, some other means may be available to record choices within a market (e.g., shopping centre scanner panels, automatic passenger counters, transport smart cards etc.). No matter how data is collected, the analyst must consider how data is to be collected on the attribute levels and socio-demographic characteristics of the decision makers operating within the market. With regard to attribute levels, two methods could be noted, collecting actual data on the real attributes levels or asking decision makers what they perceive the attribute levels to be. With regard to socio-demographic characteristics, if the analyst chooses to observe decision makers, then only simple information on socio-demographic characteristics may be obtainable (e.g., gender and possibly an age range) which may or may not be significant to preference formation. Alternatively, a questionnaire survey of decision makers may yield more useful information.

Disadvantages of RP data

RP data has some disadvantages which are described below:

Limitations on alternatives, attributes and attribute levels

As RP data is by definition data collected on choices made in real markets, these are limited to collecting data only on currently existing alternatives within those markets.

Attribute level invariance

Experience has shown that many markets provide limited variability in the levels of attributes it wishes to use for modeling purposes. Possible reasons for attribute level invariance include: market structure, lack of patent or copyright, costs in changing the marketing mix, and marketing strategies. Independent of the cause, attribute invariance poses modeling problems for the analyst.

Non-chosen alternatives

Whether one collects information directly from the market (e.g., from scanner panel data) or from respondents operating within the market, information cannot be obtained on the alternatives not chosen.

Correlation

Experience has shown that a considerable proportion of markets tend to exhibit significant levels of attribute correlations which in turn poses problems for model estimation. An example exists in the automobile market whereby higher priced vehicles come standard with airbags, an item not associated with lower priced vehicles. In such instances certain attributes and attribute levels may become associated with certain types of goods or service, often categorized using price as a heuristic.

Cost

Collection of RP data can be costly, both in terms of time and money, perhaps prohibitively so depending upon how the analyst chooses to collect the data. Given the time and cost in collecting such data, the analyst may be tempted to cut corners. Such temptation should be avoided at all costs as at the end of the day the models produced are only as good as the data collected.

Choice set specification problem

To arrive at a choice, an individual must have considered a set of alternatives. These alternatives are usually called the choice set. At least one actual choice setting must exist (e.g., choosing where to live) but there may be more than one choice (e.g., what type of dwelling to live in, whether to buy or rent, and how much to pay per week if rented). The idea that an individual may have to consider a number of choices is referred to as a set of inter-related choices. Determining the set of alternatives to be evaluated in a choice set is a crucial task in choice analysis. Getting this wrong will mean that subsequent tasks in the development of a choice model will be missing relevant information. The specification of the choice set can be a big problem in RP data.

2.3.2 Stated preference survey

Stated Preference Survey represents choices "made" or stated given hypothetical situations. This may lead to situations in which personal constraints are not considered as constraints at the time of choice. The task of the analyst is to make the hypothetical scenarios as realistic as possible.

Motivation for using stated preferences data

The hypothetical nature of SP survey offers the analyst a significant benefit over RP survey. RP survey is constrained in terms of being able to collect information solely on currently existing alternatives. As such, the alternatives, the attributes and the attribute levels are fixed in terms of what is currently on offer. Since predicting

outside of the ranges of data provides notoriously unreliable estimates from most statistical models, what is required is an approach that will either allow for accurate model predictions outside of the existing data range or alternatively an approach that allows for the collection of data outside of these ranges which may be used with conventional modeling techniques for predictive purposes. With SP experiments, the analyst must specify the attributes and attribute levels in advance. This allows the analyst to manipulate the relationship between attributes and investigate specific hypotheses about the functional form that utility should take or Interactive.

Potential sources of bias in SP data

- ❒ Indifference to the experimental task
- ❒ Policy response bias
- ❒ Justification bias
- ❒ Omission of situational constraints
- ❒ Incomplete descriptions of alternatives
- ❒ Cognitive incongruity with actual behavior

Though there are some limitations, because of the advantages of SP data they have been widely used in choice modeling.

Comparison of RP and SP survey

A comparison of RP and SP Survey is presented in Table 2.1.

Table 2.1: Comparison of RP and SP survey

	RP Survey	**SP Survey**
Preference	Choice behavior in actual market	Preference statement for hypothetical scenarios
	Cognitively congruent with actual behavior	May be cognitively incongruent with actual behavior
	Market and personal constraints are accounted for	Market and personal constraints may not be considered

Table 2.1: Comparison of RP and SP survey (Continued)

	RP Survey	SP Survey
Alternatives	Actual alternatives	Generated alternatives
	Responses to non-existing alternatives are unobservable	Can elicit preference for new (non-existing) alternatives
Attributes	May include measurement errors	No measurement errors
	Correlated attributes	Multicollinearity can be avoided by experimental design
	Ranges are limited	Ranges can be extended
Choice Set	Ambiguous in many cases	Pre specified
Number of Responses	Difficult to obtain multiple responses from an individual	Repetitive questioning is easily implemented
Response Form	Only choice is available	Various response formats are available (e.g., ranking, rating, matching)

2.3.3 SP techniques

There are several techniques of SP design such as direct (close-ended) contingent valuations (DCV), ranking exercises (RE), hypothetical referendum approaches (HRA) and stated preference choice experiment (CE). CE offers some important advantages over the other methods, principally, the ability to estimate coefficient values for attributes with relative ease and capture the trade-offs among multiple attributes of interest. Moreover, CE is referred to as the closest to reality as they provide the respondents with the kind of choices they have to actually make in a real situation. These make the CE as the most preferred approach in most of the large-scale projects in spite of the relative difficulty in survey design, data collection and model development.

Choice Experiment (CE)

The CE technique is based on the notion that a good or service can be described by attributes and levels which respondents are willing to trade-off between one

another and it differs from other approaches in terms of the nature of the choice task. In the CE approach, respondents make choices among hypothetical choice scenarios where multiple attributes can vary.

Again the expression of preferences of the respondents may vary in choice exercise. The expression of preferences may be in the form of choice, ranking, rating and matching. These four techniques of the expression of preferences are described below:

- ❒ Choice — Preference of **one** alternative relative to each of the others. The respondents are given a set of alternatives each having multiple levels of different attributes, and are asked to choose among the alternatives.
- ❒ Ranking — Preference of **each** alternative relative to each of the others. The respondents are given a set of alternatives and then asked to rank each alternative relative to each of the others.
- ❒ Rating — Respondent puts **each** alternative on a scale from good to bad.
- ❒ Matching — Relative value of attributes is being traded off. The trade-off is often done with a cost attribute. Example of the matching technique is provided in Table 2.2.

Table 2.2: Example of matching preference

Alternative 1		Alternative 2	
Cost 1	Time 1	_____	Time 2 (< time 1)
_____	Time 1 (< time 2)	Cost 1	Time 1

What cost for alternative 2 would make you indifferent between alternatives 1 and 2? Or, what is the most you will be willing to pay for alternative 2? (Ben-Akiva, 2008)

Fundamental designs of Choice Experiment (CE)

In a typical SP experiment a respondent is asked to make a series of choices. Choices are organized into a Game or Experiment. In each choice the respondent must select one of the alternatives in the choice set. An alternative is characterized by its attributes and attribute levels. The different combinations of the levels of attributes of an alternative are called profile while the combination of the attribute levels of different alternatives presented in a specific choice is called a scenario.

In principal, the simplest organization of a game, once attribute levels have been fixed, is to present all the possible combinations to each respondent. This is called a full factorial design and forms the basis from which other designs can be derived.

Full factorial design

The specification of a full factorial design is straightforward: an example is illustrated in Table 2.3, which shows the design for a game with three attributes, each of two levels. The design can also be presented numerically, as shown in the right side of the table, and in that form it is transferable to any other context of three attributes with two levels.

Table 2.3: Full factorial design: three attributes, two levels each

Scenario	Attributes		
	Fare	Time	Freq
1	High	Slow	Low
2	High	Slow	High
3	High	Fast	Low
4	High	Fast	High
5	Low	Slow	Low
6	Low	Slow	High
7	Low	Fast	Low
8	Low	Fast	High

Scenario	Attributes		
	At.1	At.2	At.3
1	0	0	0
2	0	0	1
3	0	1	0
4	0	1	1
5	1	0	0
6	1	0	1
7	1	1	0
8	1	1	1

An important characteristic of the full factorial design is that of orthogonality, that is, the values of the attributes are independent. In the full factorial design,

orthogonality applies also to interactions between the attributes, so that if the value of one attribute depends on the value of another, this can be fully identified from the experiment.

However, as the number of attributes and the number of levels increases the number of profiles required for a full factorial design can be very large. For example, if there are four attributes each with four levels, the full factorial design requires $4^4 = 256$ scenarios.

Fractional factorial design

A fractional factorial design is based on a systematic selection of a number of rows from a full factorial design. For example, using the shaded rows in table 2.3 would represent a fractional factorial Design. The obvious advantage of a fractional factorial design is that it reduces the number of scenarios that are presented to respondents.

A potential problem with fractional factorial designs is that orthogonality is lost in at least some respects. This may affect the main effects, i.e. the values of the attributes themselves become correlated, but it is not always the case, for example in the shaded rows of Table 2.3. It is very likely that it will affect interactions, i.e. it may become difficult (or impossible) to identify interactions between some or all the attributes when smaller fractional factorial designs are used. In the shaded rows in Table 2.3 the interactions are no longer orthogonal. Hence the implicit underlying assumption is that these are not significant in explaining preferences.

Creation of choice sets

The methods applied in the literature (e.g. Louviere et al., 2000) for combining scenarios to obtain choice sets fall into three typical groups. These are as follows:

Simultaneous choice set creation

The typical method of this type is the 'L^{MN}' procedure, giving choice sets of N alternatives with M attributes, each of L levels. In the example of Table 2.3, if L=2,

M=3 and N=2, then there will be 64 choices which cover all possible combinations of the levels. This design can be represented in a single table by using separate columns for the attributes of each alternative, thus obtaining N x M=6 columns, and in this form a fractional factorial design can be developed by selecting specific rows as was indicated above. For this particular problem, the smallest design that maintains orthogonality for the main effects has 8 rows, i.e. 8 choices.

Sequential choice set creation

The fold-over design procedure creates the choice sets by creating profiles for subsequent alternatives based on the profile for the first alternative. The procedure starts from a full or fractional factorial design, which forms the profiles for first alternative. The profiles for the second alternative are then formed by a systematic transformation of the attributes, changing some to the next higher value, leaving others unchanged, etc. A simple change of all the attributes to their next level is called shifting; more complicated transformations, often involving a random element (shuffle) are called fold over designs. For example, Table 2.4 shows an application of these procedures to the simple problem of Table 2.3.

Table 2.4: Two folded-overs based on fractional factorial design

Three attributes, two levels each, as in table 2.3

Fold-over without Shuffle						
Ch.	**Alt. A**			**Alt. B**		
	Att. 1	**Att. 2**	**Att. 3**	**Att. 1**	**Att. 2**	**Att. 3**
1	**0**	**0**	**0**	**1**	**1**	**0**
2	**0**	**1**	**1**	**1**	**0**	**1**
3	**1**	**0**	**1**	**0**	**1**	**1**
4	**1**	**1**	**0**	**0**	**0**	**0**

Shifting						
Ch.	**Alt. A**			**Alt. B**		
	Att. 1	**Att. 2**	**Att. 3**	**Att. 1**	**Att. 2**	**Att. 3**
1	**0**	**0**	**0**	**1**	**1**	**1**
2	**0**	**1**	**1**	**1**	**0**	**0**
3	**1**	**0**	**1**	**0**	**1**	**0**
4	**1**	**1**	**0**	**0**	**0**	**1**

Alternative A uses the scenarios of the fractional factorial design (i.e. the shaded rows in Table 2.3). Alternative B on the left side uses a fold-over, changing 0's to 1's and 1's to 0's for attributes 1 and 2 and not changing attribute 3. On the right side a shifting design is implemented in which all attributes change.

Randomised choice sets

Randomised choice sets are generally based on a full or fractional factorial design. Then scenarios are randomly selected (with or without replacement) from these to present to the respondent. When both alternatives relate to the same brand, selections are generally made from a single set; when alternatives relate to different brands, as in the example, selections are generally made from two independently created factorial designs. (Sanko, 2002)

2.3.4 Processes in setting up stated preference experiments

The processes used in generating a Stated Preference experiment are as follows:

Experimental design

The foundation for any SP experiment is an experimental design. An experiment defined in scientific terms involves the observation of the effect upon one variable, a response variable, given the manipulation of the levels of one or more other variables. The manipulation of the levels of the variables does not occur in a haphazard manner. Rather it turns to a specialized form of statistics to determine what manipulations to make and when to make them. Thus it can be told that the manipulations occur by design.

Figure 2.5 summarizes the process used to generate stated preference experiments. This process begins with a refinement of the problem, to ensure that the analyst has an acute understanding of what the research project hopes to achieve by the time of completion.

Once the problem is well understood, the analyst is required to identify and refine the stimuli to be used within the experiment. It is at this stage of the research that the analyst decides upon the list of alternatives, attributes and attributes levels to be used. This refinement may result in further scrutiny of the problem definition and as a result a return to the problem refinement stage of the process. Moving from stimuli refinement, the analyst must now make several decisions as to statistical properties that will be allied with the final design.

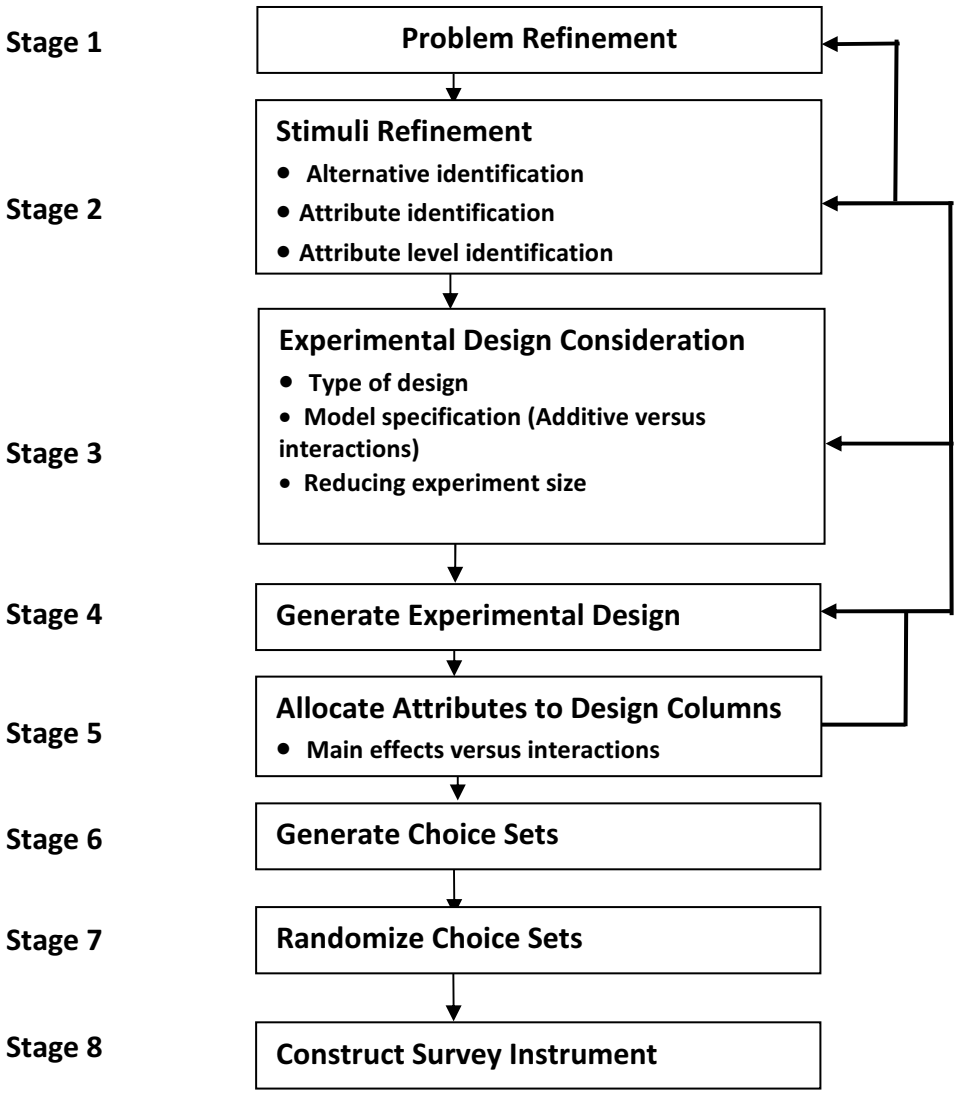


Figure 2.1: The SP experimental design process

As an aside, the first two stages of the process consist of refining the analyst's understanding of behavioral aspects of the problem as they relate to decision

makers. It is hoped that this understanding of the behavioral impacts will regulate the decision process of the analyst at the time of considering the statistical properties of the design. Often however, statistical considerations must take precedence. Statistically inefficient designs, designs which are unwieldy in size or possibly even the non-availability of a design that fits the behavioral requirements established in the earlier stages, may trigger a return to the first two stages of the design process.

Provided that the analyst is sufficiently happy to continue at this point, the experimental design may be generated. Whilst it is preferable to generate such designs from first principles, such a derivation requires expert knowledge. Several statistical packages are capable of generating simple experimental designs that may be of use (e.g., SPSS, Minitab and SAS). Following the generation of the experimental design, the analyst must allocate the attributes selected in stage two, to specific columns of the design. Again, a return to previous stages of the design process may be necessary if the design properties do not meet the criteria established at earlier stages of the process.

Once the attributes have been allocated to columns within the design, the analyst manipulates the design to produce the response stimuli. Whilst several forms of response stimuli are available to the analyst, concentration is given here on only one type, that of choice. Thus, the sixth stage of the design process sees the analyst construct choice sets that will be used in the survey instrument (e.g., a questionnaire). To overcome possible biases from order effects, the order of appearance of these choice sets are randomized across questionnaires. As such, several questionnaire versions are created for each single choice experiment undertaken. The final stage of the experimental design process is to construct the survey, by inserting the choice sets as appropriate into the different versions and inserting any other questions that the analyst may deem necessary to answer the original research problem (such as questions on RP data or socio demographic characteristics). After the survey is constructed, the step is now to collect data. After collection of data, the models are developed and results are estimated

(Hensher and Rose, 2003). The modeling techniques at disaggregate level are described in the following section.

2.4 Discrete Choice Modeling Techniques

One of the major shortcomings of the aggregate spatial interaction models was the absence of appropriate or use of inappropriate theory to describe the behavior captured in the model. Developments in the use of random utility theory to describe choices among discrete alternatives, such as the choice of travel mode provided the impetus for a new generation of models based on the study of disaggregate behavior. Decisions relating to location and travel choice have increasingly been modeled by using the discrete choice theory. The random utility model is the most common theoretical basis of discrete choice models. There are also the alternative discrete choice model forms such as Logit, Nested Logit, Generalized Extreme Value and Probit, as well as more recent developments such as Hybrid Logit and the Latent Class choice model.

2.4.1 General modeling assumptions

The framework for a discrete choice model can be presented by a set of general assumptions. It could be distinguished among assumptions regarding the:

- Decision-maker: defining the decision-making entity and its characteristics;
- Alternatives: determining the options available to the decision-maker;
- Attributes: measuring the benefits and costs of an alternative to the decision maker;
- Decision rule: describing the process used by the decision-maker to choose an alternative.

Decision-maker

Discrete choice models are also referred to as disaggregate models, meaning that the decision-maker is assumed to be an individual. The “individual” decision-making

entity depends on the particular application. For instance, it might be considered that a group of persons (a household or an organization, for example) is the decision-maker. In doing so, it might be ignored all internal interactions within the group, and consider only the decisions of the group as a whole. It is referred to "decision-maker" and "individual" interchangeably. To explain the heterogeneity of preferences among decision-makers, a disaggregate model must include their characteristics such as the socio-economic variables of age, gender, education and income.

Alternatives

Analyzing individual decision making requires not only knowledge of what has been chosen, but also of what has not been chosen. Therefore, assumptions must be made about available options, or alternatives, that an individual considers during a choice process. The set of considered alternatives is called the choice set.

A discrete choice set contains a finite number of alternatives that can be explicitly listed. The choice of a travel mode is a typical example of a choice from a discrete choice set. The identification of the list of alternatives is a complex process usually referred to as choice set generation. The most widely used method for choice set generation uses deterministic criteria of alternative availability. For example, the possession of a driver's license determines the availability of the auto drive option.

The universal choice set contains all potential alternatives in the application's context. The choice set is the subset of the universal choice set considered by, or available to, a particular individual. Alternatives in the universal choice set that are not available to the individual are therefore excluded from the choice set.

In addition to availability, the decision-maker's awareness of the alternative could also affect the choice set. The behavioral aspects of awareness introduce uncertainty in modeling the choice set generation process and motivate the use of probabilistic choice set generation models that predict the probability of each feasible choice set within the universal set.

Attributes

Each alternative in the choice set is characterized by a set of attributes. Some attributes may be generic to all alternatives, and some may be alternative-specific. An attribute is not necessarily a directly measurable quantity. It can be any function of available data. For example, instead of considering travel time as an attribute of a transportation mode, the logarithm of the travel time may be used, or the effect of out-of-pocket cost may be represented by the ratio between the out-of pocket cost and the income of the individual. Alternative definitions of attributes as functions of available data must usually be tested to identify the most appropriate.

Decision rule

The decision rule is the process used by the decision-maker to evaluate the alternatives in the choice set and determine a choice. Most models used for travel behavior applications are based on utility theory, which assumes that the decision-maker's preference for an alternative is captured by a value, called utility, and the decision-maker selects the alternative in the choice set with the highest utility.

This concept, employed by consumer theory of micro-economics, presents strong limitations for practical applications. The underlying assumptions of this approach are often violated in decision-making experiments. The complexity of human behavior suggests that the decision rule should include a probabilistic dimension.

Some models assume that the decision rule is intrinsically probabilistic, and even complete knowledge of the problem would not overcome the uncertainty. Others consider the individuals' decision rules as deterministic, and motivate the uncertainty from the limited capability of the analyst to observe and capture all the dimensions of the choice process, due to its complexity.

Specific families of models can be derived depending on the assumptions about the source of uncertainty. Models with probabilistic decision rules, like the model proposed by Luce (1959), or the "elimination by aspects" approach proposed by Tversky (1972), assume a deterministic utility and a probabilistic decision process.

Random utility models, used intensively in econometrics and in travel behavior analysis, are based on deterministic decision rules, where utilities are represented by random variables.

2.4.2 Random utility theory

Random utility models assume, as does the economic consumer theory, that the decision-maker has a perfect discrimination capability. However, the analyst is assumed to have incomplete information and, therefore, uncertainty must be taken into account. Manski (1977) identifies four different sources of uncertainty: unobserved alternative attributes; unobserved individual characteristics (also called "unobserved taste variations"); measurement errors; and proxy, or instrumental, variables.

The utility is modeled as a random variable in order to reflect this uncertainty. More specifically, the utility that individual n associates with alternative i in the choice set C_n is given by

$$U_{in} = V_{in} + \varepsilon_{in} \tag{2.1}$$

Where V_{in} is the deterministic (or systematic) part of the utility, and ε_{in} is the random term, capturing the uncertainty. The alternative with the highest utility is chosen.

Therefore, the probability that alternative i is chosen by decision-maker n from choice set C_n is

$$P(i|C_n) = P\left[U_{in} \geq U_{jn} \; \forall \, j \in C_n\right] = P[U_{in} = \max_{j \in C_n} U_{jn}] \tag{2.2}$$

The assumptions necessary to make a random utility model operational are as follows:

Location and scale parameters

Considering two arbitrary real numbers α and μ,

Where μ > 0, we have that

$$P\left[U_{in} \geq U_{jn} \; \forall \, j \in C_n\right] = P[\mu U_{in} + \alpha \forall j \in C_n] = P\left[U_{in} - U_{jn} \geq 0 \; \forall \, j \in C_n\right] \quad (2.3)$$

The above illustrates the fact that only the signs of the *differences* between utilities are relevant here, and not utilities themselves. The concept of ordinal utility is relative and not absolute. In order to estimate and use a specific model arbitrary values have to be selected for α and μ. The selection of the scale parameter μ is usually based on a convenient normalization of one of the variances of the random terms. The location parameter α is usually set to zero.

