EXAMINING CHILDREN’S WEEKDAY ACTIVITY TRAVEL PATTERNS AND MODE CHOICE FOR SCHOOL TRIPS IN DHAKA CITY, BANGLADESH

by

Naznin Sultana Daisy

MASTER OF URBAN AND REGIONAL PLANNING

Department of Urban and Regional Planning
Bangladesh University of Engineering and Technology
Dhaka

January 2013
CANDIDATE’S DECLARATION

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.

____________________________________

Naznin Sultana Daisy
ACKNOWLEDGEMENT

I would like to express my deepest sincere gratitude to my supervisor Dr. Sarwar Jahan, Professor of Urban and Regional Planning Department, BUET, Dhaka for giving me a unique opportunity to work on such an important topic and also for his patient and circumspective guidance and affectionate encouragement. I consider myself fortunate to work under his supervision.

Simultaneity, I would like to express my special appreciation to my co-supervisor, Dr. Ahsanul Habib, Assistant Professor, Civil and Resource Engineering Department, Dalhousie University, Canada for his continuous guidance, invaluable suggestions, generous help and important acumen are greatly acknowledged. His keen interest on the topic and enthusiastic support on my effort was a source of inspiration to carry out the study. He has paid much of the invaluable time and the painstaking effort for the whole research.

I am grateful to Dr. Ishrat Islam and Dr. Shakil Akther for their continuous comments and guidance in the proposal preparation stage. I also thank Dr. Afsana Haque for her comments and guidance in proposal finalization.

I gratefully acknowledge that this research was funded by a Foreign Affairs and International Trade Canada (DFAIT) grant from the Canadian Bureau for International Education (CBIE).

I would like to thank Dr. Roxana Hafiz and Dr. ATM Nurul Amin for their valuable comments on draft thesis. I also thank Department of URP, CASR and BUET for their support with logistics and facilities to accomplish this study smoothly.

I highly appreciate principals and class teachers of the eight respective schools who helped me in getting my official permission for conducting survey in their domain.

I would like to thank and pay my heartiest gratitude to all the students and their parents who responded accordingly to carry out this research authentically.

Finally, I would like to express my special indebtedness to my family and friends whose continuous encouragement and support was unremitting source of inspiration for this work.
ABSTRACT

Analysis of travel pattern is an important research topic in the field of transportation engineering and urban planning, irrespective of developed and developing countries. It provides the background information necessary to better understand the complex relationship among urban structure, transportation system and people’s activity participation. The growing volume and complexity of urban travel in developing countries has become a major concern to transportation planners, service sponsors in urban areas, and policy makers. Designing transport strategies which meet the common political aims for the environment and the society requires a deeper insight into the routines of individual travel behavior. As a large proportion of population, children’s activity travel behavior is a paramount concern to be studied. On this regard, this study uses an activity-based travel diary survey dataset, which has been done between February 08, 2012 and February 28, 2012 and it generated a sample of 245 students in grades 6-10 in Dhaka Metropolitan Area, Bangladesh.

In order to explore tradeoffs among factors that affect the frequency of out-of-home physical activity including the use of active transportation this paper utilizes a Zero-inflated Poisson (ZIP) regression model. Additionally, parametric hazard models are estimated to examine the duration of physical activities. The results of the ZIP count model suggest that personal and household characteristics, built environment attributes, and time commitments for other mandatory and discretionary activities influence the frequency of participation. For example, an increase in the number of children in households, and the presence of sidewalks, increase the frequency of out-of-home out-of-school physical activities if everything else held equal. In contrast, travel time to school, presence of traffic intersections, and time commitment for tutoring sessions negatively affect activity participation. In terms of modeling duration of out-of-home physical activities, this study finds that a Weibull parametric hazard model outperforms a log-logistic model. The duration is influenced by socio-demographic characteristics, spatial context, and escort arrangements. For instance, car ownership and parental escorting increase the duration of physical activity. It offers an in-depth behavioral understanding of children’s physical activities, particularly in the context of a developing country, which is very limited in the existing literature.

This study also examined mode choice behaviour for school trips in Dhaka City, one of the densest cities of the world. A conventional random utility-based multinomial logit model (MNL), a Mixed Logit (RPL) and a Latent Class Model (LCM) are used to examine the factors affecting mode choices. The choice set includes four different modes: car, three wheel Pedal-powered vehicles (TWPV), walk, and bus. These models were generated for school trips to determine factors affecting trip generation. The models results reveal that increase in travel time decreases the probability of choosing alternative modes. In addition, socio-economic factors such as household monthly income, home ownership, and number of children at household play vital role in choosing auto for school trips. Similarly, presence of intersection nearby the home neighbourhood reduces the probability of walking. It is also found that personal and household attributes, and transportation system characteristics has significant influence on children’s mode choices for school trips.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgement</td>
<td>i</td>
</tr>
<tr>
<td>Abstract</td>
<td>ii-iii</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>iv</td>
</tr>
<tr>
<td>List of Tables</td>
<td>viii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>ix</td>
</tr>
<tr>
<td>List of Maps</td>
<td>ix</td>
</tr>
</tbody>
</table>

## CHAPTER ONE: INTRODUCTION 1-5

1.1 Background of the Study 1  
1.2 Objective 4  
1.4 Limitation 5  
1.5 Organization of the Dissertation 5

## CHAPTER TWO: LITERATURE REVIEW 6-15

2.1 Introduction 6  
2.2 Activity-based Travel Demand Modeling 6  
2.3 Children’s Activity Pattern in Activity Based Travel Demand Modeling 7  
2.4 Physical Activity Related Studies and Findings 8  
2.5 Models Selection for Examining Physical Activity of Children 10  
2.6 Mode Choice Related Studies and Findings 12  
2.7 Models Selection for Investigating Mode Choice for School Trips 13  
2.6 Conclusion 15

## CHAPTER THREE: METHODOLOGY 16-26

3.1 Introduction 16  
3.2 Formulation of Objectives 16  
3.3 Literature Review 16
3.4 Study Design 16
3.5 Stratified Random Sampling 16
3.6 Data Collection 19
3.7 Data Preparation 20
  3.7.1 Data Preparation for Model of Physical Activity 20
  3.7.2 Data Preparation for Mode Choice Models 20
3.8 Methods Used for Empirical Studies 21
  3.8.1 Models for Examining Physical Activity 21
  3.8.2 Models for Modeling Mode Choice for School Trips 22
3.9 Sample Characteristics 23
3.10 Modeling 26
3.4 Conclusion 26

CHAPTER FOUR: DESCRIPTIVE ANALYSIS OF CHILDREN’S ACTIVITY PATTERNS 27-40

4.1 Introduction 27
4.2 Activity pattern 28
4.3 Activity Typology 28
4.4 Participation Rates and Duration for Activities 29
  4.4.1 Major Activity Types 29
    4.4.1.1 Mandatory Activity 30
    4.4.1.2 Discretionary Activity 30
    4.4.1.3 Maintenance Activity 30
  4.4.2 Duration Dimension of Activities 31
  4.4.3 Descriptive Discussion on Duration of Activities 32
    4.4.3.1 Mandatory Activities 32
      4.4.3.1.1 Sleeping 33
      4.4.3.1.2 Attending School 33
    4.4.3.2 Discretionary Activities 32
      4.4.3.2.1 Non-Structured Recreation Activities 32
      4.3.2.2.2 Organized Recreational Activities 33
      4.3.2.2.3 Spiritual/Social Activity 33
4.3.2.4 Studying/Reading at home 34
4.3.2.5 Tutoring 34
4.4.3.2 Maintenance Activities 35
4.4.3.3.1 Personal care 35
4.4.3.3.2 Meals 35
4.4.3.3.3 Get ready for school 35
4.5 Companionship Arrangement of Activities 35
4.5.1 Number of Accompaniment 35
4.5.2 Relationship with the Accompaniment 35
4.5.3 Accompaniment Arrangement for out-of-home Activities 35
4.6 Travel Dimension 38
4.6.1 Overall Modal Share 38
4.6.2 Modal Share for Out-home activities 39
4.7 Conclusion 40

CHAPTER FIVE: EXAMINING FREQUENCY AND DURATION OF OUT OF HOME PHYSICAL ACTIVITY 41-49
5.1 Introduction 41
5.2 Summary Statistics 41
5.3 Discussion of Models 43
5.3.1 Modeling Process 43
5.3.2 Model Results of the Frequency of Physical Activity Participation 44
5.3.3 Model Results of the Duration of Physical Activity 48
5.4 Conclusion 51

CHAPTER SIX: EXAMINING THE FACTORS OF MODE CHOICE FOR SCHOOL TRIPS 52-65
6.1 Introduction 52
6.2 Summary Statistics 54
6.3 Discussion 56
6.3.1 Multinomial Logit Model (MNL) 56
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3.2 Mixed logit Model (RPL)</td>
<td>59</td>
</tr>
<tr>
<td>6.3.3 Latent Class Model (LCM)</td>
<td>60</td>
</tr>
<tr>
<td>6.4 Conclusion</td>
<td>64</td>
</tr>
</tbody>
</table>

**CHAPTER SEVEN: MAJOR FINDINGS AND RECOMMENDATION**  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Major Findings</td>
<td>66</td>
</tr>
<tr>
<td>7.1.1 Findings from Activity Pattern Analysis</td>
<td>66</td>
</tr>
<tr>
<td>7.1.2 Findings from Physical Activity Analysis</td>
<td>67</td>
</tr>
<tr>
<td>7.1.2 Findings from Mode Choice Analysis</td>
<td>67</td>
</tr>
<tr>
<td>9.2 Recommendation</td>
<td>68</td>
</tr>
<tr>
<td>9.3 Conclusion</td>
<td>69</td>
</tr>
</tbody>
</table>

**Reference**  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
</table>

**Appendices**  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix A: Parents Questionnaire Form</td>
<td>83</td>
</tr>
<tr>
<td>Appendix B: Students Travel Diary</td>
<td>86</td>
</tr>
</tbody>
</table>
List of Tables

Table 3.1: List of Surveyed Schools 17
Table 3.3: Household Socio-demographic Sample Characteristics 25
Table 5.1: Summary Statistics of Variables used in Empirical Models of Physical Activity 42
Table 5.2 Parameter Estimation Results of Zero Inflated Poisson Regression Model for the Frequency of Physical Activity Participation 47
Table 5.3: Model Results of Parametric Hazard Models for the Duration of Physical Activity 50
Table 6.1: Summary Statistics of Explanatory Variables used in the Models 54
Table 6.2: Parameter Estimation Results of MNL, Mixed Logit and LCM for the Mode Choice Behaviour 62

List of Figures

Figure 3.1: Flow Chart of Data Collection and Preparation Process 19
Figure 3.2: Models used for Empirical Studies 22
Figure 3.3: Age distribution of the children in the Sample 24
Figure 3.4: Gender of the children in the Sample 24
Figure 4.1: Activity Typology along with Nature of the Activities 29
Figure 4.2: Participation in Major Activity Types 30
Figure 4.3: Participation Rate in All Activities Regards to Major Activity Types 31
Figure 4.4: Activity Wise Duration for all activities 31
Figure 4.5: Accompanishments for Out-of-home Activities 36
Figure 4.6: Accompanient Arrangement for out-of-home Activities 36
Figure 4.7: Accompanient Arrangement for All Activities 37
List of Maps

Map 3.1: Map Showing the Location of Selected Schools 18
CHAPTER ONE: INTRODUCTION

1.1 Background of the Research

Transportation researchers are increasingly becoming interested in the study of physical activity participation and time-use because of paradigm shifts towards activity-based travel behavior analysis, and the potential association between built environment and levels of physical activity participation (Sener et al., 2011; Handy et al., 2005). The focus of analysis in existing activity-based research, however, has predominantly been on the activity-travel patterns of adults (Copperman & Bhat, 2007). Children exhibit unique characteristics in activity participation and travel, for example, participating in many fixed activities such as attending tutoring session, and requiring escort arrangements for out-of-home activities. Therefore, children should be treated as a distinct group, and in-depth investigations are required to understand the determinants of their physically active travel patterns and activities (Copperman & Bhat, 2010). Children’s travel needs affect the travel patterns of other family members. Children depend, to a large extent, on household adults or other adults to drive them to activities. Such serve-passenger activities constrain adults’ activity-travel patterns in important ways. Similarly, in the case of a parent dropping a child off at school, it is not the parent’s activity but the child’s activity, and its location that determines the temporal and spatial dimensions of the trip (Kitamura, 1983). Specifically, children’s activity-travel patterns contribute directly to travel by non-drive alone modes of transportation. However, until recently the focus of analysis in existing activity-based research has almost exclusively been on the activity-travel patterns of adults (16-18 years of age and older; for instance, see Bhat and Srinivasan, 2005; Koppelman and Gliebe, 2002; Bhat and Misra, 2002). Thus, many activity-based travel demand modeling systems currently in practice or in development take a limited approach to modeling the patterns of children.
Understanding the overall time-use patterns of children, and the context of their travel, is important for promoting the health of children. Children’s non-motorized travel and physical activity participation is an issue that is gaining increasing attention at the interface of the transportation and public health fields, because of the positive correlation between physically active lifestyles and the development of strong, healthy, and intelligent children (CDC, 2006).

In recent years, there has been considerable debate regarding the impacts of the design of the transportation infrastructure (and built environment in general) on participation in physical activity (see Transportation Research Board and Institute of Medicine, 2005). It has been argued that suburban sprawl, low density, and segregated land use configurations, and the highly automobile-oriented transport infrastructure (with limited sidewalks and bicycle paths), make it extremely difficult for individuals of all ages to use non-motorized modes of transportation and engage in physically active pursuits (see Frank et al., 2003).

