GENDER AND INDIVIDUAL SPACE-TIME ACCESSIBILITY: A GIS-BASED GEOCOMPUTATIONAL APPROACH

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Hyun-Mi Kim, B.A., M.A.

*****

The Ohio State University

2005

Dissertation Committee: Approved by
Professor Mei-Po Kwan, Adviser
Professor Morton O’Kelly
Professor Michael Tiefelsdorf

________________________________________
Adviser
Geography Graduate Program
Copyright by

Hyun-Mi Kim

2005
ABSTRACT

This study aims to examine gendered accessibility experiences in space and time, through developing enhanced space-time accessibility measures with the use of geographic information systems (GIS). Various situations in which gender differences in accessibility experiences manifest will be examined using the activity/travel diary data set of Portland, Oregon.

This study provides a GIS-based geocomputational algorithm in order to enhance space-time accessibility measures with more rigorous representation of the temporal and spatial characteristics of urban opportunities (e.g. their geographical distribution and opening hours) and human activity-travel behavior (e.g. delay times, minimum activity participation time, and maximum travel time threshold). Furthermore, the proposed method takes into account the possible duration at each activity location given its opening hours and the effect of transport network, in addition to the consideration of the number and size of opportunities.

The results showed that, in addition to women’s lower accessibility in absolute terms, women’s temporal autonomy was strictly entrapped at only a particular time of day (in the late afternoon, specifically) regardless of employment status. Furthermore, the study has examined gender differences in determinants of accessibility and in travel/location/activity contexts where people participate in discretionary activities. Women’s lower levels of accessibility than men were largely due to additional constraints: household responsibilities. Compared to men, the level of availability of urban opportunities near home was found to be crucial in determining accessibility. In addition, people tend to enjoy the space-time autonomy in the work-to-home travel situation, and so the workplace and home are the most central locations of accessibility, as an origin and a destination. The importance of other locations is relatively higher for women than for men. Women have more household work, and so need to be at home more. Therefore, women’s need to be attached to home renders their accessibility more sensitive to the availability of local urban opportunities.

In summary, women and men do experience accessibility differently in space and time. These findings suggest that gendered importance of locations and timings, and accessibility context in travel/activity sequences needs to be explicitly acknowledged to better understand the gender gap in access to urban opportunities.
Dedicated to my mother, Jung-Hee Goh
I would like to express my sincere gratitude to my adviser, Dr. Mei-Po Kwan, for her intellectual and material support, encouragement, and guidance which made this dissertation possible. I admire Mei-Po for her tireless enthusiasm for research and scholarship. I also wish to thank the members of my dissertation committee, Dr. Morton O’Kelly and Dr. Michael Tiefelsdorf, for their constructive input to this research.

I appreciate the unflagging support and concern that Dr. Larry Brown has given me throughout my years of graduate study at The Ohio State University, even though I was not his advisee. Special thanks go to Joe Weber for providing the data set and a version of the geocomputational algorithm he used in his study, upon which the developmental effort of my research has been based.

I am also very grateful for having had emotional and intellectual support and encouragement of my friends, especially Sun-Yoon, Hyejin, Ho-Seop, Yongwan, Kamyoung, Gunhak, Eunyoung, Su-Yeul, Joe, and Philip. They have been a constant source of relief and strength, which made my graduate student life enjoyable and bearable. Most specially, I thank my dear friend, “wicked angel” Yushim for sharing my darkest hours and even brightening many dull moments in her own way.

I would like to thank the significant other in my life: my husband Sang-II. He truly deserves more gratitude than I could possibly express for his love, support, and patience, which has sustained me and brought me to this point. I am also deeply grateful to my parents-in-law for their support and understanding over the last couple of years. I would also like to share my happiness with my brothers, Jung-II Kim and Jung-Gi Kim, and my father.

Last but by no means least, I wish to thank my mother, Jung-Hee Goh for giving me things she never had had and encouraging me to take opportunities she wish she had had, and for always letting me know that she is there for me. She has always been, and will always be my source of inspiration in all my endeavors.
VITA

January 3, 1973 …………… Born – Nam-Hae, South Korea

1995…………………………B.A. Geography Education, Seoul National University, South Korea

1997…………………………M.A. Geography Education, Seoul National University, South Korea

1998 – present………………Graduate Teaching and Research Associate, The Ohio State University

PUBLICATIONS

Research Publication


FIELDS OF STUDY

Major Field: Geography
TABLE OF CONTENTS

Page

Abstract ................................................................................................................................. i
Dedication ............................................................................................................................. iii
Acknowledgements ............................................................................................................ iv
Vita ....................................................................................................................................... v
List of Tables ....................................................................................................................... ix
List of Figures ..................................................................................................................... x

Chapters

1. Introduction ....................................................................................................................... 1
   1.1. Introduction ................................................................................................................ 1
   1.2. Research objectives .................................................................................................. 7
   1.3. Organization of the research .................................................................................... 8

2. Literature Review .......................................................................................................... 13
   2.1. Introduction ............................................................................................................... 13
   2.2. Accessibility Measures ............................................................................................ 13
       2.2.1. Conventional spatial measures ........................................................................ 13
       2.2.2. Limitations of conventional measures ............................................................ 15
       2.2.3. Space-Time accessibility measures ................................................................... 19
   2.3. Gender and Access to Urban opportunities ............................................................. 23
       2.3.1. Commuting distance measures: work-trip length/time .................................... 24
       2.3.2. Time-budget measures: paid-work hours as an example .................................. 26
       2.3.3. Limitations ...................................................................................................... 27
   2.4. Gender, Household Responsibilities, and Gendered Spatiality ................................. 30
       2.4.1. Gender roles: individual vs. relational role constraints .................................. 30
       2.4.2. Household responsibility hypothesis (HRH) and Spatial entrapment thesis ... 32
2.5. Conclusions.........................................................................................34

3. Data and Methodology........................................................................35
   3.1. Introduction ...................................................................................35
   3.2. Study Area and Data .....................................................................37
   3.3. Limitations of Previous Space-Time Accessibility Measures .......44
       3.3.1. Representation of the space-time properties of opportunities ....45
       3.3.2. Representation of the temporal characteristics of human activity-travel behavior .................................................................49
       3.3.3. Representation of travel times and speeds on the transport network ....52
   3.4. Conceptual Framework ..................................................................54
   3.5. Operational Procedures and Geocomputational Algorithm ..........57
   3.6. An Empirical Example ...................................................................61
   3.7. Conclusions ..................................................................................73

4. Individual Accessibility in Space and Time........................................75
   4.1. Introduction ..................................................................................75
   4.2. Individual Accessibility in Portland ..............................................77
   4.3. The Significance of Including Temporal Availability into Accessibility Measure .................................................................85
   4.4. Accessibility in Space and Time .....................................................87
       4.4.1. Accessibility pattern in geographic space ...............................89
       4.4.2. Accessibility pattern in time ..................................................94
   4.5. Conclusions ..................................................................................103

5. Gender Differences in Accessibility by Employment status: Gendered Determinants and Travel/Location Contexts of Accessibility.................................108
   5.1. Introduction ..................................................................................108
   5.2. Significant Determinants of Accessibility by Gender ..................113
   5.3. Travel/Location Contexts of Accessibility ....................................117
       5.3.1. The significance of linked trips and other locations ..........118
       5.3.2. Gendered travel/location contexts of accessibility .............126
   5.4. Conclusions ..................................................................................133

   6.1. Introduction ..................................................................................136
   6.2. Household Responsibilities as Gender-role Constraints ............140
   6.3. Gendered Spatiality in terms of Activity Space .........................148
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1: The activity schedule of the person selected from the sample</td>
<td>62</td>
</tr>
<tr>
<td>3.2: Various temporal parameters used in the computation</td>
<td>64</td>
</tr>
<tr>
<td>3.3: Various space-time accessibility measures for the person on the sample day</td>
<td>72</td>
</tr>
<tr>
<td>4.1: Results of space-time individual accessibility measures</td>
<td>78</td>
</tr>
<tr>
<td>4.2: The effect of the temporal dimension incorporation into accessibility measure</td>
<td>86</td>
</tr>
<tr>
<td>5.1: Gender differential determinants significant in determining accessibility</td>
<td>115</td>
</tr>
<tr>
<td>5.2: Composition of accessibility values by each type of travel/location</td>
<td>119</td>
</tr>
<tr>
<td>5.3: Frequency of each travel and location context where people have access to urban opportunities</td>
<td>123</td>
</tr>
<tr>
<td>5.4: Average level of space-time accessibility by each travel/location type</td>
<td>124</td>
</tr>
<tr>
<td>6.1: Household characteristics with dual-earner couples in sample</td>
<td>142</td>
</tr>
<tr>
<td>6.2: Difference in household responsibilities between dual-earner couples by gender and parental status</td>
<td>147</td>
</tr>
<tr>
<td>6.3: Gender differences in number of activities by location by fixity type</td>
<td>151</td>
</tr>
<tr>
<td>6.4: Gender differences in number of fixed activities by location by activity purpose</td>
<td>154</td>
</tr>
<tr>
<td>6.5: The spatial extent of activity space with respect to distances traveled</td>
<td>156</td>
</tr>
<tr>
<td>6.6: Gender differences in average size of accessibility space</td>
<td>162</td>
</tr>
<tr>
<td>6.7: Average distance from home to PPAs by gender and parental status</td>
<td>163</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Study Areas: Portland Metro, Oregon</td>
</tr>
<tr>
<td>3.2</td>
<td>Different approaches to evaluating space-time accessibility of individuals</td>
</tr>
<tr>
<td>3.3</td>
<td>The effect of the maximum travel time threshold on the space-time prism and potential path area (PPA)</td>
</tr>
<tr>
<td>3.4</td>
<td>The proposed conceptual framework</td>
</tr>
<tr>
<td>3.5</td>
<td>Procedures implemented by the geocomputational algorithm</td>
</tr>
<tr>
<td>3.6</td>
<td>The opportunity set delimited in Step 1</td>
</tr>
<tr>
<td>3.7</td>
<td>The opportunity set delimited in Step 2</td>
</tr>
<tr>
<td>3.8</td>
<td>The opportunity set delimited in Step 3</td>
</tr>
<tr>
<td>3.9</td>
<td>The spatial pattern of possible activity duration</td>
</tr>
<tr>
<td>4.1</td>
<td>Gender differences in individual accessibility (( W_{\text{areaDur}} )) by race and employment status</td>
</tr>
<tr>
<td>4.2</td>
<td>Spatial pattern of individual accessibility (( W_{\text{areaDur}} ))</td>
</tr>
<tr>
<td>4.3</td>
<td>Spatial pattern of urban opportunity density</td>
</tr>
<tr>
<td>4.4</td>
<td>Temporal pattern of individual accessibility</td>
</tr>
<tr>
<td>4.5</td>
<td>Temporal variations in accessibility by employment status</td>
</tr>
<tr>
<td>5.1</td>
<td>Significance of each type of travels and locations on individual accessibility by gender and by employment status</td>
</tr>
<tr>
<td>6.1</td>
<td>Residential location of households with dual-earner couples in sample</td>
</tr>
</tbody>
</table>
6.2: The number of households (a) by types of gender difference in daily accessibility (WareaDur); (b) by types of gender division of labor within household in terms of daily household work hours……………………………………………………………145

6.3: Travel distances by activity purpose by gender and parental status …………………158

6.4: Two elements of accessibility space rendering gendered spatiality …………………160

6.5: Spatio-temporal pattern of fixed activities by gender by activity purpose: the occurrences of fixed activities in space and time, unweighted…………………………165

6.6: Spatio-temporal pattern of fixed activities by gender by activity purpose: the occurrences of fixed activities in space and time, weighted by activity duration….167

6.7: Spatio-temporal pattern of accessibility experiences by gender by location context: the occurrences of accessibility in space and time, weighted by the level of accessibility (WareaDur). ……………………………………………………………169

6.8: Possible relationship between accessibility space and activity space………………173
CHAPTER 1

INTRODUCTION

1.1 Introduction

Accessibility has been given much attention by a wide range of research and policy areas, such as geography, urban transportation, marketing, and urban planning and policy, for various analytical and evaluative purposes. Despite its long history, however, most researchers have not agreed upon any definitions or measurements of accessibility. As a consequence, various versions of accessibility measures have been defined and operationalized, depending on the research topics. Examples of relatively widely used definitions of accessibility are: the connectivity of places (Taaffe and Gauthier, 1973; Taaffe et al., 1996), the nearness to places (Ingram, 1971); the nearness to activities (McKenzie, 1984; Sherman et al, 1974; Wachs and Kumagai, 1973; Wickstrom, 1971; Mitchell and Town, 1977; Breheny, 1978; Talen, 1997), the potentials of opportunities for interaction (Hansen, 1959; Patton, 1976; Vickerman, 1974; Wilson, 1971; Pooler, 1987), and the ease of participating in activities (Burns, 1979; Lenntorp, 1976) -- (for extensive reviews for accessibility measures, see Pirie, 1979; Morris et al., 1979; Weibull, 1980; Jones, 1981; Pooler, 1987; Handy and Niemeier, 1997; Kwan et al., 2003).
This study basically aims to examine gendered accessibility experiences. In this regard, accessibility -- more specifically, *individual accessibility* -- is defined in this study as ‘the ease with which urban opportunities (e.g. employment, shopping, etc.) can be reached by an individual’ (see Kwan and Weber (2003) for the review of individual accessibility studies). Individual accessibility is often considered an indicator of quality of life (Koenig, 1980; Pirie, 1979; Wachs and Kumagai, 1973, Dijst and Kwan, 2005), because it is a useful measure of the social and spatial equity to urban services. For example, those who attempt to answer the question of ‘who gets what, where and how’ might employ individual accessibility measures in identifying and locating disadvantaged population groups with respect to residential area, age, gender, employment status, disability, income, race and so on; and in assessing the impact of urban policy or social/spatial changes in urban environment on the population groups of interest (Talen and Anselin, 1998; Forer and Kivell, 1981; Wachs and Kumagai, 1973; Dalvi, 1979; Kirby and McGillivray, 1979; Mitchell and Town, 1977).