Alternative specific constants

The means of the random terms can be assumed to be equal to any convenient value *c* (usually zero, or the Euler constant γ for Logit models). This is not a restrictive assumption. If the mean of the error term of alternative *i* is denoted by $m_i = E[\varepsilon_{in}]$, it can be defined as a new random variable $e_{in} = \varepsilon_{in} - m_i + c$ such that $E[e_{in}] = c$.

$$P\left[U_{in} \geq U_{jn} \; \forall \, j \in C_n\right] = P\left[V_{in} + m_i + e_{in} \geq V_{jn} + m_j + e_{jn} \forall \, j \in C_n\right] \quad (2.4)$$

Equation 2.4 represents a model in which the deterministic part of the utilities are $V_{in} + m_i$ and the random terms are e_{in} (with mean *c*). The terms m_i are then included as Alternative Specific Constants (ASC) that capture the means of the random terms. Therefore, it may assume without loss of generality that the error terms of random utility models have a constant mean *c* by including alternative specific constants in the deterministic part of the utility functions.

As only differences between utilities are relevant, only differences between ASCs are relevant as well. It is common practice to define the location parameter α as the negative of one of the ASCs. This is equivalent to constraining that ASC equal zero.

From a modeling viewpoint, the choice of the particular alternative whose ASC is constrained is arbitrary. However, Bierlaire, Lotan and Toint (1997) have shown that the speed of convergence of the estimation process may be improved by imposing different constraints.

The deterministic term of the utility

The deterministic term V_{in} of each alternative is a function of the attributes of the alternative itself and the characteristics of the decision-maker. That is

$$V_{in} = V(z_{in}, S_n) \tag{2.5}$$

Where z_{in} is the vector of attributes as perceived by individual *n* for alternative *i*, and S_n is the vector of characteristics of individual *n*.

This formulation is simplified using any appropriate vector valued function *h* that defines a new vector of attributes from both z_{in} and S_n, that is

$$x_{in} = h(z_{in}, S_n) \tag{2.6}$$

Then we have

$$V_{in} = V(z_{in}, S_n) \tag{2.7}$$

The choice of *h* is very general, and several forms may be tested to identify the best representation in a specific application. It is usually assumed to be continuous and monotonic in z_{in}. For a linear in the parameters utility specification, *h* must be a fully determined function (meaning that is does not contain unknown parameters). A linear in the parameters function is denoted as follows

$$V_{in} = \sum_k \beta_k x_{ink} \tag{2.8}$$

Or in vector form

$$V_{in} = X_{in}\beta. \tag{2.9}$$

The deterministic term of the utility is therefore fully specified by the vector of parameters β.

The random part of the utility

Among the many potential models that can be derived for the random parts of the utility functions, the most popular are Logit and Probit models.

The models within the Logit family are based on a probability distribution function of the maximum of a series of random variables, introduced by Gumbel (1958). Probit and Probit-like models are based on the Normal distribution motivated by the Central Limit Theorem.

The main advantage of the Probit model is its ability to capture all correlations among alternatives. However, due to the high complexity of its formulation, relatively few applications have been developed. The Logit model has been much more popular, because of its tractability. However, Logit imposes restrictions on the covariance structure that may be unrealistic in some contexts. Other models in the "Logit family" are aimed at relaxing restrictions, while maintaining tractability.

The Generalized Extreme Value models family

The Generalized Extreme Value (GEV) model has been derived from the random utility model by McFadden (1978). This general model consists of a large family of models. The probability of choosing alternative *i* within C_n is

$$P(i|C_n) = \frac{e^{V_{in}} \frac{\partial G}{\partial e^{V_{in}}} (e^{V_{1n}}, \ldots, e^{V_{J_n}})}{\mu G(e^{V_{1n}}, \ldots, e^{V_{J_n}})} \qquad (2.10)$$

J_n is the number of alternatives in C_n and G is a non-negative differentiable function defined on $IR_+^{J_n}$ with the following properties:

- G is homogeneous of degree $\mu > 0$,
- $\lim_{x_i \to \infty} G(x_1, \ldots, x_i, \ldots, x_{J_n}) = \infty, \forall i = 1, \ldots, J_n$
- the k^{th} partial derivative with respect to k distinct x_i is non-negative if k is odd and non positive if k is even, that is, for any distinct $i_1, \cdots i_k \in \{1, \cdots J_n\}$ we have

$$(-1)^k \frac{\partial^k G}{\partial x_{i_1} \ldots \partial x_{i_k}} (x) \leq 0 \; \forall_x \in IR_+^{J_n} \tag{2.11}$$

As *G* is homogeneous, Euler's theorem can be invoked to write

$$P(i|C_n) = \frac{e^{V_{in}+ln(G_i(e^{V_{ln}},\ldots,e^{V_{J_n n}}))}}{\sum_{j\in C_n}\left(e^{V_{jn}+ln(G_i(e^{V_{ln}},\ldots,e^{V_{J_n n}}))}\right)} \tag{2.12}$$

Where $G_i\left(e^{V_{ln}}, \ldots, e^{V_{J_n n}}\right) = \frac{\partial G}{\partial e^{V_{in}}} \left(e^{V_{ln}}, \ldots, e^{V_{J_n n}}\right)$ (2.13)

Multinomial Logit model

The Multinomial Logit Model is an instance of the GEV family, with

$$G(x) = \sum_{i=1}^{J_n} x_i^{\mu} \tag{2.14}$$

Yielding to the following probability model:

$$P(i|C_n) = \frac{e^{V_i}}{\sum_{j\in C_n}(e^{V_i})} \tag{2.15}$$

An important property of the Multinomial Logit Model is Independence from Irrelevant Alternatives (IIA). This property can be stated as follows: *The ratio of the probabilities of any two alternatives is independent of the choice set.* That is, for any choice sets C_1 and *C2* such that $C_1 \subseteq C_n$ and $C_2 \subseteq C_n$ and for any alternatives *i* and *j* in both C_1 and *C2,* we have

$$\frac{P(i|C_1)}{P(j|C_1)} = \frac{P(i|C_2)}{P(j|C_2)} \tag{2.16}$$

An equivalent definition of the IIA property is: The ratio of the choice probabilities of any two alternatives is unaffected by the systematic utilities of any other alternatives.

The IIA property of Multinomial Logit Models is a limitation for some practical applications. This limitation is often illustrated by the red bus/blue bus paradox in the modal choice context.

Nested Logit model

The Nested Logit Model, first proposed by Ben-Akiva (1973 and 1974) and derived as a random utility model and a special case of GEV by McFadden (1978), is an extension of the Multinomial Logit Model designed to capture some correlations among alternatives. It is based on the partitioning of the choice set C_n into M nests C_{mn} such that

$$C_n = \bigcup_{m=1}^{M} C_{mn} \tag{2.17}$$

And $C_{mn} \cap C_{m'n} = \emptyset \; \forall \; m \neq m'$. It is also an instance of the GEV family, with

$$G(x) = \sum_{m=1}^{M} \left(\sum_{i \in C_{mn}} x_i^{\mu_m}\right)^{\frac{\mu}{\mu_m}} \tag{2.18}$$

Where $\mu > 0$, $\mu m > 0$ and $\mu \leq \mu m$. Each nest within the choice set is associated with a composite utility

$$V_{C_{mn}} = \widetilde{V_{C_{mn}}} + \frac{1}{\mu_m} \ln \sum_{j \epsilon C_{mn}} e^{\mu_m \widetilde{V_{jn}}} \tag{2.19}$$

Where $\widetilde{V}$ denotes the partial utility common to all alternatives in the nest. The second term is called expected maximum utility, LOGSUM, inclusive value or accessibility in the literature. The probability for individual n to choose alternative i within nest C_{mn} is given by

$$P(i|C_n) = P((C_{mn}|C_n)P(i|C_{mn}) \tag{2.20}$$

Where,

$$P(C_{mn}|C_n) = \frac{e^{\mu V_{C_{mn}}}}{\sum_{l=1}^{M} e^{\mu V_{C_{ln}}}} \tag{2.21}$$

And

$$P(i|C_{mn}) = \frac{e^{\mu_m \widetilde{V_{in}}}}{\sum_{j \epsilon C_{mn}} e^{\mu_m \widetilde{V_{jn}}}} \tag{2.22}$$

Parameters μ and μ_m reflect the correlation among alternatives within the nest C_{mn}. The correlation between the utility of two alternatives *i* and *j* in nest C_{mn} can be derived

$$Corr(U_{in}, U_{jn}) = \begin{cases} 1 - \frac{\mu^2}{\mu_m^2} \text{ if } i \text{ and } j \epsilon C_{mn}. \\ 0 \; otherwise \end{cases} \quad (2.23)$$

Therefore,

$$\frac{\mu}{\mu_m} = 1 \Leftrightarrow Corr(U_{in}, U_{jn}) = 0 \quad (2.24)$$

The parameters μ and μ_m are closely related in the model. Actually, only their ratio is meaningful. It is not possible to identify them separately. A common practice is to arbitrarily constrain one of them to a specific value (usually 1). If $\mu = \mu_m$, the Nested Logit Model collapses to a Multinomial Logit Model.

A direct extension of the Nested Logit Model consists in partitioning some or all nests into sub-nests, which can in turn, be divided into sub-nests. The model described above is valid at every layer of the nesting, and the whole model is generated recursively. Therefore, a tree structure is a convenient representation of Nested Logit models. Clearly, the number of potential structures reflecting the correlation among alternatives can be very large. No technique has been proposed thus far to identify the most appropriate correlation structure directly from the data.

The Nested Logit Model is designed to capture choice problems where alternatives within each nest are correlated. No correlation across nests can be captured by the Nested Logit Model. When alternatives cannot be partitioned into well separated nests to reflect their correlation, the Nested Logit Model is not appropriate.

2.4.3 Model estimation

Maximum likelihood estimation is the most widely used technique for discrete choice model estimation (Sprott, 2000 and Severini, 2000). It aims at identifying the set of parameters maximizing the probability that a given model perfectly reproduces the observations. It is a nonlinear programming problem. The nature of the objective function and of the constraints determines the type of solution algorithm that must be used.

The objective function of the maximum likelihood estimation problem for GEV models is a nonlinear analytical function, as the probability density function has a closed form. In general, the function is not concave (except for the Multinomial Logit Model) and, therefore, significantly complicates the identification of a (global) maximum. Most nonlinear programming algorithms (Dennis and Schabel, 1983 and Bertsekas, 1995) are designed to identify local optima of the objective function.

There exists some meta-heuristics designed to identify global optima (like genetic algorithms, and simulated annealing) but none of them can guarantee that the provided solution is a global optimum. Therefore, whatever algorithm is preferred; starting it from different initial solutions is a good practice.

For the Probit or Hybrid-logit models, the objective function does not have an analytical form and must be evaluated based on Monte Carlo or Quasi-Monte Carlo methods (Morokoff and Caflish, 1995). Contrarily to MonteCarlo, Quasi-Monte Carlo techniques are deterministic. They require fewer “draws” than Monte-Carlo simulation to reach the same level of accuracy (Spanier and Maize, 1994).

Not all parameters of a model can be identified from the data. Parameter identification and model normalization issues are important to analyze before performing an actual estimation.

The parameters to be estimated must verify some constraints. First, most of them must lie within bounds in order for the model to be consistent with the theory (e.g. the homogeneous parameters of GEV functions must be non-negative) or with their

intuitive interpretation (e.g. the coefficient for house rent or travel time in a utility function is usually non-positive). Moreover, some constraints have to be verified in order for the model to be estimable (e.g. the sum of α parameters must sum up to one in a Cross-Nested Logit model). In the past, it was usually advised to ignore the bound constraints, to eliminate other constraints by incorporating them in the objective function, and to use unconstrained optimization algorithms. The increasing complexity of the models, combined with the availability of efficient software packages for constrained optimization motivates now the explicit management of constraints in the estimation process.

2.5 Summary

In this chapter, state-of-the-art residential location choice models are reviewed first followed by the literature review of residential location choice modeling in the context of Bangladesh. Review reveals that there have been few research works that focused on the residential location choice. All of these models have used RP data only and there is no evidence of using SP technique. Different survey methods are also elaborated in this chapter with special focus on SP survey design technique. Choice Exercise has been found to be the most relevant for conducting SP survey in this research work. Finally, the techniques of discrete choice modeling are presented.

On the basis of the literature review, the SP survey is designed and discrete choice models are developed in the subsequent chapters.

CHAPTER THREE

SURVEY DESIGN AND DATA COLLECTION

3.1 Overview

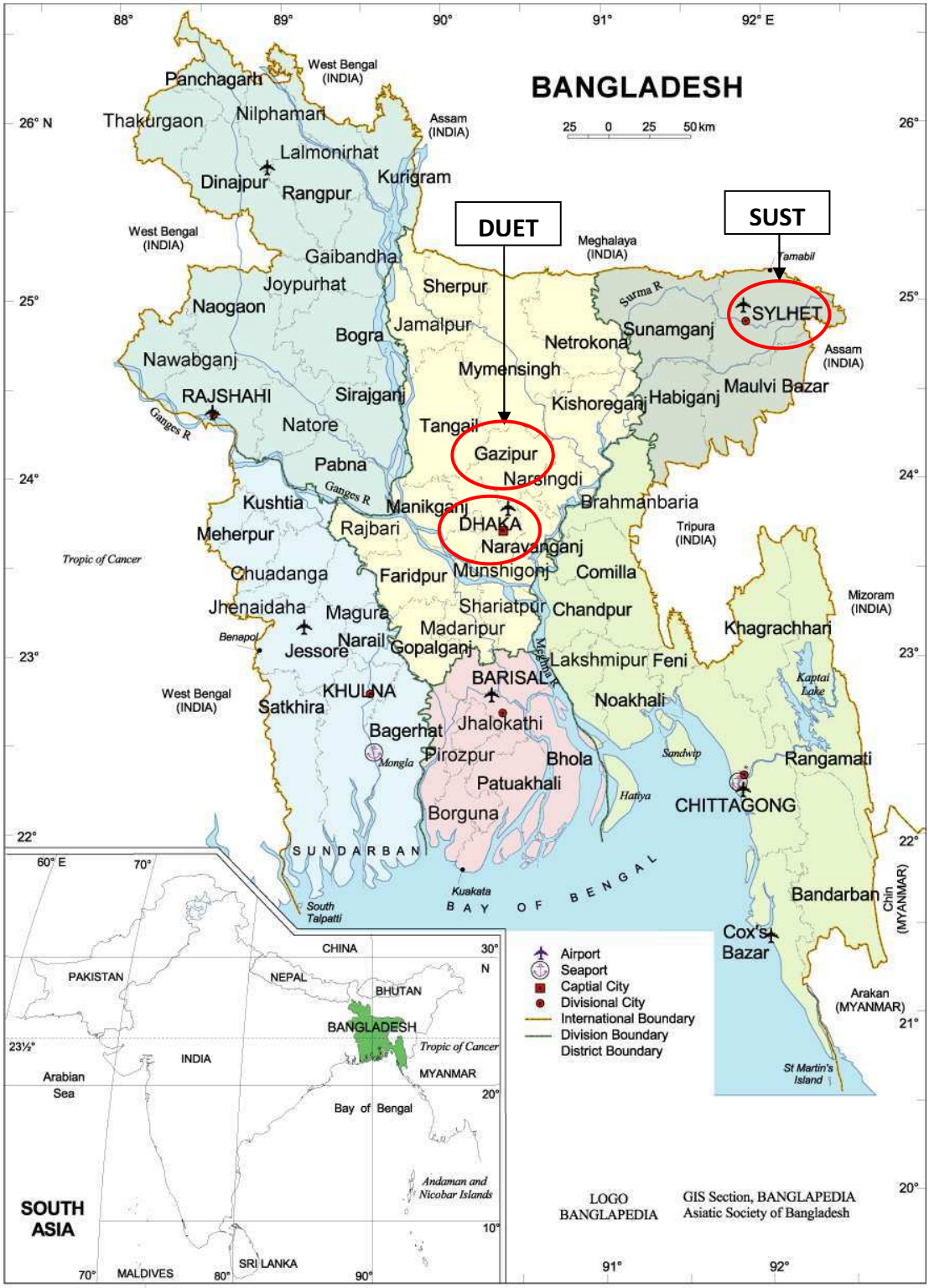
In this chapter, the survey design procedure is described and the data used for the research work is analyzed. The data set includes Revealed Preference (RP) and Stated Preference (SP) survey responses from faculty members of two public universities of Bangladesh. RP includes the current residential location choice, travel pattern and socio-economic status of the respondents. The SP survey is designed to present some hypothetical future scenarios of on-campus housing provision. These SP scenarios involve some improved facilities (attributes) with multiple levels for on-campus housing facility. In each case they are asked to choose the most preferred residential location. The survey design for the research work is conducted using the Choice Experiment (CE) Technique. The following sections of this chapter will focus on initial survey, SP survey design, main survey and data analysis.

3.2 Initial Survey

At first a focus group survey is conducted in order to identify the most influential variables affecting the choice of residential location. The survey is conducted by personal interview with the respondents. The respondents are asked questions about their current residential location and the reasons behind choosing that location. Questions about their current travel pattern and socio-economic status (e.g. age, household income, total family member, marital status, number of children etc.) are also asked. The preliminary questionnaires are presented in Appendix A.

The focus group consists of the faculty members of two public universities of Bangladesh. These are: Dhaka University of Engineering and Technology (DUET),

Gazipur and Shahjalal University of Science and Technology (SUST), Sylhet. Figure 3.1 shows the location of the cities where these universities are situated.



Map source: bangalnama.wordpress.com

Figure 3.1: Location of DUET and SUST

The findings of initial survey are presented separately for DUET and SUST.

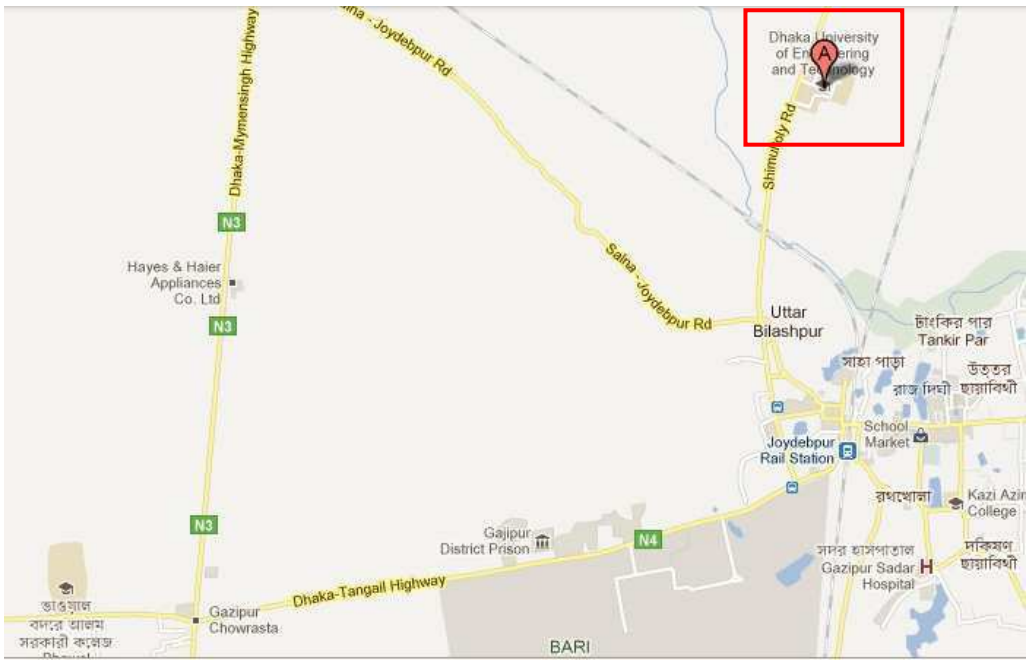
DUET:

DUET is situated at about forty kilometers north from Dhaka in Vaoal Gar under Gazipur district. The location of DUET is shown in Figure 3.2. The infrastructure of this institution was first developed as a Polytechnic Institute under the jurisdiction of Bangladesh Technical Education Board in 1979 and it was developed as an Engineering University named as Dhaka University of Engineering and Technology, Gazipur in September 1st, 2003. It is the smallest university with an area of only 20 acres among the four former BITs (CUET, KUET, RUET and DUET). At present there are 3 faculties with 9 departments having a total of 135 faculty members among which 40 are on study leave. Total officers and staffs working in different sections are 64 and 187 respectively. About 2200 students are enrolled at present.

Among the present (actively teaching) 95 faculty members 81 are male and 14 are female. About 30 percent of the teachers are unmarried.

Survey reveals that many faculty members live in Dhaka and commute daily to Gazipur, and some faculty members live outside of campus either near to DUET or in Gazipur. Rest of the faculty members live either away from the other family members (split family) or with family in campus. The faculty members who use off-campus family housing (Dhaka or, other cities) live there with their family. Therefore, according to the residential location (on-campus or, off-campus) and housing status (family or, split), the faculty members can be grouped into four classes:

- ❒ Commute from Dhaka
- ❒ On-campus family housing
- ❒ On-campus split housing
- ❒ Off-campus family housing (other than Dhaka)



Map Source: http://maps.google.com

Figure 3.2: Location of DUET

The initial survey was conducted by personal interview survey with 20 faculty members of DUET. The survey was conducted with 5 persons from each of the four groups of faculty members of different residential location and housing status as stated above so that all the possible reasons for choosing the current residential location could be identified. This ensures the choice of justified attributes and respective levels in the main survey and makes the survey design appropriate.

Most of the faculty members who currently commute from Dhaka live there mainly for education of children. About half of the faculty members defined higher standard of living (i.e. better shopping, medical facilities etc.) as a major cause and many addressed their spouse's job as an important reason. Around one third faculty members consider their professional work in Dhaka as one of the reasons for living there.

Low standard of the buildings of campus pushes some faculty members to choose residence outside of campus and some live at distant from campus in Gazipur where comparatively better schools for their children are present. Currently first class officers to fourth class employees as well as students live within the same boundary; a few faculty members expressed this mix residence pattern of DUET campus to be objectionable. They think that campus environment is not satisfactory to reside. Unavailability of on-campus facility is also a cause of living off-campus. This is to be mentioned that at present DUET lacks sufficient residence facilities to accommodate all of the teachers, employees and students. At present there are 5 residential buildings for teachers and officers among which one is for Vice Chancellor and the rest 4 buildings (with 32 flats) are shared by the teachers and the first class officers as well. There is a dormitory building with 75 rooms primarily constructed for bachelors which is now used by bachelors as well as married teachers and first class employees with small family.

A few percentage have own residence. Besides, extended family (e.g. parents, siblings) living in family-owned residences are also reasons for choosing off-campus housing in both of the cases stated above.

Almost all faculty members of on-campus family housing status live there because of office being at walking distance, and convenience to fulfill university responsibilities. Most faculty members consider security, and better power and water supply etc. as important factors in the preference of living on-campus. Almost all on-campus split faculty members are unmarried and their extended families live at different districts and this is the most preferred location for them. Few of the faculty members mentioned that they have no alternate options for which they live on-campus.

In case of mode choice, most of the faculty members living off-campus use DUET bus to go to university. Public bus is the second preferred mode. Few use private transport facilities (e.g. car). Some faculty members living near campus either walk or use rickshaw, tempo etc. to go to university. Faculty members living on-campus go to university by walking.

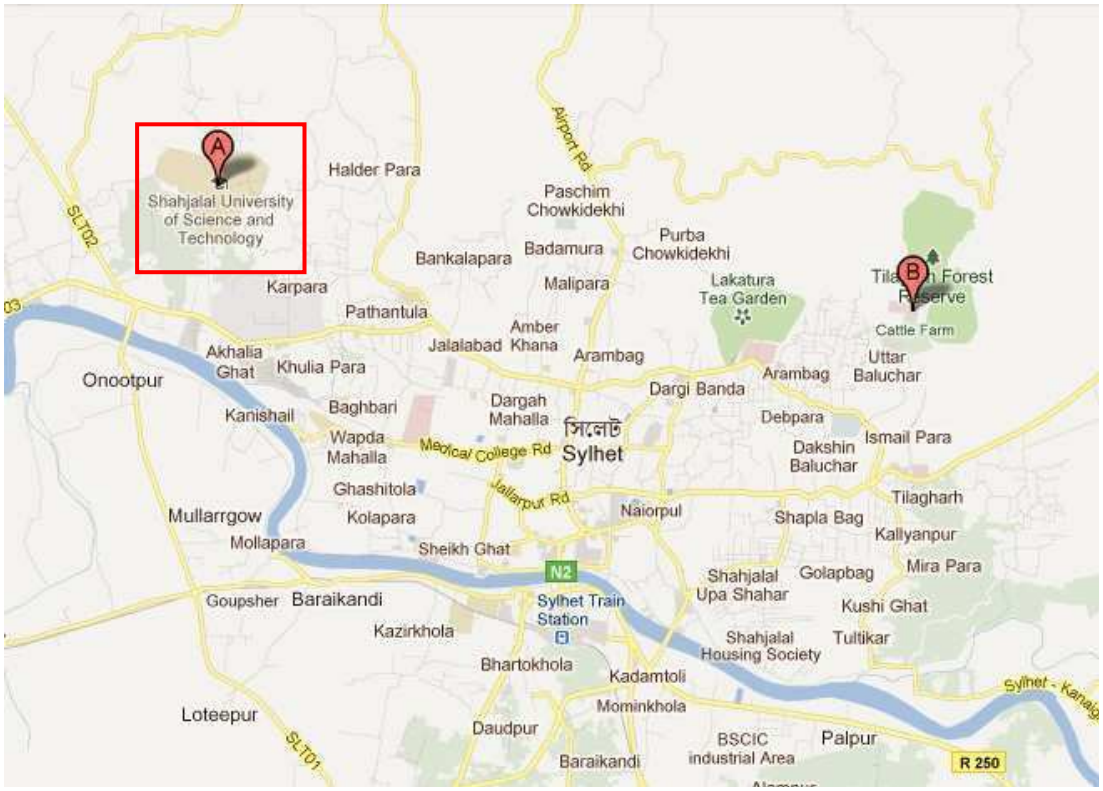
Table 3.1 shows a summary of the major causes leading the choice of present residential location of the faculty members of DUET.