Within the realm of children’s travel, mode choice to school has received the most substantial attention. Children are walking and biking to school at a much lower rate than forty years ago. Walking and biking to school made up 42% of school trips in 1969 compared to only 13% of school trips in 2001 (McDonald, 2005). As a result of the potential link between transportation and public health, transportation and public health professionals are interested in understanding the attributes (such as demographic characteristics, built environmental attributes, etc.) that have an impact on physical activity participation to promote healthy lifestyles, particularly in children (Sallis et al., 2000).

Although several authors have recently investigated children’s activity patterns in the context of developed countries, studies on children in the developing countries are very limited. Given the changing complexity of urban life in many developing countries, it is necessary to examine how children are participating in activities within that context. Particularly, recent economic growth and changing family structures in many cities in
developing countries are altering the pace of people’s lifestyles and activity patterns which are affecting children’s activity participation and health.

Dhaka, the capital city of such rapid growing developing country, is dominant in terms of population concentration, economy, trade and commerce, education, and administration of the country. It is the prime player in the transport sector because more or less half (more than 44% of country’s all vehicles) of the total transport fleets (over 77% cars, 87% taxi, 68% microbus, 40% trucks) of the country are plying on its road surface with higher intensity (BRTA, 2007). Dhaka’s transport environment is characterized by mixed-modes transports using the same road space, traffic congestion, delays, mismanagement, conflict of jurisdictions, poor coordination among organizations and increasing environmental problems. The economic loss due to congestion in Dhaka City was estimated at $140million per annum in major arterials and corridors (DCC, 2007). Whereas, air pollution results from vehicle emissions are increasingly being recognized as the dominant cause of health problems in Dhaka City (Bhuiyan, 2001). Road traffic accident is also an important problem due to rapid motorization and Dhaka is accounted for 23% of country’s road accidents (Hoque et al, 2006). Available information indicates that pedestrians are involved in half of all road collisions in Dhaka and two-thirds of all traffic related fatalities are pedestrians. Non motorized passengers are the next vulnerable road user in Dhaka involving 18% of accidents. All these factors along with complexity of modern life, changing mode of family mobility as non-active and car oriented which directly affects children’s travel patterns through immaturity and dependency on adults (Burgmanis, 2012). Increase in number of children being driven to school may seem insignificant in term of the overall transportation issues in Dhaka City, but school trips represent a significant proportion of peak hour trips in Dhaka City as the number of students up to higher secondary level is 31.5% of the total population of the city).

Nevertheless, little is known about children’s activity and travel patterns in such high-density cities of emerging economies. Recent evidence suggests that rapid densification of cities is reducing public space and environments conducive to walking in many
neighborhoods of many populous cities. Traffic congestion, pedestrian safety, and personal security concerns further restrict children’s use of physically active transportation and engagement in out-of-home physical activities. In this context, this study attempts to fill some gaps in understanding weekday activity patterns and travel behavior of children in Dhaka City, which is one of the megacities in the world.

1.2 Objective

The analysis of children’s activity-travel patterns and time-use has been gaining increasing attention in a variety of fields, driven primarily by three main considerations: 1) Understanding children’s activity-travel behavior; 2) Promoting the health of children by increasing participation in physically active activities and non-motorized travel; and 3) Encouraging children’s participation in developmentally beneficial activities. While the results of this thesis will contribute knowledge to all three aspects, the focus of this research is on the second aspect, which is to examine children’s activity pattern along with concentration on physical activity participation and active traveling. Hence the objectives of this study are as follows:

i. Descriptive analysis of children’s activity travel patterns

ii. Examining frequency and duration of out of home physical activity

iii. Examining the factors of mode choice for school trips

First objective focuses on unfolding children’s weekday activity typology with respect to duration, accompaniment arrangement, location, transport etc dimensions. Second objective intended to reveal the determinant factors of participation rate in physical activity and time spent in physical activity in a weekday with empirical models. Subsequently, third objective concentrates on the tradeoffs among determinant factors of mode choice for school trips with empirical models.
1.3 Limitation

The study has certain limitations. Parents’ detailed activity patterns (except information on escort arrangements) have not been collected in order to reduce burdens on respondents. Future studies should consider collection of these types of information since children’s activity participation is closely related with the availability of time/schedule of adults. In addition, due to small size of the sample the study could not separately examine active out-of-home activities and active travel on journeys to evaluate if different factors influence each of these. Furthermore, this study could not examine day-to-day variation of activity participation given a 24-hour of activity diary data. It will be very interesting if a subsequent study focuses on duration analysis for the multi-week period in the context of a developing country through a panel survey. However, it could be challenging given the small sample size. It would be very useful if a larger dataset can be examined.

1.4 Organization of the Thesis

The rest of this thesis is organized as follows. Chapter 2 reviews previous research on the dimensions characterizing children’s activity-travel patterns and discusses areas that warrant further research. Chapter 3 identifies the data source used in the exploratory and empirical studies, describes the sample preparation procedure, and presents sample descriptive statistics. Chapter 4 describes the reasoning behind models selection for physical activity examining and mode choice investigating. Chapter 5 and Chapter 6 undertake an exploratory analysis of the overall time-use of children in different types of activities, as well as on several dimensions characterizing the context of activity participation. Chapter 7 examines the determinants of frequency and duration of physical activity participation. Chapter 8 analyzes children’s mode choice for school trips through empirical modeling. Finally, Chapter 9 concludes the paper by discussing the major findings of this research effort and their implications in policy making and by identifying the need and opportunities for further research in the field of children’s travel behavior analysis.
CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the idea of activity based travel demand modeling and also in case of children. The rest of the chapter describes the findings and gaps in current literature related to physical activity frequency and duration modeling and modeling children’s mode choice for school trips.

2.2 Activity-based Travel Demand Modeling

The vast majority of transport planning in urban areas in USA and rest of the world is based on Urban Transport Planning System (UTPS). UTPS is a four stage aggregate model which divides analysis area into some sub-regions and predicts zone wise trip generation. Hence these models failed to recognize the existence of linkages among trips, and between trips and the activity participation of an individual. To accommodate all these cons discrete choice models were introduced which predicts travel as a derived demand from an individual’s socio-economic characteristics and the relative attractiveness of the option (Ortuzar and Willumsen, 1990). It is currently well recognized, among transportation planning professionals, that activity-based travel demand modeling is conceptually more appealing compared to the traditional trip-based (four-step) approach to travel demand analysis (Bhat and Koppelman, 1999; Kitamura, 1988; Axhausen and Garling, 1992). The activity-based approach treats travel as a demand derived from the desire and need to participate in activities. Therefore, the activity-based approach attempts to capture the behavioral basis behind households’ and individuals’ decisions to participate in specific activities at certain times and places.

An individual’s decision regarding participation in an activity is not made independently of other activities and other people’s activity-travel patterns. Therefore, the activity-based approach recognizes the need to capture the sequencing or patterns of activity
behavior, over an entire day or longer, while also taking into account other household members’ activity-travel patterns. The activity-based approach to travel analysis adopts a holistic framework which views individuals and households as the decision-making unit, focuses on the sequences of behavior, examines the timing and duration of activities and travel, incorporates spatial, temporal and inter-personal constraints, and recognizes the interdependence of activities and individuals.

This holistic approach to modeling activity-travel behavior is well suited to capture the results of congestion management policies, such as HOV lanes, congestion pricing, telecommuting, and flexible work schedules, as well as to more accurately model the choice of individuals to travel via specific modes of transportation. For example, an individual is less likely to use transit to reach a desired activity, and s/he is less likely to take advantage of travel demand management programs, such as carpooling, if s/he needs to make a stop on the way to the activity (Strathman et al., 1995; Rosenbloom and Burns, 1993). However, more than 7 million households contain working parents who drop off or pick up their children on the way to or from work, and, therefore, make a stop on the way to work (McGuckin and Nakamoto, 2004). If the linkages between parents’ and children’s activity-travel needs are not taken into account, then travel demand models may inaccurately predict the number of transit or HOV trips. The above example highlights the importance of explicitly modeling children’s activity-travel patterns within activity-based travel demand models.

2.3 Children’s Activity Pattern in Activity-Based Travel Demand Modeling

While the benefits of activity-based analysis are well known, the development and implementation of comprehensive activity-based travel demand modeling systems are still ongoing efforts. Within the last ten years, various activity-based modeling systems have been designed for metropolitan planning organizations within the United States. These micro-simulation systems attempt to replicate the decision mechanisms underlying activity engagement and travel of every individual and household within an entire metropolitan area.
Since most previous research in the area of activity-based analysis has focused on the patterns of adult workers and non-workers, many of these modeling systems take a limited approach to modeling the patterns of children and make many simplifying assumptions. For instance, the earliest versions of activity-based modeling systems did not model children at all, including the Portland METRO system formerly in implementation (Bowman et al., 1999). Some modeling systems classify activity types into three main activity categories: mandatory activities, maintenance activities, and discretionary activities (see Vovsha et al., 2003). These activity categories are assigned a scheduling priority with mandatory activities taking precedence over maintenance activities and maintenance activities taking precedence over discretionary activities.

In addition, current activity-based travel demand modeling systems contain an activity type that groups all recreational pursuits into one group, labeled a discretionary activity or recreational activity. In these systems, extracurricular activities are classified as a recreational activity, even though they have spatial and temporal fixities that more closely resemble a mandatory activity. This category becomes very broad and diverse when it is applied to children. For example, the social/recreational category would include attending music lessons, going to a friend’s house after school, and free-time playing at the park. All of these activities vary quite differently in their priority-level, intra-household needs, durations, and spatial and temporal flexibility.

### 2.3 Physical Activity Related Studies and Findings

The physical and psychosocial well-being of children is challenged by the decline in children’s involvement in physical activities in recent years (Fox & Riddoch, 2000). Since 1970s the percentage of children who are overweight has more than doubled, and the rates among adolescents have more than tripled in the United States (Hedly et al., 2004). The American Academy of Pediatrics recommends that children be physically active for at least sixty minutes per day (Pediatrics, 2009), which could include structured activities such as sports and school-based physical education classes or activities promoted through an active lifestyle, including outdoor play and walking or
biking for daily travel. However, studies suggest that a significant percentage of school-aged children fail to meet this recommended daily physical activity level in developed countries, including the US (Fox & Riddoch, 2000), Canada (Rainhman et al., 2012), and Australia (Ziviani & Scott, 2004). In developing countries, due to rapid urbanization and increased competition for land, open spaces and playfields are disappearing, and are being replaced by different profit generating land uses (Ahmed & Sohail, 2005). Places for children’s outdoor recreation are shrinking at a fast pace, reducing the opportunities for out-of-home physical activities. Recent economic growth and increased auto ownership are further influencing the way children are used to traveling to school and to other activities. Particularly, the changing structure of family life patterns (for instance, dual workers, longer work-hours) are negatively affecting children’s opportunities to play outdoors and to use active transportation since they both require suitable accompaniment arrangements (Ahmed, 2010). Increased traffic congestion, road safety issues, and personal security concerns are also possibly contributing to the reduced amount of out-of-home activities in exchange for in-home recreational activities.

Copperman and Bhat (2004) argue that most children (below 16 years of age) do not have a choice to drive and do not put extra cars in the transportation network; hence presumably less attention has been given to the modeling of children’s activity participation and travel patterns.

Several recent studies contribute to the analysis of children’s activity patterns that include children’s participation in leisure activities (Sener et al., 2008), weekend physical activities (Copperman & Bhat, 2007), discretionary activities (Sener & Bhat, 2007), and teenagers’ recreational activities (Bhat et al., 2010). Earlier research also examines children’s out-of-home time use (Huebner & Mancini, 2003) as well as the use of active transportation, specifically with regard to the modal choice to school (McMillan, 2007). Copperman and Bhat (2007) find that children spent on average 3.5 hours on recreational activities during weekdays. Another study suggests that almost 26% of students in grades 9-12 do not participate in any form of extra-curricular activities after school (Huebner & Mancini, 2003). Sener and Bhat (2007) investigate
children’s discretionary leisure activity engagements. The study suggest that in-home passive activities account for the largest amount of time spent at home that include watching television, playing video and computer games, and communicating via electronic devices.

Many studies establish linkages between children’s physical inactivity to the conditions at home, the built environment (e.g. walkable streets), and the availability of outside facilities for physical activity within reasonable distances (Dunton, 2012). The lifestyle of children is becoming more sedentary as a result of technological changes. The internet, computer, video-games and hand-held electronic devices are supplanting time devoted to structured and spontaneous physical activities outside the home (Anderson et al., 1998). Levels of physical activities are also influenced by accompaniment arrangements, road safety, and personal security issues for children. Parents are allowing children to stay home instead of engaging in outdoor activities, particularly if the neighborhood is not conducive to walking (Kimbro et al., 2010). Moreover, longer distance from home to other activity locations reduces the probability of the use of active transportation, including walking and biking (Frank, 2000). Time-budget is also an issue, since children need to participate in more fixed organized activities after school (such as homework) than the adults. Given the complexity of the factors that might affect children’s physical activities, further research is required to better understand physical activity participation.

In general, children’s physical activities are investigated using information on time-use for structured and unstructured physical activities recorded in activity diary surveys. In contrast, when activity-based data is not available, only the use of active transportation is investigated (Cao, 2006). This study however combines these two elements, representing both types of physical activity engagements.