There are two distinct approaches in measuring individual access to urban opportunities: *spatial* measures and *space-time* measures. The most widely used conventional approaches, such as gravity measures and cumulative-opportunity measures, are considered as “spatial” accessibility measures because they are based solely on the notion of locational proximity. Despite the relative ease of implementation and resulting popularity, however, these measures are not quite suitable for evaluating individual accessibility due to their inherent characteristics (Kwan, 1998). Their limitations include:
(a) dependence on zonal and disaggregated analysis; (b) a lack of consideration of the attributes of people and the importance of the temporal dimension; and (c) a lack of understanding of complex activity-travel behavior, such as interdependence between activities, and multipurpose/stop travel behaviors. Particularly, such spatial measures are likely to be gender-blind. That is, spatial measures have been criticized as inadequate for understanding the access experience of individuals and masking the existence, or the level, of gender difference in access to urban opportunities. Conventional measures based on spatial proximity alone do not allow room for incorporating situational complexities of the activity-travel behavior and space-time constraints women face every day, and therefore cannot reveal how, and to what extent, individuals (women) are disadvantaged.

Space-time accessibility measures have attracted renewed attention recently as an alternative approach to measuring individual access to opportunities. While conventional measures only consider a transport element and the spatial availability of opportunity, space-time measures highlight the importance of temporal factors as well (Burns, 1979). This type of measure, based on Hägerstrand’s (1970) time-geographic framework and the concept of “space-time prism,” evaluates accessibility in terms of an individual’s ability to reach activity locations given the person’s daily activity program and spatio-temporal constraints (Lenntorp, 1976; Burns, 1979; Landau et al, 1982; Villoria, 1989; Hong, 1997; Kwan, 1998, 1999a; Kwan and Hong, 1998; Miller, 1999; Miller and Wu, 2000; Weber, 2001, 2003; Weber and Kwan, 2002, 2003; Wu and Miller, 2002, Kim and Kwan, 2003). These space-time accessibility measures explicitly take into account the fact that
individual accessibility depends not only “on where activity sites are located vis-à-vis the person’s home and the transportation network, but also on when such sites are open and when and how much time the person has for making trips” and participating in activities at the places (Hanson, 1995).

Space-time accessibility measures explicitly acknowledge the importance of gender roles as a key social and spatial constraint for women, constraining their behavior, limiting their activities and confining them to a smaller geographic area than men. Time-geographic framework on which space-time accessibility measures are based allows us to incorporate the complex space-time budgeting problems and spatial constraints women face in their daily routines of child care and household responsibilities, with poor public transportation and so on. In a comparative study by Kwan (1998), for example, space-time measures were shown to be more sensitive to individual difference than conventional ones, and made gender differences visible.

Despite the advantage of space-time accessibility measures, however, there have been very few attempts to use them to evaluate accessibility in both operational and empirical ways, since Lenntorp (1976) and Burns (1979) proposed formulations of space-time measures in 1970s (e.g. Villoria, 1989). This might be because of the computational intensity in handling detailed geographical data. Recently, with the advent of powerful GIS functionalities, space-time measures of individual accessibility have attracted new attention. Several studies have developed network-based methods to operationalize
space-time measures (Miller, 1991, 1999; Hong, 1997; Kwan, 1998; Kwan and Hong, 1998; Miller and Wu, 2000; Weber, 2001; Kim and Kwan 2003; O’Sullivan et al., 2000) (see Kwan (2004) for the review on GIS-based space-time accessibility measures). Several studies also used this method to assess interpersonal differences in accessibility empirically with an original activity-travel diary data set (Kwan, 1998, 1999a, 1999b; Weber, 2001, 2003; Weber and Kwan, 2002, 2003; Kim and Kwan, 2003). Despite the conceptual attractiveness and robustness of space-time measures, however, only a few attempts have been made to operationalize them to date. Therefore, research that seeks to improve and examine space-time accessibility measures is still sorely needed.

Regarding gender differences in access to urban opportunities, a considerable number of studies has been undertaken through the analysis of activity-travel patterns based on time-geographic perspectives (Hanson and Hanson, 1981; Pickup, 1984, 1985; Hanson and Pratt, 1990, 1995; Kwan 1999a, 1999b, 2000a; Palm and Pred, 1974; Tivers 1985, 1988; Miller, 1982, 1983; England, 1988, 1993, 1996). In contrast, there are few empirical studies on gender differences in accessibility (either explicitly or implicitly) with the use of space-time accessibility measures (Villoria, 1989; Kwan, 1998, 1999a, 1999b; Weber, 2001, 2003; Weber and Kwan, 2002, 2003). It is mainly because of the computational difficulty and intensity and the lack of detailed travel/activity data required, as mentioned above.

Some believe that, in contemporary society, women’s better access to private cars, increased participation in the labor market, and changing attitudes of husbands and wives on gender division of household labor are diminishing gender gaps in access to urban
opportunities. It is believed that women’s lower access is because of their limited mobility due to the lack of a car and the slower transport mode use (public transport or walking) in the past, as compared to men. It is also believed that contemporary society is more egalitarian due to women’s improved status through increased participation in the paid labor market and the changing attitudes of their husbands on sharing household responsibilities, which causes gender differences to fade away when similar roles (those of breadwinner and parents) are shared by men and women. A significant amount of research has been done on gender division of labor itself (e.g. Turner and Grieco 2000; McFarlane 2000), but few attempts have been made to examine how such societal changes affect women and men’s accessibility. If society is egalitarian, women’s access to urban opportunities would be similar, or equal, to the level of men’s when transport mode, employment status and marital/parental status are controlled.

Others argue that although is true that most women participate in paid employment and travel by cars, they still face heavier responsibilities than men whether they work full-time or part-time. Because of persisting traditional gender roles socially constructed for women and men, the majority of working women continue to combine both family and paid work while men do not. Therefore, we need to keep in mind that the social perception of gender permeates and shapes different access experiences between women and men. Working women’s need to cope with multiple roles (housework, childcare and paid work) results in more complex and fragmented space-time activity schedules and leads to different accessibility experiences to urban opportunities than men in space and time.
Additionally, with the need to answer questions of the existence of a gender gap in accessibility level and the nature of contemporary society as egalitarian, there are other valuable dimensions space-time accessibility analysis should shed light on. That is, further detailed analysis on gender differences in accessibility is still needed beyond the comparison of women’s and men’s level of accessibility and those spatial patterns (Kwan 1998; Weber 2001).

1.2 Research Objectives

The major research objectives of this dissertation are twofold:

The first objective is to develop more realistic and gender-sensitive measures of individual accessibility. More specifically, this study seeks to enhance space-time accessibility measures through developing a new operational method and GIS-based algorithm that better represents the space-time characteristics of urban opportunities (e.g. their geographical distribution and opening hours) and human activity-travel behavior (e.g. delay times, minimum activity participation time, and maximum travel time threshold). The proposed method not only takes into account the number and size of opportunities, but also the possible activity duration at each activity location given its opening hours and the effect of transport network topology (e.g. one-way streets, turn restrictions and over-passes). Incorporating these elements into space-time measures helps overcome several shortcomings of previous approaches to evaluating space-time accessibility. In addition, activities associated with household responsibilities will be
explicitly incorporated as fixed activity constraints into the measure, so to evaluate the current society and whether gender role constraints still permeate and make women and men experience accessibility differently.

The second objective is to grasp a detailed picture of gendered experiences of accessibility. Previous studies on gender differences in accessibility have mainly focused on the gender gap in the level of accessibility, the identification of spatial configurations of accessibility within a city by gender, and major determinants of accessibility. Since little has been examined regarding a range of gendered dimensions of accessibility, this research attempts to unveil various aspects of gender differences in individual accessibility experiences. In contemporary societies where traditional gender roles and expectations still permeate, the analysis will examine how such gender role constraints limit women’s accessibility experience spatially and temporally, whereas it may be not the case for men in similar employment and marital/parental status.

1.3 Organization of the research

This dissertation contains seven chapters which attempt to assess and understand gender differences in accessibility experiences, through the development of enhanced space-time accessibility measures with the use of geographic information systems (GIS).

Chapter 2 presents a literature review to support later analytical chapters in this dissertation. The first phase of Chapter 2 will provide a critical overview of accessibility
measures in previous studies, focusing on how conventional spatial measures are insufficient to identify accessibility of people in general and why these measures are often criticized as gender-blind. In the next section, space-time accessibility measures are introduced as more sensitive to people’s mobility and space-time constraints beyond their position within a city (a detailed discussion of the limitations of previous space-time accessibility measures will be provided in Chapter 3). Then, in the final stage of Chapter 2, an overview of the literature regarding gender and access to urban opportunities will be presented. One of the key findings of previous research on gender and access to urban opportunities is that women’s heavier household responsibilities result in lower levels of access to urban opportunities compared to men, through higher space-time fixities women face in their everyday lives. Women’s circumstances lead them to be spatially entrapped, through shorter travels to activities (especially to work) and less out-of-home activities because of household activities, which render women home-bound.

Chapter 3 begins with a general overview of the study area, Portland, Oregon, and the activity/travel diary data set employed in this dissertation. After limitations of previous space-time accessibility measures are discussed, this chapter provides a conceptual framework, GIS-operational procedures and geocomputational algorithm in order to enhance space-time accessibility measures with more rigorous representation of the temporal and spatial characteristics of urban opportunities and human activity-travel behavior. Furthermore, the proposed method takes into account the possible activity
duration at each activity location, given its opening hours and the effect of the transport network, in addition to the consideration of the number and size of opportunities.

Chapter 4 is the first of three analytical chapters in this dissertation. The results of space-time accessibility measures proposed in Chapter 3 are reported in Chapter 4. The first phase of Chapter 4 will explore the resulting values of space-time accessibility measures, especially focusing on whether the inclusion of temporal dimension into the measure significantly affects the level of accessibility, and whether the proposed measure captures clearly the existence of gender difference in the level of access to urban opportunities. The remaining part of Chapter 4 will present spatial and temporal variations in accessibility, and further gender distinctiveness in such patterns.

Chapter 5 will examine gender differences in influential determinants and contexts (in terms of travel and location in which space-time prism are made) which affect accessibility. The first phase of Chapter 5 will attempt to identify whether critical factors of accessibility are different between women and men. In so doing, this study attempts to emphasize the importance of household responsibilities for women (as gender role constraints), as one of the key determinants, which has been ignored in most past accessibility studies based on conventional measures. The second phase of chapter 5 will illuminate distinct gendered contexts of accessibility experiences— that is, gender differences in contexts where space-time autonomy would be allowed, especially with respect to travel types (either linked or unlinked) and locations from/to which travels are
made. This chapter will try to answer a number of questions: in which travel contexts, and around which locations, urban opportunities would be accessible; and, whether there exist gender differences in travel/location context characteristics in terms of composition, frequency and average size of space-time prisms made.

In Chapter 4 and 5, the comparison of gendered accessibility will be made by employment status, since employment status has been widely identified one of the most important determinants of space-time accessibility (Weber, 2001). In Chapter 6, as the focus moves into the importance of gender roles on accessibility, the comparison between women and men will be made by parental status. Due to the lack of marriage information of other adult members within a household, comparisons of a head of household and his/her spouse only will be undertaken, since each person’s spouse information is clearly coded and marital and parental information is undoubtedly identifiable.

Chapter 6 involves an analysis of married dual-earner couples within the same household in order to further examine gendered aspects of accessibility experiences identified in Chapter 5. How gender roles (household responsibilities) differentiate accessibility experiences between women and men will be explored though the direct comparison of married dual-earner couples’ parental status. The first phase of Chapter 6 will show how gender division of labor within the household still permeates current society, despite the widespread belief of the social change toward a gender-egalitarian society. Then, the later phase of Chapter 6 will pay special attention to the way gender roles structure individual accessibility experiences of women and men differently, and, in
turn, the way such accessibility experiences take a form of gendered spatiality. The examination of gendered spatiality starts with the analysis of activity space in order to investigate women’s home-attached and spatially entrapped characteristics (through the measure of travel distances from home and the amount of in-home and out-of-home activities). Then, it is followed by the analysis of gendered spatiality in terms of accessibility space. Finally, the study will show the relationship between spatial and temporal patterns of gender-distinct constraints and accessibility experiences. It will also show that the proper interpretation of revealed activity/travel behaviors in general and activity spaces in specific would be possible through understanding possible conditions for activity/travel where the person is situated given his/her space-time constraints in general and accessibility spaces in particular.