Table 3.1: Reasons for choosing present residential location (DUET)

Faculty members living at DUET	Faculty members living off-campus in Gazipur	Faculty members living in Dhaka/ Other cities
a)Office is at walking distance b)Convenient to fulfill university responsibilities c)Security d)Good utility services such as electricity, water supply etc. e)Low house rent f)Unavailability of alternate residence.	a)Extended family lives here (e.g. parents, siblings etc.) b)For spouse's job c)Own residence d)For education of children e)Unavailability of on-campus living facility f)Mixed residence complex for all employees g)Low standard of the buildings of campus residence.	a)Extended family lives here (e.g. parents, siblings etc.) b)For spouse's job c)Own residence d)For education of children e)For professional work f)For better shopping, medical & other facilities g)Availability of good transport connection to office.

SUST:

Shahjalal University of Science and Technology (SUST) was established on 25th august, 1986 at Kumar Gaon, Sylhet. The location of SUST is shown in Figure 3.3. It has an area of 320 acre. At present there are 25 departments continuing their academic activities under 7 academic schools. Among 424 faculty members 282 are actively teaching, rest of them are on leave. Total officers and staffs working at different sections of SUST are 140 and 352 respectively. About 10,000 students are currently enrolled in the academic programs.



Map Source: http://maps.google.com

Figure 3.3: Location of SUST

The faculty members can be grouped into four classes according to the residential location (on-campus or, off-campus) and housing status (family or, split) of them which are as follows:

- ❒ On-campus family housing
- ❒ On-campus split housing

- Off-campus family housing
- Off-campus split housing

The initial survey was conducted by personal interview survey with 25 faculty members of SUST. At least 5 faculty members from each of the four residential groups and at least one from each of the departments were interviewed in the initial survey to get unbiased information regarding their present residential location choice and travel behavior in order to identify the attributes which could play significant role in changing their present locational status. More number of interviews was taken from the faculty members who are maintaining off-campus split and off-campus family status to identify the potential variables that are leading their current choices.

About one third of the total faculty members are unmarried, and most of them want to use on-campus housing facilities (Dormitory) for lower living cost. But they have to use off-campus housing facilities because of scarcity of such facilities. On the other hand, most of the married faculty members are using off-campus family housing, a few are maintaining split family (off-campus or on-campus) and the rest are using on-campus family housing facility.

Spouse's job is found to be one of the major reasons of living split for many married faculty members. Better school facilities in Dhaka and other cities necessitate family of some split faculty members living there. These faculty members have strong preference to lead family housing in Sylhet if respective facilities (e.g. spouse's job opportunity, standard school facilities etc.) are developed there. Few faculty members disagreed to shift their family from Dhaka to Sylhet being offered all the facilities in Sylhet as in Dhaka because of the strong inertia of living there.

Own residence facility is a reason for few faculty members living off-campus. Half of the faculty members using off-campus family housing do not choice on-campus housing facility because of the high rent comparative to rent of off-campus housing facility. They are most likely to choose on-campus housing facility if rent of university residence reduces 30% to 50% of the house rent provided by

government. Unavailability of on-campus facility impels about one fourth of the faculty members to live off-campus. They want to use on-campus housing facilities in existing terms and conditions but better facilities are expected. This is to be mentioned that at present there are only 16 flats for family housing and 24 rooms in the dormitory for split housing.

Many faculty members choose their residence facilities either close to spouse's job location or near schools of their children. They also intend to use on-campus family housing if their desired facilities exist very close to university. Few of them have dominant choice to live in city center because of own residence facilities or standard housing facilities with large floor space, smart decoration etc. which are normally absent in university housing facilities.

In case of mode choice, most of the faculty members living off-campus use university transport facilities. CNG or rickshaw is the next preferred mode. Few are using private transport facilities (e.g. car). Faculty members living on-campus come to the office on foot or by rickshaw sometimes.

Table 3.2 shows a summary of the main reasons leading the choice of present residential location of the faculty members of SUST.

Table 3.2: Reasons for choosing present residential location (SUST)

Faculty members living on-campus	Faculty members living off-campus
a) Office is at walking distance b) Convenient to fulfill university responsibilities c) Security d) Good utility services such as electricity, water supply etc. e)Low house rent f) Unavailability of alternate residence	a)Extended family lives here (e.g. parents, siblings etc.) b) For better shopping, medical & other facilities c) For spouse's job d) For education of children e) Low house rent f) Own residence g) Unavailability of on-campus living facility h) Low standard of the buildings of campus residence

3.3 SP Survey Design

There are several techniques of Stated Preference survey design among which the Choice Experiment (CE) has some advantages. In the CE approach, respondents make choices among hypothetical choice scenarios where multiple attributes can vary. Compared to other SP techniques, the trade-offs among various attributes of a product or service (e.g. improved school facilities, reduced house rent etc. in this context) can be captured relatively easily with the CE technique. Therefore, the survey design for the research work is conducted using the CE technique. The steps of survey design are described below.

3.3.1 Selecting attributes with focus group consultation

On the basis of the consultation with the faculty members of the universities, five attributes are selected to design the SP scenarios. Table 3.3 summarizes the attributes.

Table 3.3: Description of the SP attributes

School facilities	Improved school facilities with different mediums (e.g. Bengali, English version, English medium) are used in the SP scenarios.
Rent of university residence	Rent is found to be an important issue in case of SUST faculty members in not choosing on-campus housing facility. Different levels of reduced university rent are used in order to identify its impact on the utility of on-campus housing.
Spouse's job opportunity	Preference for spouse's job at or near the university.
Professional work scope	Scope of professional work (e.g. part time job, consultancy)
Additional Utility	Presence of some additional utility (e.g. branches of reputed private university, shopping mall) as better utility services near university location increases the attractiveness of university residence.

3.3.2 Defining attribute levels

The attribute levels are chosen as realistic as possible so that these are justifiable to the respondents to compare with the revealed condition. Table 3.4 and Table 3.5 describe the different levels of the attributes selected for SP design.

Table 3.4: Attributes and their levels for DUET

Attributes	**Levels**
School facilities	Same as now Branches of reputed Bengali Medium Schools (e.g. VNS, VNC, NDC, etc.) Branches of reputed English Medium Schools leading to SSC/HSC (e.g. St. Joseph, VNS, VNC) Branches of reputed English Medium Schools leading to GCSE (e.g. Scholastica)
Rent of university residence	Same as now 20% less than now 30% less than now 40% less than now
Spouse's job opportunity	Same as now Will get preferential appointment at DUET
Professional work scope	Same as now Same scope of consultancy, part-time job etc. in Gazipur as in Dhaka
Additional Utility	Same as now Branches of reputed private universities (e.g. NSU, AUST) Big shopping malls (e.g. branches of Bashundhara Mall, Agora, etc.) Excellent medical facilities (e.g. branches of Appolo, Square etc.)

Table 3.5: Attributes and their levels for SUST

Attributes	Levels
School facilities	Same as now Branches of reputed Bengali Medium Schools (e.g. VNS, VNC, NDC, etc.) Branches of reputed English Medium Schools leading to SSC/HSC (e.g. St. Joseph, VNS, VNC) Branches of reputed English Medium Schools leading to GCSE (e.g. Scholastica)
Rent of university residence	Same as now 20% less than now 30% less than now 40% less than now
Spouse's job opportunity	Same as now Will get preferential appointment at SUST
Professional work scope	Same as now Same scope of consultancy, part-time job etc. in Sylhet as in Dhaka
Additional Utility	Same as now Branches of reputed private universities (e.g. NSU, AUST) Big shopping malls (e.g. branches of Bashundhara Mall, Agora, etc.) Excellent medical facilities (e.g. branches of Appolo, Square etc.)

3.3.3 Creating SP scenarios

The profiles of the on-campus housing are generated with the statistical software SPSS (http://spss.en.softonic.com/) using fractional factorial design. From the generated profiles unrealistic ones are discarded and extreme/dominant combinations (where one option is better than the other option in terms of all attributes) are eliminated from the choice sets.

The respondents are presented with three SP scenarios (each showing different levels of the five attributes) and are asked which alternative (residential location) they will choose from the four alternatives (e.g. commute from Dhaka, on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka in case of DUET) in each of the three scenarios. Therefore, three SP observations are found from each respondent.

3.3.4 Survey format and description of preliminary questions

Questions on current status

This section includes the questions about socio-demographics and current residential location pattern of the respondents. In the first part of the section, questions on the socio-economic status of the respondents are asked. These questions include: designation, age, sex, marital status, number of family members, spouse's occupation, number of children and their current education level, monthly family income, and car ownership. The second part consists of questions about the current residential location of the respondents. In case of DUET faculty members, these are grouped into three categories according to their present location (living at DUET, living off-campus in Gazipur and living in Dhaka/ Other cities). In case of SUST, these categories are: living at SUST, living in Sylhet (off-campus) and family living in Dhaka/ Other cities (off-campus). Separate sets of multiple choices are given to them to identify the reasons of choosing their current location. The questions are selected on the basis of the initial survey with each group of respondents. The on-campus family and split housing are grouped as similar choices in this case because split family refer to unmarried faculty members living apart from their extended families (parents, siblings) and most of the reasons of choosing this location are same in these two groups.

The third part includes questions about the current travel pattern of the faculty members. The fourth part queries about the spouse's job location and travel pattern. The last part questions about the travel pattern of children. The full questionnaires of DUET and SUST are presented in Appendix B.

SP scenario

In this section, the respondents are presented with three hypothetical scenarios in each of which they must make a choice among the four location alternatives; an example of such a scenario is provided in Table 3.6.

Table 3.6: Example of an SP choice scenario
Scenario 1

Attributes	**Future scenarios at or near DUET**	**Dhaka/other cities**
Children's school & college facilities	Same as now	Same as now
Rent of university residence	Same as now	
Spouse's job opportunity	Will get preferential appointment at DUET	
Professional work scope	Same scope of consultancy, part-time job etc. in Gazipur as in Dhaka	
Additional utility services	Branches of reputed private universities (e.g. NSU, AUST)	

What type of residential option will you choose in Scenario 1?

a. Commute from Dhaka	b. On-campus family housing
c. On-campus split housing	d. Off-campus family housing (other than Dhaka)

3.4 Main Survey

3.4.1 Data collection

Data were collected from the faculty members of Dhaka University of Engineering and Technology (DUET), Gazipur and Shahjalal University of Science and Technology (SUST), Sylhet. 82 responses were obtained from DUET among which 1 was discarded due to improper answering and 169 valid responses were obtained out of 172 from SUST. Almost all data were collected with the assistance of surveyors and

the responses without the surveyor's assistance were checked carefully and all invalid responses were discarded from the data set.

There are four observations per respondent: one RP and three SP observations. Therefore, there are a total of 324 responses with 81 RP and 243 SP (81 respondents, 3 observations each) responses from DUET. In case of SUST, there are a total of 704 responses with 169 RP and 507 SP (169 respondents, 3 observations each) responses.

The full inventory of data is separately presented in Table 3.7 and Table 3.8 for DUET and SUST respectively. The number of valid samples is included in parenthesis.

Table 3.7: Data inventory for DUET

Residential Location	**Numbers of data collected from DUET**
Commute from Dhaka	25 (24)
On-campus family housing	21(21)
On-campus split housing	24(24)
Off-campus family housing (other than Dhaka)	11(11)
Total	82(81)

Table 3.8: Data inventory for SUST

Residential Location	**Numbers of data collected from SUST**
On-campus family housing	13 (13)
On-campus split housing	17 (17)
Off-campus family housing	105 (103)
Off-campus split housing	37 (36)
Total	172 (169)

3.4.2 Data analysis

Socio-demographics

Some important observations on the respondents from data analysis are as follows:

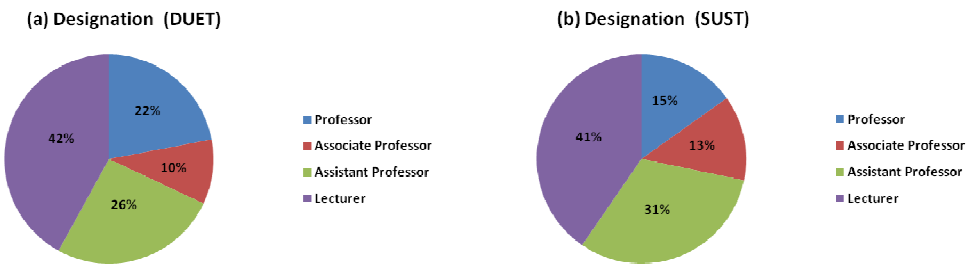
DUET:

- ❒ 42 percent respondents are Lecturers
- ❒ 45 percent are of age ranged between 25-30 years
- ❒ 14 percent respondents are female
- ❒ 73 percent faculty members are married
- ❒ 31 percent spouses are employed
- ❒ 17 percent faculty members own car

SUST:

- ❒ 40 percent respondents are Lecturers
- ❒ 46 percent are of age ranged between 31-40 years
- ❒ 19 percent respondents are female
- ❒ 72 percent faculty members are married
- ❒ 40 percent spouses are employed
- ❒ 14 percent faculty members own car

Figure 3.4 illustrates the findings on socio-economic Attributes.



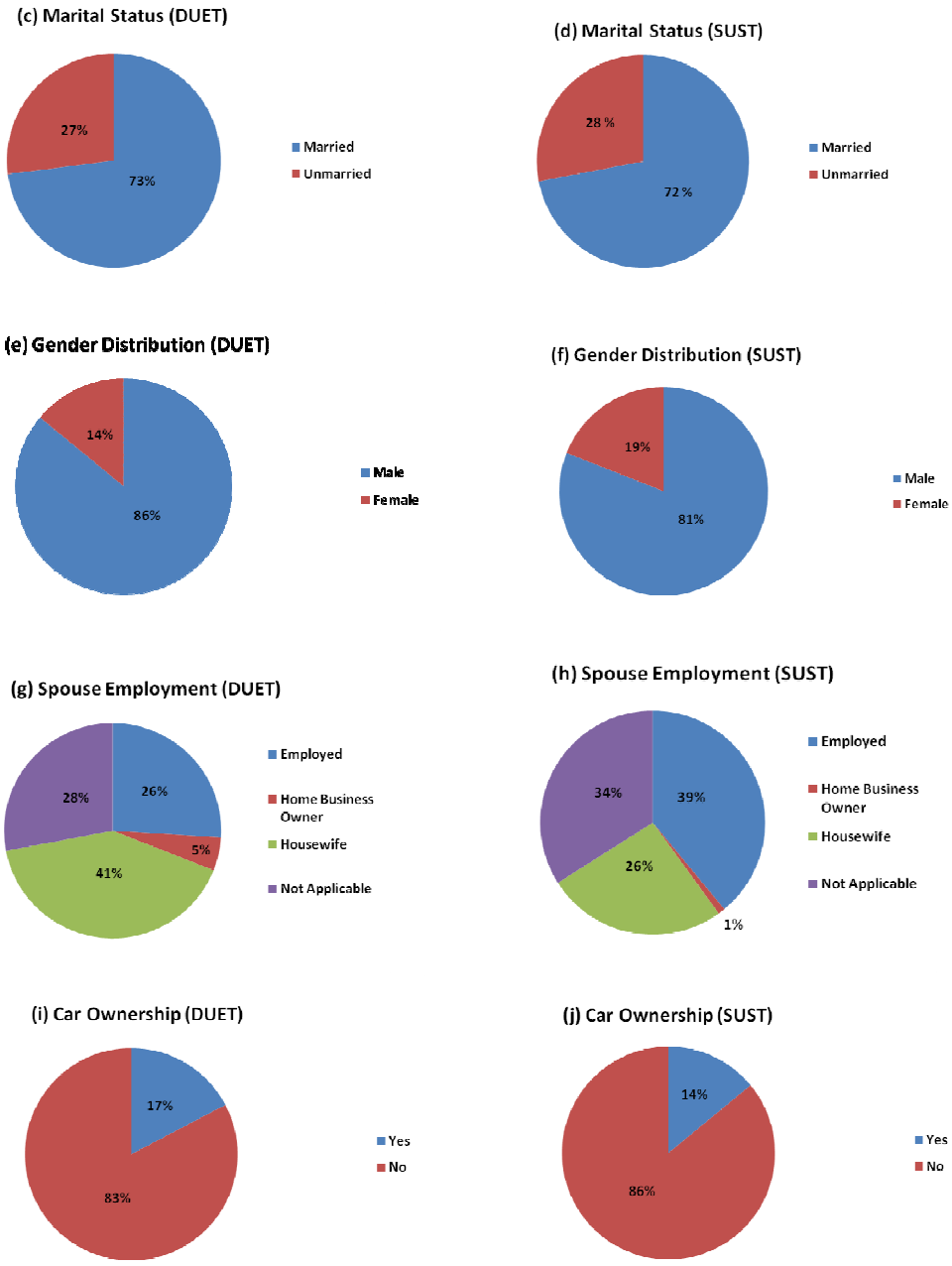


Figure 3.4: Findings on socio-economic attributes

Residential status

From the data analysis it is found that almost 50 percent of DUET respondents are at present using off-campus housing facility. Among the data set, the proportion of respondents commuting from Dhaka is the highest 31 percent, second is the on-campus split proportion with 30 percent for DUET. In case of SUST, off-campus family is the dominant housing choice with 60 percent faculty members using off-

campus housing facility among all. Off-campus housing proportion is high with a total of 82 percent among the respondents. Figure 3.5 illustrates the proportion of present residential location and status of the respondents.

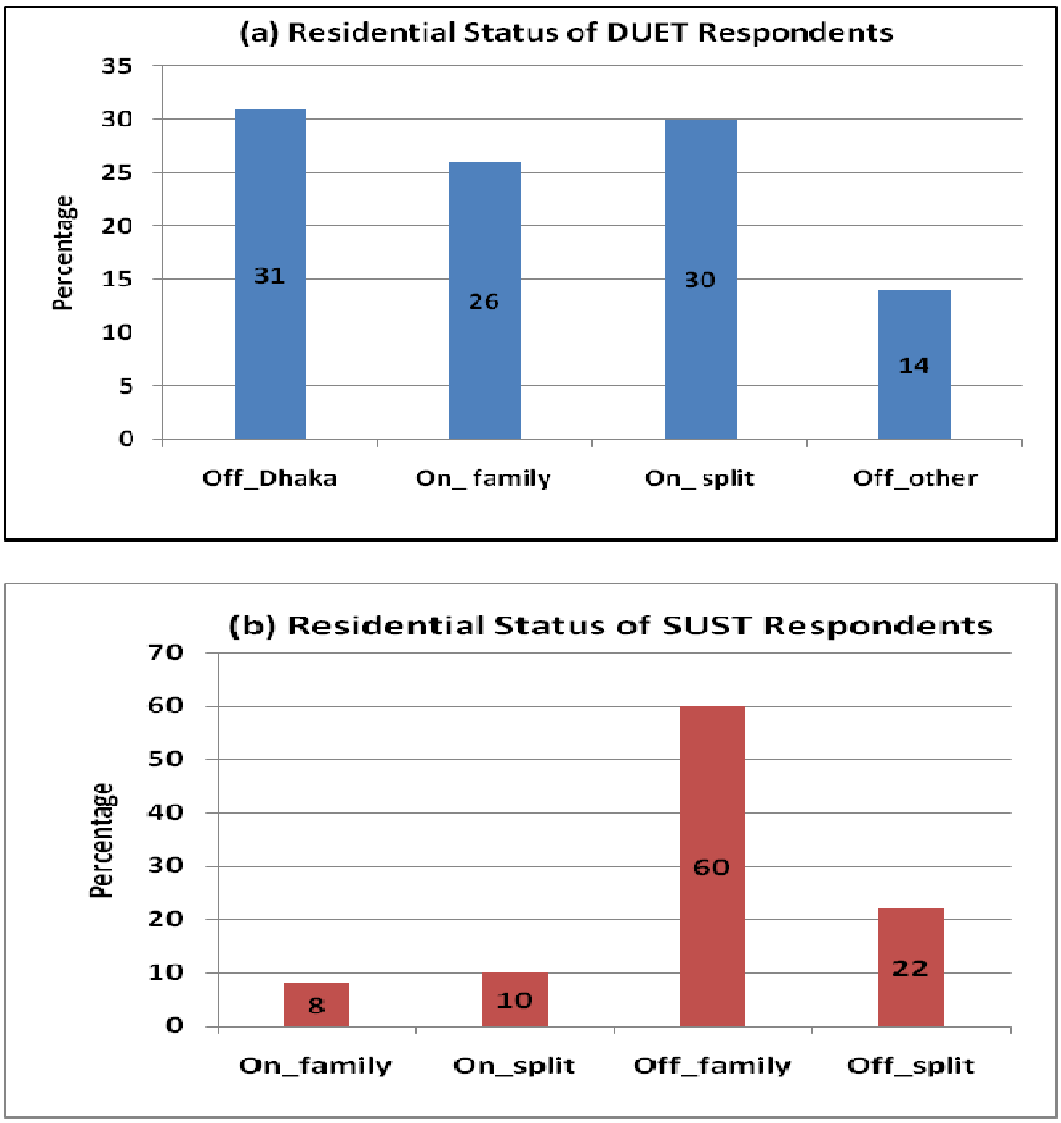


Figure 3.5: Present residential status of the respondents

In Figure 3.5 (a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka for DUET respectively. In Figure 3.5 (b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing for SUST respectively.

Calculation of Vehicle Miles Travelled (VMT)

Commute vehicle miles travelled (VMT) of off-campus faculty members of DUET and SUST are calculated and analyzed to quantify the impact of improved facilities of on-campus housing provision on these. The average speed of different modes for calculating VMT is taken from DHUTS, 2010 for DUET and from Haque, 2008 for SUST. The analyses are conducted using two-way daily commute VMT of 36 off-campus faculty members of DUET and 137 off-campus faculty members of SUST. Data analysis shows that in the presented SP scenarios, if the faculty members are provided with the facilities for which they are currently using off-campus facility, then 61 percent commute trips are likely to be reduced in case of DUET and 78 percent commute trips are likely to be reduced in case of SUST. The analysis also shows that 68 percent commute VMT are likely to be reduced with a reduction of two-way daily commute VMT of 690 for DUET and 78 percent commute VMT are likely to be reduced with a reduction of two-way daily commute VMT of 891 for SUST in the presented SP scenarios.

The analyses of VMT are illustrated in Figure 3.6 and Figure 3.7. In Figure 3.6 (a) and Figure 3.67 (a), RP represents the proportion of faculty members who are at present living off-campus and commute to university, and SP represents the proportion of faculty members who are likely to choose off-campus housing facility and commute to university after given the SP choice scenarios.

It is shown from Figure 3.6(a) and Figure 3.7(a) that, commute VMT per day is substantially reduced in case of the faculty members of both of the universities. Figure 3.6(a) shows that the proportion of faculty members of DUET whose commute VMT are currently 0.1-10 reduces to 14 percent (from 25 percent). This indicates that these 11 (subtraction of 14 from 25) percent faculty members are likely to choose on-campus housing facility after given the improved facilities of on-campus housing in the SP choice scenarios. Similarly, 31 percent faculty members whose commute VMT are currently 40.1-50 show significant reduction representing only 6 percent of them intended to use off-campus housing facility after given the

SP choice scenarios. Figure 3.7(a) shows that the proportion of SUST faculty members whose commute VMT are currently 0.1-10, reduces to only 15 percent which was at first 64 percent before given the improved scenarios of on-campus housing.