### 2.4 Models Selection for Examining Physical Activity of Children

The body of recent activity-based travel behavior research is enormous in both the North American and the European contexts. Literature on the participation and time-use of
different types of activities include the home-stay duration of in-home activity episodes (Mannering et al., 1994), mandatory skeletal activities (Habib & Miller, 2006), shopping (Bhat, 1996), inter-shopping (Bhat et al., 2004), out-of-home non-work activities (Damm, 1980), recreation (Bhat & Gossen, 2004), and social activities (Lee & Timmermans, 2007). Several studies investigate the time use of multiple activities of considering the total time allocation for all activities (Spissu et al., 2009) as well as modeling of joint activities (Gliebe & Koppelman, 2002). Additionally, activity generation and scheduling processes are investigated in order to micro-simulate activity patterns (Auld & Mohammadian, 2012). Broadly speaking, current activity-based transportation research follows two major streams: (a) the instances and time allocation of individuals (Mannering et al., 1994; Habib & Miller, 2006; Lee & Timmermans, 2007; Spissu et al., 2009), and (b) activity generation/scheduling models (Auld & Mohammadian, 2012). The majority of studies, however, focus on modeling adults’ activities only. The main purpose of modeling activities is to contribute in developing activity-based travel models. Since children are often required to be chauffeured by adults, perhaps modeling activity generation and the scheduling process of the adults has been given higher priority in the earlier studies.

Several methodological approaches have been used in the literature in activity analysis. Sener and Bhat (Sener & Bhat, 2007) have proposed a discrete-continuous modeling method, which requires comprehensive amount of data (such as in-home and out-of-home time allocation as well as detailed travel attributes for all types of activities), which is difficult to obtain for Dhaka City. For modeling single-type of activities, several authors used count data models such as Poisson regression models (Ma & Goulias, 1999) to explain the frequency of activity participation. Due to the existence of excessive zeros (i.e. no participation in physical activities), this chapter utilizes a Zero-Inflated Poisson (ZIP) model. On the other hand, a proportional hazard model (PHM) is the most widely used model in activity duration analysis. Previous transportation studies have provided considerable evidence that the assumption of a proportional effect within the PHM is violated (Lee & Timmermans, 2007). As such this chapter examines a
parametric accelerated failure-time (AFT) hazard model. Applications of such models are still limited in transportation and related fields, specifically in the modeling of children’s physical duration. The next section sets out the methodology used in this chapter.

2.5 Mode Choice Related Studies and Findings

Mode-specific trip rates, individual mode split or mode specific travelled distances has been studied in travel mode choice studies in trip-based models (e.g. Vance et al., 2005) and individual-based models (e.g. Cao et al., 2009). Many empirical studies show the interrelations between travel mode choice and distances, built environment, socio-economic profile of the users, attributes of the modes etc (see for overviews and empirical studies Cervero, 2002; Schwanen et al., 2004; Guo and Chen, 2007). Cities of developing countries being characterised with high density population and high mixed land use pattern are more prone to traffic congestion and air pollution due to continuing rapid growth of their population which increases the demand of mobility and modes (Schafer, 1998; Afroz et al., 2003). Accordingly, traffic congestion brings economic loss and environmental degradation. It is particularly true for cities of developing countries like Bangladesh.

Though parental safety concerns such as traffic, crime and travel distance are associated with inactive commuting to school (Black et al., 2001; Boarnet et al., 2005), factors such as components of built environment such as the presence of sidewalk, bike lanes are positively associated with walking or biking to school as well as active commuting to school (Timperio et al., 2004; Ewing et al., 2004; McMillan, 2003), whereas children from high density areas are more likely to use non-motorized modes (McMillan, 2003; McDonald, 2005). Another contributing factor to inactive commuting to school is the increasing travel distance between home and school (Godfrey et al., 1998; McMillan, 2003; McDonald, 2005). In case of developing countries like Bangladesh long distance has been triggered by terrific traffic congestion and result in longer travel time. Characteristics of child like age, gender also have significant influence on mode choice.
for school trips (McDonald, 2005; Vovsha and Peterson, 2005, Guo et al., 2005). Household characteristics like presence of multiple number of child at households has a positive influence (McDonald, 2005; Guo et al., 2005; McMillan, 2003) whereas higher income or auto ownership exerts a greater probability of travelling by car (DiGuiseppi et al., 1998; Vovsha and Peterson, 2005, Guo et al., 2005). Some other factors such as the presence of working mother (DiGuiseppi et al., 1998), higher monthly income (McDonald, 2007), adverse weather conditions (Muller et al., 2008) have negative impacts on active commuting to school.

Though school trips are the most universal opportunity for incidental physical activity among children (Pediatrics, 2009) but motorized mode use for school trips is promoting future unsustainable travel mode choice (Line et al, 2010). On the contrary, walking or biking to school trips increases physical activity and reduces health related problems (Kerr et al., 2005; Alexander et al., 2005), but school travel patterns, mobility, health and overall physical activity as well as overall life style has been changed due to the dramatic increase of car use for daily trips to school over the last 15-20 years (McDonald, 2007). Apart from, driving to school increases traffic congestion and environmental pollution while at the same time limits children’s independent mobility and cognition of neighbourhood (DiGuiseppi et al, 1998). A study on four schools in Dhaka city also found, due to safety and security concern of parents, the rate of parental escorting is as high as 55 percent and due to the absence of school zone boundary, more than 60% students travel more than 1.00 Kilometer for schooling (Daisy et al., 2011).

### 2.6 Models Selection for Investigating Mode Choice for School Trips

From the literature review, it has been found that a wide variety of factors influence school mode choice for children. Though mode choice models for children’s travel behaviour are few and mostly recent but empirical results show that home to school distance, socio-economic characteristics, built environments attributes, household characteristics, etc. Previously researchers worked on whether or not to walk or bike without acknowledging public transport and school bus. Mitra et al. (2010) used spatial
auto correlation measures for identifying high walking zones; Vovsha and Peterson (2005) and Guo et al. (2005) used CEMDAP model to accommodate interdependencies between activity travel pattern of children and parents. Ulfarsson and Shankar (2008), attempt to capture correlations between alternatives using a covariance heterogeneity specification. Other researchers used MNL model for measuring relative influence and tradeoffs among factors of children’s mode choice for school trips (McDonald, 2007). Although multinomial logit model (MNL) provided the foundation of discrete choice modeling but it’s assumption of independence form irrelevant alternatives motivated researchers to consider alternative specifications (McFadden and Train, 2000). Whereas mixed logit model accommodates heterogeneity across respondents through expressing the parameters of the random distribution as a function of covariates and latent class model (LCM) also accommodates heterogeneity across respondents but with class allocation model (Greene and Hensher, 2003). The vector of taste coefficient in mixed logit follows a random distribution taste that varies across respondents not across choices for the same respondent, but in class allocation model (LCM), tastes across respondents are accommodated by making use of separate classes with different values for the vector of taste coefficients (Hess et al., 2011). In mixed logit, attributes very across alternatives while the estimated coefficients stay constant across alternatives but in LCM attributes normally stay constant across classes while the parameters vary across classes. Mixed logit provides random representation of taste heterogeneity, but in LCM, taste heterogeneity is accommodated as a mixture of deterministic and random approach. Due to the socio-economic heterogeneity and complex context of the developing world, mixed logit and LCM models are attempted to address this heterogeneity among respondents. A study by Daisy et al. (2011) attempts multinomial logistic regression model for modeling mode choice for school trips. Thus, this study aims to fill the gap in the study of children’s mode choice by accommodating activity linkages in context of Dhaka City while at the same time representing the continuous and discrete heterogeneity of some influential factors using mixed logit and latent class model (LCM).
2.7 Conclusion

From the above discussion it is evident that activity-based travel behavior research is limited in the context of cities located in the developing countries (such as Dhaka City), children’s activity patterns and travel behaviors are mostly unknown. Although several authors have recently investigated children’s mode choice for school trips in the context of developed countries, studies on children in the developing countries are very limited. Whereas considering the complexity of urban life, rapid economic growth and increasing traffic congestion, it is necessary to examine what factors are affecting mode choice and participation in physically active out-of-home activities of children within that context. This study attempts to fill some gaps, mainly through investigating the determinants of frequency and duration of children’s physical activity participation and mode choice for school trips along with the detail weekday activity scheduling.
CHAPTER THREE: METHODOLOGY

3.1 Introduction

The research has been conducted following a methodology with conformity to the scopes and objectives of the study. The methodology is described in detail as below:

3.2 Formulation of Objectives

Contextualizing the current fast pace of shrinkage of open space, play fields and parks, this study intended to explore current activity pattern, level physical activity and mode choice for school trips among children of Dhaka City. Based on this motivation, three research objectives have been formulated.

3.3 Literature Review

Literatures on children’s activity patterns, physical activity, active travel, activity based modeling etc have been reviewed comprehensively for this study.

3.4 Study Design

For obtaining the objectives, depending on the literature review, co-ordination schema for the study has been designed. Based on the schema, questionnaire for parents and travel diary for weekday activities of children has been prepared.

3.5 Stratified Random Sampling

In Bangladesh, up to college level study, schools and colleges can be divided in several ways. Based on the ownership pattern, there are two kinds of schools: public and private schools. On the other hand, based on the medium of education, schools can be sub-divided into two segments, for example Bengali medium schools and English medium schools. For this study, a stratified random sampling method was used to recruit participants in the survey. First based on the medium of instructions, only Bengali
medium schools were considered. This is due to the lacking of detail information of school enrolment among English medium schools. Then, from ten zones of Dhaka City Corporation (DCC), eight schools having zone wise highest number of students have been selected as the sample schools for this study (Table 3.1 & Map 3.1). In this case, both public and private schools were considered based on their number of students enrolment. Then, schools selection also have been done on it’s type (e.g. Girls, boys and co-education) so that complete mixture of both male and female students can be gathered for the study. Selection process also maintains equal mixture of schools from two parts of DMA (north and south). Upon approval from administrations of the selected schools, a of 15 to 20 minutes presentation on how to conduct the survey was made among the students of class six to ten. Then, the participants were randomly recruited with the help of class teachers based on their willingness to participate.

Table 3.1: List of Surveyed schools

<table>
<thead>
<tr>
<th>Institute Name</th>
<th>Thana Name</th>
<th>Zone</th>
<th>Student</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viqarunnisa Noon School &amp; College</td>
<td>Ramna</td>
<td>5</td>
<td>6,084</td>
<td>Girls</td>
</tr>
<tr>
<td>Motijheel Model High School &amp; College</td>
<td>Motijheel</td>
<td>4</td>
<td>4,846</td>
<td>Co-education</td>
</tr>
<tr>
<td>Monipur High School</td>
<td>Mirpur</td>
<td>7</td>
<td>3,896</td>
<td>Co-education</td>
</tr>
<tr>
<td>Saleha High School</td>
<td>Lalbagh</td>
<td>3</td>
<td>2,219</td>
<td>Co-education</td>
</tr>
<tr>
<td>M.D.C. Model Institute</td>
<td>Mirpur</td>
<td>8</td>
<td>1,645</td>
<td>Co-education</td>
</tr>
<tr>
<td>Ahmed Bawany Academy (School &amp; College)</td>
<td>Kotwali</td>
<td>2</td>
<td>1,553</td>
<td>Co-education</td>
</tr>
<tr>
<td>Residential Model School &amp; College</td>
<td>Mohammadpur</td>
<td>6</td>
<td>1,472</td>
<td>Boys</td>
</tr>
<tr>
<td>Nakhal Para Hossain Ali High School</td>
<td>Tejgaon</td>
<td>9</td>
<td>1,390</td>
<td>Co-education</td>
</tr>
</tbody>
</table>
Map 3.1: Showing the Location of Selected Schools

3.6 Data Collection
This study uses data from an activity-based travel survey, which was conducted between February 08, 2012 and February 28, 2012 among class 6-10 students in eight different schools. Each student reported all activity engagements in a 24-hour cycle for the surveyed weekday. Students completed an activity-based travel diary, mainly reporting various types of structured and non-structured in-home and out-of-home activities for the given weekday. Whereas the structural activities involve a regular participation schedule such as extracurricular pursuits, lessons, enrichment activities, scouting, clubs, and organized games and meets, the non-structural activities include unorganized hobbies and sports, outings, playing, television viewing, and music. The travel diary also collected detailed information about the activity, such as start time, end time, location, mode used, travel time, travel cost, accompanying person, and number of accompanying persons for different types of activities. This questionnaire was completed in the classroom under teachers’ supervision.

A second questionnaire is designed for parents in order to collect socio-economic and other relevant information, which was distributed to the students. Parents completed the questionnaire at home, and returned those to the class teacher within a specified time period. Information collected through this survey includes age of parent, household income, car ownership, tenure type, household size, employment status, number of children and their associated travel arrangements. Since Geographic Information System
(GIS)-based detailed built environment data is currently unavailable for Dhaka City, parents were also asked to report certain built environment attributes, such as the presence of sidewalks around their home, and presence of nearby traffic intersections. In total, 510 surveys were distributed; however, only 276 complete responses were obtained. After cleaning for missing information, responses from 245 participants were found usable for further analysis.