Chapter 7 is the final chapter of the dissertation. It consists of a summary and conclusions drawn from the findings of previous chapters, which have attempted to elucidate manifold dimensions of gendered accessibility experiences. The directions for future research will be discussed.
2.1 Introduction

Chapter 2 reviews several accessibility measures and studies on gender differences in access to urban services in order to set a broad context for later analytical work in this dissertation. Accessibility measures can be divided into spatial measures and space-time measures. Major characteristics of current accessibility measures and their limitations are addressed in the first section. Then, general concepts and studies on gender differences in access to urban opportunities are discussed.

2.2 Accessibility Measures

2.2.1 Conventional spatial measures

Conventional accessibility measures describe locations which could be reached by a given travel mode. The most commonly used indicators of accessibility are of two
kinds: opportunities weighted by an impedance (a decreasing function of travel cost or time) and isochronic definition (number of opportunities reached within a given travel time). The former accessibility measures are known as gravity-based measures, and the latter are cumulative opportunities measures.

The gravity-based measures are the most common measures of accessibility proposed by Hansen (1959), and are based on spatial interaction framework. As shown in the equation [1], this type of measure weights opportunities by impedance, generally a decreasing function of travel time or travel cost.

\[ A_i = \sum_{j=1}^{n} O_j f(C_{ij}) \]  

where 
- \( A_i \) = Accessibility from zone i to the considered type of opportunities 
- \( O_j \) = Opportunities in zone j (employment places, shops, etc) 
- \( C_{ij} \) = Travel time, distance, or cost from i to j 
- \( f(C_{ij}) \) = Impedance function (negative exponential, power, or modified Gaussian functions are most often used)

The cumulative opportunities measures evaluate accessibility in terms of the number of opportunities reached within a specified travel time (or distance, x) from the origin of interest and, thus, give some sense of the range of choice available. They can be seen as a specific form of the gravity-based measure (equation [1]), with an impedance function equal to 1 for travel time less than x, and 0 beyond x. They are called isochronic indices, as a measure of ‘equivalent attraction,’ which does not discount measures of opportunity over distance (McKenzie, 1984; Sherman et al, 1974; Wachs and Kumagai, 1973; Wickstrom, 1971; Breheny, 1978; Talen, 1997).
2.2.2 Limitations of conventional measures

Even with the popularity and computational simplicity of such conventional measures for individual accessibility (Hansen, 1959; Ingram, 1971; Patton, 1976; Vickerman, 1974; Wilson, 1971), these types of measures have been criticized for their inherent problems in both a conceptual and operational sense (Breheny, 1978; Pirie, 1979; Handy and Niemeier, 1997).

First, even though accessibility levels are highly sensitive to the choice of parameter values on the travel-impedance term or a cutoff distance limit, these values cannot be innately determined (Breheny, 1978; Handy and Niemeier, 1997). Furthermore, such a predetermined parameter tends to be applied universally without the consideration of possible differences among population groups in different situations and with different mobility.

Second, the aggregate nature of most of the gravity measures limits its usefulness. Conventional measures, due to their analysis unit as zone, have been criticized with respect to their strong association with the Modifiable Areal Unit Problem (MAUP) and the Ecological Fallacy problem. Zone-based conventional measures are severely affected by the size and the shape of zones and by aggregation level (Dalvi and Martin, 1976; Davidson, 1977; Pirie, 1979; Bach, 1981), and are also associated with the self-potential problem (accessibility of a zone to itself) (Pooler, 1987; Frost and Spence, 1995). In
addition, zone-based conventional measures essentially assume that all individuals within a zone face the same set of opportunities and, as a result, ascribe the same level of accessibility to different individuals in the same zone (Ben-Akiva and Lerman, 1979; Vickerman, 1974; Pirie, 1979). Zonal measures overlook the fact that individuals within any zone differ in their access to transport modes and therefore in their ability to reach activity sites (Pirie, 1979; Kwan, 1998, 1999a; Hanson and Swab, 1987). Although the MAUP or the ecological fallacy problem might be reduced if a disaggregated approach is used, conventional accessibility measures, however, still have problems as individual accessibility measures because of their lack of the recognition of the temporal constraints and their failure to grasp complex travel behavior (Recker et al., 1986a, 1986b).

Third, little recognition of the importance of temporal aspects in shaping accessibility has been found in these conventional accessibility measures (Kwan, 1998, 1999a, 1999b; Hanson and Schwab, 1986; Miller, 1999). Two types of temporal dimensions that should be considered for individual accessibility measures are overlooked in conventional measures: temporal aspects of environment (activities and transport) and of individual circumstances. While conventional measures are just interested in the locations of opportunities, in reality, however, most activity opportunities are not always available since they have their own opening hours and closing hours. And, public transportation systems such as buses, trains, or rails have specific timetables and cannot be accessed during certain periods of time (such as late night to early morning). In addition, temporal dimensions of personal condition are also
neglected in the conventional accessibility measures. Accessibility is not just a function of the travel environment and the spatial distribution of opportunities, but also the ability of individuals to use the opportunities based on their activity schedule associated with certain amount of temporal constraints. Such activity-related contextual effects cannot be captured by conventional accessibility measures (Miller, 2000; Kwan, 1998).

Fourth, with the single reference assumption, the conventional measures cannot grasp complex travel behavior (Kwan, 1999b; Hanson, 1995). As conventional measures see accessibility as locational proximity of opportunities with respect to a single reference location such as home or workplace, they assume all potential trips start from that single point. Accessibility measures based solely on travel impedances from a single point are too limited, because a considerable number of trips are, in fact, not home-based. It is also because many locational decisions are based on proximity to non-home activities. As Richardson and Young (1982) pointed out, the failure to understand the effect of linked-trip or trip-chaining behavior in conventional accessibility measures would result in considerable under-estimation of accessibility to activities located at non-central urban areas. Spatial proximity between an origin and intermediate facilities, and between the intermediate facilities and a destination plays a significant role in determining the level of accessibility of an individual. Especially, in the case of women with young children, for example, access to jobs not only depends on where the jobs are, but also on the location of child care facilities, which makes some job locations are more feasible than others.
even when the distances from home are the same (Palm and Pred, 1974; Kwan, 1999b; Hanson and Pratt 1990; Pickup, 1984, 1985, 1989; England, 1996).

Finally, ignoring the role of space-time constraints in determining individual accessibility makes conventional accessibility measures problematic (Kwan, 1999a). People have certain types of obligatory activities in their everyday lives and thus face some degree of spatial-temporal constraints, which limits when, where and how long they can travel. Therefore, individual accessibility is determined not only by how many opportunities are located nearby, but also by how many opportunities are within reach given space-time constraints and adaptive capacity (Kwan, 1999b; England, 1993, 1996). The extent to which spatial-temporal fixity plays an important role in determining accessibility may vary among different subgroups of people. According to Pickup (1985), conventional spatial measures of accessibility are not that suitable for the analysis of women’s access to urban opportunities like jobs because women’s activity choices have additional time constraints because of their gender role (heavy household-associated activities and child care activities), and because such gender-role-related space-time constraints are more important than travel mobility or costs in determining women’s job locations (Tivers, 1985, 1988; Turner and Niemeier, 1997; Turner and Grieco, 2000; Kitamura et al., 1990; Kondo and Kitamura, 1987; Koppelman and Pas, 1985; Kwan, 1999a, 1999b, 2000a).
2.2.3 **Space-Time accessibility measures**

In contrast to conventional measures, which focus only on spatial components, space-time accessibility reflects three components (spatial, temporal, and transportation) of accessibility. Additionally, the attractiveness of the space-time approach in measuring individual accessibility stems basically from its better ability to cover a multiplicity of factors in the formulation, and largely from its sensitivity to person-specific situations, which reveals gender differences in levels of access to urban opportunities caused by the differential limiting effects of various factors. In so doing, space-time accessibility has been shown as a promising measure of individuals’ access to urban opportunities, through a series of comparative and empirical studies (Villoria, 1989; Kwan, 1998, 1999a, 1999b; Weber, 2001; Weber and Kwan, 2002).

The space-time accessibility measures evaluate the level of space-time autonomy (or space-time feasibility) by examining the space-time prism determined by locations of activities (or distances between relevant locations), total amount of time available for travel and activity participation, and travel velocities. (Hägerstrand, 1970; Burns, 1979; Villoria, 1989). The space-time prism determines the feasible set of locations for travel and activity participation in a bound expanse of space and a limited interval of time. People are confined in certain spatial boundaries for travel and activity due to their limited mobility and daily activity schedules with space-time fixities. The space-time prism of people who have a slower travel mode, more space-time constraints and therefore less time for flexible activities is expected to be much smaller than those who
have faster travel mode, less space-time constraints and, therefore, more time. The potential path area (PPA) is the projection of three-dimensional space-time prism onto two-dimensional planar space. The PPA delimits the purely spatial extent or area within which the individual can travel.

As the space-time accessibility measures, the volume of the space-time prism, and the area delimited by the potential path area (PPA) were initially proposed by Lenntorp (1976). Later, Burns (1979) included transport network geometry, non-uniform travel speed, and a combination of different travel modes on the accessibility measures. Following Hägerstrand’s (1970) conceptualization of travel/activity patterns as space-time paths, temporal aspects, and complexities of activity/travel behavior (such as linked and interdependent trips) are taken into account in the space-time accessibility measure.

Lenntorp (1976) and Burns (1979) originally proposed the operational formulations of space-time accessibility measures by using the space-time prism as a key for an operational measure of accessibility. Villoria (1989) implemented the prism construct in an operational sense with a large real world data set, and evaluated the level of accessibility among different subpopulation groups using different transportation modes. As in the study of Villoria (1989), most past attempts to operationalize the space-time prism used mathematical and geometric methods based on the Euclidean distance between fixed activities (Newsome et al, 1998; Nishii and Kondo, 1992). The PPA derived by such a geometric method takes a shape of an ellipse, which is simple but far from being a realistic representation of urban space as a potential path area of individuals. Villoria calculated the sum of the space-time reach of each individual as the space-time
accessibility measure. The assumption of a constant and uniform travel speed throughout the urban environment, the ignorance of movement confined by the geometry of the transport network, and the lack of understanding of uneven distribution of opportunities even within a PPA make such a geometric space-time measures unrealistic.

Recently, GIS capabilities help to tackle problems associated with geometric methods. Instead of uniform and constant speed-based, and Euclidean distance-based PPA, Miller (1991) proposed an operational method for deriving the network-based space-time prism constructs, using GIS procedures based on point-to-point travel distances on the network. By using different network-based space-time accessibility measures, Kwan (1998) and Weber (2001) implemented the GIS procedures empirically with real world data. Kwan and Hong (1998) extended the Burns’ (1979) formulation of the space-time prism by incorporating the effect of store hours, minimum threshold activity duration, delay times into their formulation as well as cognitive constraints such as spatial knowledge and locational preference.

However, regarding operationalizing space-time accessibility using space-time prism constructs from network-based GIS methods, there are still many aspects to be improved. Above all, previous approaches tend to lose some of the important temporal properties of accessibility when operationalizing the measures. In the process of converting the 3-D space-time prism into the 2-D potential path area, the temporal dimension of accessibility as expressed in a form of the volume has been disregarded (Hong, 1997; Kwan, 1998, 1999a; Kwan and Hong, 1998; Weber, 2001, 2003; Weber and Kwan, 2002, 2003), and only spatial extent has been utilized for identifying the
number of feasible opportunities as a space-time accessibility indicator. In fact, the space-time prism’s volume gives valuable information with respect to better representation of individual accessibility (further detailed discussion will be made in Chapter 3). Furthermore, although precise and realistic calculation of travel times over the transportation network is crucial for the enhancement of space-time measures, previous measures often overlooked the existence of one-way streets (predominant in downtown where a great amount of urban opportunities are present) and congestion effects, and some behavioral characteristics (a certain time threshold for activity participation and travel). Relatively little effort has been made to operationalize the space-time accessibility measures using the space-time prism, and so improvement to these measures are still required. Some aspects to be further enhanced will be discussed in a greater detail in Chapter 3.

Furthermore, many studies have stressed the importance of multi-stop and multi-purpose trips in everyday life experiences of individuals (Burnett and Thrift, 1979), and, therefore, pointed out one of the critical weak points of previous measures, as they cannot capture such behavioral characteristics in their formulation. However, no study has empirically examined and stressed the importance of the incorporation of such complex travel possibilities into the accessibility measure, and further possible gender differences in travel/activity situations in which the levels of accessibility are primarily determined. Previous individual accessibility studies have focused on the level of accessibility, but have not paid attention to the location/travel/activity contexts in which accessibility occurs. Attempts to answer such questions of in which travel contexts, and around which
locations, urban opportunities would be accessible, and whether there are gender differences in situational and locational characteristics could provide valuable insight.

2.3 Gender and Access to Urban opportunities

In addition to several problems in individual accessibility measures, previous spatial measures have also been criticized by their problems of gender blindness and, accordingly, gender invisibility in their outcomes. Their exclusive emphasis on a spatial factor and the lack of acknowledgement of the totality of everyday life experiences in determining people’s accessibility has lead to the need for other ways to examine women’s access to urban opportunities.