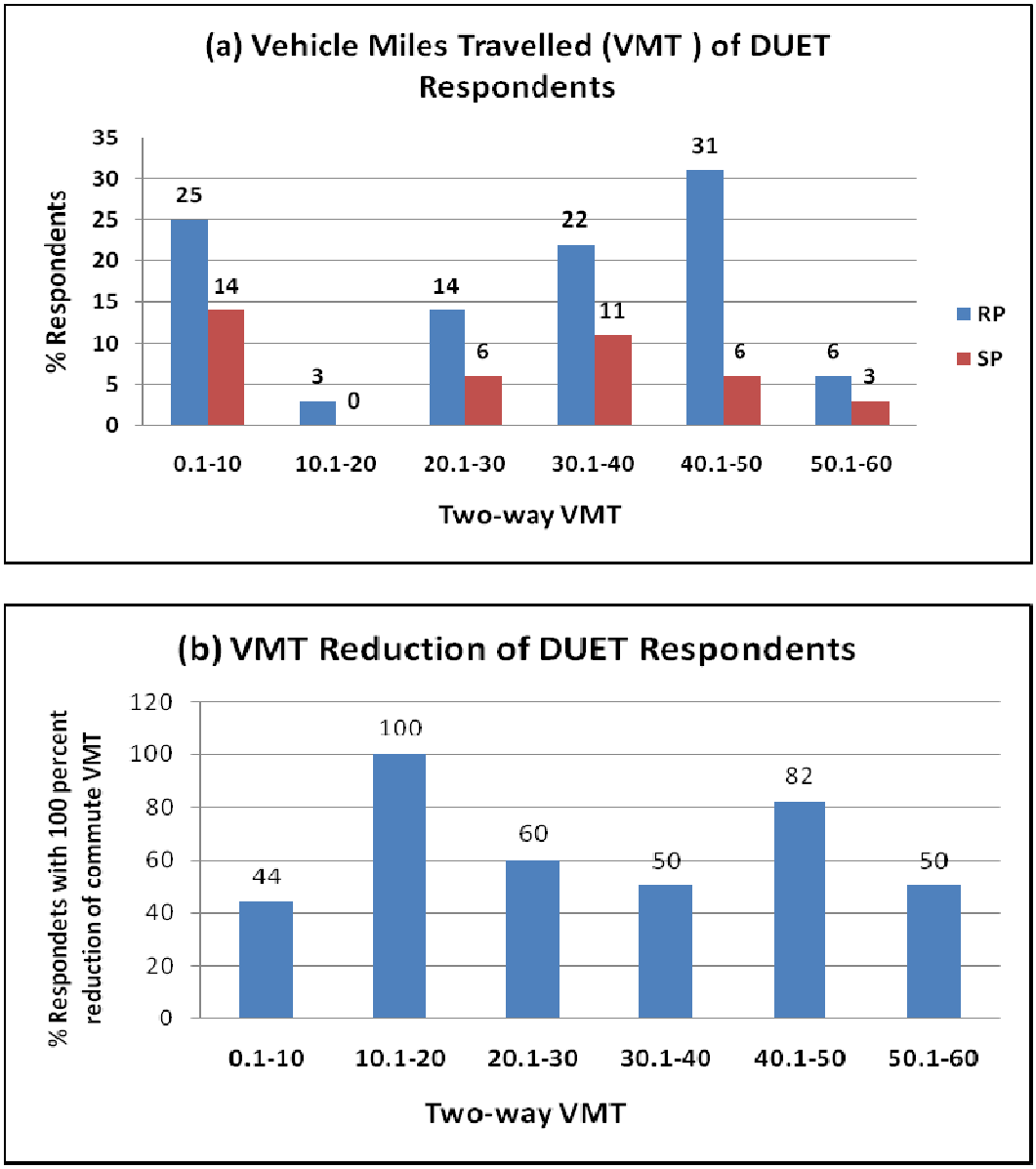


Figure 3.6: Effect on VMT of DUET respondents

Figure 3.6(b) shows that in case of DUET, 100 percent respondents whose commute VMT are 10.1-20 shows 100 percent reduction of commute VMT which indicates that all of the respondents whose commute VMT range is 10.1-20 are likely to choose on-campus housing provision. Similarly, 82 percent of the respondents

whose commute VMT range is 40.1-50 may choose on-campus housing given the improved facilities of on-campus housing. The minimum percent of respondents whose commute VMT range is 0.1-10 and have higher likelihood of choosing on-campus housing is 44.

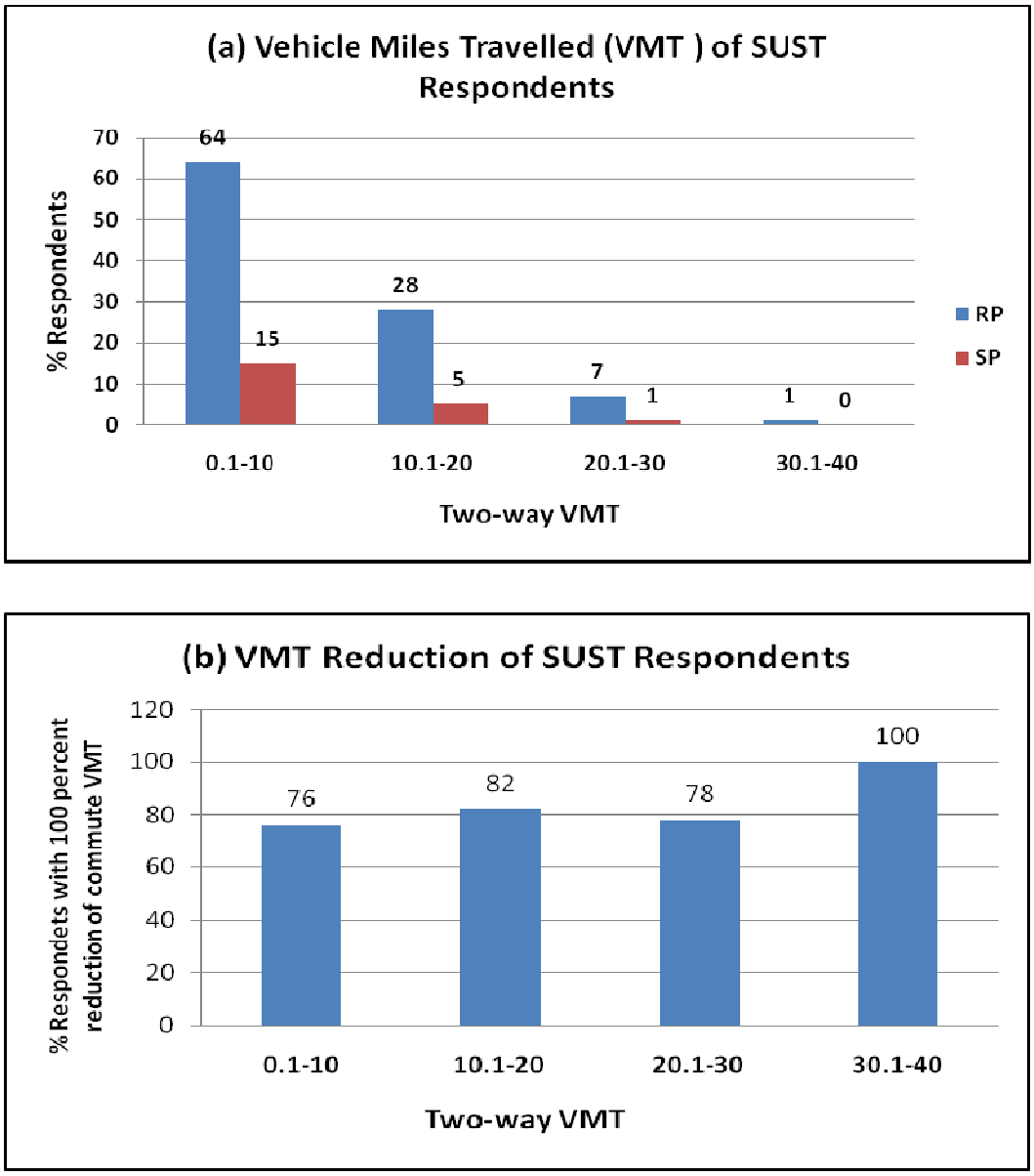


Figure 3.7: Effect on VMT of SUST respondents

In case of SUST, significant reductions of VMT are found also. Figure 3.7 (b) shows that all of the respondents whose commute VMT are 30.1-40 are likely to choose on-campus housing with 100 percent reduction of commute VMT. The 82, 78 and 76 percent respondents representing 100 percent reduction of commute VMT of

ranges 10.1-20, 20.1-30 and 0.1-10 respectively also indicate huge reductions of commute VMT of the faculty members who are currently living off-campus.

Effects of socio-economic factors

The effects of socio-economic variables on the choice of residential location are analyzed. Analysis is performed to find out the effect of designation on the choice of location which is shown in Figure 3.8.

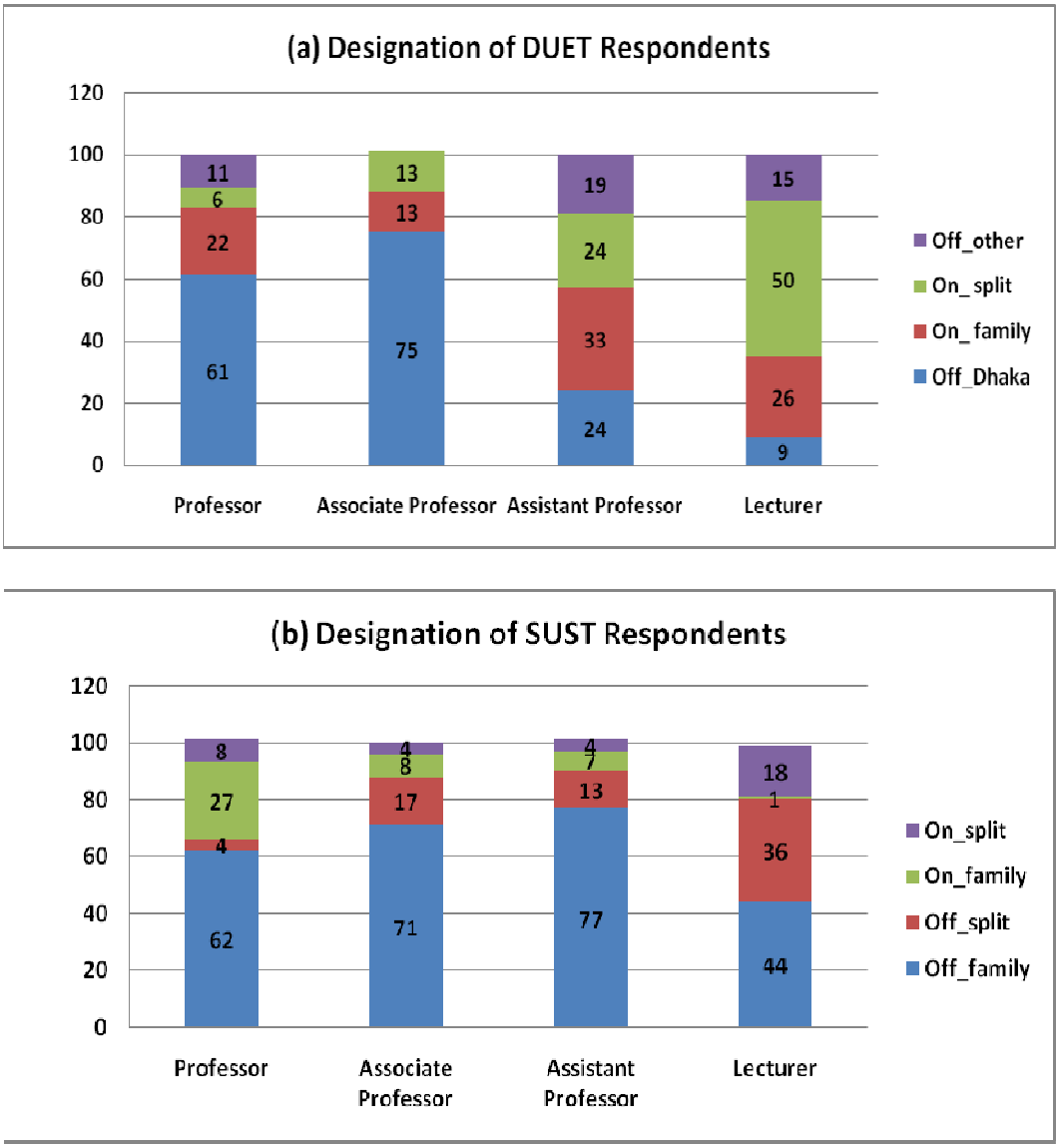


Figure 3.8: Proportion of respondents in different locations according to designation

In Figure 3.8(a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing

and off-campus family housing other than Dhaka respectively. In Figure 3.8(b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

Figure 3.8 shows that most of the Professors and Associate Professors live off-campus in both universities, and commute from Dhaka in case of DUET and lead off-campus family housing in case of SUST. Assistant Professors seem to be indifferent in choosing location in DUET whereas, different scenarios are found in case of SUST showing major proportion (77 percent) using off-campus family housing. Most of the unmarried Lecturers use on-campus split housing and married Lecturers prefer on-campus family housing at DUET. On the other hand, Lecturers of SUST use off-campus family housing (married faculty members), off-campus split housing (for unavailability of on-campus facility) as well as on-campus split housing.

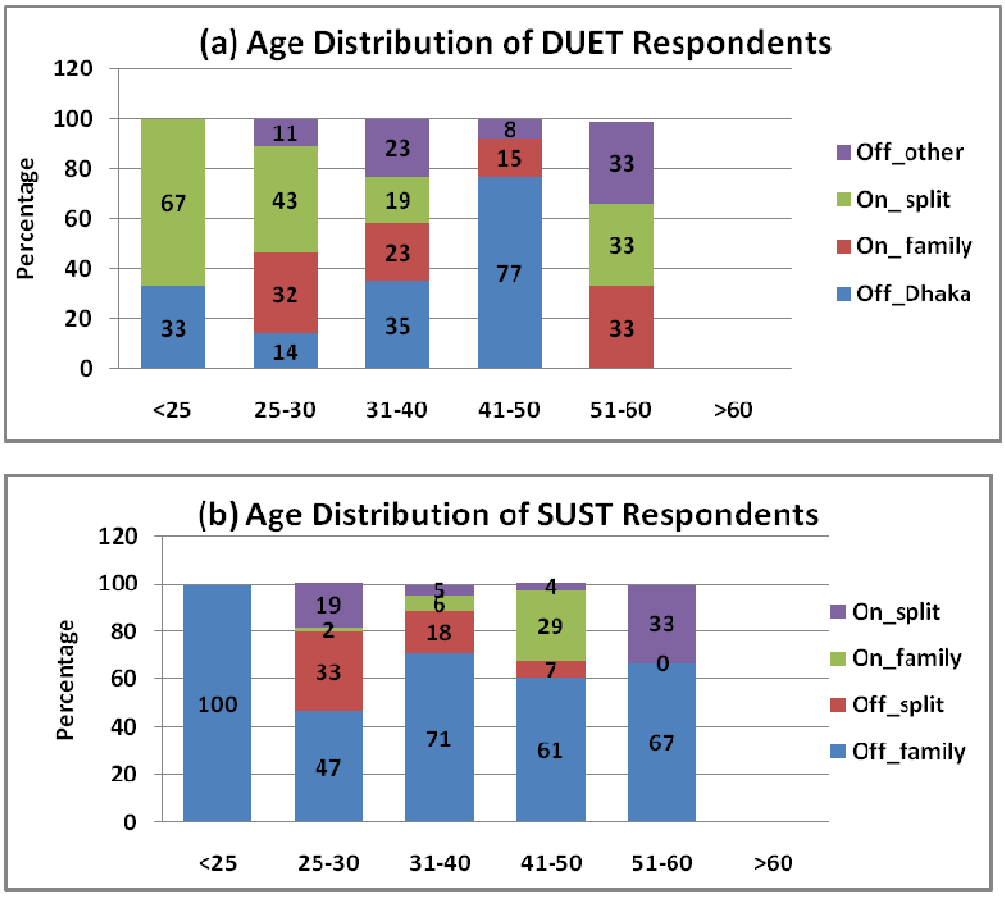


Figure 3.9: Age distribution of the respondents

Data analysis shows that age is correlated with designation (Figure 3.9). Faculty members of DUET of age range 41-50 years prefer to live in Dhaka where as faculty members of SUST of age greater than 31 years mostly choose off-campus family housing.

In Figure 3.9 (a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka respectively. In Figure 3.9 (b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

Income analysis shows that 48 percent of DUET respondents living in Dhaka have average monthly family income >Tk. 65000 whereas only 10 percent respondents with on-campus family status fall in this group as shown in Figure 3.10(a). Most of the respondents with average monthly family income up to Tk. 35000 live on-campus.

On the other hand, Figure 3.10 (b) shows that most of the off-campus split and on-campus split respondents of SUST fall in Tk. 25000 income group. It is shown that 76 percent of off-campus family status respondents have average monthly family income > Tk. 45000 which is 42 percent in case of on-campus family respondents.

In Figure 3.10 (a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka respectively.

In Figure 3.10(b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

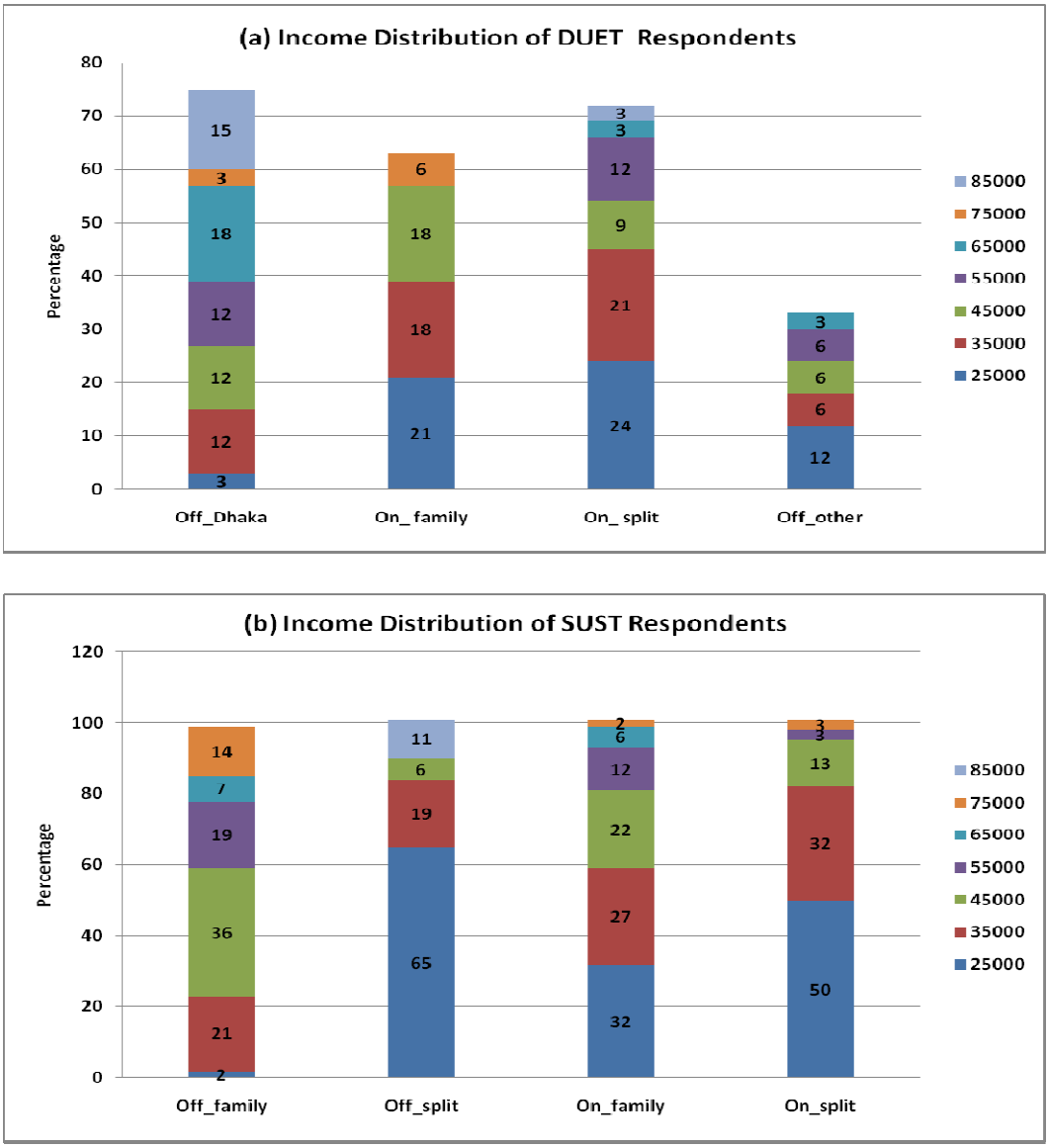


Figure 3.10: Income distribution of the respondents

Figure 3.11 (a) shows that majority of the DUET respondents are married and live either in Dhaka (off-campus family housing) or at DUET (on-campus family housing) as expected. In this figure, the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka respectively. Distinct scenarios are found at SUST in this case as in Figure 3.11 (b). 50 percent and 39 percent among the on-campus split housing and off-campus split housing respondents respectively are married. Survey reveals that these faculty members live split because, in most cases their family live in Dhaka for their children's better

education and spouse's job purpose. In Figure 3.11 (b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

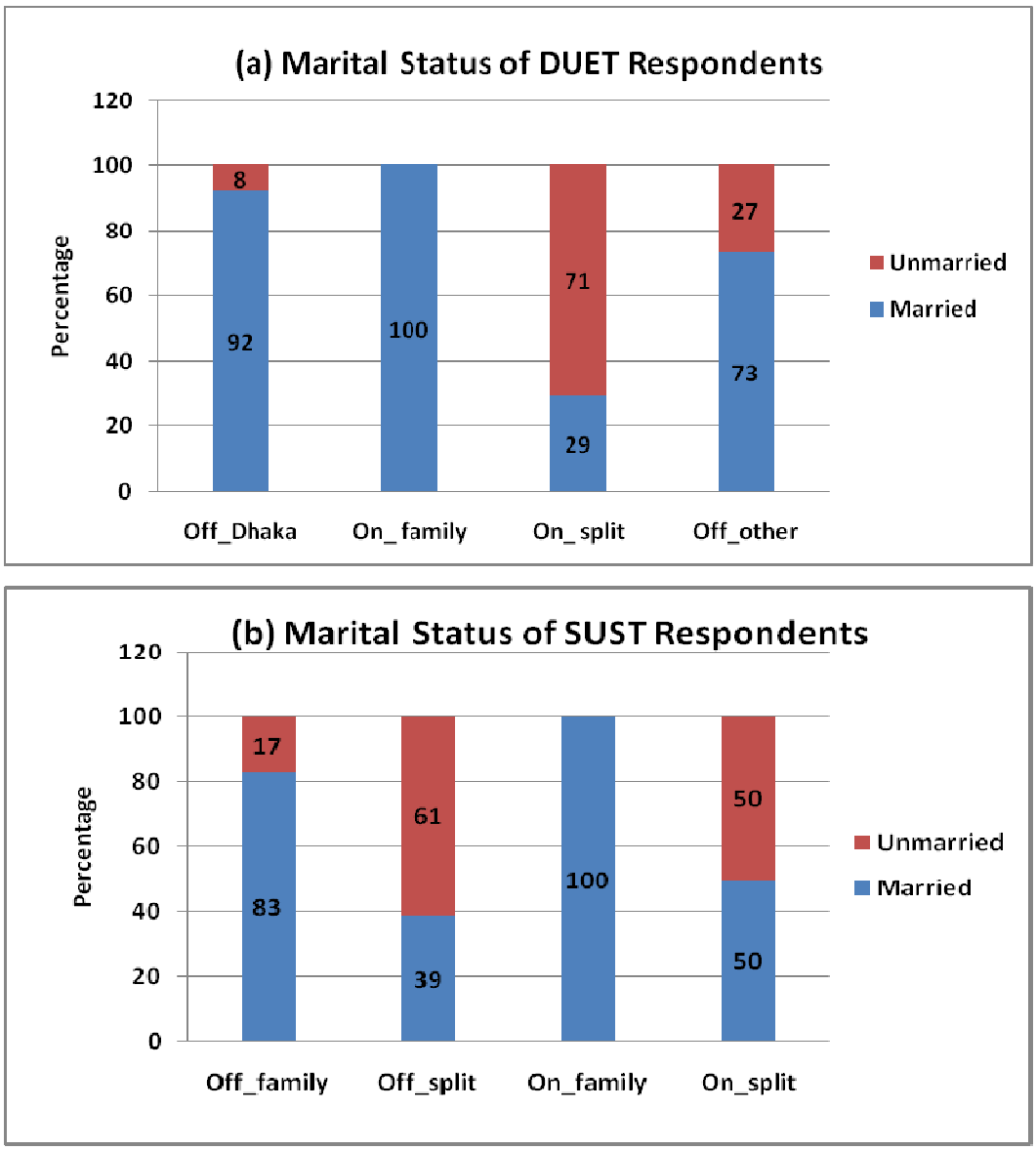
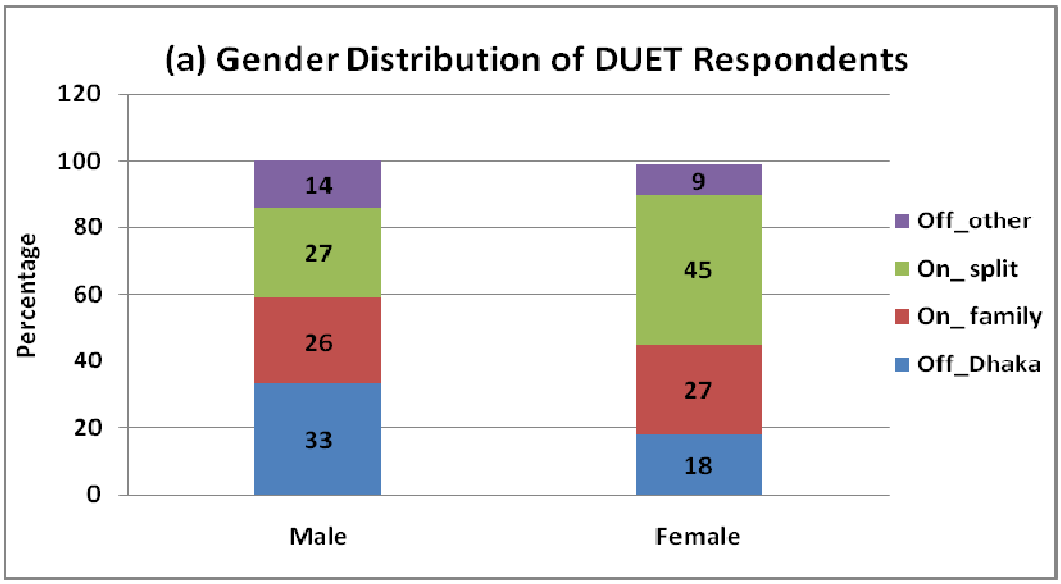


Figure 3.11: Marital status of the respondents

Female faculty members of DUET are more likely to choose on-campus housing facility with 45 percent of them living on-campus split and 27 percent of them using on-campus family housing as shown in Figure 3.12 (a). SUST female faculty members, on the other hand, use off-campus family housing mostly showing a higher percentage (71 percent) as in Figure 3.12 (b).