### 3.7 Data Preparation

#### 3.7.1 Data Preparation for Models of Physical Activity

Activity-based surveys were coded in SPSS. Data preparation for this study involves several stages: data entry and validation; preparation of the database (i.e. data tables, and relationships); preparation of a code-book; and running queries to generate datasets for modeling. Initially, activities reported by the students were re-coded based on the activity typology used in Bhat and Lockwood (40). SQL-based data queries were applied to identify out-of-home non-school activities (sports, playing at the park/ play field, social activity, extracurricular activity etc). In this study, participation in physical activities includes engagements in the physically active activities as well as the use of active transportation such as walking. Since mode choice was identified separately in the survey (i.e. the information was not included in the chronological reporting of activities), queries were used to identify and merge required attributes for this type of physical activity within the dataset. Reported travel time was considered as the duration of the physical activity if active transportation was used to reach any type of out-of-home activities. For other structured and non-structured activities the duration is calculated based on the start time and end time of the reported activities. Finally, an activity-based dataset was generated for duration modeling. On the other hand, a person-based dataset was generated for ZIP modeling that identifies total counts of physical activity participation by each student in a given weekday. In both cases, children’s personal characteristics, household characteristics and other relevant attributes were merged for hypothesis testing during the modeling process.
3.7.2 Data Preparation for Mode Choice models

For modeling mode choice, a subset of the data was generated using relevant techniques in SPSS. Data preparation included several steps, for example, household characteristics were gathered for all 245 respondents, and associated attributes of only school trips were merged into the dataset. As no travel demand forecasting model currently exists for Bangladesh, so travel times and travel costs for non-selected modes are estimated from the relationship between travel time/travel costs and distance of surveyed responses. In case of forecasting travel time/travel costs following steps are followed: at first, linear regression equation for all four mode types has been calculated from relation between travel time/cost and distance of all activities. Then average travel time for mode specific observed responses and non-selected unobserved responses are calculated and compared. The travel times for unobserved modes those are estimated are less than those are observed. This was because travel time is calculated for walk and NMT mode which are chosen for short trips. After calculating mode specific variables, travel time and cost; these two variables were merged with the earlier dataset.

3.8 Methods Used for Empirical Studies

3.8.1 Models for Examining Physical Activity

In modeling the frequency of children’s physical activity participation in Dhaka City, this study estimates a Zero-Inflated Poisson regression model (Figure 3.2). One important property of this Poisson model is that it restricts the mean and variance of the distribution to be equal, limiting its use for modeling over-dispersion in the count dataset. A particular kind of over-dispersion occurs when there are excess zeros in the data than is consistent with a Poisson distribution. For instance, a large proportion of respondents may not be found engaging in any physical activity in a given day. In this study, about 43% of children in Dhaka City reported zero physical activity during the surveyed weekday. Since the number of zero observations is quite high, it violates the basic assumption of a Poisson model, and hence, a zero-inflated methodology is required. A suitable approach for analyzing such case is a zero-inflated Poisson (ZIP)
model, which assumes that there are two latent classes that contribute to the excess of zeros (Lambert, 1992)

To enhance the understanding of the factors that affect time spent on physical activities, the paper uses a continuous time hazard-based duration modeling approach (Figure 3.2). Hazard models recognize the dynamics of physically active duration of children in a given weekday, since the likelihood of termination of a physical activity is measured based on the length of time spent from the initiation of an activity. The key principles and statistical properties of the hazard-based duration models are discussed in Hougaard (38). Although it is possible to uncover baseline distribution in semi-parametric models, this study prefers parametric models since they provide direct inference on the duration dependence. Empirical applications in different research fields have employed a wide variety of distributions for the parametric models. This paper examines a monotonic (Weibull) and a non-monotonic (log-logistic) distribution for the parameterization of the baseline hazard. In accommodating the effects of external covariates in the models, this paper assumes that the covariates directly re-scale time. This accelerated failure time (AFT) assumption implies that the covariates either accelerate or decelerate the termination of physical activity duration.

Figure 3.2: Models used for Empirical Studies
3.8.2 Models for Modeling Mode Choice for School Trips

In modeling the travel modes for school trips, this study considers four modes choice obtained through a survey conducted in Dhaka City: (1) Private Car, (2) Three wheeled Pedal powered Rickshaw, (3) walk, and (4) bus mode. The choice model was formulated following a random utility-based discrete choice modeling approach. The underlying assumption is that individuals will maximize their utility by choosing an alternative within the choice set, and the utility of choosing an alternative is composed of two components: systematic utility and random utility. Although the MNL model has been widely used for many years in choice modeling, but assessing unobserved attitudinal variations across individuals is challenging, and often ignored in conventional MNL models (Handy et al., 2005). While, consumer preferences for goods and services are characterized by heterogeneity. Heterogeneity is difficult to examine in the random utility model because an individual’s characteristics are invariant among a set of choices. Researchers have recently addressed the preceding issue in one of two ways. Kamakura and Russell (1989) accounted for unobserved heterogeneity across households in a logit model by assuming the existence of a finite number of segments. Each segment consists of a set of overall identical characterized households. It is termed as latent class approach and it used to estimate logit model parameter for each of the parameters of each segment. The second approach dealing with unobserved heterogeneity is to use a random-coefficients specification in which parameters of the household-level logit model and treated as realization of random variables representing the preferences of households. These random variables are assumed to follow a continuous probability distribution (Gonul and Srinivasan, 1993; Jain et al. 1994). Hence this study undertakes MNL, MLM and LCM to obtain the unobserved heterogeneity among respondents (Figure 3.2).

3.9 Sample Characteristics

For both the exploratory analysis and the empirical modeling, only individuals aged eleven through sixteen who were enrolled in secondary school were considered for the
analysis. However, the exploratory analysis examines children’s activity patterns on typical weekdays and therefore, only children who filled out travel diaries on the weekday and whose parents filled up the questionnaire regarding socio-economic and demographic household characteristics were included in this sample. Based on these criteria, a total of 245 children were selected for the exploratory analysis. Thus the sample includes children who filled out at least a weekday diary and have complete supplemental information.

The sample descriptive statistics for child demographics, including age and gender, are provided in Figure 3.3 and Figure 3.4. The statistics indicate that the sample includes a slightly higher percentage of school going children aged 11 to 13 years of age, and slightly lower percentage of adolescents aged 14 to 16 years of age, compared to the City’s percentage of the of the respective age range.

![Figure 3.3: Age distribution of the children in the Sample](image)
The sample descriptive statistics for household socio-demographics, including household size, number of total school going children, home ownership, auto ownership, mother’s employment pattern and family income, are provided in Table 3.3. The total size of household is the representative of the national household size. The number of multiple school going children in the households is also comply with the household size. The home ownership of having own home in the sample is slightly higher than the city’s home ownership (27.7%) and the status of tenant is slightly less than the City’s tenant resident status (72.3%) (BBS, 2011). The auto ownership of the sample is higher than the city’s overall auto ownership pattern (7%) (BBS, 2011). In case of mother’s employment pattern, the number of employed mother is less the city’s overall context. The total monthly income reveals that there is high gap between the low income and high income range and the standard deviation is 28432 BDT. whereas more than 50% respondent’s total monthly income is less 25000 BDT.

<table>
<thead>
<tr>
<th>Household socio-demographics</th>
<th>Frequency</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 to 5 Persons</td>
<td>223</td>
<td>91.4</td>
</tr>
<tr>
<td>6 to 11 Persons</td>
<td>21</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Table 3.3: Household Socio-demographic sample Characteristics
<table>
<thead>
<tr>
<th>Household socio-demographics</th>
<th>Frequency</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Monthly HH income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below 15000 BDT.</td>
<td>56</td>
<td>22.9</td>
</tr>
<tr>
<td>15001 -25000 BDT.</td>
<td>75</td>
<td>30.6</td>
</tr>
<tr>
<td>25001-35000 BDT.</td>
<td>45</td>
<td>18.4</td>
</tr>
<tr>
<td>35001-45000 BDT.</td>
<td>14</td>
<td>5.7</td>
</tr>
<tr>
<td>45001-60000 BDT.</td>
<td>34</td>
<td>13.9</td>
</tr>
<tr>
<td>Above 60000 BDT.</td>
<td>21</td>
<td>8.6</td>
</tr>
<tr>
<td>Total</td>
<td>245</td>
<td>100</td>
</tr>
</tbody>
</table>

3.10 Modeling
Models for physical activity frequency and duration have been estimated in STATA 9.1 licensed software. For physical activity frequency modeling the total sample size was 245 but for duration modeling the total number of physical activities were 356. On the other hand, mode choice models were programmed in NLOGIT 4 series of licensed LIMDEP software. In case of mode choice models, the total number of sample was 245.

3.11 Conclusion

The study effort employs both the exploratory analysis of Chapter Four and empirical modeling of Chapter Five & Six. The final samples include 245 children for the exploratory analysis, and 245 children for the empirical modeling. Sample characteristics for the samples were presented in this chapter.
CHAPTER FOUR: DESCRIPTIVE ANALYSIS OF CHILDREN’S ACTIVITY PATTERNS

4.1 Introduction

The pattern of children’s travel, while in itself a result of the interplay between existing social, geographic, economic and environmental factors, conditions the behavior of the next generation and influences the travel behavior of the society in the future. Children and students have the highest number of non-work/non-school fixed activity commitments (Frusti et al, 2003). Frusti et al. (2003) also highlight the importance of fixed activities in determining how responsive an individual will be to a change in transportation policy. In the contrary, children participate in all non-school activities, at a much higher rate and for longer durations during the after-school period than the before-school period (Copperman and Bhat, 2007). Moreover, children are most likely to be accompanied by adults and the rate is as high as 84% in UK (DiGuiseppi et al., 1998). The school travels with fixed location, start time and end time based on the residential location take place during peak hours make the congestion problem severe in developing countries. In this situation, it is necessary to know the activity pattern of school going children to determine the travel needs to reduce the localized congestion. Moreover, if the travel demand can be modeled, it is possible to take travel demand management initiatives and policies to reduce congestion at peak hours. Regular journey patterns are often easier to target with road safety programs or travel demand management strategies since large numbers of people travelling to the same place at the same time increase not only the efficiency with which safety programs can be delivered, but also the potential for shared services (such as car pooling, school bus services and improved public transport services). School escort trips journeys use to be accounted for a large proportion of travel by households (Morris et al., 2001).
4.2 Activity pattern

The daily activity pattern of a child is the set of activities performed in home or outside the home during the course of a day and travel pattern to accomplish these activities. There are many dimensions that comprise a child’s daily activity-travel pattern, including the (1) decision to participate in an activity and the number of episodes of participation (generation dimension), (2) activity participation duration and time of day of participation (temporal dimension), (3) activity episode location (spatial dimension), (4) episode sequencing, (5) mode, route, and duration of travel to episodes (travel dimension), and (6) accompanying individuals (with-whom dimension).

4.3 Activity Typology

As discussed in the literature review (Chapter Two), activity typologies utilized in current activity-based travel demand models are enormously done for adults and for children it is limited to represent children’s activities and their associated dimensions due to the application of common categorization for children and adults. On the other hand, an important difference between children’s and adults’ patterns is that children participate in a higher number of non-school/non-work, but fixed, out-of-home activities. Similar to school, these fixed, or structured, activities tend to be planned in advance, are fixed in both time and space, and take place on a regular basis. They are obligatory in nature and, therefore, take a high precedence, directly behind school participation, in an individual and his/her escort’s time-use scheduling. The activity typology, as described below, defines a separate structured non-school activity category to account for the salient characteristics of activities in this category.

Children were found to participate in various types of activities in a typical weekday. These activities have been categorized in three major types: mandatory, maintenance, and discretionary activities.
4.4 Participation rates and Duration for Activities

The generation and temporal dimensions of a child’s activity-travel pattern are discussed by activity purpose. The activity purposes include habitual and mandatory activities that take place on a regular basis and have a relatively set time period of participation (i.e., sleep, and school on weekdays), maintenance activity (i.e., get ready for school, personal care, meals), discretionary activities (i.e., home work, recreation and spiritual/social).

4.4.1 Major Activity Types

Among all the activities, participation rate in discretionary activities is highest.
4.4.1.1 Mandatory Activity

Attending school and sleeping are classified as mandatory activities for children. And as expected, number of daily participation in schooling is higher than sleeping frequencies.

4.4.1.2 Discretionary Activity

Studying at home, tutoring, organized and non-organized recreational activities, social/spiritual activities have been classified as discretionary activities for children. Among all the activities, the rate of participation in tutoring is highest.

4.4.1.3 Maintenance Activity

Meals, personal care and preparation time for schooling have been classified as maintenance activities for children. And as expected partaking meals activity is highest among other maintenance activities.
4.4.2 Duration Dimension of Activities

Among all the activities children spent in sleeping at an average of 5.6 hours in a weekday. And the descriptive on duration spent in all the activities is in section 4.4.3.
4.4.3 Descriptive Discussion on Duration of Activities

4.4.3.1 Mandatory Activities

4.4.3.1.1 Sleeping

From the exploratory analysis it has been found that time spend for sleeping varies substantially by age and with the increase of the age, the amount of performing sleeping activity reduces. A survey conducted by the National Sleep Foundation (2004) found that elementary aged children spend, on average, 9-10 hours per night sleeping, while Wolfson and Carskadon (1998) report that adolescents sleep, on average, for 7.5 hours per weeknight.

4.4.3.1.2 Attending School

The study shows that students spent more than 4 hours a day in school while travelling to and travelling from school also takes 0.5 to 2 hours in a day. In case of most of the students the time spent on travelling to school needs more than 0.5 hours. Similar to work for working adults, school-aged children participate in school during the work week. School is a highly obligatory (or mandatory) activity, occurs regularly every weekday, and has a fixed duration, start and end time, and location. Therefore, for most children, school is a rigidly constrained activity around which all other weekday activities must be scheduled. The time at school comprises the highest percentage of a child’s waking hours, averaging 6.5 hours per day (Hofferth and Sandberg, 2001).

4.4.3.2 Discretionary Activities

4.4.3.2.1 Non-Structured Recreation Activities

Non-structured recreational activities include unorganized hobbies and sports, outings, playing, television viewing, and music. The studies on non-structured recreational activity participation focused on specific types of recreational activities. In this study 70% child aged from 11 to 16 spent at least 0.5 hour a day in playing to the nearest play
field, watching television or playing at home. Some other 20% student spent 0.5 to 1.0 Hour in a day in such recreational activities. While studies show that 90% of children watch television at least once a day for on an average of 2.5 hours per day (Hofferth and Sandberg, 2001) reported that 94% of children, less than 13 years of age, spend time playing (defined as unstructured games) each week, averaging over 2 hours per day. The study also reveals that the percentage of children spending time in such unorganized recreational activities increases with the increase of age may be due to the independent mobility increases with the age and children can go for playing outside alone. Approximately 15-22% of children participate in hobbies each day for about an hour per day (Hofferth and Sandberg, 2001).