So far, most of the literature on women’s access to urban opportunities has been exclusively skewed toward revealed (actual) travel/activity patterns (i.e. actual patterns) – e.g. commuting distances, number and duration of activities and travels made. Little has been studied in terms of the accessibility level itself, in other words, possible activity participation. It is largely because most of research on gender differences in access has been focused on women’s access to employment; and to some extent, it is because of the operational difficulties to calculate individual accessibilities with sophisticated treatment of spatial, temporal, and transport characteristics of people’s activities and travels. Commuting distance/time measures and time budget measures are one of the most widely used approaches in examining gender difference in access to urban opportunities.
2.3.1 Commuting distance measures: work-trip length/time

The commuting time or distance is widely used as an empirical indicator of accessibility (Blumen, 1994). Instead of distances to multiple potential urban opportunities throughout a city, spatial proximity of two locations is of concern in this type of measure: home and workplace. The commuting distance measure is mainly used to assess a particular type of urban opportunity -- jobs. However, the relationship between accessibility and the degree of spatial separation of home and workplace could be interpreted in a different way, depending on the context of research. Unlike the case of spatial measures, the distinction between the journey to work distance (or time) as a factor and as an indicator needs to be carefully made. Commuting distance measures have a slight gap between interpretation as a factor and as an accessibility indicator, while spatial measures show the direct relationship between the factor of accessibility and the indicator -- the distance to urban opportunities or the nearby urban opportunity density.

As a factor, a longer journey to work either in terms of distance or time reduces accessibility since it reduces time which could be spent for other discretionary activities. By contrast, as an indicator, a longer journey to work could imply either lower accessibility or higher accessibility of an individual. For example, a comparison of different transport mode users views that longer commuters have higher accessibility. According to transportation mode-oriented studies, longer distance to a workplace is assumed to be an empirical indicator of better mobility and a larger pool of jobs: person with a faster transport mode can travel longer given amount of time and in turn would
have more job opportunities accessible, compared to those who walk or use a public bus. Traditionally, women or urban poor have been recognized to be less accessible to private cars and tend to have a shorter commuting distance.

On the contrary, according to studies emphasizing the segregated local labor markets, longer commuting, either time or distance, is interpreted as a result of the lack of local job opportunities – therefore, as an indicator of lower accessibility. However, even within the approaches stressing the relationship between labor markets and commuting lengths, different interpretations are possible. That is, different underlying theories have used the commuting time or distance as an indicator of accessibility to job opportunities in different ways. For example, the spatial entrapment thesis sees the shorter commuting time as an indicator of the lack of accessibility to urban opportunities. In the case of women—especially, whites in suburban settings—, a shorter commuting time or distance compared to men indicates their lower accessibility. This approach emphasizes the time-poor situation of suburban working mothers as a key dimension on women’s shorter commutes. By contrast, according to the spatial mismatch theory-based interpretation, the longer commute of minority women in the central city, due to the lack of nearby job opportunities appropriate for them, is seen as indicative of their lower accessibility. It implies that the length of travels cannot be directly employed to assess people’s accessibility since both short and long commutes can be different ways of manifestation of women’s disadvantage in access to urban opportunities.

In addition to its uncertain relationship with individual accessibility, another problem with this factor is that the empirical findings on such differences in commuting time or
distance by gender, race, or location of residence, themselves, have been mixed and inconclusive. What makes people have lower accessibility to urban opportunities or job opportunities cannot be easily and directly answered by just observing how long they commute. Either long or short work trips can be taken as indicators of spatial inequality in the access to employment (McLafferty and Preston, 1997). What is needed is the careful interpretation of the relationship between individual accessibility and commuting, based on the contextualized understanding of the life situations of individuals, beyond the simple treatment of commuting in isolation and its direct use as an indicator of individual accessibility.

2.3.2 Time-budget measures: paid-work hours as an example

Previous spatial accessibility measures or transportation-oriented studies emphasize spatial separation to urban opportunities which could be represented as the CBD, urban regional centers, nearby urban opportunities surrounding home, or workplace, as mentioned earlier. Accessibility measures based on activity-based analysis or time-use studies, on the other hand, pay attention to different ways of time allocation to various activities among population groups. One of the most widely used factors and indicators is hours spent for paid-work. Longer work hours generally mean the lower accessibility to urban opportunities, as there is a trade-off between work hours and discretionary activity hours.
One of the problems with the use of a temporal factor as an individual accessibility indicator is its ignorance of spatial characteristics of the urban environment: that is, the availability of urban opportunities is not taken into account at all. Hence, actual lower quality of life of rural residents due to the lack of many and diverse urban opportunities within reach, compared to urban residents, cannot be captured with this type of measure.

2.3.3 Limitations

Although such approaches are basically capable of showing gender differences in access through the empirical analysis, they are not without limitations in evaluating gender difference in access to urban opportunities. Limitations with actual activity/travel pattern analysis include the neglect of various meaningful locations other than home, as a single, fixed reference point, and/or workplace and the person-specific sources of space-time constraints; and the failure to recognize the contingent relationship between what could be possible and what is actually revealed through the complex decision processes of individuals.

First, the recognition of increasing importance of other locations, beyond home and workplace, in everyday lives in determining accessibility and spatiality of people is strongly needed. Previous conventional measures have used home and/or workplace as the focal points: home in the spatial accessibility measures, and both home and workplace in the commuting distance measures. The measure of urban opportunities near home or the spatial proximity to workplace from home could not satisfactorily portray the
accessibility of a person who has to perform more multi-stop and multi-purpose trips, and, in turn, has the spatial proximity to various locations other than home or workplace contribute more to his/her accessibility. For example, given the recent social change of increasing female participation in the labor market, the mere spatial proximity between home and workplace becomes a less meaningful measure for examining accessibility to jobs for a particular group of people, especially working mothers with young children. Compared to men, women’s journey to work shows a higher tendency of the multi-purpose/multi-stop travel pattern, as women with young children tend to have the primary responsibility of dropping off and picking up their children at daycare centers. Therefore the availability of jobs to working mother is not just limited by their spatial proximity to the home locations, but also further constrained by their spatial proximity to daycare facilities.

Second, the importance of workplace and work hours on accessibility tends to be overemphasized by conventional measures. The measure of the distance to the workplace or the work hours isolates travels and activities from the context of everyday lives. In fact, home and work are inseparable and dynamically interdependent spheres of everyday lives (Kwan, 1999; Hanson and Pratt, 1990, 1991,1995). As in the case of the journey to work, the importance of work hours in determining accessibility should be examined in the wider context of everyday life on which a particular person is situated. Various sources of space-time constraints affect individual accessibility, and a major source of such constraints would differ among population groups. The significance of the constraining effect of work hours on the overall accessibility experience in everyday life
could vary among population groups, as different sources of space-time constraints other than work hours could be more influential. For example, working mothers tend to carry out disproportionately more and longer domestic work and to make more travels, associated with household responsibilities, which are, like paid-work hours, mostly spatially and temporally fixed. The simple measure of work hours would likely to overestimate the level of accessibility of part-time working mothers by masking the reality of their low space-time autonomy due to their heavy household responsibilities, compared to their male counterparts.

Third, the mixed and inconclusive findings on women’s shorter commuting distances than men’s may be not only because of the lack of acknowledgement of interconnectedness and interdependency of home, work, and out-of-home none-employment activities, but also because of the very nature of revealed patterns which are in fact a product of the complex interaction of various factors such as characteristics of local labor markets, individuals’ space-time fixities, and personal choice and preference within such a limited condition. Therefore, whether findings through revealed activity/travel patterns well represent possible access to urban opportunities needs to be explicitly examined. Hence, space-time accessibility measures, conventional accessibility measures and previous approaches on gender difference in access will be critically examined and compared in later Chapters.
2.4 Gender, household responsibilities, and gendered spatiality

This section will introduce some important concepts which will serve to form the substantive backbone of this dissertation. The basic hypothesis of this research is that, although society is changing in that husbands share more household work than past while women participate more in the labor workforce and commute with better transport modes than before, still ongoing social and cultural expectations on gender roles and gender relations, which are traditional and patriarchal, put women into a significantly different situations compared to men, especially with respect to access to urban opportunities; and that gender role constraints are crucial elements in understanding women and men’s accessibility experiences.

2.4.1 Gender roles: individual vs. relational constraints

Gender roles are “socially created expectations for masculine and feminine behavior” (Lipman-Blumen, 1984, p. 2). Such culturally constructed gender roles should be distinguished from biologically based sex roles (that is, behaviors stemming from biological sexual differences), because gender roles represent a more complex conceptualization than sex roles. The basic argument of this dissertation is that gender gap in accessibility, if any, would reflect the gendered reality of women’s lives. In other words, gendered accessibility experiences do not stem from biological differences; rather they are socially constructed and conditioned.
Space-time constraints can be classified into two categories in terms of the nature of their sources: *individual* and *relational*. And the relative importance of each type of constraint varies between women and men. Space-time fixities produced by paid work, school attendance, medical care or professional service stem from an individual’s own need. On the other hand, those fixities produced by a majority of household-associated work stem rather from the need of significant others (children, partners, old/sick parents), not simply his/her own individual needs. In other words, space-time constraints of employed men tend to be *individual* in nature (that is, employment and personal appointment). On the contrary, women’s constraints are more likely *relational*. As Davies (2001) pointed out “the relational context of women’s time,” women’s spatial and temporal fixities are closely related to other family members’ needs, in addition to paid-work and personal appointments as in the case of men. Caring for others is socially expected to be another central axis of women’s work. In this light, women’s time can be characterized as ‘other-oriented.’ In other words, whereas men’s lives are governed mainly by individual constraints, women’s lives are highly affected by relational constraints in addition to individual constraints. Therefore, it is very difficult for women to enjoy their part-time status (short work hours and often daytime time budget) as the needs of others, especially young children, constantly circumscribe their space-time autonomy for discretionary activities for themselves. Therefore, the need to care for others reduces the amount of women’s non-work time budget to a greater extent than men’s, and their time window often become fragmented into smaller pieces of time, whereas men are more likely to enjoy the large and continuous chunks of time. Moreover,
for women, the demands of others creates additional pegs in space, which further limits the possible location for their discretionary activities and the spatial extent.

Therefore, the social construction of gender roles further constrains women’s access to urban opportunities not only in the overall level of accessibility but also the spatial extent to which urban opportunities are within reach. Household responsibility hypothesis (HRH) and spatial entrapment or spatial containment thesis refers to such aspects.

2.4.2 Household responsibility hypothesis (HRH) and Spatial entrapment thesis

One of the influential perspectives which address the significance of gender roles on women’s lower access to urban opportunities is so called ‘household responsibility thesis (HRH)’ (Johnston-Anumonwo, 1992). In spite of women’s increased workforce participation and the general beliefs of social change toward a more egalitarian society, many studies have found that traditional gender roles and expectations (i.e. women doing housework at home and men working in the labor market) still permeate. According to the HRH, “employed women tend to have greater household and child-care responsibilities and, as a result, face greater time constraints and ultimately choose shorter commutes than employed men” (Turner and Niemeier, 1997). Studies on the associations between gender roles, household responsibilities, and access to urban opportunities have overly focused on commuting distances/times -- an indirect measure
of access to job opportunities (for thorough reviews, refer to Turner and Niemeier (1997)). For example, Hanson and Pratt’s work (1990, 1995) showed that primary responsibility for children and family commitments may be an important factor reducing women’s commutes. Women tend to make more household/family-support trips and spend more time in household/family support activities than men (Hanson and Hanson, 1980; Hanson and Johnson, 1985).

The spatial entrapment (Nelson, 1986) or containment thesis emphasizes the aspect of gendered spatiality associated with women’s heavier household responsibility and shorter commuting distances. Not only do a smaller time-budget and more complex space-time fixities due to household responsibilities result in shorter commutes; women’s perceived obligations do, also. Hanson and Pratt (1990) showed that women’s shorter commutes are associated with household responsibility: marital status and the presence of children do affect women’s journey to work lengths significantly, whereas not so for men. Socially defined gender roles make working mothers consider close proximity of work to childcare and/or school in case of emergencies; and job hours which fit with the school schedule and/or childcare arrangements as important job attributes, while men comparatively do not. Having a primary responsibility for household work, working mothers want to be able “to get home quickly for kids, emergencies, family reasons” (Hanson and Pratt, 1990). If they commute long distance or are employed full-time, sometimes they were reported to feel guilty (England, 1993).
2.5 Conclusions

This chapter provided a broad background for the analytical work performed in the following chapters. Some limitations of current accessibility measures and gender gap in access research were addressed first, and then several relevant concepts associated with research interests of this dissertation were briefly mentioned.

Why space-time, rather than spatial, measures, and why possible, rather than actual, activity analysis (accessibility analysis) are more appropriate to capture gender differences in access to urban opportunities have been discussed. Additionally, while most studies have found some support for the household responsibility hypothesis and spatial entrapment thesis through analyzing actual travel/activity patterns, few studies have examined the hypotheses with respect to accessibility measures. In this regard, this study will provide a useful insight on gender differences in accessibility through exploring the relationship between household responsibility, activity space, and accessibility spaces.
3.1 Introduction

The major purpose of this study is to analyze a variety of situations in which gender differences in daily accessibility experiences are manifested, which will be examined using the example of Portland, Oregon. In order to achieve this goal, appropriate data and accessibility measures were necessary for this research.