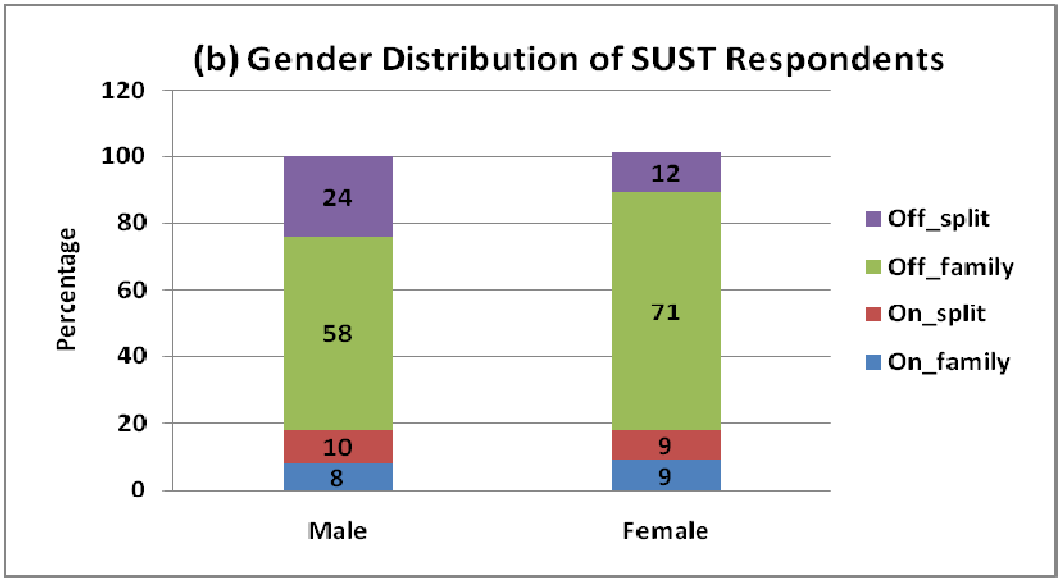


Figure 3.12: Gender distribution of the respondents

In Figure 3.12 (a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka respectively. In Figure 3.12 (b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

Among the respondents living in Dhaka a maximum of 44 percent spouses are involved in some occupation (either employed or home business owner) as shown in Figure 3.13 (a) for DUET. In case of SUST, among the respondents living off-campus, 44 percent spouses are either employed or home business owner whereas this proportion for faculty members living at SUST campus is 86 percent as shown in Figure 3.13 (b). Survey reveals that almost all the spouses of the faculty members living at SUST are employed at SUST also and for this reason they represent 50 percent employment status of spouse in this location.

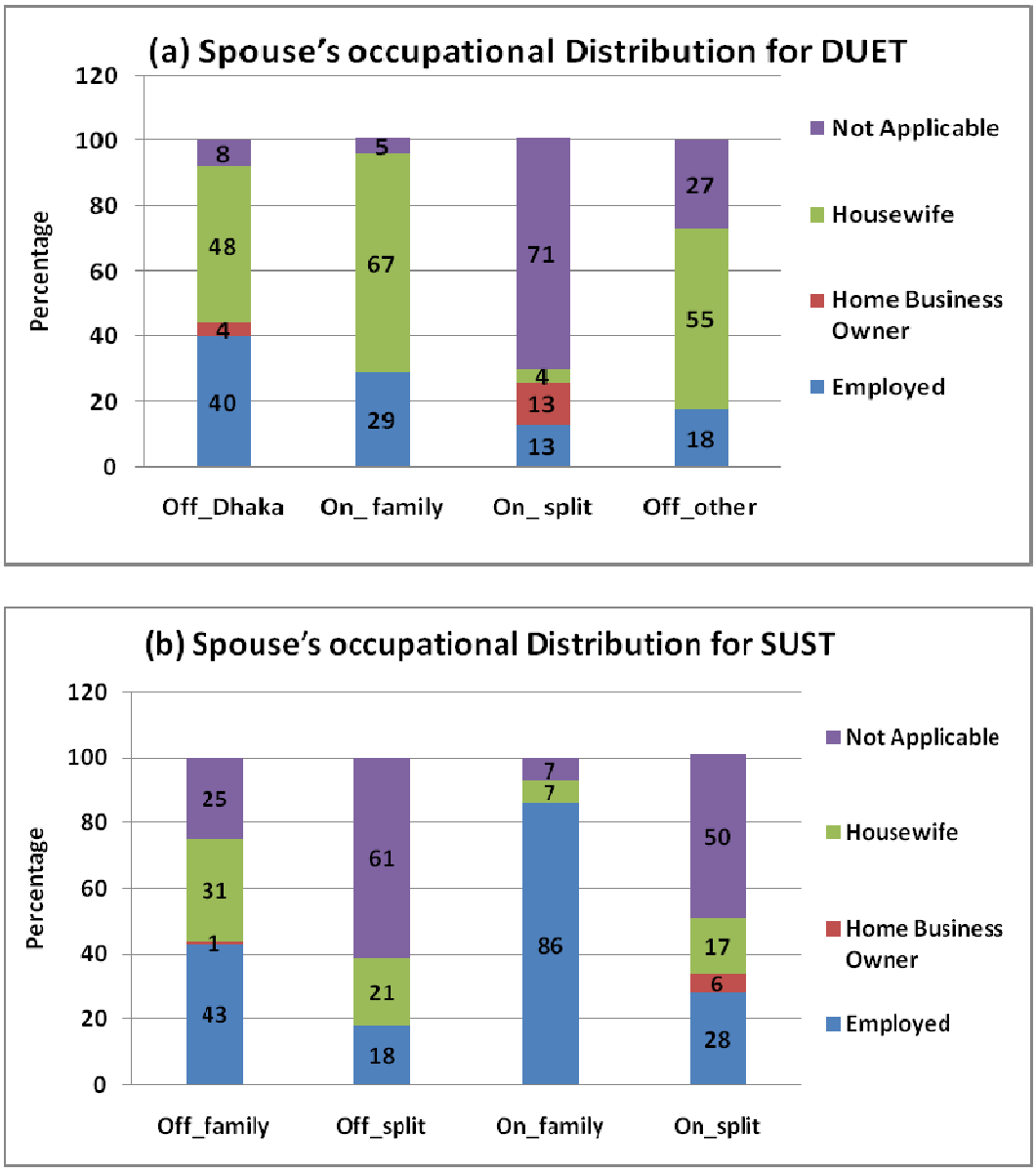


Figure 3.13: Spouse's occupational distribution

In the above figures, the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka for DUET respectively. In case of SUST, the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

79 percent of the DUET faculty members who own car live in Dhaka as shown in Figure 3.14 (a), whereas this percent is very low for other three locations. In case of SUST, Figure 3.14(b) shows that 63 percent faculty members who have car ownership use off-campus family housing.

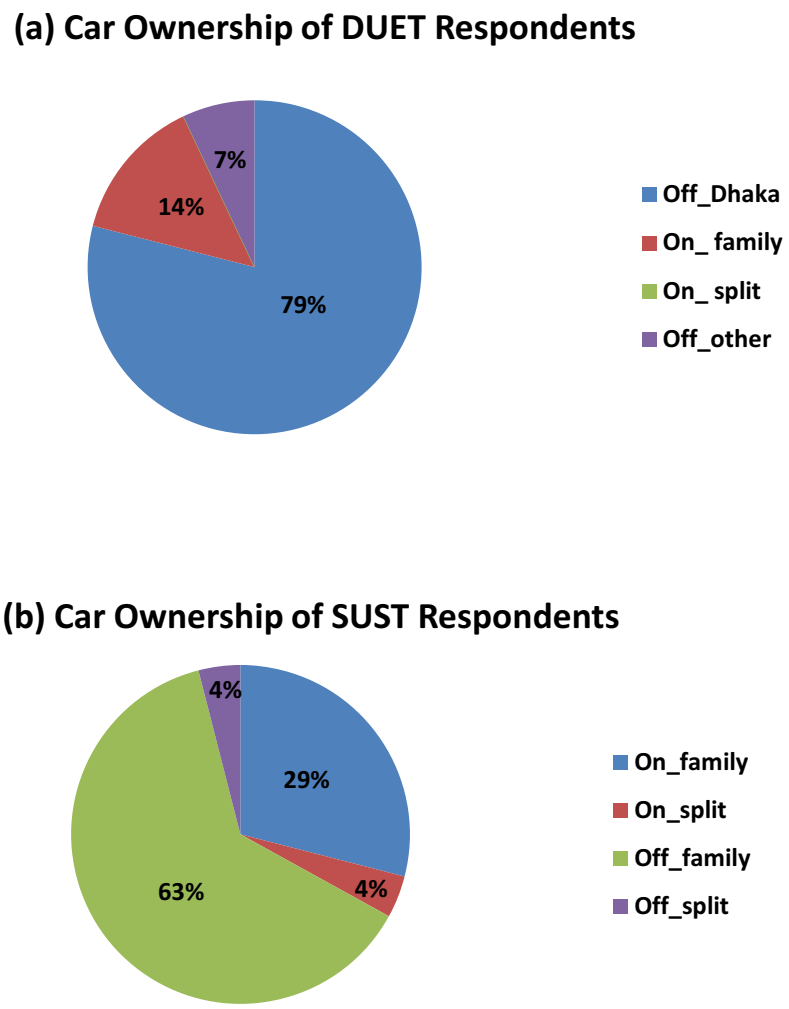
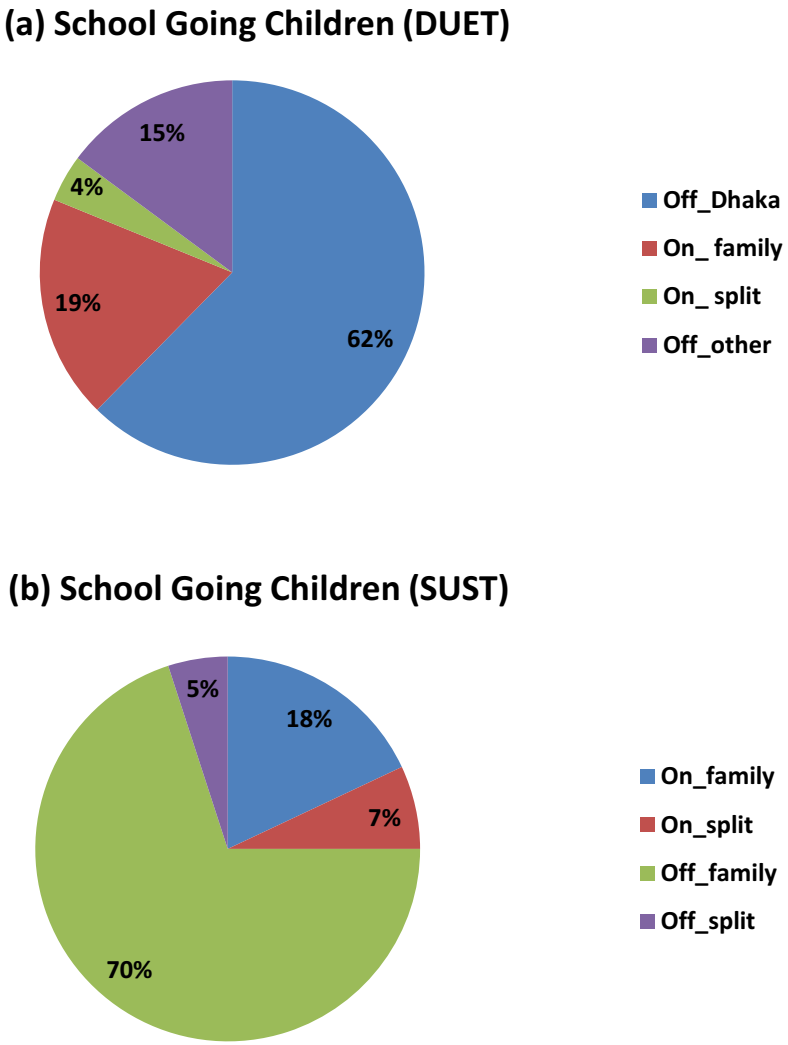


Figure 3.14: Car ownership

In Figure 3.14 (a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka respectively. In Figure 3.14 (b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

Number of school going children shows significant impact on the choice of residential location as shown in Figure 3.15.



(b)

Figure 3.15: Proportion of school going children

In Figure 3.15 (a), the Off-Dhaka, On-family, On-split and Off-other represent living off-campus in Dhaka; leading on-campus family housing, on-campus split housing and off-campus family housing other than Dhaka respectively. In Figure 3.15 (b), the On-family, On-split, Off-family and Off-split represent on-campus family housing, on-campus split housing, off-campus family housing and off-campus split housing respectively.

The figures show that 68 percent of the respondents among the proportion living in Dhaka have school going children which is only 24 percent in case of the proportion living at DUET campus. This percentage is also highest (76 percent) for the proportion living off-campus for the respondents of SUST. Again 33 percent of the off-campus split faculty members have school going children which indicates the reason of their living split from their family.

Reasons for choosing current residential location

The statistics of the potential reasons for which respondents are living in their current location is illustrated in Figure 3.16 to 3.19 in case of DUET and in Figure 3.20 to 3.23 in case of SUST. It may be noted that the respondents are given multiple options to mark as the reasons for choosing their current location.

As evident from Figure 3.16, faculty members who commute from Dhaka live there mainly for:

- ❒ Education of children
- ❒ Better shopping, medical & other facilities
- ❒ Spouse's job
- ❒ Professional work
- ❒ Extended family living there (e.g. parents, siblings etc.)

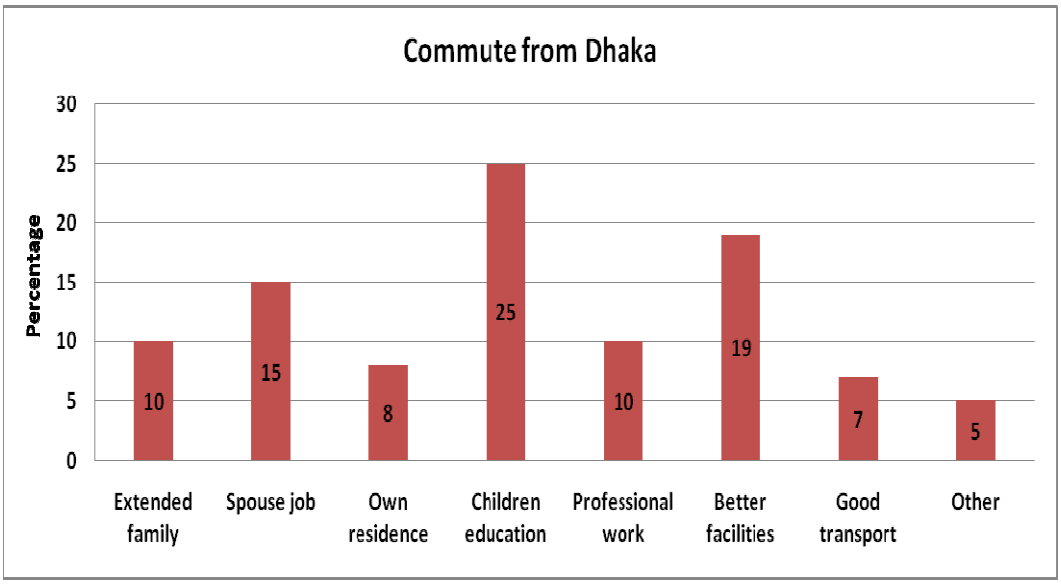


Figure 3.16: Reasons for DUET faculty members commuting from Dhaka

As evident from Figure 3.17 and 3.18, the main reasons for on-campus living are as follows:

- ❒ Office is at walking distance
- ❒ Convenient to fulfill university responsibilities
- ❒ Security
- ❒ Utility services such as electricity, water supply etc. are good

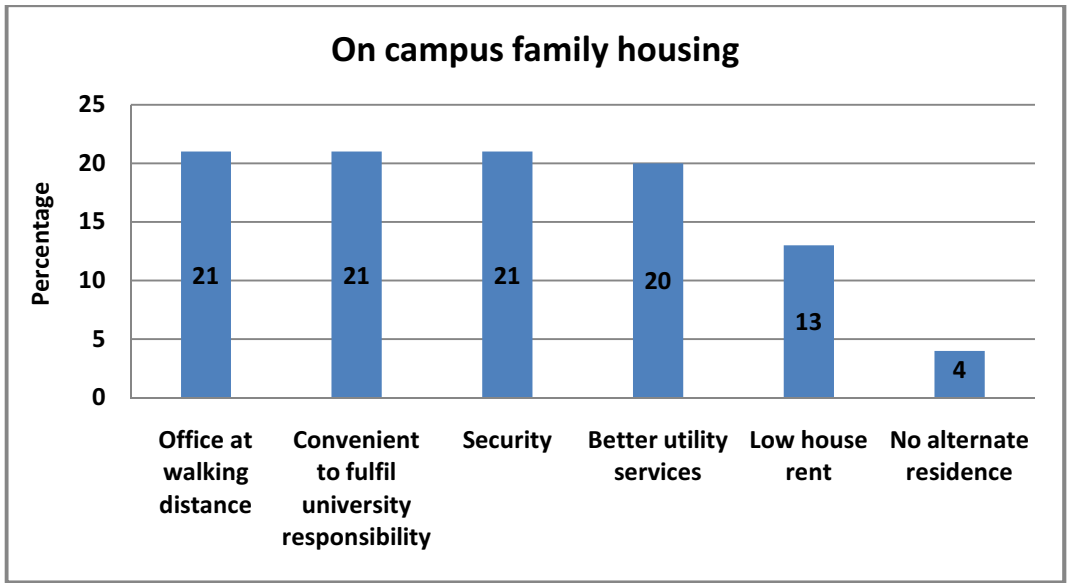


Figure 3.17: Reasons for DUET faculty members choosing on-campus family housing

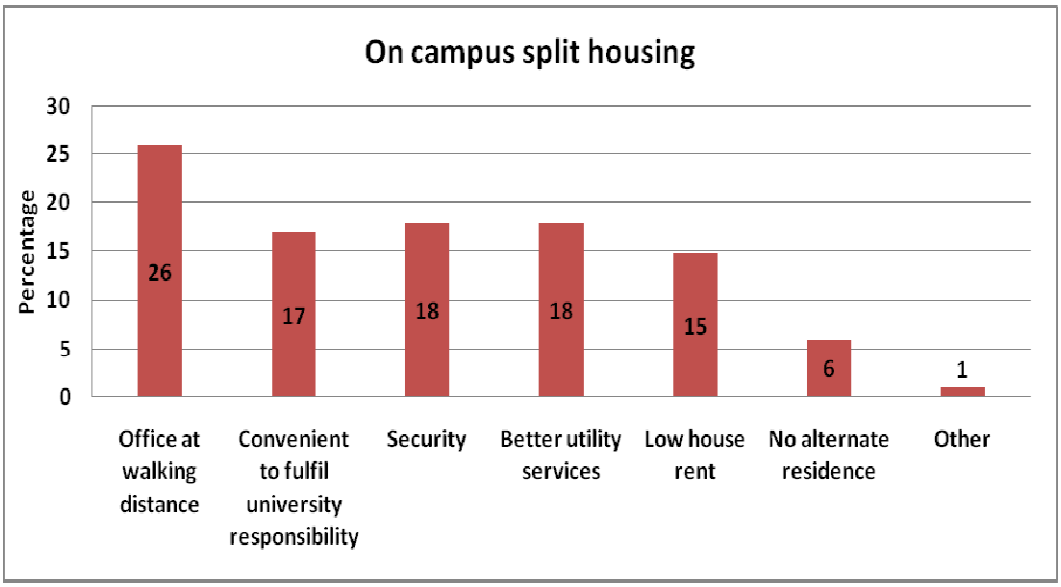


Figure 3.18: Reasons for DUET faculty members choosing on-campus split housing

As evident from Figure 3.19, the main reasons for faculty members living off-campus (other than Dhaka) are:

- ❒ Unavailability of on-campus living facility
- ❒ Other

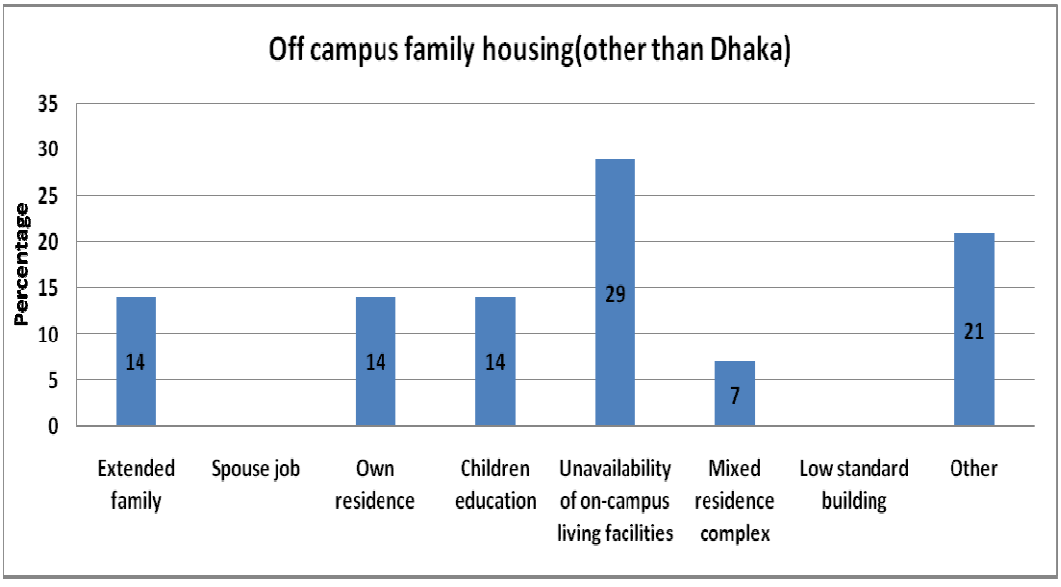


Figure 3.19: Reasons for DUET faculty members choosing off-campus family housing (other than Dhaka)