4.4.3.2.2 Organized Recreational Activities

Organized activities involve a regular participation schedule, are led by an adult activity leader or coach, emphasize skill-building, require sustained attention, and include performance feedback (Sener et al., 2008). These activities include extracurricular pursuits, lessons, enrichment activities, youth groups, meetings, clubs, and organized games and meets. The rate of participating in extracurricular activities in the study area increases with the increase of age. But only 22% students participate in organized recreational activities for enhancing their skill in a particular aspect. On the other hand, 80% students who take part in organized activities spent less than 2 hours a day while 20% student spent more than 2 hours per day. It also found that among the students performing these activities; more than 93% students are female. Studies show that participation rates per day range from 11-12% for younger children to 20-23% for older children and adolescents (Hofferth et al., 1991). Children who participate in organized activities spend, on average, 1 ¾ hours per day (Barnes et al., 2007).

4.4.3.2.3 Spiritual/Social Activity

In this study religious activity has been considered as an organized discretionary activity. Hence, it has been found that with the increase of age, the percentage of performing organized religious activity increases by age and 52% student spent less than
half an hour for performing religious activity. Studies show that approximately one quarter of elementary and middle school children and over one third of high school children attend religious activities at least once a week (Hofferth and Sandberg, 2001). Hofferth and Sandberg (2001) found that children participate in religious activities for approximately 1.5 hours per week.

4.4.3.2.4 Studying/Reading at home

In this study it has been found that with the increase of age, the percentage of studying at home increases significantly and all the students use to study in a week day. It also found that more than 57% student spent 2.0 to 4.5 hours a day in studying at home. In the contrary, several studies have examined participation levels in studying, homework, and reading. These studies have found that between 40-62% of children study on a daily basis on weekdays (Hofferth and Sandberg, 2001). High school and middle school children spend over 1 ¼ hours studying on weekdays, while elementary school children spend only 30-50 minutes per day studying (Barnes et al., 2007; Hofferth and Sandberg, 2001). This study also found that the rate of undertaking at home study is higher in girls than boys but several studies also show that girls spend more time studying than boys (Barnes et al., 2007).

4.4.3.2.5 Tutoring

In developing countries, school going children also have to perform another fixed location based organized activity that is tutoring. This is because sometimes just attending to school is not enough for students to perform their best in study. In this study more than 80% student participate in tutoring service and spent 2.0 to 4.5 hours a day in taking tutoring service.
4.4.3.3 Maintenance Activities

4.4.3.3.1 Personal care

With the increase of the age, the rate of undertaking this activity increases. More than 70% students spent 0.5 to 1.5 hour a day for personal care. It also accompany with the findings of the Hofferth and Sandberg, 2001 that children spend, on average, an hour per day in personal care.

4.4.3.3.2 Eating

Study reveals that students solely spent 0.5 to 2.0 hours in eating. While Hofferth and Sandberg (2001) did examine the eating activity. They found that, in general, including in-home and eat-out meals, all children spend some amount of time eating either as the primary activity or in combination with other activities. They also report that children spend approximately an hour per day eating.

4.4.3.3.3 Get ready for school

This is an in-home activity which has precedence over attending school activity. All the children spent some time for making themselves ready for school and more than 90% student spent less than 0.5 hour to 1.0 hour a day for this activity. It also found that girls undertake this activity higher than the boys.

4.5 Companionship Arrangement of Activities

4.5.1 Number of Accompaniment

Only 9.4% children travel alone for partaking out-of-home activities where as all other (more than 90%) children are accompanied by one or more than one adults.
4.5.2 Relationship with the Accompaniment

For out-of-home activities, children are mostly accompanied by mother where as a significant number is accompanied by friends.
4.5.3 Accompaniment Arrangement for out-of-home Activities

Among out-of-home activities, children mostly accompanied by mother for both mandatory (schooling) and discretionary (tutoring) activities. For organized and unorganized recreational activities, children are accompanied mostly by friends.

As expected, non-driving age children depend to a large extent on their parents to drive them to activities. Weston (2005) found that children aged 13-15 are driven by their parents on 61% of all trips while this study shows that more than 70% children are accompanied by their parents for school trips. Students also make school trips with relatives, siblings, neighbors and maid. Nearly 60% children are accompanied by parents for trips undertaken for tutoring activities while more than 30% children made tutoring trips with their friends and only 9% with their siblings. Out-home unorganized activities like playing trips are solely made with friends while organized trips for extracurricular activities are made with parents and friends both. McDonald (2005) noted that mother’s
take-up more of the escorting responsibilities compared to fathers (McDonald, 2005; Sener and Bhat, 2007; Yarlagadda and Srinivasan, 2007). Clifton (2003) found that 33% of teenagers are accompanied by household members directly after school, while 37% of teenagers are accompanied by non-household members. Weston (2005) observed that older siblings accompany children aged 13-15 on over 4% of trips, while other friends’ parents escort children on 8% of trips. Many children also travel independently to activities. Clifton (2003) found that 38% of teenagers travel alone on their trip directly after school though it does not comply with this study as parents have to much more careful in developing countries for permitting their children as alone mover due to traffic accidents and safety and security issues.

4.6 Travel Dimension

4.6.1 Overall Modal Share

For out-of-activities children mostly use rickshaw and walking mode while they also made auto-driven trips.

![Figure 4.8: Modal Share of Children](image)
4.6.2 Modal Share for Out-home activities

For schooling, rickshaw mode is the highest used mode, whereas walking is the next highest one. For other activities, there is dominance of using walk mode for traveling.

More than 47% student undertake school trips by TWPPV (non-motorized vehicle), 31% students perform school trips by walking while only 17% student made school trips by private car. Only 3% students use school bus or public bus for their school trips. The reason behind not using the bus lies in level of bus service, residing within 1.5 miles of the school and higher travel time due to congestion in main road. In case of overall outside activity performing students mostly use TWPPV (42.3%), walk (39.4%) and car (15.3%). There are three studies that have descriptively examined mode choice using the 2001 U.S. National Household Travel Survey (NHTS) (see McDonald, 2005; Weston, 2005). Each of the studies examined modal split as a percentage of all trips, but for different age groups of children. McDonald (2005) examined all children under the age of eighteen, and Weston (2005) concentrated on children aged 13-15. The results of
these studies show that car trips make up the highest percentage of children’s travel, ranging from 65.7 – 75% of all trips. Walking is the second most frequent choice of mode, constituting between 12.0 - 16.5% of all trips. The third highest mode utilized is school bus, followed by biking and transit. In addition, two studies in Canada found that car trips makes up the highest percentage of all children’s trips, followed by walking (Stefan and Hunt, 2006).

For other non-school activities like tutoring 42.8% students make trips by TWPPV, 42.4% students make trips by walking and some other 15% made their trips by auto. In case of attending in unorganized out-home activities like playing outside; students solely make trips by walking. More than 81% outside home non-structured or unorganized activity trips are made by walking and another 12.1% and 6.9% are made by auto and TWPPV respectively. Studies also show that children, overall, make 20% of social trips by walking, while young teenagers make close to 30% of social trips by walking. Sports trips also have a high proportion of non-motorized mode use with, close to 40% of sports trips made by either walking or biking (McDonald, 2005; Weston, 2005).

### 4.7 Conclusion

These are the several findings from the descriptive analysis of the activities children participate in a typical weekday. This chapter summarizes the frequency and duration in all types of activities, along with the location, with-whom, travel dimensions. From above discussion it is prominent, children undertakes serve-passenger out-of-home activities. Among all these activities, the next chapter model the frequency and duration of out-of-home physical activity as this category is the most important one for children’s physical and psychological health.
CHAPTER FIVE: EXAMINING FREQUENCY AND DURATION OF PHYSICAL ACTIVITY

5.1 Introduction

This chapter aims to explore the factors that affect the frequency of physical activities including the use of active transportation, and the duration of such engagements. The rest of the chapter is organized as follows: it begins with a brief review of recent literature in physical activity participation and duration modeling. Next, it provides an overview of the data that form the basis of the subsequent model estimation. This is followed by a discussion of the empirical results. Finally, the chapter concludes with a summary of contributions.

5.2 Summary Statistics

The descriptive analysis reveals that among 245 responses about 57% of respondents are engaged in at least one physical activity. The average count of physical activity is approximately 1.41 with a standard deviation of 1.45 (minimum=0 and maximum=6). On the other hand, the average (total) duration of the surveyed children is 33.69 minutes, which is below the recommended level by the American Academy of Pediatrics. In total, 356 continuous episodes of physical activities were reported. The average continuous length of physical activities in the sample is 23.18 minutes with a standard deviation of 24.92 and a maximum of 150 minutes. Note that these continuous episodes (sometimes referred to as “spell” or “bout” in the literature) are used as the dependent variable in the duration modeling of physical activity. Table 5.1 shows the summary statistics of the dependent variables considered in the ZIP model and the duration model, and independent variables (such as children’s personal attributes, households’ socioeconomic characteristics, built environment, escort arrangement and activity attributes) retained in the final model specification.
Table 5.1: Summary Statistics of Variables used in Empirical Models of Physical Activity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean/Percent</th>
<th>Stan. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Activity Count</td>
<td>1.41</td>
<td>1.45</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Duration of Physical Activity (minutes)</td>
<td>23.18</td>
<td>24.92</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td><strong>Independent Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Person and Household Attributes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of the Children</td>
<td>14.13</td>
<td>1.154</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Number of Children at Household</td>
<td>1.83</td>
<td>0.77</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Age of the Parent</td>
<td>42.54</td>
<td>5.19</td>
<td>25</td>
<td>58</td>
</tr>
<tr>
<td>Monthly Household Income (2012 USD)</td>
<td>331.39</td>
<td>284.14</td>
<td>150</td>
<td>2800</td>
</tr>
<tr>
<td>Total Household Size</td>
<td>4.33</td>
<td>0.86</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Home Ownership (dummy, 1 if the household is a homeowner, 0 otherwise)</td>
<td>29.5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Car Ownership (dummy, 1 if the household owns at least one car, 0 otherwise)</td>
<td>11.2%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Built Environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of Sidewalk around Home (dummy, 1 if sidewalk exist adjacent to the home, 0 otherwise)</td>
<td>43.7%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Presence of Intersection nearby Home (dummy, 1 if any intersection exist nearby home, 0 otherwise)</td>
<td>41.6%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Activity Attributes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parental Escort (dummy, 1 if the child is accompanied by the parent, 0 otherwise)</td>
<td>40.2%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Accompanied by Friends (dummy, 1 if</td>
<td>49.4%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
the child is accompanied by the friends, 0 otherwise)
Activity performed in the Play field or Park location (dummy, 1 if the activity is performed in the play field or park location, 0 otherwise)

<table>
<thead>
<tr>
<th>Activity</th>
<th>12.9%</th>
<th>-</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Travel Time to School</td>
<td>48.30</td>
<td>29.69</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td>Total Travel Time to Tutoring</td>
<td>17.37</td>
<td>19.24</td>
<td>5</td>
<td>85</td>
</tr>
<tr>
<td>Duration of Mandatory Activity</td>
<td>813.37</td>
<td>101.19</td>
<td>480</td>
<td>1065</td>
</tr>
<tr>
<td>Duration of Homework</td>
<td>281.97</td>
<td>84.75</td>
<td>15</td>
<td>570</td>
</tr>
<tr>
<td>Duration of Tutoring (taking lessons from a tutor outside school in a fixed time and location)</td>
<td>127.62</td>
<td>94.01</td>
<td>0</td>
<td>360</td>
</tr>
<tr>
<td>No. of Out-of-home Out-of-School Activities</td>
<td>1.61</td>
<td>1.53</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

5.3 Discussion of Models

5.3.1 Modeling Process

Prior to modeling, correlation tests are performed between all pairs of explanatory variables. Variables that exhibit low correlations (<0.4) among pairs of independent variables are considered in the final model specification. For example, household income is correlated with car ownership and home ownership; but car and home ownership are not correlated with each other. Therefore, household income has not been considered with the correlated variables (car/home ownership) in the same model. Various model specifications were tested with a comprehensive list of variables identified in the existing literature. The final model was selected based on the model-fit, agreement with prior hypotheses and statistical significance of explanatory variables.
5.3.2 Model Results of the Frequency of Physical Activity Participation

The parameter estimation results of the ZIP count model that examines the frequency of physical activity participation among the school going children in Dhaka City are presented in Table 5.2. The majority of independent variables retained in the ZIP model are statistically significant at least at the 95% confidence interval (i.e. $t$-statistics greater than 1.96 for a two-tailed test). Few variable exhibit lower $t$-statistics than the threshold value. These variables are retained in the final model since they offer important behavioral insights, with an assumption that if a larger dataset were available, these parameters might show statistical significance. The model results suggest that the key determinants of the frequency of physical activity participation are the presence of sidewalks around the home, presence of nearby traffic intersection, and the total number of out-of-home out-of-school activities performed by the children. Whereas the presence of sidewalks increases the frequency of physical activity, the presence of traffic intersection nearby decreases the frequency of participation all else being equal. The relative contributions of the presence of sidewalk and intersection are 0.513 and –0.454 respectively. Among children’s personal characteristics, age exhibits a negative relationship, implying that older children participate in physical activity less frequently than younger children. This is consistent with the prior expectation. Older children usually take more household responsibilities and require to spend more time for their studies. The model results also suggest that the frequency of physical activity increases for a given child as the number of children increases in a household. Presumably, multiple children in a household get higher opportunities for out-of-home physical activities. For instance, parents can allow a younger child to go to nearby playfield with his/her older siblings. Similarly, children can walk or bike together to school or other places close to their home.