In order to measure an individual’s level of access to urban opportunities, first, not only basic socio-economic and demographic data at the individual and household level, but also highly detailed and disaggregated activity and travel behavior data of individuals, along with associated information such as their location, time of day, duration, activity purpose, and so on, are required. In addition, spatial data on urban context is also needed: (a) spatial and temporal availability of urban opportunities which contains location, area, land use type (employment, retail, and other services), opening/closing hours, and so on; and (b) a street network data that includes estimates of travel times (segment-dependent, location-dependent, and time-of-day-dependent), and information of network direction (e.g. one-way) and turn prohibition, in order to calculate the level of mobility of
individuals in a more realistic and accurate way. Travel time estimation with consideration of segment-specific, location-specific, and time-specific street network speed; and the turn prohibition from/to freeways information (done by Weber (2000)) was used in this study, but, with the recognition of the importance of one-way streets downtown increasing travel times and, as a result, reducing reachable urban opportunities, the street network was modified to include one-way street information for more accurate travel time estimation for the research.

Finally, accessibility measures are needed which are able to accurately calculate an individual’s level of access to urban services, based on the well-founded understanding of travel/behavior characteristics in general, and the fact of differently situated women and men and the associated effect on their different accessibility experiences in every day life. As mentioned in the previous Chapter, space-time accessibility measures have received much attention in recent years due to their sensitivity to differences in individual ability to participate in activities in space and time, when compared to conventional accessibility measures. Despite the conceptual attractiveness and robustness of space-time measures, only few attempts have been made to operationalize them to date. Research that seeks to improve space-time accessibility measures is still sorely needed.

This study seeks to enhance space-time accessibility measures through developing a new operational method and GIS-based algorithm that better represents the space-time characteristics of urban opportunities (e.g. their geographical distribution and opening hours) and human activity-travel behavior (e.g. delay times, minimum activity
participation time, and maximum travel time threshold). The proposed method not only takes into account the number and size of opportunities, but also the possible activity duration at each activity location given its opening hours and the effect of the transport network topology (e.g. one-way streets, turn restrictions and over-passes). Incorporating these elements into space-time measures helps overcome several shortcomings of previous approaches to evaluating space-time accessibility.

This Chapter begins with a general overview of the study area and data set employed for the analysis (Section 3.2). After the detailed discussion of the limitations of previous space-time accessibility measures in Section 3.3, a conceptual framework for further enhanced space-time accessibility measures will be proposed in Section 3.4. Then, a new series of space-time accessibility measures is formulated, and the GIS procedures for operationalizing it will be described. The geocomputational algorithm proposed will be presented in Section 3.5, followed by an empirical example which provides a detailed picture of how such operational procedures and geocomputational algorithm would work in Section 3.6.

3.2 Study Area and Data

In order to examine gender differences in terms of individual accessibility level and accessibility experience with enhanced space-time accessibility measures, Portland Metro,
Oregon is chosen as a study area and a large activity/travel diary data set of this region was used.

The Portland Metropolitan Service District (known as Metro) is the directly-elected regional government that serves more than 1.3 million residents in three counties (Clackamas, Multnomah and Washington), and the 24 cities in the Portland, Oregon, metropolitan area, as shown in Figure 3.1 (U.S.DOT, 1996; see the Metro homepage (http://www.metro-region.org/) for further in-detail information). The largest city in the region is the city of Portland in terms of both size and population (498,747 people in 1995), and especially, the Portland CBD is found to be a center of the major freeways and highways which are structured in a hub and spoke pattern in the Metro. However, about 70% of the total population in Portland Metro resides within suburban areas (U.S. Census Bureau, 2001): Graham (79,431 people) to the east of Portland has the second largest population, followed by Beaverton (62,573), Hillsboro (47309) and Tigard (35,054) to the west, Lake Oswego (33,606), Milwaukie (19,977), and Tualatin (19,353) to the south. Several regional urban centers are located around these suburban municipalities, in addition to the major urban center, located at Portland CBD.

Portland Metro is responsible for preparing the regional transportation plan and land use strategy, establishing and maintaining the region’s Urban Growth Boundary, protecting open space and parks, and managing garbage disposal and recycling for those who reside in this area. The Portland Metro conducted a regional Household Activity and Travel Behavior Survey during 1994 and 1995 with an objective of supporting the
region’s transportation planning and travel demand modeling needs. It is used in this research to implement geocomputational operations for measuring space-time accessibility.

Figure 3.1: Study Area: Portland Metro, Oregon
Activity/travel data were collected for household members from Oregon and Southwest Washington, regardless of age (parents were instructed to assist children under 12 years old) over two consecutive days. In this survey, out-of-home activities and in-home activities which last longer than 30 minutes were included. The survey included household characteristics, vehicle information, personal characteristics, as well as activity/travel data for each surveyed household member. The original large activity-diary data set (the Activity and Travel Survey in Portland Metropolitan Area in Oregon in 1994 and 1995) includes information about 122,348 activities and 67,891 trips performed by 9,471 persons from 4,451 households, who reside in Multnomah County, Clackamas County, Washington County, and partial areas of Yamhill County and Columbia County. All activities and home locations were geocoded with their x-y coordinate information to an accuracy of 200 feet. According to the data collected, average household size was 2.3 persons per household and the average number of vehicles per household was 1.73. In addition, average trip rate per household per day was 8.04 and average activity rate per household per day was 14.48 (U.S.DOT, 1996).

While the Portland activity/travel survey includes a variety of transport modes, this research deals only with those who stated car availability for travels (private automobile) in between consecutive obligatory activity locations during a day. Furthermore, only those employed either part-time or full-time were used in this research. The private automobile is the most predominant transport mode in American cities and driving alone to work has consistently increased over decades without interruption (U.S. DOT, 1993).
For example, 73.19% of all U.S. workers drove alone, 13.36% carpooled, 5.27% used public transit, 3.90% walked, 0.41% used bicycles, 0.21% used motorcycles, and 0.70% stated other (2.96% work at home) in American cities. Portland shows similar pattern: 74.10% of Portland workers drove alone to work by a private automobile in 1990, 12.28% carpooled, and 5.42% used public transit. Given the fact that mobility within the Portland area is heavily auto dependent, and the average number of vehicles per household was 1.73, women as well as men can be expected to have almost equal level of availability of vehicles for travels. By restricting the sample data to car drivers, and therefore removing the effect of transport modes on mobility, the examination of another source of gender differences in accessibility will be focused on in this study. It also helps simplify the computation of accessibility as travel time estimation can be made only for automobiles, instead of considering complex travel time calculations by different and combined transport modes in the measure, delay time possibilities (e.g. waiting time for bus, walking from/to bus stops or transits), and incorporation of other conditions, such as different maximum spatial limit due to physical ability (e.g. smaller maximum spatial reach by walking than by car), different bus transport networks (i.e. bus routes as well as streets), etc.

In addition, for the analysis, the data set was further restricted to (1) one day, instead of two-consecutive days, and to activity/travel information (2) during weekdays, instead of including weekend activities. Activities are classified into two categories in terms of their fixity in nature. Several obligatory activities in the activity-travel diary data set are
treated as fixed activities in this study. These include work, household obligations, pick-up or drop-off of passengers, medical or professional business, and school activities. Discretionary activities such as shopping, entertaining, relaxation and so on are defined as flexible activities.

As a result of the subsample data selection, 1,713 persons were selected who reside and work in Portland Metro, travel by private automobile, and have activities during a weekday located within Portland Metro. 95.8% of the subsample data were Whites and 87.7% of those employed were full-time. The proportion of women is almost the same as men (54.8% for men, and 45.2% for women). A total of 10,567 activities of 1,713 persons are analyzed in Chapter 4 and Chapter 5.

In Chapter 6, the sample data set was further extracted in order to examine differences between husbands and wives within households of dual-earner couples, focusing on the effect of gender and parental status on gender division of labor and accessibility experiences. Only 271 households (where both husbands and wives are present), from the sample data used in Chapter 4 & 5, were chosen. Consequently, 3,647 activities performed by 542 persons (271 husbands and 271 wives) are analyzed in Chapter 6.

The geographic data sets used in this research are the digital transport network with 130,141 arcs and 104,048 nodes and the centroids of all of the 27,749 commercial and
industrial land parcels (as urban opportunities) of the study area. These digital geographic data are provided by Metro (the regional government of Portland Metropolitan Region, Oregon). Additional data incorporated into the database includes time-specific and location-specific travel speeds, dynamic delay times along the streets, turn prohibition from/to highways, and weighted areas of opportunities and business hours. These data were constructed and provided by Weber (2001) (see also Weber, 2003; Weber and Kwan, 2002, 2003).

In addition to these data on street networks, urban opportunities and facility opening hours (9AM-5PM for industrial land use, and 9AM – 9AM for commercial land use), other elements are added and incorporated into the database, in order to allow for a more realistic and rigorous estimation of travel times and individual space-time accessibility. For example, the effect of the morning peak-period (7 AM ~ 9 AM) on travel speeds, as well as the evening peak (4-6PM), is incorporated in the operational procedure. Following Kwan and Hong (1998), Weber (2001, 2003) and Weber and Kwan (2002, 2003), who based their estimation upon field observations in Portland, Oregon, travel times are adjusted upward by 25% to take into account dynamic delays. Besides such dynamic delay times, static delay times are also assigned for delays that happen after arriving at or before leaving flexible activity locations in between two consecutive fixed activities. In this research, the static delay times before and after each location were assumed to be 5 minutes each.
Further, the effect of one-way streets, minimum activity duration, and maximum travel time threshold on the space-time prism is taken into account. The effect of one-way streets is explicitly taken into account through using a field named “ONEWAY” in the digital street data. Based upon the directional arrows of the one-way streets shown on a large-scale map of the study area, this field contains a value that indicates the direction of permitted traffic (e.g. “TF” indicates that travel is permitted from the start to the end of the line only; “FT” indicates that travel is permitted from the end of the line to the start of the line only; “N” means that travel is not permitted in either direction). Also, minimum activity duration was set to 10 minutes, and maximum travel time threshold on the space-time prism assumed to be 60 minutes in this research.

3.3 Limitations of previous space-time accessibility measures

Space-time accessibility measures are based on the construct of the space-time prism proposed by Hägerstrand (1970) and elaborated by Lenntorp (1976). The projection of the three-dimensional space-time prism onto two-dimensional geographical space is called the potential path area (PPA). It delimits the area within reach given an individual’s space-time constraint. Space-time accessibility measures evaluate individual accessibility by delimiting the space-time prism, which is determined by the locations of activities, the distances between relevant locations, the amount of time available for travel and activity participation, as well as travel speeds (Burns, 1979). The space-time prism delimits the feasible opportunity set (FOS) for travel and activity participation in a
bounded region in space-time (Kwan, 1998, 1999; Weber and Kwan 2002, 2003; Dijst and Vidakovic, 2000). Previous space-time accessibility measures need enhancements due to limitations in their representation of the space-time properties of urban opportunities, the temporal characteristics of human activity-travel behavior, and the transport network. A discussion of these limitations follows.

3.3.1 Representation of the space-time properties of opportunities

Representation of certain spatial and temporal properties of urban opportunities by previous space-time accessibility measures still calls for improvement. These properties include the volume of the space-time prism, the spatial distribution of opportunities, the maximum activity participation time at each opportunity within the prism, and the temporal availability of each opportunity. To illustrate these limitations more concretely, Figure 3.2 identifies six possible types of space-time accessibility measures. Figures 3.2a-3.2e show different methods of evaluating accessibility used in previous space-time accessibility measures. Figure 3.2f provides a preliminary conceptual framework proposed in this study that retains more detailed temporal properties of the space-time prism for the evaluation of individual accessibility. This framework will be discussed in greater detail in Section 3.4 below.

The first type of accessibility measures (Figure 3.2a and 3.2b) is geometric or mathematical calculation of accessibility (see Lenntorp, 1976; Burns, 1979; Villoria,
Figure 3.2: Different approaches to evaluating space-time accessibility of individuals:

(1) the focus exclusively on spatial properties of accessibility, potential path area (left column) vs. the inclusion of temporal properties from space-time prism (right column); (2) the geometric calculation of accessibility (a and b) vs. the identification of feasible opportunity set (c–f); and (3) accessibility measures without (a–d) or with (e and f) the consideration of the effect of facility opening hours.
For example, Lenntorp (1976) and Burns (1979) used the volume of the space-time prism and/or the area delimited by the potential path area (PPA) formed by the prism’s projection onto geographical space as an accessibility indicator. By simply measuring the spatial extent of the reachable area given the space-time constraint of an individual, this type of formulation, as shown in Figure 3.2a, does not take into account of any of the space-time properties of the prism (e.g. the geographical distribution and temporal availability of opportunities). Measuring the volume of the prism as shown in Figure 3.2b is another type of geometric method based upon the Euclidean distance between two fixed activities. The space-time prism takes the form of two equal-sized cones with a common base, and the PPA takes the shape of an ellipse (Burns 1979). This formulation of the prism and the PPA (Figure 3.2a and 3.2b), however, does not represent the space-time properties of opportunities and the urban space realistically. It ignores the uneven spatial distribution of opportunities, the restricted mobility due to the geometry of the transport network, variable travel speeds throughout the urban environment, and the temporal availability of opportunities associated with limited opening hours.

Recently, GIS methods have been used to overcome the limitations of geometric methods. For instance, instead of assuming an even distribution of opportunities, uniform and constant travel speed, or using Euclidean distance, Kwan (1998, 1999a), Kwan and Hong (1998), Miller (1999), Miller and Wu (2000), Weber (2001, 2003), Weber and
Kwan (2002, 2003) developed various operational methods for deriving a network-based space-time prism that takes the spatial distribution of urban opportunities into account.