As evident from Figure 3.20, the main reasons for faculty members living on-campus family are:

- ❒ Office is at walking distance
- ❒ Convenient to fulfill university responsibilities
- ❒ Security

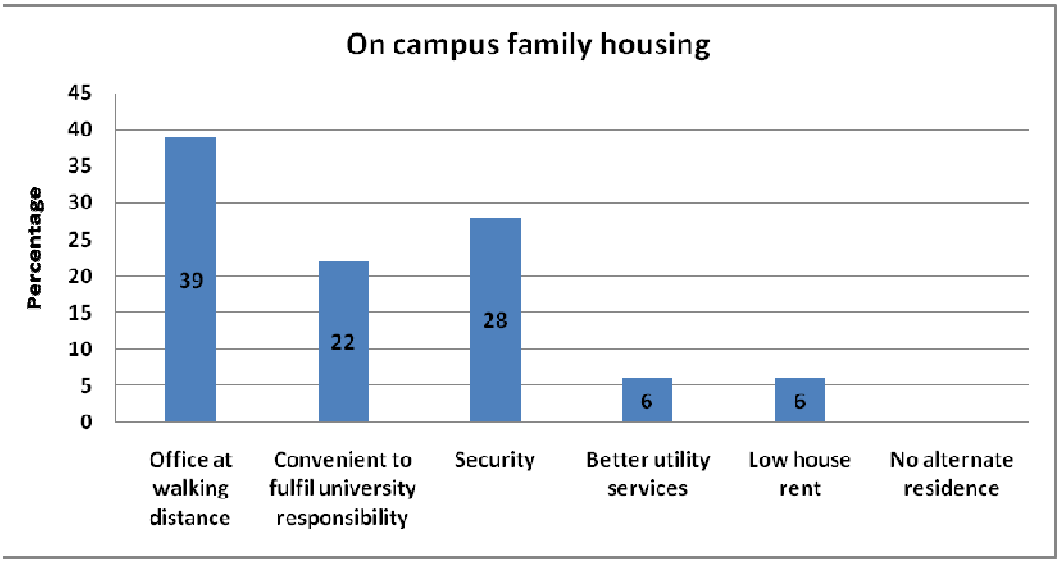


Figure 3.20: Reasons for SUST faculty members choosing on-campus family housing

As evident from Figure 3.21, the main reasons for faculty members living on-campus split are:

- ❒ Office is at walking distance
- ❒ Convenient to fulfill university responsibilities
- ❒ Security
- ❒ Low house rent
- ❒ Utility Services such as electricity, water supply etc. are good

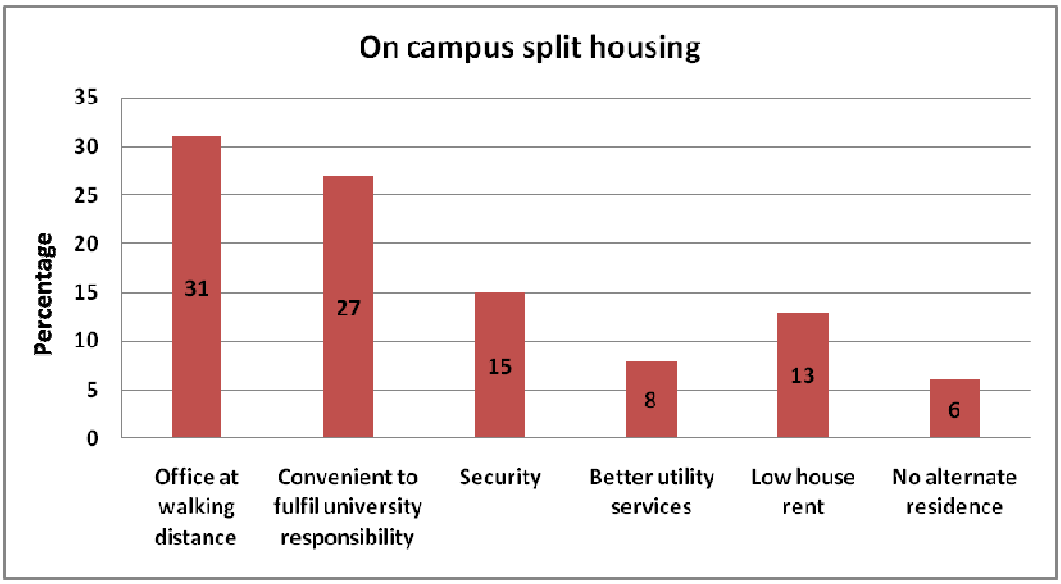


Figure 3.21: Reasons for SUST faculty members choosing on-campus split housing

As evident from Figure 3.22, the main reasons for faculty members living off-campus family are:

- ❒ Education of children
- ❒ Better shopping, medical & other facilities
- ❒ Own residence
- ❒ Low living cost

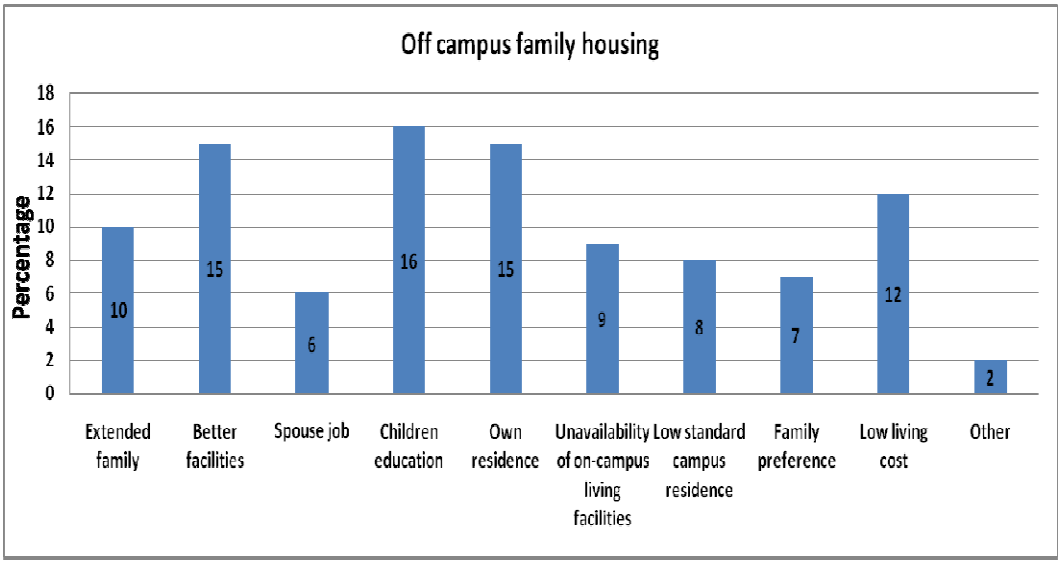


Figure 3.22: Reasons for SUST faculty members choosing off-campus family housing

As evident from Figure 3.23, the main reasons for faculty members living off-campus split are:

- ❒ Unavailability of on-campus living facility
- ❒ Low standard of the buildings of campus residence
- ❒ Better shopping, medical & other facilities
- ❒ Education of children
- ❒ Spouse's job

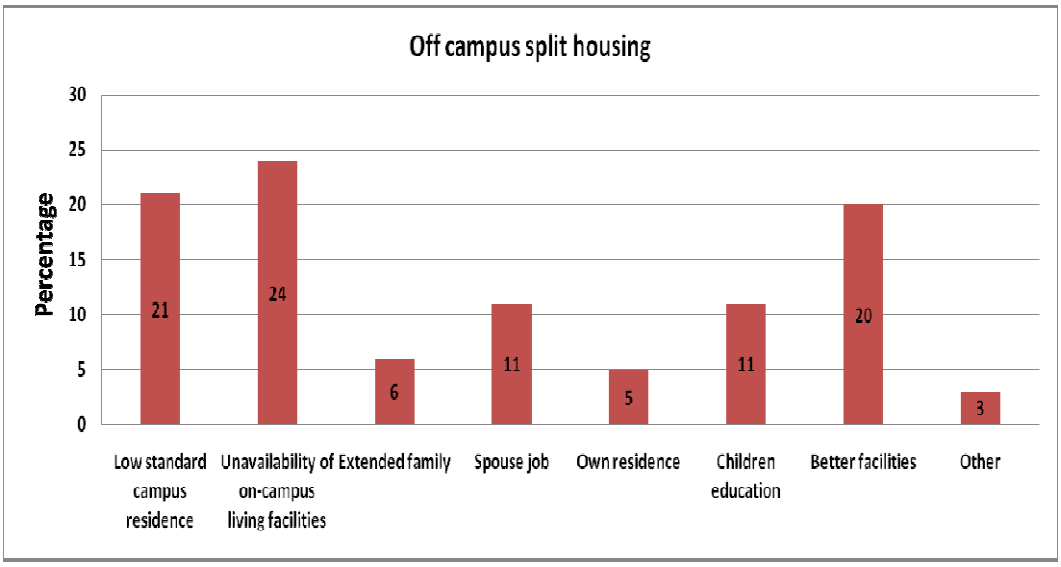


Figure 3.23: Reasons for SUST faculty members choosing off-campus split housing

3.5 Summary

This chapter describes the survey design and data analysis part of the research work. The SP scenarios are generated using statistical software SPSS by eliminating the dominant choices. The attributes and levels of the SP scenarios are determined on the basis of an initial survey. Data are collected from the respondents by personal interview survey and findings of the analysis are presented. Analysis of data indicates that though there are some similarities in the reasons behind the choice of residential locations between the two universities, there are significant dissimilarities between them as well. For example, high rent of SUST residence is

one of the most important reasons for the faculty members of the university for using off-campus housing whereas it is not a significant factor for the DUET faculty members. Another distinction is found among the female faculty members in the choice of housing location. Female faculty members of DUET mostly use on-campus housing facility whereas almost all female faculty members of SUST live off-campus. These dissimilarities lead to development of separate models for DUET and SUST rather than pooling the data and development of a single model.

CHAPTER FOUR

MODEL ESTIMATIONS

4.1 Overview

In this chapter, the model structures are developed for the focus groups and the model parameters are estimated. The software package BIOGEME (http://roso.epfl.ch/biogeme) is used to estimate the model parameters. As found from the statistical analysis of survey data in Chapter 3, there are significant differences in the choice of residential location between the faculty members of DUET and SUST. Because of this reason, separate models are needed to be developed for them. In the following sections of this chapter the model development procedure is described first. This is followed by details of DUET and SUST models. In each case, model specifications are presented first which are followed by estimation results.

4.2 Model Development and Estimation Results

The development process of a model specification is a mixture of applications of formal behavioral theories and statistical methods with subjective judgments of the model builder. In this research work, residential location choice models are developed with the discrete choice analysis technique using the SP data obtained from the survey. The software BIOGEME is used to estimate the models using maximum likelihood estimation (MLE) technique.

Separate models are developed for the two universities (DUET and SUST). Different Multinomial (MNL) andl Nested Logit (NL) Model specifications are tested and the final models are chosen based on the informal tests and overall goodness-of-fit.

The tests that have been used to compare the fit of different model specifications are presented below:

Informal Tests

The most basic test of the model estimation output is the examination of the relative values and signs of the estimated parameters. Signs and relative magnitudes of estimated coefficients must agree with a-priori expectations.

The t-statistic

The statistical significance of the parameters is tested at 90% and 95% level of confidence. For two tailed test the critical value of t-statistics are 1.645 and 1.960 at 90% and 95% level of confidence respectively.

Test of generic attributes

An important aspect of the specification of discrete choice models is the distinction between alternative-specific and generic attributes. A generic specification imposes restrictions of equality of coefficients on a more general model with alternative-specific attributes. Thus the likelihood ratio test statistic for the null hypothesis of generic attributes is

$$-2\left(\mathcal{L}(\hat{B}_G) - \mathcal{L}(\hat{B}_{AS})\right)$$

Where G and AS denote the generic and the alternative specific models respectively. It is χ2 distributed with the number of degrees of freedom equal to the number of restrictions, or (KAS – KG).

Overall goodness of fit measure

The overall goodness of fit of a model specification is measured with the adjusted rho-square values. The adjusted rho square can be expressed as in Equation (4.1).

$$\bar{\rho}^2 = 1 - \frac{\mathcal{L}(\hat{\theta}_{MLE}) - K}{\mathcal{L}(\hat{\theta} - 0)} \qquad (4.1)$$

Where, $\mathcal{L}(\hat{\theta} - 0)$ represents the log-likelihood with zero coefficients (which results in equal likelihood of choosing each available alternative), $\mathcal{L}(\hat{\theta}_{\mathrm{MLE}})$ represents the log-likelihood for the estimated model and K is the number of degrees of freedom (parameters) used in the model.

The models of DUET and SUST are described separately in the following section.

4.2.1 DUET model

Model Specifications

The respondents of DUET have four alternate residential location options:

- ❒ Commute from Dhaka
- ❒ On-campus family housing
- ❒ On-campus split housing
- ❒ Off-campus family housing (other than Dhaka)

In SP the on-campus options are presented with improved facilities. The five attributes included in SP scenario are:

- ❒ School facilities
- ❒ Rent of university residence
- ❒ Spouse's job opportunity
- ❒ Professional work scope
- ❒ Additional utility

In addition, socioeconomic variables are also likely to affect the choices of location.

The priori hypotheses about different candidate variables are presented in Table 4.1.

Table 4.1: Priori assumptions about the socio-economic characteristics and location attributes for SP choice model of DUET

Variables	Characteristics
Age	Faculty members of age range up to 30 years are more likely to choose on-campus living facility as most of them are either unmarried or married having no school going children. Respondents of average age 35 years are likely to be indifferent in choosing on-campus and off-campus housing provision. Faculty members of average age 45 years may choose off-campus living provision for better quality of life. Faculty members of age higher than 50 years are more likely to reside in campus or nearer to campus because of being aged.
Designation	Most of the Professors and Associate Professors are likely to live in Dhaka and travel to go to DUET whereas majority of the Lecturers are more likely to choose on-campus housing facility. On the other hand, Assistant Professors are likely to use both on-campus and off-campus living facility. There is likely to be a strong correlation between designation and age.
Gender	Female faculty members are more likely to choose on-campus housing provision or they may reside nearer to campus rather than commuting from Dhaka. Unmarried female faculty members need to live split from their family for their job purpose as their parents live in different districts and may consider having no alternate residence as a cause of living on-campus. Married ones may also choose to live on-campus because of the convenience of fulfilling their office and family responsibilities as well. It may be noted that the transport system in Bangladesh may be a reason for discouraging women to travel a long distance to commute to office and thus decreases the attractiveness of Dhaka as their housing location.
Marital status	Most of the unmarried faculty members are likely to choose on-campus split housing as their extended family live apart from them in different districts and also because of lower rent of university residence. Married faculty members may reside both on-campus and off-campus considering various factors associated with their family.
Car ownership	Faculty members having cars are more likely to live in Dhaka. One of the reasons might be their flexibility to use car to go to office.

Table 4.1: Priori assumptions about the socio-economic characteristics and location attributes for SP choice model of DUET (Continued)

Variables	Characteristics
School facilities	Faculty members having school going children are more likely to give high preference on availability of better school facilities in choosing residential location. People are likely to live in the vicinity of their children's school and even don't mind to travel longer distances to go to office for this reason.
Spouse's occupation	Spouse's occupation is likely to be a potential variable in the choice of residential location. Faculty members whose spouse's are employed are more likely to choose off-campus living facility because of their spouse's job location.
House rent	Reduction of on-campus house rent with high standard housing facility is likely to attract off-campus faculty members choosing on-campus housing facility.
Professional work	Professional work purpose necessitates some faculty members living in Dhaka and therefore makes it a significant factor for them to choose residential location. Therefore, creating the same professional work scope in Gazipur as in Dhaka may increase the proportion of faculty members choosing on-campus housing facility.
Additional utility	People value the existence of utility services in choosing their residential location. Improved facilities such as big shopping malls, better medical facilities, branches of reputed private universities closer to university are likely to attract faculty members to choose on-campus housing provision.

Model Structure

At first Multinomial Logit Model (MNL) structure is developed and different specifications are tested to find out the best model specification. The model structure is illustrated in Figure 4.1.

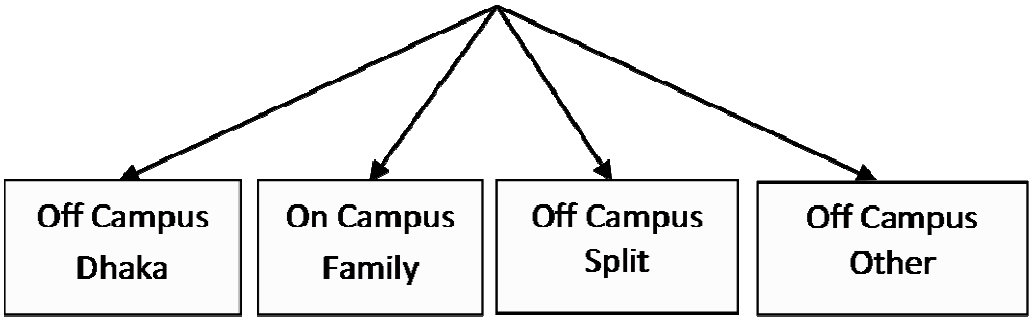


Figure 4.1: Multinomial logit model (MNL) structure for DUET

In addition, different Nested Logit (NL) structures are tested to find out the final model specification. The model structures are illustrated in Figure 4.2. As seen in Figure 4.2 (a), the fist nested structure is tested with the location alternatives (on-campus and off-campus) placed at upper nest. In the second nested structure (Figure 4.2 b) location is nested within housing status (family and split). The third nested structure considers that housing status is nested within Dhaka and local as seen in Figure 4.2 (c).

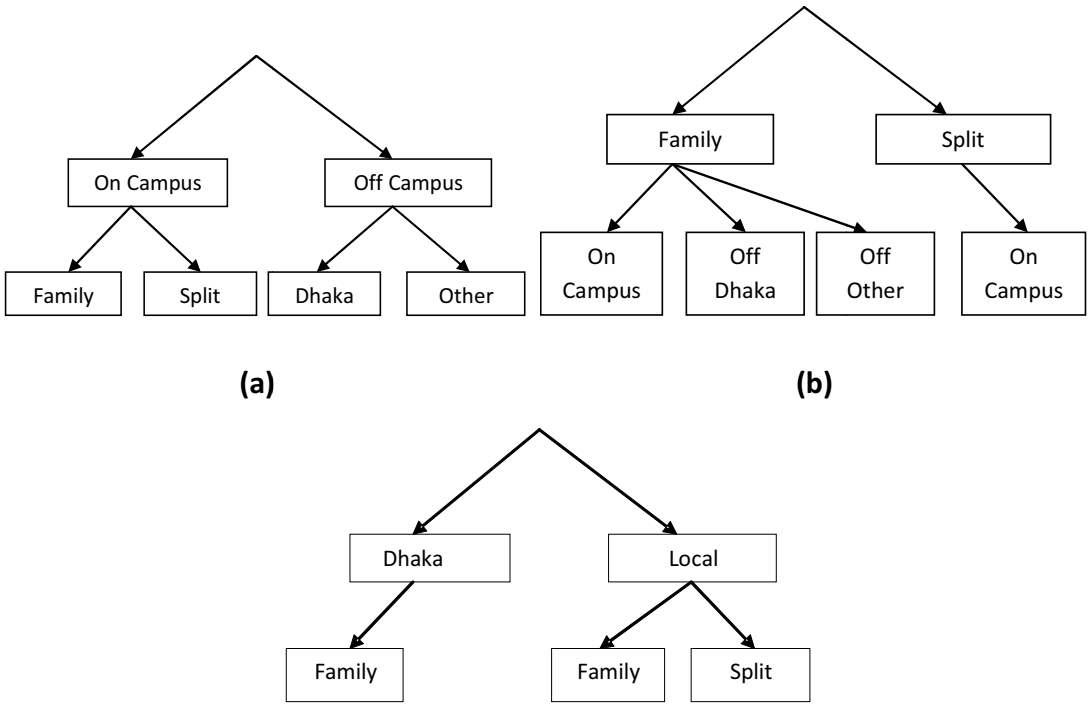


Figure 4.2: Nested logit model (NL) structures for DUET

The model estimation starts with the generic coefficients of all the SP attributes and the Alternative Specific Constants (ASCs) of location alternatives: off-campus Dhaka, on-campus family, on-campus split and off-campus other. Alternative specific coefficients are then incorporated in the utility equations and are retained or rejected based on the sign of the coefficients and also on the overall goodness of fit measure (Adjusted rho square). Generic as well as alternative specific socioeconomic variables (e.g. age, gender, marital status, income etc.) with a-priori hypotheses are tested with all possible combinations.

Generic and alternative specific coefficients of school facilities for Bengali medium, English medium leading to SSC/HSC and English medium leading to GCSE are estimated but results are found inconsistent and insignificant. Addition of married dummy variable to off-campus utility equations (alternately unmarried dummy to on-campus split) gives inconsistent signs.

Different age dummies are tested but the age 45 (respondents of average age 45 years) dummy with off-campus Dhaka and off-campus other fits best. Use of income dummies gives inconsistent results as because it may not be mentioned by the respondents appropriately and therefore, is discarded from the model specification. Generic female dummy shows good t statistics and is added to on-campus family and on-campus split. The car ownership dummy shows poor t-statistics (insignificant at 90% level of confidence) and as because not a potential socioeconomic parameter in this particular case, is rejected also.

Generic and alternative specific coefficients of travel time and travel cost to office are estimated but finally rejected because of inconsistent signs. Different variations of combined house rent (e.g. summation of average off-campus house rent and on-campus split rent, summation of 50% average off-campus house rent and on-campus split rent, etc.) for on-campus split respondents are tested but the signs of the coefficients are inconsistent. This implies that the unmarried faculty members living split in campus do not share the house rent of their parents living apart from them actually.

Estimation Results

The utility functions for the location alternatives of the best model of DUET are presented below:

$$V_{Off\_Dhaka} = ASC_{Off\_Dhaka} * one + \beta_{School\_facilities} * Sgchild\_dummy + \beta_{Off\_House\_Rent} * Off\_House\_Rent + \beta_{Prof\_work} * one + \beta_{Age\_45} * Age\_45 + \beta_{Spouse's\_job\_opp} * one \quad (4.2)$$

$$V_{On\_Family} = ASC_{On\_Family} * one + \beta_{School\_facilities} * School\_facilities + \beta_{Prof\_work} * Prof\_work + \beta_{OnF\_House\_Rent} * On\_House\_Rent + \beta_{Female} * Female\_dummy + \beta_{Spouse's\_job\_opp} * Spouse's\_job\_opp \quad (4.3)$$

$$V_{On\_Split} = ASC_{On\_Split} * one + \beta_{Prof\_work} * Prof\_work + \beta_{OnS\_House\_Rent} * On\_House\_Rent + \beta_{Female} * Female\_dummy \quad (4.4)$$

$$V_{Off\_Other} = ASC_{Off\_Other} * one + \beta_{Off\_House\_Rent} * Off\_House\_Rent + \beta_{Age\_45} * Age\_45 + \beta_{Spouse's\_job\_opp} * one \quad (4.5)$$

The variables descriptions are presented in Table 4.2.

Table 4.2: Description of the variables for final model of DUET

Variables	**Description**
Sgchild_dummy	1 for respondents having school going children 0 for respondents having no school going children
Off_House_Rent	Off-campus hose rent in BDT 1,000
On_House_Rent	On-campus house rent BDT 1,000
School_facilities	Improved school facilities with Bengali and English (version or GCSE) medium
Prof_work	1 for provision of similar professional work scope as in Dhaka 0 for same as now
Spouse's_job_opp	1 for preferential appointment at DUET 0 for same as now
Age 45 dummy	1 for respondents of average age 45 years 0 for respondents of other ages
Female dummy	1 for female respondents 0 for male respondents

The estimation results of the best model are presented in Table 4.3.