Age of the parent is also found to be significant in the model. A negative parametric value of the variable suggests that the higher the age of the parent, the lower will be the propensity of the child in participating in out-of home physical activity. Recent evidences suggest that younger parents in Dhaka City are more educated and health-

45
conscious than the previous generation. As such they possibly are more concerned about their children’s health and may try to offer an increased number of opportunities for engaging in physical activities. The results also reveal that household monthly income has a negative impact on children’s physical activities. Poor facilities for walking/biking as well as road safety and personal security concerns often make outdoor activities less desirable for children in Dhaka City. Hence, parents with higher purchasing power might prefer to arrange for sedentary in-home activities for their children by purchasing electronic devices (such as video games, hand-held gaming devices and computers) as a means to alternative recreational activities.

As indicated earlier, built environment attributes exhibit significant influence on the frequency of out-of-home activities of children in Dhaka City. Walking is an incidental physical activity, which depends on the quality of built environment, such as the availability of sidewalks in the residential neighborhood. As expected, the sign of the dummy variable, presence of sidewalk around the home is positive, meaning that children’s participation rate in out-of-home physical activities will increase if sidewalks are available near their home. In addition to the potential use of active transportation for short-distance trips, the availability of sidewalks may also offer possibilities for children to engage in out-of-home activities in a nearby play field or park, which can be reached by walking or biking. Another aspect of built environment that affects the physical activity participation is the presence of traffic intersections near the home. This dummy variable is used as a proxy variable to account for traffic interference. As expected, the coefficient value of this variable is negative. Traffic intersections raise road safety concerns, and children will need accompaniment arrangements for travelling to locations where out-of-home physical activities can be performed. As such, it is hypothesized that the presence of an intersection near the home will decrease the frequency of out-of-home activity participation, which is confirmed by the model results with reasonable statistical significance (at 99% confidence level).

The model results also reveal that activity-related attributes influence physical activity participation, particularly certain fixed activities that are considered near to mandatory
in the context of developing countries. For instance, private tutoring before and/or after school is common in Dhaka City, and is considered mandatory since the level of education provided in schools does not match parents’ expectation. As expected, total time-commitment for tutoring (i.e. specialized daily lessons from private tutors in a fixed location outside of the school curriculum) is found to negatively affect the frequency of activity participation. Similarly, total time spent on homework (mainly in-home) is found to reduce the amount of out-of-home physical activity, all else being equal.

In Dhaka City, there is no designated school-zone boundary for any public or private school. Students compete to get admitted in quality schools, which in many cases could be far from their homes. Therefore, total travel time to the school could be an important factor in explaining physical activity participation. It is hypothesized that the longer the time it requires for a child to reach school the lower the frequency of out-of-home physical activity would be. Because longer distance travel will increase the total time spent for schooling, thereby reducing the opportunities for a child in engaging in discretionary-type of physical activities. Additionally, schools far from home might reduce the possibility of walking to school. A similar effect was expected for the total travel time to attend to a private tutoring location (which is an extra routine travel for the child). As expected, the parameter values of the travel time to the school and the tutoring location are found to be negative for the sample, which are –0.008 and 0.027 respectively.

Finally, the results of the ZIP count model suggest that the increase in total number of out-of-school and out-of-home (passive, such as grocery shopping with parents) activities increases the frequency of physical activity participation of children and vice versa. Perhaps, increased counts of out-of-home activities create opportunities for walking to take short trips which are common in predominantly mixed land use-based urban structure in Dhaka City.
Several other variables are tested during model estimation. However those hypotheses could not be confirmed due to lack of reasonable statistical significance. For example, it is hypothesized that mother’s employment status could have an impact on the frequency of children’s physical activity participation since dual worker households might have scheduling challenges. But the dummy variable exhibits poor statistical significance. The goodness-of-fit statistics of the model are evaluated in terms of pseudo Rho-square, which indicates 1 minus the ratio of log-likelihood of the full model to the log-likelihood of the constant-only model. The pseudo Rho-square value is 0.256 that indicates a reasonable model-fit.

Table 5.2 Parameter Estimation Results of Zero Inflated Poisson Regression Model for the Frequency of Physical Activity Participation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Zero Inflated Poisson Regression Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
</tr>
<tr>
<td>Age of the Children</td>
<td>-0.086</td>
</tr>
<tr>
<td>Number of Children in the Household</td>
<td>0.137</td>
</tr>
<tr>
<td>Age of the Parent</td>
<td>-0.029</td>
</tr>
<tr>
<td>Total Household Monthly Income (USD)</td>
<td>-0.001</td>
</tr>
<tr>
<td>Presence of Sidewalk around Home (dummy, 1 if sidewalk exist adjacent to the home, 0 otherwise)</td>
<td>0.513</td>
</tr>
<tr>
<td>Presence of Intersection nearby Home (dummy, 1 if any intersection exist nearby home, 0 otherwise)</td>
<td>-0.454</td>
</tr>
<tr>
<td>Duration of Tutoring</td>
<td>-0.002</td>
</tr>
<tr>
<td>Duration of Homework</td>
<td>-0.001</td>
</tr>
<tr>
<td>Total Travel time to School</td>
<td>-0.008</td>
</tr>
<tr>
<td>Total Travel Time to Tutoring</td>
<td>-0.027</td>
</tr>
<tr>
<td>Number of Out-of-home Out-of-School Activities</td>
<td>0.552</td>
</tr>
<tr>
<td>Constant</td>
<td>2.986</td>
</tr>
</tbody>
</table>
5.3.3 Model Results of the Duration of Physical Activity

The parameter estimation results of the duration model for children’s physical activities are presented in Table 5.3. As mentioned earlier, a monotonic (Weibull) and a non-monotonic (log-logistic) baseline distribution are assumed in the duration model. The models are evaluated in terms of AIC. The model results suggest that the Weibull model outperforms the log-logistic model. The AIC value of the Weibull model (86.36) is considerably lower than the log-logistic model (94.16). Hence, the Weibull model is selected as the final model. All variables in the Weibull model are statistically significant at least at the 99% confidence interval. Since the shape parameter ($p$) of the Weibull model is greater than one, the effect of duration is monotonically increasing, and vice versa. This study takes an accelerated failure-time (AFT) assumption; therefore the interpretation of the effects of explanatory variables is quite straightforward. A positive coefficient for a variable in the model implies that the duration of physical activity increases with an increase in the value of that variable.

The final model results reveal that car and home ownership, escort arrangements and activity location (dummy, if the activity is performed in the playfield or park) are the most important predictors of the duration of physical activity for the sample obtained from Dhaka City. In terms of children’s personal characteristics, age is found to be negative, implying that older children duration per activity episode is lesser than their younger counterparts. Household size also influences the duration of physical activities which shows a positive parametric size. Presumably, if the household size is larger, the opportunity to arrange accompaniment for children is higher, which might increase the duration of an activity episode.
Additionally, the parameter of the age of the parent in the model is positive. This implies that children with older parents spend more time on an activity episode than those with younger parents. The ZIP count model (discussed in the earlier section) suggests that children of older parents have a lesser chance of engaging in physical activities. Combining the results of two models, it can be concluded that although children of older parents get the chance to engage in fewer physical activities, they spend a longer time on an activity in comparison to children with younger parents.

The home ownership dummy shows a negative coefficient value (−0.271). It implies that the duration of a physical activity is shorter for children who live in their own home compared to the children of tenants. This variable acts as a proxy to household income, since homeownership is very costly in Dhaka City. As indicated earlier, higher income households can afford to buy electronic gadgets, contributing to more time spent by children on sedentary in-home activities. Interestingly, car ownership has a positive effect on duration of engaging in out-of-home physical activity. Participating in organized out-of-home physical activities generally requires a vehicle. If convenient transport is available, children can easily travel further distance to get involved in places where more organized extra-curricular physical activities are available. As a result, they can spend more time per activity episode those do not have access to a private vehicle.

Escort arrangements are also found to be significant in explaining the duration of out-of-home physical activities. The dummy representing parental escort shows a positive coefficient value in the duration model. It indicates that the time spent in out-of-home physical activities by a child is longer if they are accompanied by their parents. In contrast, if a child is accompanied by friends only, the duration is shorter for particular out-of-home physical activity.

The model results also show that the duration for mandatory activities and homework reduces the duration of out-of-home physical activities. This is because the more time is allocated to fixed activities, the less time is available for discretionary activities, such as physical activities. Finally, the dummy representing playfields or parks as activity
locations exhibits a positive parameter value. The duration of activities in those locations will be longer since children might get involved in sports or other types of organized physical activity.

Table 5.3: Model Results of Parametric Hazard Models for the Duration of Physical Activity

<table>
<thead>
<tr>
<th>Variables</th>
<th>Weibull Duration Model</th>
<th>Log-Logistic Duration Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-statistics</td>
</tr>
<tr>
<td>Age of the Children</td>
<td>-0.120</td>
<td>-2.42</td>
</tr>
<tr>
<td>Household Size</td>
<td>0.099</td>
<td>2.21</td>
</tr>
<tr>
<td>Age of the Parent</td>
<td>0.032</td>
<td>3.86</td>
</tr>
<tr>
<td>Car Ownership (dummy, 1 if the household owns at least one car, 0 otherwise)</td>
<td>0.363</td>
<td>2.47</td>
</tr>
<tr>
<td>Home Ownership (dummy, 1 if the household is a homeowner, 0 otherwise)</td>
<td>-0.271</td>
<td>-2.39</td>
</tr>
<tr>
<td>Parental Escort (dummy, 1 if the child is accompanied by the parent, 0 otherwise)</td>
<td>0.218</td>
<td>4.56</td>
</tr>
<tr>
<td>Accompanied by Friends (dummy, 1 if the child is accompanied by the friends, 0 otherwise)</td>
<td>-0.212</td>
<td>-4.41</td>
</tr>
<tr>
<td>Duration of Mandatory Activities (time spent in school and sleeping)</td>
<td>-0.004</td>
<td>-8.93</td>
</tr>
<tr>
<td>Duration of Homework</td>
<td>-0.004</td>
<td>-5.07</td>
</tr>
</tbody>
</table>
Activity performed in the Play field or Park location (dummy, 1 if the activity is performed in the play field or park location, 0 otherwise)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6.057</td>
<td>6.79</td>
<td>6.045</td>
<td>6.30</td>
</tr>
<tr>
<td>Shape Parameter ($p$)</td>
<td>3.353</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Likelihood (Constant Only Model)</td>
<td>-109.44</td>
<td>-82.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log Likelihood (Full Model)</td>
<td>-29.18</td>
<td>-33.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>86.36</td>
<td>94.16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5.4 Conclusion

This chapter presents findings of models that investigate children’s physical activities in the Dhaka City, Bangladesh. A Zero-Inflated Poisson (ZIP) regression model is used to explore the frequency of children’s physical activities that include the use of active transportation. This chapter contributes in several ways. Although abundant contributions are available for adults’ activity analysis, less attention is given to understanding children’s activity patterns. This study enhances our understanding in this regard. Particularly, this is a pioneering study in the context of Dhaka City that takes an activity-based approach in analyzing children’s time use and travel behavior. Since studies on physical activity participation and time use patterns for school going children in the context of developing countries are surprisingly absent, this study fills the gap, specifically in understanding the factors affecting participation in out-of-home physical activities, including the use of active transportation.
CHAPTER SIX: MODELING MODE CHOICE FOR SCHOOL TRIPS

6.1 Introduction

This chapter presents the findings of mixed logit model and latent class logit model to examine the determinant factors of mode choice for school trips of school going children in Dhaka City, Bangladesh. Whereas school-going population has been increasing over the past two decades (Shin, 2005) in United States, for the city like Dhaka rapid urbanization and growing inclination for school enrollment of children a higher growth rate can be presumed. Moreover, school children are the most vulnerable group at risk of traffic accidents involve in walking and cycling (Morris et al, n.d). As a result, parental safety and security concerns over traffic safety, crime and travel distance are associated with non-active commuting (Kerr et al, 2005; Rose, 2000). Since school trips are considered to be the most universal opportunity for incidental physical activity among children (Boarnet et al.,2005), understanding activity travel pattern has become important to transportation and urban planners, public health officials, and other policy makers to ensure active travel for children (Yarlagadda and Srinivasan, 2008; Boarnet et al, 2005; McDonald, 2005). Several studies have shown that children who use walking or biking to and from school trips are more physically active than who do not (Sidharthan et al, 2010; Cooper et al. 2003; Loucaides and Jago, 2008). However, the public health implications of school bound trips have gotten little attention in developing countries vis-à-vis developed countries. Thus, the contribution of built environment and influential factors to promote the use of active transportation for school trips is limited. Moreover, the school travel patterns of children are critical for reasons such as alleviating localized congestion near schools around start and closing times which is a leading imperative for transport system in Dhaka. Children’s mode of school travel is needed to be modeled to expand benefits from policies and programs like Safe Routes to School (Yarlagadda and Srinivasan, 2008) while, school travel also have strong spatial,
temporal, and modal linkages with travel patterns of parents and children have (Malone, 2001).

Although several authors have recently investigated children’s mode choice for school trips in the context of developed countries, studies on children in the developing countries are very limited. Whereas considering the complexity of urban life, rapid economic growth and increasing traffic congestion, it is necessary to examine what factors are affecting mode choice of children within that context. Nevertheless, with the rising purchasing power due to globalization and newly adopted financial mechanisms that support vehicle ownership, the City is experiencing continued annually 37,000 cars numerically in the streets and the annual growth rate is 10% (Chowdhury, 2010) Driving to school increases congestion and pollution and limits children’s independent mobility.