Figure 3.2c describes a GIS-based method that sums up the number or area of the opportunities within a PPA (PPAs with irregular shapes are schematically represented as ellipses in Figures 3.2c to 3.2f) (e.g. Kwan 1998, 1999a). This method considers the uneven distribution of opportunities, varying mobility due to the transportation configuration and speeds over space. The method, however, does not consider the geographical distribution of opportunities within the PPA by focusing mainly on creating bounded space and identifying the feasible opportunity set (FOS) within it. It therefore ignores the activity participation time possible at a particular opportunity location and the temporal availability of opportunities in the PPA.

Another type of GIS-based method takes the effect of the spatial distribution of opportunities within a PPA into account (Figure 3.2d) (e.g. Miller 1999; Miller and Wu 2000). This type of measures considers the maximum activity participation time possible at each opportunity and thus allows the researcher to differentiate the contribution of different opportunities within a PPA to individual accessibility. The effect of facility opening hours, however, is still ignored in this type of formulation.

The temporal availability of opportunities within a PPA is taken into account by the method implemented in Weber (2001, 2003) and Weber and Kwan (2002, 2003) (Figure 3.2e). This method, however, paid no attention to the effect of the geographical distribution of opportunities inside the PPA and the possible activity participation time on individual space-time accessibility, as all opportunities reachable during their opening
hours are equally weighted. Beyond simple consideration of the absence/presence of each opportunity with respect to its opening hours, the measure as proposed in Figure 3.2f should be able to explicitly consider the reduction in activity duration and the exclusion of some opportunities even within their opening hours due to the temporal mismatch between the timing of possible activity participation and the opening hours of each opportunity.

The method proposed in this study, therefore, seeks to contribute to research on individual accessibility in space-time through evaluating whether activities can be performed at particular locations and incorporating the possible duration of activities (given the opening hours of facilities) into the measure. It shows that space and time are closely linked, in that the location of an opportunity will affect the duration of its availability. The study therefore goes beyond the two-dimensional geospatial representation of opportunities in previous research through a representation that also takes the temporal dimension into account.

### 3.3.2 Representation of temporal characteristics of human activity-travel behavior

Besides the effect of the geographical distribution of opportunities and facility opening hours, this study attempts to further improve space-time accessibility measures by incorporating several temporal characteristics of human activity-travel behavior not fully recognized in previous measures. These include the minimum time required for
meaningful participation in particular activities, various types of delay times, and the maximum travel time threshold. No previous measures have integrated all of these elements into a single coherent framework when operationalizing space-time accessibility measures.

Based on the recognition that travel is a derived demand (see Kitamura 1988; Jones et al. 1990), the accessibility measure proposed in this study incorporates the effect of the minimum activity participation time at each opportunity and the maximum travel time threshold. Since people usually do not travel for a long distance for undertaking an activity for just one or two minutes, a certain amount of activity participation time is necessary to make travel worthwhile and also to make the measure more realistic. Further, travel times to activity locations need to be limited to an acceptable length to most individuals. Consider, for instance, an individual who has a 5-hour time budget for flexible activities between two fixed activities. The resulting maximum travel time (2.5 hours) will generate a PPA that covers an area much larger than what a person would normally travel for ordinary discretionary activities in any particular day (Figure 3.3a). It is unreasonable to assume that people will travel for 2.5 hours in order to participate in a discretionary activity for just one minute. Rather, people would likely spend time on participating activities within certain acceptable travel distances, as shown in Figure 3.3b. Studies that ignore this behavioral attribute may render extremely large and unrealistic PPAs. It is therefore necessary to implement some reasonable thresholds on activity participation time and travel time in order to identify a meaningful opportunity set when evaluating space-time accessibility.
Figure 3.3: The effect of the maximum travel time threshold on the space-time prism and potential path area (PPA).
Further, there are several types of delay times that need to be included into the algorithms of space-time accessibility measures since the arrival and departure times at activity locations are subject to random variation (Villoria, 1989). They stem mainly from two sources: (1) static delay time required for looking for a parking space, walking from/to opportunities before/after parking, or waiting for buses; and (2) dynamic delay time spent during travel associated with traffic lights, turns, and traffic accidents. In this study, the former type of delay time is combined together with the minimum activity duration as the extended minimum activity time required. The latter type of delay time is combined with the travel time between two locations as the extended travel time ($Shrt_T$). The inclusion of delay times in the proposed method takes into account the fuzzy boundary of a PPA or FOS (as suggested by Villoria, 1989).

### 3.3.3 Representation of travel times and speeds on the transport network

Space-time accessibility measures can also be enhanced through more realistic estimation of travel speeds and times on the transport network. Although some recent operational methods of space-time measures attempt to incorporate this dimension into the geocomputational algorithm (e.g. Kwan, 1998; Miller, 1999), and different travel speeds for different types of road segments are used, there is still room for further enhancement as travel speeds may be different among different road segments of the same type. As Weber and Kwan (2003) demonstrated, travel velocities are both spatially and temporally uneven as well as segment-dependent. Travel speeds may vary depending
on the location of the streets (e.g. CBD versus rural areas) or on the time of day (e.g. peak versus off-peak period). The fact that congestion does not uniformly and equally affect all areas of a city should be taken into account by space-time measures (Weber and Kwan, 2002).

Further, previous approaches are often based upon unrealistic assumptions about the directionality and topology of the transport network that ignore the unequal travel speeds along different directions of the same network segment and the effect of turn prohibitions. They therefore ignore the existence of many one-way streets and cross-sections with turn restrictions in the urban environment. In this light, it can be argued that previous space-time measures tend to overestimate individual accessibility as considerable urban opportunities are found in CBD, where congestion can be a chronic problem and the existence of many one-way streets cannot be ignored.

Finally, most previous space-time measures use the street network data with a planar structure and assume that turns can be made from any link to any link. However, as turns cannot be made when the cross-section actually represents an overpass or underpass - which lead to different shortest paths and affect travel times considerably - their effects need to be taken into consideration when evaluating individual accessibility using space-time measures. This study follows the Weber and Kwan (2002, 2003) study, in which the effect of turn prohibitions from/to freeways is incorporated through creating a turntable
with the node numbers where turns are made between and linking it to the street network data.

3.4 Conceptual framework

This research seeks to enhance space-time accessibility measures with a more rigorous representation of the temporal and spatial characteristics of opportunities and human activity-travel behavior. Figure 3.4 describes the method proposed in this study which takes into account both the possible activity participation time based on the spatial distribution and the temporal availability of opportunities. Using this framework, this study evaluates space-time accessibility based not only on the number of accessible opportunities but also on the duration for which an individual can enjoy them given the space-time constraint. As shown in Figure 3.4, the size of the space-time prism used in this study is smaller than those specified in previous approaches due to the inclusion of static and dynamic delay times, minimum activity duration, and maximum travel time threshold (compare the boundary of the prism delimited by the solid line with those delimited by dashed or dotted lines). Further, the number of feasible opportunities within the space-time prism and the possible activity duration at each opportunity are reduced due to the effect of facility opening hours. At each opportunity within the space-time prism, the size of two types of bars indicates the possible difference between the maximum activity participation time (ACT) and the possible duration due to the effect of its temporal availability (DUR). The opportunities within the potential path area (PPA)
can be excluded according to their temporal availability (i.e. \( T = 1 \) if available, otherwise \( T = 0 \)) or are weighted according to the possible activity duration (\( DUR \)).

Six cases are included in Figure 3.4 to illustrate the effect of these factors on the space-time prism. Opportunity A is available to the individual throughout the entire duration within the prism given its opening hours (i.e. \( ACT = DUR \)). In contrast, opportunity B can be reached but is not available because it is closed throughout the entire duration within the prism (i.e. \( ACT \neq DUR \)). This opportunity should therefore be excluded from the feasible opportunity set. Opportunity C should be included only if the individual is willing to wait for its opening. In this situation, some amount of the possible activity time will be lost due to the time spent in waiting. For opportunity D, the individual needs to arrive early enough in order to be able to undertake that activity with a duration that exceeds the minimum activity duration. Since activity at the opportunity location is impossible after the closing hour, some portion of the possible activity participation time would be lost. Opportunity E can be enjoyed only during its opening hours even with the more time available for activity. Therefore, the activity time budget before and after the opening hours will be lost. Lastly, opportunity F, although reachable within the space-time prism, has possible activity duration smaller than the minimum activity participation time. It should therefore be excluded from the feasible opportunity set when evaluating individual accessibility. Operational space-time measures should differentiate between these possibilities and should exclude and weight opportunities with possible activity duration accordingly.
Figure 3.4: The proposed conceptual framework.
3.5 Operational procedures and geocomputational algorithm

To implement the conceptual framework outlined above, this section proposes a new GIS-based geocomputational algorithm for deriving the space-time prism and for evaluating individual accessibility. The method is based partly on Kwan (1998) and partly on Weber (2001), in which the segment-, location- and time-specific travel velocity on the transport network and the weighting scheme for urban opportunities are incorporated. In this new framework, the attractiveness of an opportunity is defined in terms of its weighted area ($W_{Area}$). Individual accessibility measures proposed in this research are derived by summing up the weighted areas of opportunities ($W_{Area}$) multiplied by the possible activity participation time ($Dur$) for all PPAs of an individual for a particular day (daily PPA). The GIS procedures for deriving the potential path area (PPA) and for calculating space-time accessibility are implemented using Avenue, the object-oriented programming language in ArcView GIS.

The key idea of the geocomputational algorithm is to efficiently identify all of the feasible opportunities within the space-time prism using several “Find Service Area” operations in ArcView GIS, while limiting the spatial search boundary with information about the travel and activity participation time available between two fixed activities. This algorithm was developed based upon numerous tests of the computational efficiency of different methods and a series of experiments using a large activity-travel diary data set and a digital street network.
Figure 3.5 describes the concept behind the proposed algorithm (where the network-based service areas are represented schematically by circles and the potential path area (PPA) by an ellipse for simplicity purpose). Conceptually the feasible opportunities within a PPA comprise a set of activity locations where the total amount of the travel times from the origin and to the destination fixed activity are less than or equal to the total time budget (in this case, $Total_T$) beyond the minimum activity time. The shaded area delimited by the boundary in bold indicates where the spatial search for feasible opportunities will initially take place (Step 1). Since there is no simple and direct method to delimit the boundary of the PPA, this research draws on the initial spatial search area as small and close as possible to the PPA boundary for efficiency. The spatial search boundary is defined by half of the total time budget ($Total_T/2$) and the shortest-path travel time ($Shrt_T$) between the two fixed activities in the manner shown in Figure 3.5. The resulting feasible opportunity candidate set (FOSc) within the spatial search boundary is identified in Step 1. After this step, some opportunities outside the potential path area will be removed from the FOSc. In other words, travel times from the first fixed activity to each urban opportunity in the search area and from each opportunity to the next fixed activity are computed in order to choose opportunities only within the PPA ($FOS$) out of the FOSc. If the sum of these two travel times is greater than the time budget ($Total_T$), the opportunity is eliminated from the feasible opportunity candidate set (FOSc). In Step 3, each opportunity in the FOS generated in Step 2 is screened with respect to whether and how long it is available given its opening hours and the arrival and departure time.
After identifying the FOS within the PPA, the level of accessibility is evaluated in terms of attractiveness of opportunities and the possible activity duration at each opportunity given its temporal availability. Simplified pseudo code of the geocomputational algorithm is as follows:

Figure 3.5: Procedures implemented by the geocomputational algorithm.

After identifying the FOS within the PPA, the level of accessibility is evaluated in terms of attractiveness of opportunities and the possible activity duration at each opportunity given its temporal availability. Simplified pseudo code of the geocomputational algorithm is as follows:

\[
\begin{align*}
\text{Total}_T/2 & \\
\text{Shrt}_T & \\
(\text{Total}_T - \text{Shrt}_T)/2 & \\
(\text{Total}_T + i & \\
\end{align*}
\]
**Step 0. Initialize**

Step 0.1. For each individual, set up variables.
Step 0.2. For each fixed activity of an individual, calculate time budget between $i$ and $j$ ($Total_T$).

- **StartTime** = departure time at first fixed location, $i$
- **EndTime** = arrival time at next fixed location, $j$
- **ExtMinAct** = the extended minimum activity time
- **Total_F** = EndTime – StartTime
- **Total_T** = Total_F – ExtMinAct

Step 0.3. Set up the Network Cost Field for Step 0.4 ($NetCost1$). Depending on the time of day for travel, either the peak period ($CongFlow$) or off-peak period travel speed ($FreeFlow$) is assigned.

Step 0.4. Calculate the Shortest Path Travel Time from $i$ to $j$ ($Shrt_T$) with $NetCost1$.

Step 0.5. Check if Space-Time prism can be made ($Total_T \geq Shrt_T$). If not, go to step 0.2 to work with the next set of activities.

**Step 1. Delimit the initial search areas for feasible opportunity sets using Service Area functions and find the opportunity candidates within the search area**

Step 1.1. Calculate the service area radii for both $i$ and $j$.

- **Serv_Tbig** = $Shrt_T + \frac{(Total_T - Shrt_T)}{2}$
- **Serv_Tsm** = $\frac{TotalT}{2}$

Step 1.2. Check if the maximum travel time threshold (MAX) needs to be set. If any of resulting service radii from Step1.1 is greater than the maximum travel time threshold (MAX), then set the service radius to be MAX.

Step 1.3. Set up network cost field for service areas ($NetCost2$).