Table 4.3: Estimation results of the final model of DUET

Number of estimated parameters	12
Number of observations	243
Null log-likelihood	-336.87
Log-likelihood at Convergence	-209.594
Adjusted rho-square	0.342
Utility Parameters	**Estimated values (t-statistics)**
Alternative specific constant for off-campus Dhaka, ASC_{Off_Dhaka}	0.558 (0.66)
Alternative specific constant for off-campus other, ASC_{Off_Other}	0.990 (1.17)
Alternative specific constant for on-campus family, ASC_{On_Family}	1.07 (1.68)
Coefficient of age dummy, β_{Age_45}	1.11 (2.26)
Coefficient of female dummy, β_{Female}	1.67 (2.54)
Coefficient of school facilities, $\beta_{School\_facilities}$	0.544 (4.05)
Coefficient of off-campus house rent (in '000 Taka) , $\beta_{Off\_House\_Rent}$	-0.0662 (-1.89)
Coefficient of on-campus family house rent (in '000 Taka), $\beta_{OnF\_House\_Rent}$	-0.378 (-1.85)
Coefficient of on-campus split house rent (in '000 Taka), $\beta_{OnS\_House\_Rent}$	-0.905 (-1.79)
Coefficient of professional work scope, β_{Prof_work}	0.542 (1.67)
Coefficient of spouse's job opportunity , $\beta_{Spouse's\_job\_opp}$	0.426 (1.39)
Off-campus nest coefficient	2.35 (2.18)

As seen from the estimation results of table 4.3, it can be said that all things remaining the same, on-campus family housing is the most preferred housing location and on-campus split is the least preferred.

School facilities have higher significance in choosing residential location as hypothesized which is indicative from the sufficiently large absolute value of the t statistic of its coefficient. The generic coefficient of school facilities implies that its sensitivity does not vary among different locations.

The co-efficient of professional work scope is significant at 90% level of confidence with an expected positive sign indicating that faculty members value the existence of professional work scope in selecting residential location. Though the coefficient of spouse's job opportunity is insignificant but with a positive sign as expected, it is remained in the model because of the strong a-priori hypothesis.

Location specific house rent coefficients are estimated and found significant with the expected negative signs indicating that utility of a housing location decreases with the increase in house rent. The sensitivity of faculty members towards house rent does significantly vary over off-campus and on-campus housing location. The values of the coefficients of on-campus family house rent and on-campus split house rent indicate that split faculty members are more sensitive to house rent than faculty members leading family housing in case of on-campus living.

A positive coefficient of generic age 45 dummy justifies the hypothesis that, all else being equal, faculty members of average age 45 years prefer to live off-campus for better quality of life. Female faculty members prefer to use on-campus living facility as the coefficient of female dummy is significant at 95% level of confidence with an expected positive sign.

The utility equations of the final model `are presented below:

V_{Off_Dhaka} = *0.558 * one + 0.544 * Sgchild_dummy - 0.0662 * Off_House_Rent + 0.542 * one + 1.11 * Age_45 + 0.426 * one* (4.6)

V_{On_Family} = *1.07 * one + 0.544 * School_facilities + 0.542 * Prof_work - 0.378 * On_House_Rent +* 1.67 ** Female_dummy + 0.426 * Spouse's_job_opp* (4.7)

V_{On_Split} = 0.542 ** Prof_work - 0.905 * On_House_Rent + 1.67 * Female_dummy*

(4.8)

V_{Off_Other} = *0.990 * one - 0.0662 * Off_House_Rent + 1.11 * Age_45 + 0.426 * one*

(4.9)

The structure of the best model is presented in Figure 4.3 below.

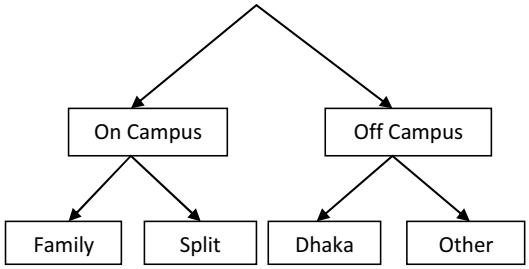


Figure 4.3: Final model structure for DUET

Since the off-campus nest coefficient is significant at 95% level of confidence, it validates the nesting structure of the model. The value of off-campus nest coefficient indicates that the variance of error term of on-campus nest is 2.35 times higher than the variance of error term of off-campus nest.

4.2.2 SUST model

Model Specifications

The respondents of SUST have four alternate residential location options:

- ❒ On-campus family housing
- ❒ On-campus split housing
- ❒ Off-campus family housing
- ❒ Off-campus split housing

The five attributes included in SP scenario are:

- School facilities
- Rent of university residence
- Spouse's job opportunity
- Professional work scope
- Additional utility

In addition, socioeconomic variables are also likely to affect the choices of residential location.

The priori hypotheses about different candidate variables are presented in Table 4.4.

Table 4.4: Priori assumptions about the socio-economic characteristics and location attributes for SP choice model of SUST

Variables	Characteristics
Age	Young faculty members of age less than 30 years are more likely to live split as they find this comfortable to fulfill their university responsibilities. Mid age (30-50 years) faculty members are likely to choose off-campus family housing.
Designation	Faculty members designated as Lecturer are more likely to maintain split housing and unavailability of on-campus facilities pushes them to live off-campus split. Assistant professors very often may choose off-campus family housing for high standard living facilities. If both of the spouses work in SUST (in most cases, one of them is a Professor), they have higher likelihood of choosing on-campus family housing. There is likely to be a strong correlation between designation and age.
Gender	Female faculty members of SUST are more likely to choose off-campus living facility the reason for which may be the consideration for their spouse's job and children's school location. As SUST is nearer to the city center and SUST bus is available every hour they find it convenient to travel to university rather living on-campus.
Marital Status	Unmarried faculty members are likely to choose split housing both at campus and outside of campus as their family (e.g. parents) live in different cities impel them to do so.

Table 4.4: Priori assumptions about the socio-economic characteristics and location attributes for SP choice model of SUST (Continued)

Variables	Characteristics
Car ownership	Car ownership may increase the utility of off-campus family housing as faculty members have the flexibility of including car as a travel mode to go to university in their choice set.
School facilities	People are likely live in the vicinity of their children's school and even don't mind to travel longer distances to go to office for this reason. A significant proportion of off-campus faculty members live there for the reason stated above. Some married faculty members live split because their family live in Dhaka for better school and college facilities for their children. If better facilities are developed inside or next to campus, they may rethink about their residential location and choose on-campus family housing.
House rent	University residence cost for SUST faculty members vary from BDT 10,000 to 13,000 except the Lecturers which is very high compared to the house rent outside of campus. Reduction of on-campus house rent with high standard housing facility are, therefore, likely to attract off-campus faculty members choosing on-campus housing facility.
Spouse's occupation	In case of dual carrier family, there is likely to be a tendency of choosing a residential location which is nearer to both of the husband and the wife's office. Faculty members whose spouses are employed are, therefore, more likely to choose off-campus living facility because of their spouse's job location.
Professional work	Scope of professional work near campus may give extra financial support to the faculty members and is likely to attract faculty members residing at job place with their family.
Additional utility	Additional facilities including better health care, big shopping mall, private universities next to campus may enhance to live on-campus with family housing.

Model Structure

Multinomial Logit Model (MNL) structure is developed first and different specifications are tested. The model structure is illustrated in Figure 4.4.

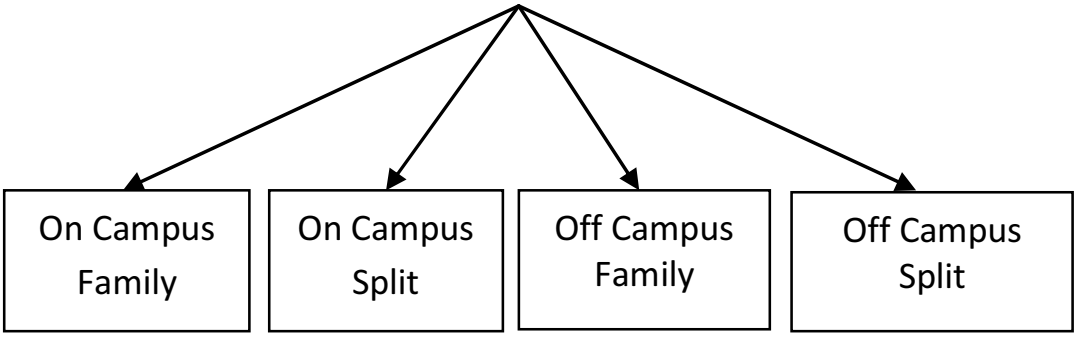


Figure 4.4: Multinomial logit model (MNL) structure for SUST

Different Nested Logit (NL) structures are tested also to find out the best model specification. The model structures are illustrated in Figure 4.5.

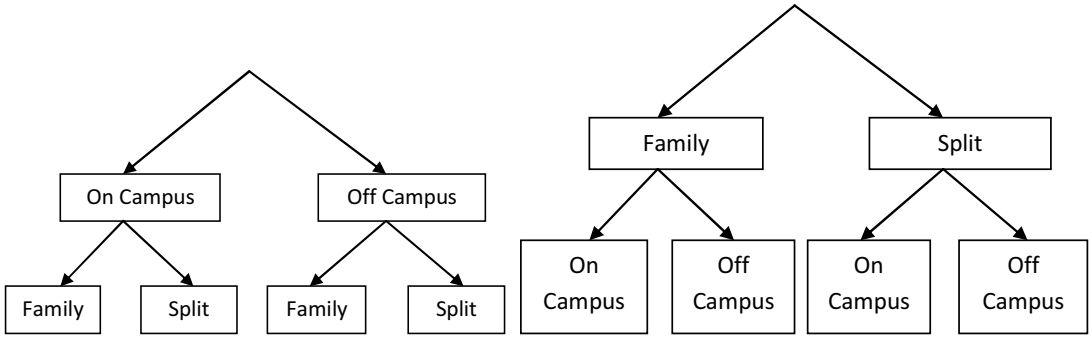


Figure 4.5: Nested logit model (NL) structures for SUST

In the first NL structure housing status (family and split) is nested within location (on-campus and off-campus) and the other structure considers on-campus and off-campus at the lower nest providing family and split status at upper.

To find out the best model specification, at first generic coefficients of all the SP attributes and the Alternative Specific Constants (ASCs) of location alternatives (on-campus family, on-campus split, off-campus family and off-campus split) are incorporated into the model specification. Alternative specific coefficients are tested after that and are retained or rejected based on the sign of the coefficients and also on the overall goodness of fit measure.

Alternative specific coefficients of school facilities are tested but the generic coefficient shows better fit to specification. Different age and income dummies are tested but none fits the model specification well. Generic female dummy added to off-campus family shows significant t statistics and remained in the model. Generic and alternative specific coefficients of travel time and travel cost to university are estimated but give inconsistent results.

Different variations of combined house rent for on-campus and off-campus split faculty members are tested but finally rejected for inconsistent signs. This implies that faculty members who are living split do not share the house rent of their families living apart from them. The coefficients of spouse's job and professional work scope show inconsistent signs and are statistically insignificant also and therefore, are rejected.

Estimation Results

The utility functions for the location alternatives of the best model of SUST are presented below:

$$V_{On\_Family} = ASC_{On\_Family} * one + \beta_{OnF\_House\_Rent} * On\_House\_Rent + \beta_{School\_facilities} * School\_Bengali \quad (4.10)$$

$$V_{On\_Split} = ASC_{On\_Split} * one + \beta_{OnS\_House\_Rent} * On\_House\_Rent + \beta_{Unmarried} * Unmarried \quad (4.11)$$

$$V_{Off\_Family} = ASC_{Off\_Family} * one + \beta_{Off\_House\_Rent} * Off\_House\_Rent + \beta_{School\_facilities} * one + \beta_{Female} * Female + \beta_{Car\_ownership} * Car\_ownership \quad (4.12)$$

$$V_{Off\_Split} = ASC_{Off\_Split} * one + \beta_{Off\_Hose\_Rent} * Off\_House\_Rent + \beta_{Unmarried} * Unmarried \quad (4.13)$$

The variables descriptions are presented in Table 4.5.

Table 4.5: Description of the variables for final model of SUST

Variables	**Description**
School_Bengali	1 for improved Bengali medium school 0 for same as now
Off_House_Rent	Off-campus hose rent in BDT 1,000
On_House_Rent	On-campus house rent BDT 1,000
Female dummy	1 for female respondents 0 for male respondents
Car-ownership dummy	1 for respondents who own car 0 for respondents who have no car
Unmarried dummy	1 for unmarried respondents 0 for married respondents

The results of the estimated parameters of final model are presented in Table 4.6

Table 4.6: Estimation results of the final model of SUST

Number of estimated parameters	10
Number of observations	507
Null log-likelihood	-702.851
Log-likelihood at Convergence	-433.712
Adjusted rho-square	0.369
Utility Parameters	**Estimated values (t-statistics)**
Alternative specific constant for off-campus family, ASC_{Off_Family}	1.84 (5.03)
Alternative specific constant for on-campus family, ASC_{On_Family}	2.98 (7.94)
Alternative specific constant for on-campus split, ASC_{On_Split}	2.96 (7.56)

Table 4.6: Estimation results of the final model of SUST (Continued)

Utility Parameters	**Estimated values (t-statistics)**
Coefficient of female dummy, β_{Female}	0.511 (2.02)
Coefficient of school facilities, $\beta_{School\_facilities}$	0.391 (1.83)
Coefficient of off-campus house rent (in '000 Taka), $\beta_{Off\_House\_Rent}$	-0.0701 (-2.58)
Coefficient of on-campus family house rent (in '000 Taka), $\beta_{OnF\_House\_Rent}$	-0.068 (-2.31)
Coefficient of on-campus split house rent (in '000 Taka), $\beta_{OnS\_House\_Rent}$	-1.13 (-4.42)
Coefficient of car-ownership dummy, $\beta_{Car\_ownership}$	0.777 (2.71)
Coefficient of unmarried dummy, $\beta_{Unmarried}$	0.922 (3.15)

Estimated coefficients indicate that, all things remaining the same, on-campus family housing is the most preferred housing location and off-campus split is the least preferred housing location.

The positive coefficient of school facilities indicates that, all else being equal, presence of Bengali medium school increase the utility of on-campus family housing. The generic coefficient implies that faculty member's sensitivity towards school facilities does not vary significantly over locations.

The positive female dummy justifies the hypothesis that, all else being equal, female faculty members of SUST are more likely to choose off-campus housing; the reason for may be the consideration for their spouse's job and children's school location.

The higher value of the coefficient of on-campus split house rent indicates that split faculty members are more sensitive to house rent than faculty members living with their family in case of on-campus housing.

A positive coefficient of car ownership dummy implies that, all else being equal, faculty members who own car prefer off-campus family housing as their residential location. Unmarried faculty members prefer to live split given all else being equal, as the unmarried dummy proves the hypothesis true having positive sign and statistical significance at 95% level of confidence.

The utility equations of the final model are presented below:

$$V_{On\_Family} = 2.98 * one - 0.068 * On\_House\_Rent + 0.391 * School\_Bengali \quad (4.14)$$

$$V_{OnSplit} = 2.96 * one - 1.13 * On\_House\_Rent + 0.922 * Unmarried \quad (4.15)$$

$$V_{Off\_Family} = 1.84 * one - 0.0701 * Off\_House\_Rent + 0.391 * one + 0.511 * Female + 0.777 * Car\_ownership \quad (4.16)$$

$$V_{Off\_Split} = - 0.0701 * Off\_House\_Rent + 0.922 * Unmarried \quad (4.17)$$

The structure of the best model is presented Figure 4.6 below.

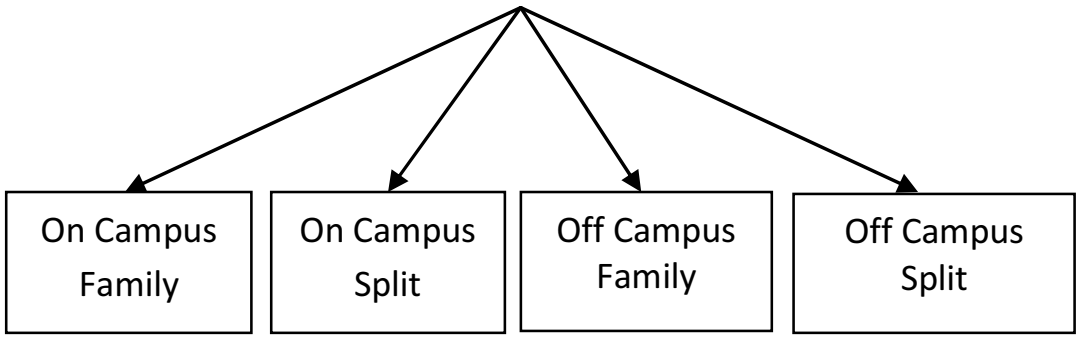


Figure 4.6: Final model structure for SUST

It may be noted that all potential nesting structures (presented in Figure 4.5) have been tested but no nesting structure has been supported by the data.

4.3 Summary

This chapter focuses on the development of SP models and the estimation of model parameters. The process of model development begins with the estimation of parameters with a priori theory, or set of assumptions, that is consistent with a large number of model specifications. Different specifications of the models are tested, and a variety of formal and informal tests are done to narrow down the

range of alternative specifications. At various stages of this process some aspects of a priori assumptions that do not agree sufficiently with the statistical findings are revised. Some assumptions are discarded and new ones are devised in order to find the best model specification. Finally, among the specifications the ones that perform best according to "goodness-of-fit" measures and statistical significance tests are taken as the final model. The model parameters are estimated using the software package BIOGEME. A nested Logit Model (NL) and a Multinomial Logit Model (MNL) fits best for DUET and SUST respectively. Better school facilities with Bengali as well as English medium (leading to SSC/HSC and GCSE), house rent, spouse's job opportunity, professional work scope, and two socio-economic variables: age and gender are found to be significant in choosing residential location for DUET faculty members. In case of SUST, improved Bengali medium school and house rent are found to be the most influential SP attributes affecting the choice of residential location. Gender, marital status and car ownership are the significant socio-economic variables in choosing residential location for SUST faculty members. The estimated equations can be used to predict the probabilities of shifting to on-campus facilities in response to a certain policy change (e.g. establishment of a branch of a reputed English medium school, 5% reduction of house rent, 10% reduction of house rent, etc.). These probabilities can then be used to calculate the corresponding change in VMT. The transferability of the models to other segments of the population is yet to be tested. It is however expected that even if the model parameters are not directly transferable, the modeling framework and the variables used in this research are likely to be applicable in the residential location choice of the other segments of the population. The sensitivity of the variables may be different though. Therefore, the findings of this research work can be a useful tool for formulating policy guidelines in future development of transport sector in Bangladesh.

CHAPTER FIVE

CONCLUSION

5.1 Overview

This chapter describes the summary of the research work and points out major research contributions. Finally directions for future research are suggested.

5.2 Summary of Research

In this research, residential location choice decisions have been analyzed to capture the heterogeneity in commute vehicle miles travelled for faculty members of two public universities (DUET and SUST) of Bangladesh. A framework for residential location choice model and associated VMT for commute trips has been developed in this regard to identify the factors that affect the choice of residential location and ultimately affect the commute vehicle miles travelled of the respondents. The survey includes the current Revealed Preference (RP) data regarding choice of residential locations, as well as Stated Preference (SP) data where the faculty members have been given some hypothetical future scenarios which include some improved facilities at or near university campus and have been asked to choose a location among alternative residential locations. The SP scenarios have been generated using the statistical software SPSS and each scenario includes multiple levels of five attributes (better school facilities, reduced rent of university residence, spouse's job opportunity, professional work scope and some additional facilities including better health care, big shopping mall etc.).

The socio-economic characteristics (e.g. age, gender, income etc.) of the faculty members have been analyzed to identify their impacts on the choice of residential location. Commute VMT of off-campus faculty members of the two universities have been calculated to quantify the impacts of improved facilities of on-campus housing provision on these. Data analysis shows that in the presented SP scenarios, if the faculty members are provided with the improved facilities (e.g. better school

facilities, spouse's job opportunity, professional work scope etc.) for which they are currently using off-campus facility, then 61 percent commute trips are likely to be reduced in case of DUET and 78 percent commute trips are likely to be reduced in case of SUST. The analysis also shows that 68 percent commute VMT are likely to be reduced with a reduction of two-way daily commute VMT of 690 for DUET and 78 percent commute VMT are likely to be reduced with a reduction of two-way daily commute VMT of 891 for SUST in the presented SP scenarios.

Discrete choice technique has been used to model the choice of residential location. Though the two universities have some similarities in the preference of residential location, there are some significant dissimilarities as well. This necessitates the development of separate models for them. A Nested Logit Model with housing status nested within location has been found as the best model for DUET and a Multinomial Logit (MNL) model has been found as the best model for SUST. Since the two universities stand at different locations (one at the periphery of the Capital and the other at major cities other than Capital) distinct features have been found in the consideration of housing location between the faculty members of the two universities. One significant difference can be seen in the current housing location and status of them. In case of DUET, split faculty members live only at campus and 70 percent of them are unmarried and find this more comfortable to live on-campus as their parents live at different districts. All off-campus faculty members of DUET maintain family housing whereas 22 percent SUST faculty members live off-campus split and 39 percent among these off-campus split are married. 10 percent SUST faculty members live on-campus split among which 50 percent are married. In most cases the families of these split married faculty members live in Dhaka for better school facilities for children and spouse's job. This scenario is quite different from DUET. Another distinction is between the university house rent of the two universities. The house rent allowances are deducted from salary of the SUST faculty members who use university residence. Survey reveals that the standard of the residence buildings are not satisfactory whereas faculty members can live outside of campus with higher standard living

facilities at comparatively low house rent. Therefore, faculty members are more likely to choose off-campus housing facility. On the other hand, house rent of DUET residence is much lower compared to off-campus house rent although the standard is not satisfactory. Therefore, house rent does not play as a significant factor for them for living off-campus.

The model estimation results show that, all else being equal, on-campus family housing is the most preferred housing location for faculty members of both of the universities. The results also show that better school facilities with Bengali as well as English medium, reduced house rent, professional work scope and spouse's job opportunity are the potential variables of choosing on-campus housing facility for DUET faculty members. Age and marital status have been found to be significant socio-economic variables in affecting their choice of residential location. Faculty members of average age 45 years have less likelihood of choosing on-campus facility whereas female faculty members are more likely to choose on-campus housing facility in DUET. On the other hand, higher standard Bengali medium schools and reduced rent are the most influential variables in the choice of residential location for SUST faculty members. Socio-economic variables have been found to have significant impacts in choosing residential location of them. Female faculty members of SUST have higher likelihood of choosing off-campus housing facility which is quite a different scenario from DUET. The faculty members of SUST who own car are more likely to choose off-campus housing facility. The unmarried faculty members of SUST have higher likelihood of living split from their family.

The estimated equations can be used to predict the probabilities of shifting to on-campus facilities in response to a certain policy change (e.g. establishment of a branch of a reputed English medium school, 5% reduction of house rent etc.). These probabilities can then be used to calculate the corresponding change in VMT.

5.3 Research Contribution

The major research contributions of the study are summarized below:

In the context of Bangladesh, there have been very limited researches that focused on the choice of residential location. All of these models have used RP data only. Further, none have involved rigorous mathematical modeling. This is the first attempt that involves rigorous mathematical modeling to develop a residential location choice model using SP data in the context of Bangladesh.

An extensive SP survey has been designed and conducted to capture the preferences of residential location of the faculty members of two public universities (DUET and SUST) of Bangladesh. Discrete choice models have been developed using the survey responses using maximum likelihood estimation (MLE) technique. A Nested Logit Model with housing status (family and split) nested within location (on-campus and off-campus) has been found as the best model for DUET. In case of SUST, a Multinomial Logit Model has been found as the best model since no nested structure has been supported by the data.

The findings of the study may help transport policy makers and university authorities in formulating policy guidelines to promote on-campus housing. The estimated equations can be used to predict the probabilities of shifting to on-campus facilities in response to a certain policy change (e.g. establishment of a branch of a reputed English medium school, 5% reduction of house rent, 10% reduction of house rent, etc.). These probabilities can then be used to calculate the corresponding change in VMT.

Further, the methodology used in this research work may be used in future researches on residential location choice modeling of other segments of population. Though the models are not directly applicable for them, the modeling framework and the variables that have been used in this research work can be used in modeling their choice of residential location. The sensitivity of the variables may be different though.

5.4 Directions for Future Research

In this research, residential location choice models have been developed to capture the preferences of commute vehicle miles travelled. The research extensively used SP data, and SP models have been developed using this data. Further research can be conducted to develop a combined RP and SP model.

Again, this study has focused on the faculty members of the public universities only. A more extensive model can be developed considering both public and private universities as well. Also further researches can be conducted on the other segments of population which will help developing a generalized comprehensive model.

Further, this model can be extended to include other dimensions of choice like transport mode choice and work location choice.

The estimated equations can be used to predict the probabilities of shifting to on-campus facilities and calculating the corresponding change in VMT in response to a certain policy change. However, detailed policy analysis has not been done as part of this research and can be explored in future.

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APPENDICES

Appendix A

Initial Questionnaire for DUET

Developing a Residential Location Choice Model to Capture the Heterogenity in Commute Vehicle Miles Travelled (VMT).