Affordability is another issue of concern, which dictates travel behaviour of school going children. Providing safe and convenient transportation for children has also become a challenge for households for a variety of other reasons, including absence of walk-able streets, poor safety and security conditions, and a growing number of dual-earner households. Beyond these, due to the absence of any zonal restriction in enrollment and marked diversity in school qualities, children of Dhaka City travel longer distance for schooling. Thus, in peak hours school trips are adding troubles in the transportation network of Dhaka. Studies show that, the need for longer daily travel, general tendency of using unsustainable mode of transportation, and daily exposure to congestion and vehicular emissions are not only affecting the physical and mental health of the students but also impeding their performances in the classroom (Godfrey et al., 1998). In this context, this study attempts to fill some gaps in understanding travel behaviour of children in Dhaka City, which is one of the megacities in the world. Expectedly, the findings of this study will inform future policy concern for sustainable transportation system for Dhaka. The rest of the chapter is organized as follows: it begins with a brief review of the data that form the basis of the subsequent model estimation. This is followed by a discussion of the empirical results. Finally, the chapter concludes with a summary of contributions.
6.2 Summary Statistics

The descriptive analysis of the sample reveals that among 245 responses (used in the empirical application) the modal share of private car, Rickshaw, walk mode and public/school bus are 16.5%, 48.4%, 30.14% and 4.9% respectively. While the average travel time for school trips is approximately 28.25 minutes with a standard deviation of 15.05 minutes (minimum=12minutes and maximum=124minutes). Other socio-economic variable like home ownership among respondents (37.6%) is higher than the national percentage (27.7%). Table 8.1 shows the summary statistics of the dependent variable considered in empirical models and independent variables (such as alternative specific variable, children’s personal attributes, household characteristics, built environment, and escort arrangement) retained in the final model specification.

As explained earlier, mixed logit model and latent class logit model are used to explore determinants of each type modes. Several types of explanatory variables are tested during model estimation, including children’s characteristics, household socio-economic characteristics, trip attributes, built environment characteristics, and escort arrangement. Table 6.1 shows the summary statistics of the independent variables retained in the final model specification. For a broad illustration of the effects of the variables, a conventional multinomial logit model (MNL) is estimated using the same variables retained in the mixed logit and latent class model (LCM) (see Table 6.2).

Table 6.1: Summary Statistics of Explanatory Variables used in the Models

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean/Percent</th>
<th>Stan. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private Car</td>
<td>16.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rickshaw</td>
<td>48.44%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>30.14%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public/School Bus</td>
<td>4.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Independent Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Alternative Specific Characteristics

| Travel Time | 28.25 | 15.05 | 12 | 124 |

### Person and Household Attributes

<table>
<thead>
<tr>
<th>Age of the Children</th>
<th>14.13</th>
<th>1.154</th>
<th>11</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender of the Children</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(dummy, 1 if the Child if Female, 0 otherwise)</td>
<td>50.4%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Number of Children at Household</td>
<td>1.83</td>
<td>0.77</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Monthly Household Income (2012 USD)</td>
<td>331.39</td>
<td>284.14</td>
<td>150</td>
<td>2800</td>
</tr>
<tr>
<td>Total Household Size</td>
<td>4.33</td>
<td>0.86</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Home Ownership (dummy, 1 if the household is a homeowner, 0 otherwise)</td>
<td>29.5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Built Environment

| Presence of Sidewalk around Home | 43.7% | - | - | - |
| Presence of Intersection nearby Home | 41.6% | - | - | - |
| Home to School Distance | 43.3% | - | - | - |

### Parental Escort Characteristics

| Parental Escort (dummy, 1 if the child is accompanied by the parent, 0 otherwise) | 40.2% | - | - | - |
6.3 Discussion

A series of choice models were estimated to arrive at the preferred mixed logit and LCM models. To facilitate comparisons the set of attributes and their generic vs. alternative specific specifications are restricted to a common condition.

8.3.1 Multinomial Logit Model (MNL)

The utilities of other modes (private car, Rickshaw and walk) were modeled relative to bus mode. While, travel time has been specified as an alternative specific parameter which will have generic coefficient estimates on the argument that the marginal utility of time is dependent on the circumstances under which travel occurs. This is similar to differentiate travel time on public transport in contrast to the car. Hence, the estimated coefficients on the travel time variable (e.g. -.0581) has the expected negative sign since the utility of a mode decreases as the mode becomes slower and is considered as disutility (Table 6.2). The expected negative sign of this coefficient, in turn, implies that this will reduce the choice probability of the corresponding mode.

In case of car mode choice, female children add utility to choose to the mode as the coefficient value for female children is positive. This goes with the parental concerns of safety and security from traffic and crime is higher for female than male children due to the current state of road accidents and stranger danger. Among the children’s household characteristics, household monthly income has a positive coefficient value indicating the increasing utility of choosing car mode for school trips. It can be related with purchasing power of private car which results from increasing affordability as well as monthly income. This complies with the recent trend of high income affluent society of having car for all trip purposes. Thus higher household monthly income is associated with the propensity of using car mode while it reduces the utility for other alternative modes. In contrast, negative sign of the coefficient for the size of the household parameter indicates that car mode choice decreases when the household size is larger. This relates with the presence of multiple children at the household or having the presence of adults who can escort children through other modes. On the contrary, parental escort increases
the probability of choosing the car mode, this is arguably because of their other household chores or workplace responsibilities which encourage them to drop or pick up their children at the starting and closing times of school. The most important factor that adds disutility to choose car is the distance between home and school. As expected, the dummy variable of school within 1.00km to home indicates that if the children lives near to school (within 1.00km), it will reduce the choice probability of car.

The model results for non motorized three wheeled Rickshaw indicate that, the utility of Rickshaw increases with the increase in age of the children, thus have a positive coefficient value. Among the household characteristics, household monthly income has a negative coefficient value implying the decrease in utility for Rickshaw mode with the increase in monthly income. Similarly, disutility of Rickshaw mode increases with the increase of home ownership among children’s households. Both higher monthly income and home ownership stand for possessing car ownership in the household which replaces the choice probability of other modes. It also reflects the existing scenario of higher income group to use private car for their daily travel needs. The most important factor which enhances the utility in choosing Rickshaw mode is the parental escorting for school trips. It presumably represents parental decision of choice of mode for school trips over public bus and walking. The built environment factor that affects the choice of non-motorized mode is the presence of intersection nearby home. The coefficient has negative sign which arguably represents that the high density mixed land uses or busy streets near residence consequently motivates the choice of motorized modes like private car or public bus rather than non-motorized mode Rickshaw (Sidharthan et al., 2010).

On the contrary, for walk mode, age of the children deters decreasing level of utility with the increase in age of the children. This is consistent with the prior expectation that older children face more trade-off with their household responsibilities and studying. Moreover, in existing context of Dhaka City, older children have to travel long distances than their counter part for schooling as high school standard varies among schools. Additionally, school shift for older students also presume at noon when it becomes tough to walk for school and at the closing children are too exhausted to walk to home.
It is also found that an increase in number of children in the household increases utility for choosing walk mode. This may reflect that with the increased number of children in the household, it is easier to walk to and from school for multiple children together. Parents can presumably leave the younger child with their older siblings for walking together to school. As expected, in the context of developing countries, household monthly income has a disutility on choosing walk mode for school trips for children. Poor level-of-service for walking, and inadequate road safety and personal security make walk mode less desirable. Hence parents with higher purchasing power might prefer to send their children to school through private car or Rickshaw other than walk. In developing countries, where safety and security is the prime concern of choosing school modes is also strongly related with the home to school distance. Additionally, the dummy variable of distance within 1.00km from school has positive sign indicates the increase in choice probability of walk mode for school trips among children whose trip length is less than 1.00km.

As indicated earlier, built environment attributes exhibit significant influence on choosing walk mode for school trips in Dhaka City. Walking is an incidental physical activity, which depends on the quality of built environment, such as the availability of sidewalks in the residential neighborhood. As expected, the sign of the dummy variable, presence of sidewalk around home is positive, meaning that children’s choice of walk mode for school trips will increase if sidewalks are available near their home. Another aspect of the built environment that decreases the utility of walk mode for school trips is the presence of traffic intersections near the home. This dummy variable is used as a proxy variable to account for traffic interference, given that detailed GIS or transportation network-related information is not available for Dhaka City. As usual, the coefficient value of this variable is negative. Traffic intersections raise road safety issues, and children will need accompaniment arrangements for travelling to school.

The goodness-of-fit statistics of the MNL model (i.e. an adjusted R-square) is 0.50032. On the other hand, the mixed logit and Latent class model (LCM) exhibit higher adjusted R-squared values, 0.51880 and 0.61754 respectively. It can reasonably be
concluded that both mixed logit and the latent class model (LCM) outperformed the MNL in terms of the model fit. Moreover, mixed logit and LCM account heterogeneity, allowing parameter variations across respondents. Hence, this chapter considers mixed logit and LCM as better model than the conventional Logit model. The following section presents a discussion of mixed logit and LCM results.

6.3.2 Mixed logit Model (RPL)

Table 6.2 shows the parameter estimates of all the variables retained in the mixed logit model. The majority of the variables exhibit statistical significance at least at the 95% confidence interval ($t$ - statistic greater than 1.96). In some cases, the $t$ -statistic is less than the threshold value; however, those variables are retained in the final model since they offer intuitively important behavioral insights, with an assumption that if a larger dataset were available, these parameters might show statistical significance. However, the majority of the variables show considerable variations both in terms of parametric values and relationships. Also, alternative specific variable Travel time shows higher significance in mixed logit model along with standard deviation (0.0522). This arguably implies that accounting for random taste heterogeneity increases the scope for deterministic heterogeneity in the model by adding the unobserved heterogeneity in the model.

In case of private car mode choice, gender of the children shows similar positive results along with increase in significance level. Among household characteristics, household monthly income shows similar positive coefficient value whereas household size similar negative coefficient value. But household also incorporates the continuous heterogeneity among the respondents having the standard deviation of 0.185. In contrast parental escort exerts similar positive utility in private car choice probability and dummy variable of distance within 1.00km from home to school offers disutility.

For three wheeled Rickshaw mode, all the variables show similar sign while the utility of age of the children decreases and positive utility of parental escort for choosing Rickshaw increases from 2.11 to 3.23. Additionally home ownership variable, household
monthly income variable and presence of intersection variables have increased disutility in choice equation which on the other hand reduces the choice probability of Rickshaw mode. The random parameter estimate of presence of intersection nearby home is normally distributed with calculated standard deviation of 0.285.

Later on, the choice of walk mode increases in mixed logit model along with reduction in significance level. In case of walk mode choice, variables exerting disutility such as presence of intersection around home, household monthly income and age of the children has similar negative coefficient value and sign. Though the variable, age of the children was insignificant in MNL model but become significant in mixed logit model. Variables adding utility in choice probability function, such as presence of sidewalk for pedestrian, distance from home to school and multiple school going children show similar positive influence on walk mode choice while the coefficient values increased from MNL to mixed logit. Standard deviation of presence of sidewalk variable is 4.4 which implies the high influence of this built environment component over children’s mode choice.

6.3.3 Latent Class Model (LCM)

The LCM results presented in Table 6.2 suggest that significant heterogeneity exists among the sampled individuals. The model is assumed to follow two latent classes. However, the majority of the variables show considerable variations both in terms of parametric values and relationships.

In case of private car mode choice, CLASS 1 of LCM shows that the variables such as gender of the children, parental escort, household monthly income add utilities for choosing private car mode for school trips while household size, distance within 1.00km from home to school variable withstand for disutility in private car mode choice probability equation. It exhibits a lower choice probability than MNL model as well as mixed logit model. Except the coefficient value of parental escort, other values are similar to MNL and mixed logit model, though the distance variable becomes insignificant. Comparatively, variables in CLASS 2 of LCM models have similar sign
along with high coefficient value of all the variables except gender of the children and household income.

With regard to Rickshaw mode choice, household monthly income, parental escort add utility whereas presence of intersection nearby home, home ownership, and age variables add for choice probability of Rickshaw mode in CLASS 1 of LCM. Though signs of variables are similar to MNL and mixed logit model but household monthly income becomes insignificant which was a significant parameter in both MNL and mixed logit model. In contrast to CLASS 1, CLASS 2 represents that only age variable adds utility for Rickshaw mode choice probability and presence of intersection nearby home, household monthly income, home ownership and parental escort add disutility to the choice probability. This may represent that CLASS 2 is the group of respondents where parental escort reduced the use of Rickshaw mode due to higher level of intersection presence around home and having higher level of monthly income which probably stands for auto ownership among households. While CLASS 1 is the group of respondents having high level of parental escort but the income level is not high enough to have private car and thus the variable is insignificant too. Hence, probability of Rickshaw mode choice is highly lower among CLASS 2 respondents than respondents of CLASS 1.

In case of walk mode, CLASS 1 of LCM shows similar signs for parameters of presence of intersection nearby home, age of the children, and household monthly income those add disutility in choosing walk mode whereas presence of sidewalk around home, residence within 1.00km from school and number of children in the households increases the choice probability of walk mode by increasing the utilities. So, CLASS 1 may represent the group of respondents who choose walk mode having multiple children in the household, have sidewalk around home and those who lives within 1.00km of the school. Compared to CLASS 1, CLASS 2 of LCM belong to group of respondents who choose walk mode mostly due to the presence of sidewalk around home, as this is the only parameter having significant influence on walk mode choice. Respondents group of CLASS 2 also stands for those who are older in age while have sidewalk around school
and living within 1.00km from school. Number of child showing negative influences on walk mode choice in CLASS 2, which also differs from MNL, mixed logit and CLASS 1 of LCM, arguably for those respondents who do not choose walk mode due to presence of multiple children which may on the hand implies the multiple children going to multiple schools and probably escorted by parents.