Step 1.4. Create Network-based Service Areas from $i$ to $k$ ($Serv1$) and from $k$ to $j$ ($Serv2$) with travel time $Serv_Tbig$ with $NetCost2$.

Step 1.5. Create Network-based Service Areas from $i$ to $k$ ($Serv3$) and from $k$ to $j$ ($Serv4$) with travel time $Serv_Tsm$ with $NetCost2$.

Step 1.6. Delimit the initial search area from the four service areas where ($Serv1 \cap Serv2) \cap (Serv3 \cup Serv4$).

Step 1.7. Find the Opportunity Candidates (FOSc) within the initial search area.

**Step 2. Identify opportunities within the potential path area and calculate the maximum activity duration possible at each opportunity location.**
Step 2.1. For each $k$ in FOSc, calculate travel times from $i$ to $k$ ($OPCost$) and from $k$ to $j$ ($PDCost$).

Step 2.2. Calculate total travel times from $i$ to $j$ through $k$ ($OPDCost = OPCost + PDCost$).

Step 2.3. Calculate the maximum activity participation time available at $k$ ($ACT$).

$$ACT = (Total_T + ExtMinAct) - OPDCost$$

Step 2.4. Check if the opportunity candidate at $k$ is feasible. If the activity duration at $k$ ($ACT$) is smaller than minimum activity duration specified, then remove $k$ from FOSc.

Step 2.5. Go to Step 2.1 and repeat the steps until the end of records $k$.

**Step 3. Identify the final FOS given the effect of facility opening hours and calculate accessibility of an individual**

Step 3.1. For each opportunity $k$ in FOS, get the weighted area values from $k$.

Step 3.2. Check if the activity time at feasible opportunity candidate $k$ falls into its opening hours. If outside, remove $k$ from the FOS.

Step 3.3. Calculate the possible activity duration ($DUR$) at $k$ regarding its opening hours.

Step 3.4. Multiply the possible activity duration ($DUR$) by the weighted area ($WArea$) at $k$ ($WAreaDur$).

Step 3.5. Sum up the accessibility values ($WAreaDur$) for all the opportunities within a PPA.

Step 3.6. Go to Step 3.1 and repeat the steps until the end of records $k$.

Step 3.7. Sum up the accessibility values of all PPAs during a day.

Step 3.8. Go to Step 0.2 and repeat the steps until the end of fixed activity records for the individual.

Step 3.9. Go to Step 0.1 and repeat the steps until the end of records for all the individuals.

3.6 An empirical example

The activity program of the selected person is shown in Table 3.1. The person is a married, female full-time worker, who commuted by a car and undertook 9 activities in the sample day. Activities are classified as either fixed or flexible depending on the nature of the activity in question. The last activity is considered fixed since the person has
to return home in the evening - even though the activity was reported as amusement at home. Therefore the person undertook 6 fixed activities and 3 flexible activities in the sample day. There are 3 time windows for deriving the space-time prism (i.e. Activity ID 2~4, 5~7, and 7~9).

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Type</th>
<th>Activity Location</th>
<th>Activity Start Time</th>
<th>Activity End Time</th>
<th>Activity Fixity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>drop-off</td>
<td>residence</td>
<td>7:20 AM</td>
<td>7:21 AM</td>
<td>fixed</td>
</tr>
<tr>
<td>2</td>
<td>work</td>
<td>workplace</td>
<td>8:00 AM</td>
<td>2:00 PM</td>
<td>fixed</td>
</tr>
<tr>
<td>3</td>
<td>meal</td>
<td>at work</td>
<td>2:00 PM</td>
<td>2:30 PM</td>
<td>flexible</td>
</tr>
<tr>
<td>4</td>
<td>work</td>
<td>workplace</td>
<td>2:30 PM</td>
<td>5:00 PM</td>
<td>fixed</td>
</tr>
<tr>
<td>5</td>
<td>pick-up</td>
<td>residence</td>
<td>5:20 PM</td>
<td>5:21 PM</td>
<td>fixed</td>
</tr>
<tr>
<td>6</td>
<td>amusements</td>
<td>home</td>
<td>5:45 PM</td>
<td>6:30 PM</td>
<td>flexible</td>
</tr>
<tr>
<td>7</td>
<td>household obligation</td>
<td>kid's school</td>
<td>6:40 PM</td>
<td>8:30 PM</td>
<td>fixed</td>
</tr>
<tr>
<td>8</td>
<td>visiting</td>
<td>home</td>
<td>8:40 PM</td>
<td>9:15 PM</td>
<td>flexible</td>
</tr>
<tr>
<td>9</td>
<td>amusement</td>
<td>home</td>
<td>9:15 PM</td>
<td>11:00 PM</td>
<td>fixed</td>
</tr>
</tbody>
</table>

Table 3.1: The activity schedule of the person selected from the sample.

As described in Table 3.2, the time budget for travel and activity (Total_T) is first identified by subtracting the minimum activity duration and static delay times from the total time budget (Total_F) between two consecutive fixed activities. The travel time between these two fixed activities (Shrt_T) is then computed using the appropriate travel speed.
Regarding travel speeds to be applied, if the midpoint (MidTime) of travel start time and travel end time falls within the traffic peak periods, then congested speeds (CongFlow) are used in the computation; otherwise, free flow speeds (FreeFlow) are used. A comparison of the shortest-path travel time (Shrt_T) with the available time budget (Total_T) determines whether the procedure will continue or not. If the time budget (Total_T) is smaller than the shortest-path travel time for two consecutive fixed activities (Shrt_T), no discretionary flexible activity can be undertaken and the procedure will go to the next step without specifying a space-time prism.

A minimum duration is required for meaningful participation in any discretionary activity and static delay time takes into account the stochastic travel behavior. In this study, the minimum activity duration is assumed to be 10 minutes and the static delay times before and after each activity location are assumed to be 5 minutes each.

No space-time prism is constructed for the first pair of fixed activities because the available time budget (Total_T) does not allow the person to travel and participate in any discretionary activity. This explains why the person stayed at the workplace instead of going out for lunch as shown in Table 3.1. The second time window between fixed activities (activity 5~7) - from the passenger pick-up to the child’s school - allowed 49 minutes for discretionary activities beyond the minimum activity duration and delay times. A space-time prism can be constructed with the 49-minute time budget (Total_T) and 9.41-minute travel time between the two fixed activities (Shrt_T).
<table>
<thead>
<tr>
<th>Type</th>
<th>Location</th>
<th>Trip (Minutes)</th>
<th>Time Budget (minutes)</th>
<th>Travel Cost (minutes)</th>
<th>Search Area Radius (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Start Time</td>
<td>End Time</td>
<td>Mid Time</td>
<td>Total_F</td>
</tr>
<tr>
<td>1</td>
<td>drop-off</td>
<td>residence</td>
<td>840</td>
<td>870</td>
<td>855</td>
</tr>
<tr>
<td>2</td>
<td>work</td>
<td>workplace</td>
<td>840</td>
<td>870</td>
<td>855</td>
</tr>
<tr>
<td>3</td>
<td>work</td>
<td>workplace</td>
<td>1,041</td>
<td>1,120</td>
<td>1,081</td>
</tr>
<tr>
<td>4</td>
<td>pick-up</td>
<td>residence</td>
<td>1,230</td>
<td>1,275</td>
<td>1,253</td>
</tr>
<tr>
<td>5</td>
<td>household obligation</td>
<td>kid’s school</td>
<td>1,230</td>
<td>1,275</td>
<td>1,253</td>
</tr>
<tr>
<td>6</td>
<td>Amusement</td>
<td>home</td>
<td>1,230</td>
<td>1,275</td>
<td>1,253</td>
</tr>
</tbody>
</table>

Note:  
* Total_T = Total_F – (Minimum activity duration + Static Delay time) = Total_F – (10 + 20)  
** Serv_Tbig = (Total_T + Shrt_T) / 2  
*** Serv_Tsm = Total_T / 2

Table 3.2: Various temporal parameters used in the computation.
The boundary of the initial spatial search in Step 1 of the algorithm (see Figure 3.5) is delimited by using four service areas at the origin and destination with two different radii. The radius of the small service area (in terms of travel time) from \(i\) or to \(j\) is half of the possible time budget (i.e. \(\text{Serv}_{Tsm} = \frac{\text{Total}_T}{2} = \frac{49}{2} = 24.5\) minutes) and that of the big service area is half of the possible activity duration and the shortest travel time (i.e. \(\text{Serv}_{Tbig} = \frac{(\text{Total}_T + \text{Shrt}_T)}{2} = \frac{(49 + 9.410)}{2} = 29.205\) minutes). Since none of these two radii exceeds the maximum travel time threshold, they are used for delimiting the initial spatial search boundary. If either of these two radii exceeds the threshold, the maximum travel threshold will be used instead of the computed \(\text{Serv}_{Tbig}\).

The initial spatial search boundary delimited by this procedure is shown in Figure 3.6. It contains 10,223 opportunities.

In Step 2, opportunities in this set that do not meet the time budget constraint are eliminated (i.e. those locations where the sum of the travel times is greater than the time budget are removed from the set). This step delimits the potential path area as indicated in Figure 3.5 by the dotted ellipse. The number of opportunities (\(\text{Num}\)) is reduced to 9,847 after this step, as some opportunities in the eastern peripheral areas within the search boundary created in Step 1 are removed (Figure 3.7).

In Step 3 of the algorithm, some of these opportunities are further removed in consideration of facility opening hours. Limited facility opening hours are assigned based on the type of land-use of a parcel. Industrial opportunities are assumed to be available
Figure 3.6: The opportunity set delimited in Step 1.
Figure 3.7: The opportunity set delimited in Step 2.
from 9 A.M. to 5 P.M. and commercial opportunities from 9 A.M. to 9 P.M., as in the case of Weber and Kwan (2002). In this example, the end time of the fixed activity at the origin is 5:21 PM and the start time of the fixed activity at the destination is 6:40 PM. Since industrial facilities are assumed to close at 5 PM, all opportunities for industrial land use are considered unavailable to the person and are therefore removed.

Figure 3.8 shows opportunities based on their temporal availability \((T)\). Only 7,745 \((NumT)\) are available out of the 9,847 identified in Step 2 due to limited facility opening hours (see Table 3). Figure 3.9 shows the spatial pattern of the level of possible activity duration \((DUR)\) at the feasible opportunities derived in Step 3, given their business hours and the time budget constraint of the individual in question. In general, the closer an opportunity to either of the fixed activity locations, the longer the possible activity duration at that opportunity.

Another feasible opportunity set (FOS) is created for the last pair of fixed activities from the child’s school to home (activity 7~9). The FOS contains 592 opportunities \((NumT)\) out of a total of 606 \((Num)\) due to limited facility opening hours. In addition to the reduction in the number of feasible opportunities, the temporal availability of opportunities also reduced the possible activity duration \((Dur)\) within the space-time prism due to a slight temporal mismatch between the facility opening hours and the arrival and departure time for the activities at the origin and destination. Therefore, possible activity duration \((Dur)\) is much smaller than the maximum activity duration \((Act\) or \(ActT)\).
Figure 3.8: The opportunity set delimited in Step 3.
Figure 3.9: The spatial pattern of possible activity duration.
Various space-time accessibility measures are finally derived through summing up the values from these two FOSs for the day. The accessibility measures for each space-time prism are shown in Table 3.3. Various space-time accessibility indicators are a function of the attractiveness of opportunities (Num, Area, WArea), and the activity duration available within the space-time prism (Act, ActT or Dur) either with or without the consideration of facility opening hours (T). The suffix “T” represents measures incorporating the effect of the temporal availability of opportunity (i.e. reachable and non-reachable). “Area” refers to the sum of the unweighted area of opportunities and “WArea” refers to the sum of the weighted area of opportunities. “Act” represents the maximum activity duration at each feasible opportunity as determined by the space-time prism. Excluding those opportunities not available because of opening hours gives “ActT.” While “ActT” represents the maximum activity duration of opportunities reachable within their opening hours, “Dur” refers to the possible activity duration at each opportunity given its opening hours and the timing of the activity. The measure proposed in this research as the most desirable is “WAreaDur” which is a sum of opportunities weighted by their areas and possible activity duration.

As shown in Table 3.3, all space-time accessibility measures become smaller after considering the effect of facility opening hours (T). This suggests that space-time accessibility measures that do not consider this effect will tend to over-estimate individual accessibility.
<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Location</th>
<th>Num</th>
<th>NumT</th>
<th>Area</th>
<th>AreaT</th>
<th>WArea</th>
<th>WAreaT</th>
<th>Act</th>
<th>ActT</th>
<th>Dur</th>
<th>WAreaDur</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>drop-off</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>workplace</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>workplace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>pick-up</td>
<td>9,847</td>
<td>7,745</td>
<td>9,452.78</td>
<td>6,616.90</td>
<td>10,698.14</td>
<td>7,856.96</td>
<td>249,729.72</td>
<td>204,485.34</td>
<td>204,485.34</td>
<td>147,288.04</td>
</tr>
<tr>
<td>7</td>
<td>kid's school</td>
<td>606</td>
<td>592</td>
<td>949.133</td>
<td>876.741</td>
<td>1,199.89</td>
<td>1,127.50</td>
<td>8,975.91</td>
<td>8,794.12</td>
<td>8,140.52</td>
<td>5,584.39</td>
</tr>
<tr>
<td>9</td>
<td>home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>DPPA</strong> (# of PPA = 2)</td>
<td>10,453</td>
<td>8,337</td>
<td>10401.92</td>
<td>7,493.64</td>
<td>11,898.04</td>
<td>8,984.46</td>
<td>258,705.63</td>
<td>213,279.46</td>
<td>212,625.86</td>
<td>152,872.43</td>
</tr>
</tbody>
</table>

Table 3.3: Various space-time accessibility measures for the person on the sample day.
After identifying the FOS and space-time prism for different pairs of fixed activities, daily space-time accessibility measures are generated by summing up the individual accessibility scores for a particular measure. As shown in Table 3.3, the person had time for discretionary activities (pick up a family member) only in the evening after work. Due to the person’s tight activity schedule, she was not able to undertake other discretionary activities on the sample day. As she was not able to reach many urban opportunities during their opening hours, the number of feasible opportunities and the possible activity duration at feasible locations were considerably reduced.