Preliminary Questionnaire Survey for the faculty members of DUET

We are going to conduct a study to develop a residential location choice model for University faculty members of Bangladesh. For this, we need some information regarding your present residential location, travel pattern, socioeconomic status etc. Your responses are very important for our research. Please write not applicable (N/A), if you feel any question is not related with you.

General Informations		
Your Name:		
Designation:		
Age:	<25 / 25-30 / 31-40 / 41-50 / 51-60 / >60	
Sex:		
Marital Status:	Married	Unmarried
Socio economic/Family status		
Spouse's occupation:		
Spouse's job location:		
No of kids:		
Kid1		
Age:	<5/ 5-10/ 10-15/ 15-20/>20	
Education level:	Primary/ Secondary/ Higher secondary/ Graduation/ Job	
Kid2		
Age:	<5/ 5-10/ 10-15/ 15-20/>20	
Education level:	Primary/ Secondary/ Higher secondary/ Graduation/ Job	
Monthly family income:		
Do you have any car?	Yes	No
If yes then how many cars do you have?		
Regarding Residential Location		
Housing location:	On campus	Off campus
Locality of your present residence (e.g. Mohakhali, Dhanmondi, Shimultoli, Campus, etc.):		
Housing Category:	Family housing	Split or Single
Why do you choose off campus living facilities? (you can give multiple answers)	Unavailability of on campus living facilities / Lack of Professional work scope / Far away from school facilities / Far away from spouse's job location / Own residence facilities / Others…….	
If split family, family housing location:		
Causes to lead split family: (you can give multiple answers)	Family lives in other districts/ Spouse's works place/ Children's education/ High standard living facilities/ Own residence facilities/ Low income/ Others...	
Regarding Travel behaviour		
Regarding Travel behaviour of you		
Travel Mode (most of the time) :	Private Car / University bus / CNG / Public bus / Rickshaw / Walk / Others…	
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…	
Travel time:		
Travel cost:		
Second mode in absence of 1st one:	Private Car / University bus / CNG / Public bus / Rickshaw / Walk / Others…	

Regarding Travel behaviour of Spouse	
Travel Mode (most of the time) :	Private Car / Public bus / CNG / Office bus / Rickshaw / Walk / Others…
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…
Travel time:	
Travel cost:	
Second mode in absence of 1st one:	Private Car / Public bus / CNG / Office bus / Rickshaw / Walk / Others…
Regarding Travel behaviour of kid 1	
Travel Mode (most of the time) :	Private Car / Public bus / CNG / School bus / Rickshaw / Walk / Others…
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…
Travel time:	
Travel cost:	
Second mode in absence of 1st one:	Private Car / Public bus / CNG / School bus / Rickshaw / Walk / Others…
Regarding Travel behaviour of kid 2	
Travel Mode (most of the time) :	Private Car / Public bus / CNG / School bus / Rickshaw / Walk / Others…
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…
Travel time:	
Travel cost:	
Second mode in absence of 1st one:	Private Car / Public bus / CNG / School bus / Rickshaw / Walk / Others…
Future Situation/ Stated preference	
Suppose that in near future there will be significant improvement at or near university campus in various sectors which will provide similar facilities as in Dhaka. For example, there will be standard school/ college/ university facilities (both Bengali and English medium), preference for spouse's job at or near university, professional work scope etc. Please consider the new situations and menion which residential location you will choose in that situations.	
Residential Location (Faciities which will lead shifting of family to Gazipur from Dhaka)	
If standard school/ college/ University facilities (both Bengali and English medium) for your kids are developed in Gazipur or branches of renowned academic institutions like Vikarurnesanoon school, Ideal School, Notordame College, North South University etc. are opened very close to your university area, Which decision will you take regarding your family living?	
Your family will be shifted at campus	*They will stay at present location*
If spouse's job facility is provided at DUET/Gazipur or job transfer facility for spouse already in service is provided, Which decision will you take regarding your family living?	
Your family will be shifted at campus	*They will stay at present location*
If your salary structure increases at different levels as stated below, in which situation will you shift your family to campus?	
Increase 20% / 30% / 40% / 50% / Never Shift	
Residential Location (Faciities which will lead faculty members using on campus family housing who are currently living off-campus at Gazipur/ other areas)	
If sufficient housing facilities with better school facilities and shopping facilities near university campus are developed, which residential location will you choose?	
Commute from Dhaka / On-campus family housing / On-campus split housing / Off-campus family housing(other than Dhaka)	
If rent on University housing facility reduces as follows. In which situation will you choose on campus housing facility?	
30 % of house rent provided by govt. / 40 % of house rant provided by govt. / 50 % of house rant provided by govt.	
Which facilities can be significant for you to lead on campus family housing?	

Regarging your department		
It is difficult and time consuming to survey on all faculty members but for detailed survey we need few information regarding all of them. For this, we want to know some general informations regarding your colleagues from you. Please help us.		
Total number of faculty members :		
Active :		
On-leave :		
How many are unmarried ?		
How many lead split family (he/she lives in campus and his/her family lives in Dhaka or other cities)?		
Do you know why do they maintain split family ?		

Thanks for your cordial cooperation

Initial Questionnaire for SUST

Developing a Residential Location Choice Model to Capture the Heterogenity in Commute Vehicle Miles Travelled (VMT).

Preliminary Questionnaire Survey for the faculty members of SUST

We are going to conduct a study to develop a residential location choice model for University faculty members of Bangladesh. For this, we need some information regarding your present residential location, travel pattern, socioeconomic status etc. Your responses are very important for our research. Please write not applicable (N/A), if you feel any question is not related with you.

General Informations		
Your Name:		
Designation:		
Age:	<25 / 25-30 / 31-40 / 41-50 / 51-60 / >60	
Sex:		
Marital Status:	Married	Unmarried
Socio economic/Family status		
Spouse's occupation:		
Spouse's job location:		
No of kids:		
Kid1		
Age:	<5/ 5-10/ 10-15/ 15-20/>20	
Education level:	Primary/ Secondary/ Higher secondary/ Graduation/ Job	
Kid2		
Age:	<5/ 5-10/ 10-15/ 15-20/>20	
Education level:	Primary/ Secondary/ Higher secondary/ Graduation/ Job	
Monthly family income:		
Do you have any car?	Yes	No
If yes then how many cars do you have?		
Regarding Residential Location		
Housing location:	On campus	Off campus
Locality of your present residence (e.g. Upashar, Subidbazar, Campus, etc):		
Housing Category:	Family housing	Split or Single
Why do you choose off campus living facilities? (you can give multiple answers)	Unavailability of on campus living facilities / High rent / Far away from school facilities / Far away from spouse's job location / Own residence facilities / Others…….	
If split family, family housing location:		
Causes to lead split family: (you can give multiple answers)	Family wants to live at Dhaka/ Spouse's works place/ Children's education/ High standard living facilities/ Own residence facilities/ Low income/ Others...	
Regarding Travel behaviour		
Regarding Travel behaviour of you		
Travel Mode (most of the time) :	Private Car / University bus / CNG / Motorcycle / Rickshaw / Walk / Others…	
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…	
Travel time:		
Travel cost:		
Second mode in absence of 1st one:	Private Car / University bus / CNG / Motorcycle / Rickshaw / Walk / Others…	

Regarding Travel behaviour of Spouse	
Travel Mode (most of the time) :	Private Car / University bus / CNG / Office bus / Rickshaw / Walk / Others…
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…
Travel time:	
Travel cost:	
Second mode in absence of 1st one:	Private Car / University bus / CNG / Office bus / Rickshaw / Walk / Others…
Regarding Travel behaviour of kid 1	
Travel Mode (most of the time) :	Private Car / University bus / CNG / School bus / Rickshaw / Walk / Others…
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…
Travel time:	
Travel cost:	
Second mode in absence of 1st one:	Private Car / University bus / CNG / School bus / Rickshaw / Walk / Others…
Regarding Travel behaviour of kid 2	
Travel Mode (most of the time) :	Private Car / University bus / CNG / School bus / Rickshaw / Walk / Others…
Reasons for choosing this mode: (you can give multiple answers)	Low travel time / Low travel cost/ High frequency /Comfort / Privacy/ Others…
Travel time:	
Travel cost:	
Second mode in absence of 1st one:	Private Car / University bus / CNG / School bus / Rickshaw / Walk / Others…
Future Situation/ Stated preference	
Suppose that in near future there will be significant improvement at or near university campus in various sectors which will provide similar facilities as in Dhaka. For example, there will be standard school/ college/ university facilities (both Bengali and English medium), preference for spouse's job at or near university, professional work scope etc. Please consider the new situations and menion which residential location you will choose in that situations.	
Residential Location (Faciities which will lead shifting of family to Sylhet from Dhaka or others area)	
If standard school/ college/ University facilities (both Bengali and English medium) for your kids are developed in Sylhet city or branches of renowned academic institutions like Vikarurnesanoon school, Ideal School, Notordame College, North South University etc. are opened very close to your university area, Which decision will you take regarding your family living?	
Your family will be shifted to Sylhet	*They will stay at present location*
If spouse's job facility is provided at Sylhet or job transfer facility for spouse already in service is provided, Which decision will you take regarding your family living?	
Your family will be shifted to Sylhet	*They will stay at present location*
If your salary structure increases at different levels as stated below, in which situation will you shift your family to Sylhet ?	
Increase 20% / 30% / 40% / 50% / Never Shift	
Residential Location (Faciities which will lead faculty members using on campus family housing who are currently living off-campus at Sylhet)	
If sufficient housing facilities with better school facilities and shopping facilities near university campus are developed, which residential location will you choose?	
On-campus family housing / On-campus split housing / Off-campus family housing / Off-campus split housing	
If rent on University housing facility reduces as follows. In which situation will you choose on campus housing facility?	
30 % of house rent provided by govt. / 40 % of house rant provided by govt. / 50 % of house rant provided by govt.	
Which facilities can be significant for you to lead on campus family housing?	

Regarging your department		
It is difficult and time consuming to survey on all faculty members but for detailed survey we need few information regarding all of them. For this, we want to know some general informations regarding your colleagues from you. Please help us.		
Total number of faculty members :		
Active :		
On-leave :		
How many are unmarried ?		
How many lead split family (he/she lives in Sylhet and his/her family lives in Dhaka or other cities)?		
Do you know why do they maintain split family ?		

Thanks for your cordial cooperation

Appendix B

Final Questionnaire for DUET

Bangladesh University of Engineering and Technology (BUET)

Questionnaire Survey

Traffic congestion has become a serious problem in many cities of Bangladesh. Residential location significantly influences many of our travel decisions (e.g. when and where to travel, which mode to use, etc.) and has a direct effect on trip length and level of congestion.Therefore, modeling residential location choice is an important component of transport demand modeling.

The scope of this study is to develop a residential location choice model for faculty members of different universities in Bangladesh. Your responses are very important for our research.You can fill up the form in Bengali if needed. Please write not applicable (N/A), if you feel any question is not related to you.

All responses will be kept confidential and anonymous. Thanks in advance for your help.

1. Your designation a) Professor b) Associate Professor c) Assistant Professor d) Lecturer

2. Age (in years): a) < 25 b) 25-30 c) 31-40 d) 41-50 e) 51-60 f) > 60

3. Sex: a) Male b) Female

4. Marital Status: a) Married b) Unmarried

5. Total family members: ☐

6. Spouse's occupation: a) Employed b) Home Business Owner c) Housewife d) Not Applicable

7. No. of children: a) 0 b) 1 c) 2 d) 3 e) >3

8. Current education level of children

A.Child 1:a) <Primary b) Primary c) Secondary d) Higher secondary e) Undergraduate/Postgraduate f) In service

B.Child 2:a) <Primary b) Primary c) Secondary d) Higher secondary e) Undergraduate/Postgraduate f) In service

C.Child 3:a) <Primary b) Primary c) Secondary d) Higher secondary e) Undergraduate/Postgraduate f) In service

9. Monthly **family** income (in thousands of Taka): a) 20-30 b) 30-40 c) 40-50 d) 50-60 e) 60-70 f) 70-80 g) > 80

10. Number of private cars: a) 0 b) 1 c) 2 d) 3

Now we would like to ask you some questions regarding your residential location.

11. Locality of your present residence (e.g. Mohakhali, Mohammadpur, Shimultoli,Campus, etc): ☐

12. Housing category: a) Family housing b) Split (You and your family lives at different places) c) Other

13. Type of residence: a) Own house b) Own apartment c) Off-campus rented d) On-campus rented

14. If rented, then how much is the rent (in Taka)? a) <5000 b) 5000-7000 c) 7000-10000 d) 10000-15000 e) 15000- 20000 f) > 20000

15. The year when you moved to this location (e.g. 2000): ☐

16.Reason(s) for choosing this location (You can give multiple answers)

A. For family living at DUET (on-campus)

a) Office is at walking distance b) Convenient to fulfil university responsibilities c) Security d) Utility Services such as electricity, water supply etc. are good e) Low house rent f) I have no alternate residence g) Other

B. For family living at Gazipur(off-campus):

a) My extended family lives here (e.g. parents, siblings etc.) b) For my spouse's job c) Own residence d) Education of children e) Unavailability of on-campus living facility f) Mixed residence complex for all employees g) The buildings in the campus is of low standard h) Other

C. For family living at Dhaka/ Other cities (off-campus)

a) My extended family lives here (e.g. parents, siblings etc.) b) For my spouse's job c) Own residence d) Education of children e) For my professional work f) Better shopping, medical & other facilities g) Good transport connection to office is available h) Other

Now we would like to ask you some questions regarding your travel pattern.

17. Most frequently used mode to go to your university (Primary mode)

a) Private car b) CNG/Taxi c) Rickshaw d) Public Bus e) DUET Bus f) Maxi/ Tempo g) Train h) Walking i) Other

18. Reason(s) for using this mode (You can give multiple answers)

a) No alternate mode is available b) Low fare c) Faster d) Directly reaches to the destination e) Safe f) More comfortable g) Other

19. On a typical day, travel time to university using this mode: _____ hr _____ min

20. Travel cost : _____ tk/trip

21. Other available modes that link your residence with office (You can give multiple answers)

a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) DUET bus f) Maxi/ Tempo g) Train h) Walking i) None j) Other

If you are not married/ your spouse does not work please skip this section:

22. Spouse's job location (e.g. Mohakhali, Mohammadpur, Shimultoli,Campus, etc): _____

23. Mode of transport most frequently used to go to his/her job place

a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) DUET bus f) Maxi/ Tempo g) Train h) Walking i) Office bus/car j) Other

24. Travel time to go to his/her workplace using this mode: _____ hr _____ min

25. Travel cost : _____ tk/trip

If you have no children please skip this section:

26. Mode of transport most frequently used to go to school/ work

A.Child 1: a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) DUET bus f) School or college bus g) Maxi/ Tempo h) Train i) Walking j) Other

B.Child 2: a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) DUET bus f) School or college bus g) Maxi/ Tempo h) Train i) Walking j) Other

C.Child 3: a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) DUET bus f) School or college bus g) Maxi/ Tempo h) Train i) Walking j) Other

27. Travel time to go to school/ college using this mode?

A. Child 1: ☐ min B. Child 2: ☐ min C. Child 3: ☐ min

28. Travel cost :

A. Child 1: ☐ tk/trip B. Child 2: ☐ tk/trip C. Child 3: ☐ tk/trip

Now we would like to present you some future scenarios

These scenarios will include some additional facilities near the campus. For example, some future scenarios will include enough scope for professional works (e.g. consultancy, part-time job etc.), some will include new branches of famous school/ college/ private universities, some will include dual – career privileges (which means spouses will get preferential appointment at DUET). For each scenario compare the alternatives and state which option you would choose in that scenario.

29. Scenario 1

Attributes	Gazipur in Future	Dhaka/other cities
Childrens school & college facilities	Same as now	Same as now
Rent of university residence	Same as now	
Spouse job opportunity	Will get preferential appointment at DUET	
Professional work scope	Same scope of consultancy, part-time job etc. at Gazipur as in Dhaka	
Additional utility services	Branches of reputed private university (e.g. NSU, AUST)	

A. What type of residential option will you choose in Scenario 1?

a. Commute from Dhaka b. On-campus family housing c. On-campus split housing d. Off-campus family housing (other than Dhaka)

Please evaluate the following scenarios in the same manner

30. Scenario 2

Attributes	Gazipur in Future	Dhaka/other cities
Childrens school & college facilities	Branches of reputed English Medium Schools leading to GCSE (e.g. Scholastica)	Same as now
Rent of university residence	30% less than now	
Spouse job opportunity	Will get preferential appointment at DUET	
Professional work scope	Same scope of consultancy, part-time job etc. at Gazipur as in Dhaka	
Additional utility services	Same as now	

A. What type of residential option will you choose in Scenario 2?

a. Commute from Dhaka b. On-campus family housing c. On-campus split housing d. Off-campus family housing (other than Dhaka)

31. Scenario 03

Attributes	Gazipur in Future	Dhaka/other cities
Childrens school & college facilities	Branches of reputed Bangla Medium Schools (e.g. VNS, VNC, NDC, etc.)	Same as now
Rent of university residence	30% less than now	
Spouse job opportunity	Will get preferential appointment at DUET	
Professional work scope	Same scope of consultancy, part-time job etc. at Gazipur as in Dhaka	
Additional utility services	Branches of reputed private university (e.g. NSU, AUST)	

A. What type of residential option will you choose in Scenario 3?

a. Commute from Dhaka b. On-campus family housing c. On-campus split housing d. Off-campus family housing (other than Dhaka)

Thank you very much for your kind cooperation to make the research successful

Final Questionnaire for SUST

Bangladesh University of Engineering and Technology (BUET)

Questionnaire Survey

Traffic congestion has become a serious problem in many cities of Bangladesh. Residential location significantly influences many of our travel decisions (e.g. when and where to travel, which mode to use, etc.) and has an direct effect on trip length and level of congestion.Therefore, modeling residential location choice is an important component of transport demand modeling.

The scope of this study is to develop a residential location choice and mode choice model for faculty members of different universities in Bangladesh. Your responses are very important for our research.You can fill up the form in Bengali if needed. Please write not applicable (N/A), if you feel any question is not related to you.

All responses will be kept confidential and anonymous. Thanks in advance for your help.

1. Your designation a) Professor b) Associate Professor c) Assistant Professor d) Lecturer

2. Age (in years): a) <25 b) 25-30 c) 31-40 d) 41-50 e) 51-60 f) >60

3. Sex: a) Male b) Female

4. Marital Status: a) Married b) Unmarried

5. Total family members: ☐

6. Spouse's occupation: a) Employed b) Home Business Owner c) Housewife d) Not Applicable

7. No. of children: a) 0 b) 1 c) 2 d) 3 e) >3

8. Current education level of children

Child 1 :a) <Primary b) Primary c) Secondary d) Higher secondary e) Undergraduate/Postgraduate f) In service

Child 2 :a) <Primary b) Primary c) Secondary d) Higher secondary e) Undergraduate/Postgraduate f) In service

Child 3 :a) <Primary b) Primary c) Secondary d) Higher secondary e) Undergraduate/Postgraduate f) In service

9. Monthly **family** income (in thousands of Taka): a) 20-30 b) 30-40 c) 40-50 d) 50-60 e) 60-70 f) 70-80 g) > 80

10. Number of private cars: a) 0 b) 1 c) 2 d) 3 ; Number of motor cycle: a) 0 b) 1 c) 2 d) 3

Now we would like to ask you some questions regarding your residential location.

11. Locality of your present residence (e.g. Upashar, Subidbazar, Campus, etc): ☐

12. Housing category: a) Family housing b) Split (You and your family live at different places) c) Other

13. Type of residence: a) Own house b) Own apartment c) Off-campus rented d) On-campus rented

14. If rented, then how much is the rent (in Taka)? a) <5000 b) 5000-7000 c) 7000-10000 d) 10000-15000 e) 15000- 20000 f) > 20000

15. The year when you moved to this location (e.g. 2000): ☐

16.Reason(s) for choosing this location (You can give multiple answers)

For you/ your family living at SUST (on-campus)

a) Office is at walking distance b) Convenient to fulfil university responsibilities c) Security d) Utility Services such as electricity, water supply etc. are good e) Low house rent f) I have no alternate residence g) Other

For you/ your family living at Sylhet (off-campus):

a) My extended family lives here (e.g. parents, siblings etc.) b) Better shopping, medical & other facilities c) For my spouse's job d) For education of children e) Own residence f) Unavailability of on-campus living facility g) The buildings in the campus is of low standard h) My family prefers to live here i) Lower living cost j) Other

For your family living at Dhaka/ Other cities (off-campus)

a) My extended family lives here (e.g. parents, siblings etc.) b) For my spouse's job c) Own residence d) Education of children e) Better shopping, medical & other facilities f) Other

Now we would like to ask you some questions regarding your travel pattern.

17. Most frequently used mode to go to your university (Primary mode)

a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) SUST bus f) Maxi/ Tempo g) Motor cycle h) Walking i) Other

18. Reason(s) for using this mode (You can give multiple answers)

a) No alternate mode is available b) Low fare c) Faster d) Directly reaches to the destination e) Safe f) More comfortable g) Other

19. On a typical day, travel time to university using this mode: ☐ hr ☐ min

20. Travel cost : ☐ tk/trip

21. Other available modes that link your residence with office (You can give multiple answers)

a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) SUST bus f) Maxi/ Tempo g) Motor cycle h) Walking i) Other

If you are not married/ your spouse does not work please skip this section:

22. Spouse's job location (e.g. Upashar, Subidbazar, Campus etc): ☐

23. Mode of transport most frequently used to go to his/her job place

a) Private car b) CNG/Taxi c) Rickshaw d) Public bus e) SUST bus f) Office car/bus g) Maxi/ Tempo h) Motor Cycle i) Walking j) Other

24. Travel time to go to his/her workplace using this mode: ☐ hr ☐ min

25. Travel cost : ☐ tk/trip

If you have no children please skip this section:

26. Mode of transport most frequently used to go to school/ work

Child 1: a) Private car b) CNG/Tempo c) Rickshaw d) Public bus e) SUST bus f) School/college bus g) Walking h) Other

Child 2: a) Private car b) CNG/Tempo c) Rickshaw d) Public bus e) SUST bus f) School/college bus g) Walking h) Other

Child 3: a) Private car b) CNG/Tempo c) Rickshaw d) Public bus e) SUST bus f) School/college bus g) Walking h) Other

27. Travel time to go to school/ work using this mode?

Child 1: ☐ min Child 2: ☐ min Child 3: ☐ min

28. Travel cost:

Child 1: ☐ tk/trip Child 2: ☐ tk/trip Child 3: ☐ tk/trip

Now we would like to present you some future scenarios

These scenarios will include some additional facilities near the campus. For example, some future scenarios will include enough scope for professional works (e.g. consultancy, part-time job etc.), some will include new branches of famous school/ college/ private universities, some will include dual – career privileges (which means spouses will get preferential appointment at SUST). For each scenario compare the alternatives and state which option you would choose in that scenario.

Scenario 1

Attributes	Future scenario of or next to SUST	Sylhet and other city
Children school & college facilities	Same as now	Same as now
Rent of university residence	Same as now	
Spouse job opportunity	Will get preferential appointment at SUST	
Professional work scope	Same as now	
Additional utility services	Excellent medical facilities (e.g. branches of Appolo, Square, etc.)	

What type of residential option will you choose in Scenario 1?

a) On-campus family housing b) On-campus split housing c) Off-campus family housing d) Off-campus split housing

Please evaluate the following scenarios in the same manner

Scenario 02

Attributes	Future scenario of or next to SUST	Sylhet and other city
Children school & college facilities	Branches of reputed Bangla Medium Schools (e.g. VNS, VNC, NDC, etc.)	Same as now
Rent university residence	20% less than now	
Spouse job opportunity	Will get preferential appointment at SUST	
Professional work scope	Same as now	
Additional utility services	Branches of reputed private university (e.g. NSU, AUST, etc.)	

What type of residential option will you choose in Scenario 2?

a) On-campus family housing b) On-campus split housing c) Off-campus family housing d) Off-campus split housing

Scenario 03

Attributes	Future scenario of or next to SUST	Sylhet and other city
Children school & college facilities	Branches of reputed English Medium Schools leading to SSC/HSC (e.g. St. Joseph, VNS, VNC)	Same as now
Rent of university residence	30% less than now	
Spouse job opportunity	Same as now	
Professional work scope	Same as now	
Additional utility services	Big shopping malls (e.g. branches of Bashundhara Mall, Agora, etc.)	

What type of residential option will you choose in Scenario 3?

a) On-campus family housing b) On-campus split housing c) Off-campus family housing d) Off-campus split housing

Thank you very much for your kind cooperation to make the research successful