The goodness-of-fit statistics of the mixed logit model (i.e. an adjusted R-square) is 0.51880. On the other hand, the latent class model exhibits a higher adjusted R-squared value (0.68052). It can reasonably be concluded that the latent class model (LCM) outperformed the mixed logit (mixed logit) in terms of the model fit. Moreover, mixed logit (1.20173) has a higher AIC value than LCM (1.04181). Comparing different models is always a challenging task given the many domains of contrasts. Based on the log likelihood values, MNL model can be safely rejected in favor of either mixed logit or LCM. Since, mixed logit and LCM are not nested the comparison on a likelihood ratio test is not appropriate. Hence, this chapter considers mixed logit model and LCM model better than the conventional logit model (MNL).

Table 6.2: Parameter Estimation Results of MNL, Mixed Logit and LCM for the Mode Choice Behaviour

<table>
<thead>
<tr>
<th>Alternative Specific Variable</th>
<th>MNL Coefficient (t-stat)</th>
<th>MIXED LOGIT Coefficient (t-stat)</th>
<th>CLASS 1 Coefficient (t-stat)</th>
<th>CLASS 2 Coefficient (t-stat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>-0.058(-1.618)</td>
<td>-0.143(-2.407)</td>
<td>-0.576(-3.064)</td>
<td>3.305(0.832)</td>
</tr>
<tr>
<td>Car Mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender of the Children</td>
<td>0.262(0.905)</td>
<td>0.473(1.061)</td>
<td>1.568(1.657)</td>
<td>0.623(0.146)</td>
</tr>
<tr>
<td>Household Size</td>
<td>-0.908(-3.469)</td>
<td>-1.182(-3.055)</td>
<td>-1.163(-2.899)</td>
<td>-26.361(-1.568)</td>
</tr>
<tr>
<td>Household Income</td>
<td>0.005(3.137)</td>
<td>0.006(2.320)</td>
<td>0.017(3.412)</td>
<td>0.166(1.646)</td>
</tr>
<tr>
<td>Home to School</td>
<td>-2.740(-2.670)</td>
<td>-2.682(-2.299)</td>
<td>-7.664(-0.649)</td>
<td>-32.169(-0.603)</td>
</tr>
<tr>
<td>Distance</td>
<td>Parental Escort</td>
<td>1.909(3.829)</td>
<td>3.022(3.917)</td>
<td>44.598(2.898)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Non-motorized Three wheeled Rickshaw</td>
<td>Age of the Children</td>
<td>0.257(1.428)</td>
<td>0.223(1.045)</td>
<td>-0.479(-0.967)</td>
</tr>
<tr>
<td></td>
<td>Household Monthly Income Home Ownership</td>
<td>-0.006(-3.932)</td>
<td>-0.007(-3.087)</td>
<td>0.002(0.602)</td>
</tr>
<tr>
<td></td>
<td>Parental Escort Presence of Intersection Nearby Home</td>
<td>2.112(6.557)</td>
<td>3.229(4.918)</td>
<td>47.766(2.967)</td>
</tr>
<tr>
<td></td>
<td>Presence of Intersection Nearby Home Walk Mode</td>
<td>-1.625(-4.045)</td>
<td>-1.863(-3.694)</td>
<td>-1.739(-1.954)</td>
</tr>
<tr>
<td></td>
<td>Age of the Children</td>
<td>-0.334(-1.512)</td>
<td>-0.640(-1.820)</td>
<td>-3.670(-1.718)</td>
</tr>
<tr>
<td></td>
<td>Number of Multiple School going Children</td>
<td>0.481(2.157)</td>
<td>1.063(2.104)</td>
<td>15.873(2.543)</td>
</tr>
<tr>
<td></td>
<td>Household Monthly Income</td>
<td>-0.012(-6.502)</td>
<td>-0.016(-4.462)</td>
<td>-0.229(-2.964)</td>
</tr>
<tr>
<td></td>
<td>Distance from home to school</td>
<td>2.549(6.078)</td>
<td>5.667(4.378)</td>
<td>52.394(2.888)</td>
</tr>
<tr>
<td></td>
<td>Presence of Sidewalk Around Home</td>
<td>2.202(5.815)</td>
<td>3.437(4.357)</td>
<td>27.587(2.786)</td>
</tr>
<tr>
<td></td>
<td>Presence of Intersection Nearby Home</td>
<td>-2.195(-4.025)</td>
<td>-2.967(-3.544)</td>
<td>-68.117(-2.981)</td>
</tr>
<tr>
<td>Constants (Reference=Public/School Bus Mode)</td>
<td>Car Mode</td>
<td>0.777(0.577)</td>
<td>-0.333(-0.171)</td>
<td>-13.169(-3.064)</td>
</tr>
<tr>
<td></td>
<td>Rickshaw</td>
<td>-0.542(-0.199)</td>
<td>-1.257(-0.387)</td>
<td>-3.325(-0.551)</td>
</tr>
<tr>
<td></td>
<td>Walk Mode</td>
<td>6.119(1.819)</td>
<td>7.029(1.316)</td>
<td>45.987(1.629)</td>
</tr>
<tr>
<td>Standard Deviation of Parameter Distribution of Mixed Logit Model</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Variable</td>
<td>Coefficient (Standard Error)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel Time</td>
<td>0.522 (1.275)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of Intersection nearby Home (NMT)</td>
<td>0.285 (0.211)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household Size (Car)</td>
<td>0.185 (1.068)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of Sidewalk around home (Walk)</td>
<td>4.409 (3.636)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Class Allocation Membership model of LCM**

| Probability of Class1                        | 0.696 (47.463) |
| Probability of Class1                        | 0.303 (9.207)  |
| LL (constant only)                           | -518.7938      |
| LL (at convergence)                          | -254.6022      |
| Adjusted R-sq                                | 0.50032        |
| AIC                                           | 1.22590        |

### 6.4 Conclusion

From above models, it is prominent that car mode choice increases with the increase in home to school distance, household monthly income, parental escorting and female children is more likely user of car mode. In case of non-motorized rickshaw mode choice, household monthly income, presence of intersection nearby home, home ownership have negative coefficient values whereas parental escort, increase in children’s age have positive coefficient values. On the contrary, walk mode choice increases with the increase in number of children in the household, less 1.00km distance from home to school, and presence of sidewalk around home. Whereas, intersection nearby home, household monthly income and increase in age of the children add
disutility in walk mode choice probability. From the discussion it is also evident that mixed logit model and latent class model performs better than conventional multinomial logit model through addressing the heterogeneity among respondents.
CHAPTER SEVEN: FINDINGS AND RECOMMENDATIONS

7.1 Findings

The independent mobility effects mental, emotional, and physical development and walking is the best exercise of physical activity which provides spatial recognition. Childhood habits continue in later life and best exercise of childhood physical activity is walking to school. Major findings of the study are as follows:

7.1.1 Findings from Activity Pattern Analysis

There are several important findings from the study. First, from the amount of discretionary activities, it has been found that most of children pursue at least one out-of-home activity after school. This result confirms the importance of examining children’s post-school activity-travel patterns, since in many cases it is the location and timing of children’s activities that are dictating the activity-travel patterns of other household members. From descriptive analysis it is also evident that children engage in regular tutoring activities in fixed location and temporal dimension. Participation in extracurricular activities which are organized in nature is higher for female students and among the students performing these activities; more than 93% students are female. From travel dimension of out-of-home activities, it was found that only 2.96 percent students are independent traveler who make alone travel whereas the other 97 percent are being escorted by adults or friends or siblings. Children are mostly accompanied by their mother and a significant portion (25.42 percent) is being accompanied by friends. As reported by sample students, from home to all the places of unorganized recreational activities are accompanied by friends. The most used modes are rickshaw (42.42 percent) and then walking (39.46 percent) for children’s out-of home activities. The rest of the activities are performed through motorized traffic.
7.1.2 Findings from Physical Activity Analysis

The results of the ZIP model reveal that the key determinants of the frequency of out-of-home physical activity participation are the built environment attributes. It is found that whereas the presence of sidewalks increases the frequency of physical activity, the presence of traffic intersections nearby decreases the frequency of participation. Parametric hazard models are used to examine the determinants of duration of physical activity episodes. The results suggest that a Weibull model outperforms the log-logistic model in terms of model-fit. Parameters estimates reveal that car ownership, tenure type, activity location and escort arrangements are the most notable predictors of physical activity duration. For instance, parental escort increases the duration of physical activities and vice versa. The results of both models offer some interesting behavioral insights. It is found that older children engage in fewer physical activities, and also spend less time per activity episode than their younger counterparts. On the other hand, although children of older parents get fewer chances to engage in physical activities, they spend more time per activity compared to children of younger parents.

7.1.2 Findings from Mode Choice Analysis

On the contrary, from mode choice modeling it is evident that walk mode choice increases with the increase in number of children in the household, less 1.00km distance from home to school, and presence of sidewalk around home. Whereas, intersection nearby home, household monthly income and increase in age of the children add disutility in walk mode choice probability. From the discussion in Chapter Six, it is also evident that mixed logit model and latent class model performs better than conventional multinominal logit model through addressing the heterogeneity among respondents. From LCM, it is evident that there is latent class of heterogeneity among the respondent with regard to socio-economic status.
7.2 Recommendations

In addition to demographic characteristics, attitudinal, and others’ activity-travel pattern variables have an impact on children’s after school activity engagement patterns. These results confirm the importance of going beyond simple analysis of age, gender, and household income level when examining travel behavior, and support the collection of detailed geospatial information and the inclusion of questions on perceptions and attitudes in travel surveys. Furthermore, participation and time-allocation to episodes of different activity purposes are affected by different factors, depending on the location of participation. Therefore, studying the location type of activity participation will contribute to more accurate location modeling within activity-based travel demand modeling systems and should be further explored in future studies.

It is evident from the model results (Table 5.2) that presence of sidewalk nearby home increases the rate of physical activity participation, thus providing sidewalk in the residential neighbourhood will increase the frequency of physical activity participation in Dhaka City. From the duration model (Table 5.3), it is evident that duration of physical activity episode increase if the activity place is play field or park, hence it is important to preserve play fields and parks which are disappearing rapidly in the city due to high demand for housing and other uses. ZIP model (Table 5.2) also verdicts that home to school travel time and tutoring affect the participation rate of physical activity significantly. Therefore, the city should also consider demarcation of school-zone boundaries in order to reduce longer-distance school-trips for children in Dhaka’s congested network. Furthermore, the quality of public schools should be improved so that additional tutoring (fixed activities) could be reduced. Such initiatives will allow more time for physical activities that are essential for physical and psychosocial well-being of children of this developing nation. Future studies should also focuses on how all the components and land use of built environment affect physical activity level and mode choice of children. In addition, studies should focus on how neighbourhood design and sidewalk increases the level of walking.
Increase in number of children being driven to school may seem insignificant in term of overall transportation issues in Dhaka City, but school trips represent a significant proportion of peak hour trips in Dhaka City as the number of students up to higher secondary level is one-third of the total population of the city. From mode choice models (Table 6.2), presence of intersection nearby home reduces walking whereas sidewalk presence increases. Hence, the pedestrian facility and level of service of sidewalks should be improved to promote the choice of walk mode among children to ensure sustainable mode of transport as well as to increase the level of active travel among children. Nevertheless, pedestrian zone can be declared around school as the choice probability of walk mode is the highest. As the presence of intersection reduces the choice of both walk mode and non-motorized mode choice, thus neighbourhood design should focus on providing least number of intersections in a neighbourhood. Moreover, the neighbourhoods where there are intersections, there should be pedestrian friendly signal or crossing system so that children can travel alone and safely. As the distance and travel time affects walk mode choice prominently due to the lack of a defined proximal geographic catchment for the school thus regulation of neighbourhood school enrolment system can be introduced to keep home to school distance within 1.00km and to reduce travel time for schooling.

7.3 Conclusion

This study aims to fill the gap in the study of children’s mode choice by investigating the context of developing countries which will help to promote safe route to school as well as to enhance sustainable transportation for school trips in Dhaka City. Thus, a child’s activity-travel pattern is impacted by not only household members, but also friends and other non-household members. Children mostly participate with other individuals (rather than alone) in out-of-home activity episodes, and a significant proportion of these joint participations are with individuals who are not family members. In addition, a significant number of out-of-home activities take place at tutor’s home. These results highlight the need to examine children’s inter-household interactions, as well as children’s intra-household interactions, within a joint framework. Travel surveys
should make a greater effort to incorporate questions on with whom individuals travel and participate in activities with, as well information on the social networks, and location of social networks, that comprise an individual’s daily social contacts.

Controlling of factors such as travel time and physical barriers, a comprehensive series of pan-metropolitan studies of children walking to school needs to be mounted. They should investigate residual elements such as socioeconomic status, household routine (e.g. parent drop offs en route to work; non-working parent/s with spare transport capacity), car ownership, influence of family supporters, routing and frequency of public transport, previous accidents and injuries and so on. In this way, the jigsaw of variables including climate, ethnicity, urban population density and income can be assembled. Extensions of walking studies could, of course, be envisaged, as older children cycle or take public transport to cover greater distances to and from school (Carlin et al., 1997). Either of these transit modes is more physically demanding than just being driven. Allied studies can thus be beneficial in designing policy interventions. Targeted measures (e.g. walk to school/work campaigns, encouragement of use of public transport, restrictive measures on car use or, more broadly, densification and urban consolidation programmes) would be beneficial for school going communities as well as for wider metropolitan health education and transportation policies.


Rose, G. Safe Routes to School’ Implementation in Australia, Australia Road and Transport Research, Vol. 9, No. 3, 2000, pp. 3-16.