### 3.7 Conclusions

The purpose of this Chapter is to enhance space-time accessibility measures through developing a new operational method and GIS-based algorithm to better represents the space-time characteristics of urban opportunities (e.g. their geographical distribution and opening hours), human activity-travel behavior (e.g. delay times, minimum activity participation time, maximum travel time threshold) and the effect of transport network topology (e.g. one-way streets, turn restrictions and over-passes). Using this framework, this study evaluates space-time accessibility based not only on the number or size of accessible opportunities but also on the duration for which an individual can enjoy them given an individual’s space-time constraints and the spatial and temporal availability of opportunities. Incorporating these elements into space-time measures helps to overcome several shortcomings of previous approaches to evaluating space-time accessibility.
With the results from the space-time accessibility measures proposed in this Chapter, variations in accessibility among population groups, especially between women and men, will be examined in the following Chapters. In Chapters 4 and 5, the comparison of different types of space-time accessibility measures will be also undertaken, and the key determinants of accessibility of women and men will be identified. In addition, compositional analysis will also be carried out in order to scrutinize the context of activity and travel which allows individuals’ space-time autonomy in a different way between women and men by their employment status.

Then, Chapter 6 will explore how gender roles situate women and men differently (dual-earner couples only), and in turn structure gendered spatiality through the analysis of activity space and accessibility space in space and time.
CHAPTER 4

INDIVIDUAL ACCESSIBILITY IN SPACE AND TIME

4.1 Introduction

This chapter will explore gender differences, and spatial and temporal patterns of individual accessibility in Portland, Oregon, based on several space-time accessibility measures calculated with the geocomputational procedures proposed in the previous chapter. First, with the results of accessibility measures, accessibility differences among population subgroups will be investigated. Second, the implication of incorporating a temporal dimension into accessibility measures will be examined. And third, the spatial and temporal variation of individual accessibility in Portland, Oregon, and its gender differences will be investigated.

By doing so, the validity of arguments from the previous chapter will be examined. The previous chapter suggested that an enhanced conceptual framework and a new computational algorithm should simultaneously take into account both size and duration of feasible opportunities within space-time prisms in the measure. Furthermore, the
significance of incorporating a temporal dimension of accessibility into the measure was emphasized. Those arguments need to be proven with empirical analysis whether such new measures make estimates, not only conceptually more reasonable, but also practically more sensitive to interpersonal differences.

So far, little accessibility research has fully considered the dimensions of spatiality and temporality to be fundamental to all social processes in general, to the level of access to urban opportunities in particular. Not only the absolute level of difference in accessibility by individuals, but also the existence of both spatial and temporal differences in accessibility, could give additional dimension to our understanding of the accessibility experiences of people. Such findings would give helpful insight in assessing, evaluating and guiding when, where, and to whom certain actions should be undertaken.

In this study, not only paid work, but also domestic work was considered in the measure as space-time fixities in limiting individual accessibility. While discourse about social change toward a more egalitarian society (in terms of gender division of domestic labor in households) has emerged, attempts to examine such a trend have been sparse in the body of research of individual accessibility. If any, the measures did not include domestic work as fixed activity when calculating accessibility (for example, Weber, 2001). With a space-time accessibility measure which explicitly and fully recognizes the interconnections and linkages between the public and private, home and paid workplace, this study will explore whether, and to what extent, the socially constructed nature of gender relations in the context of the gender division of labor would significantly affect gender differences in accessibility in society.
4.2 Individual Accessibility in Portland

Table 4.1 shows the results of individual accessibility in Portland, Oregon, based on several space-time accessibility measures calculated with the geocomputational procedures proposed in the previous chapter.

Measures are indicators of the size and/or temporal duration of feasible opportunity sets within space-time prisms: a prefix “Num” represents how many opportunities are within reach of an individual. A prefix “Area” represents the area of feasible opportunity sets and “Warea” represents the weighted area of the feasible opportunity sets. A prefix “Act” represents the maximum activity duration possible at each opportunity within a prism with no consideration of the business hour. A suffix “T” represents the opportunities of which opening hours are within reach. A measure with a suffix T considers opportunities of which the mid-point of the time window falls within business hours but doesn’t further consider whether possible activity time exceeds the minimum activity duration with respect to the business hour. By contrast, “Dur” represents the feasible activity duration at each opportunity with respect to its business hours. Therefore, this type of accessibility measure enhances the temporal representation of feasible activity duration through incorporating both the business hour effect and the resulting possible activity duration.

Table 4.1a includes the accessibility measures of the number (Num) or the area (Area or Warea) of feasible opportunities. Table 4.1b demonstrates the accessibility measures of either activity duration (Act, Dur) or the combination of both size and
<table>
<thead>
<tr>
<th></th>
<th>N (%)</th>
<th>Num</th>
<th>NumT</th>
<th>Area</th>
<th>AreaT</th>
<th>Warea</th>
<th>WareaT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Individual Accessibility</strong></td>
<td>1,713</td>
<td>100</td>
<td>18641.31</td>
<td>15914.81</td>
<td>22185.57</td>
<td>17998.84</td>
<td>23411.39</td>
</tr>
<tr>
<td><strong>Standardized Accessibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1,633</td>
<td>95.33</td>
<td>99.79</td>
<td>99.73</td>
<td>99.73</td>
<td>99.75</td>
<td>99.65</td>
</tr>
<tr>
<td>Non-White</td>
<td>80</td>
<td>4.67</td>
<td>104.29</td>
<td>105.46</td>
<td>105.51</td>
<td>107.53</td>
<td>105.20</td>
</tr>
<tr>
<td><strong>Employment Status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>1,503</td>
<td>87.74</td>
<td>99.87</td>
<td>99.64</td>
<td>99.61</td>
<td>99.07</td>
<td>99.64</td>
</tr>
<tr>
<td>Part-time</td>
<td>210</td>
<td>12.26</td>
<td>100.95</td>
<td>102.57</td>
<td>102.81</td>
<td>106.66</td>
<td>102.56</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>939</td>
<td>54.82</td>
<td>99.92</td>
<td>99.77</td>
<td>100.18</td>
<td>100.33</td>
<td>100.17</td>
</tr>
<tr>
<td>Female</td>
<td>774</td>
<td>45.18</td>
<td>100.10</td>
<td>100.28</td>
<td>99.78</td>
<td>99.60</td>
<td>99.79</td>
</tr>
<tr>
<td>White Full-time</td>
<td>1,432</td>
<td>83.60</td>
<td>99.75</td>
<td>99.44</td>
<td>99.42</td>
<td>98.78</td>
<td>99.47</td>
</tr>
<tr>
<td>White Part-time</td>
<td>201</td>
<td>11.73</td>
<td>100.04</td>
<td>101.84</td>
<td>101.94</td>
<td>105.68</td>
<td>101.69</td>
</tr>
<tr>
<td>Non-White Full-time</td>
<td>71</td>
<td>4.14</td>
<td>102.14</td>
<td>103.76</td>
<td>103.40</td>
<td>104.87</td>
<td>103.07</td>
</tr>
<tr>
<td>Non-White Part-time</td>
<td>9</td>
<td>0.53</td>
<td>121.26</td>
<td>118.88</td>
<td>122.14</td>
<td>128.50</td>
<td>121.98</td>
</tr>
<tr>
<td>White Male</td>
<td>886</td>
<td>51.72</td>
<td>98.77</td>
<td>98.58</td>
<td>98.89</td>
<td>98.90</td>
<td>98.90</td>
</tr>
<tr>
<td>White Female</td>
<td>747</td>
<td>43.61</td>
<td>101.00</td>
<td>101.10</td>
<td>100.73</td>
<td>100.50</td>
<td>100.75</td>
</tr>
<tr>
<td>Non-White Male</td>
<td>53</td>
<td>3.09</td>
<td>119.18</td>
<td>119.59</td>
<td>121.89</td>
<td>124.29</td>
<td>121.41</td>
</tr>
<tr>
<td>Non-White Female</td>
<td>27</td>
<td>1.58</td>
<td>75.07</td>
<td>77.73</td>
<td>73.35</td>
<td>74.62</td>
<td>73.38</td>
</tr>
<tr>
<td>Full-time Male</td>
<td>870</td>
<td>50.73</td>
<td>99.53</td>
<td>99.32</td>
<td>99.79</td>
<td>99.57</td>
<td>99.78</td>
</tr>
<tr>
<td>Full-time Female</td>
<td>633</td>
<td>36.95</td>
<td>100.32</td>
<td>100.09</td>
<td>99.36</td>
<td>98.38</td>
<td>99.45</td>
</tr>
<tr>
<td>Part-time Male</td>
<td>69</td>
<td>4.03</td>
<td>104.79</td>
<td>105.45</td>
<td>105.16</td>
<td>109.88</td>
<td>105.03</td>
</tr>
<tr>
<td>Part-time Female</td>
<td>141</td>
<td>8.23</td>
<td>99.07</td>
<td>101.17</td>
<td>101.66</td>
<td>105.08</td>
<td>101.35</td>
</tr>
<tr>
<td>White Full-time Male</td>
<td>824</td>
<td>48.10</td>
<td>98.60</td>
<td>98.29</td>
<td>98.72</td>
<td>98.38</td>
<td>98.73</td>
</tr>
<tr>
<td>White Full-time Female</td>
<td>608</td>
<td>35.49</td>
<td>101.32</td>
<td>100.98</td>
<td>100.37</td>
<td>99.33</td>
<td>100.47</td>
</tr>
<tr>
<td>White Part-time Male</td>
<td>62</td>
<td>3.62</td>
<td>101.00</td>
<td>102.41</td>
<td>101.12</td>
<td>105.76</td>
<td>101.09</td>
</tr>
<tr>
<td>White Part-time Female</td>
<td>139</td>
<td>8.11</td>
<td>99.61</td>
<td>101.59</td>
<td>102.31</td>
<td>105.64</td>
<td>101.95</td>
</tr>
<tr>
<td>Non-White Full-time Male</td>
<td>46</td>
<td>2.69</td>
<td>116.26</td>
<td>117.63</td>
<td>118.99</td>
<td>120.94</td>
<td>118.60</td>
</tr>
<tr>
<td>Non-White Full-time Female</td>
<td>25</td>
<td>1.48</td>
<td>76.15</td>
<td>78.24</td>
<td>74.71</td>
<td>75.30</td>
<td>74.50</td>
</tr>
<tr>
<td>Non-White Part-time Male</td>
<td>7</td>
<td>0.41</td>
<td>138.34</td>
<td>132.45</td>
<td>140.92</td>
<td>146.32</td>
<td>139.89</td>
</tr>
<tr>
<td>Non-White Part-time Female</td>
<td>2</td>
<td>0.12</td>
<td>61.50</td>
<td>71.33</td>
<td>56.38</td>
<td>66.12</td>
<td>59.28</td>
</tr>
</tbody>
</table>

Note: *italics* indicates that differences are statistically significant at p < 0.05
*Bold* indicates that differences are statistically significant at p < 0.01

Table 4.1: Results of space-time individual accessibility measures (continued):
(a) measures of the number or area of feasible opportunities, and (b) measures of activity duration at feasible opportunities.
Table 4.1: continued.

<table>
<thead>
<tr>
<th>(b)</th>
<th>Act</th>
<th>ActT</th>
<th>AreaAct</th>
<th>AreaActT</th>
<th>WareaAct</th>
<th>WareaActT</th>
<th>Dur</th>
<th>AreaDur</th>
<th>WareaDur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Individual Accessibility</td>
<td>2349735.30</td>
<td>2099175.22</td>
<td>2612432.05</td>
<td>2249105.88</td>
<td>2751774.72</td>
<td>2385752.83</td>
<td>1815987.75</td>
<td>2049910.16</td>
<td>2184746.34</td>
</tr>
<tr>
<td>Standardized Accessibility</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>98.62</td>
<td>98.57</td>
<td>98.57</td>
<td>98.52</td>
<td>98.59</td>
<td>98.54</td>
<td>98.72</td>
<td>98.61</td>
<td>98.64</td>
</tr>
<tr>
<td>Non-White</td>
<td>128.07</td>
<td>129.13</td>
<td>129.13</td>
<td>130.23</td>
<td>128.68</td>
<td>129.74</td>
<td>126.18</td>
<td>128.35</td>
<td>127.58</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>98.99</td>
<td>98.62</td>
<td>99.06</td>
<td>98.50</td>
<td>99.05</td>
<td>98.52</td>
<td>98.16</td>
<td>97.79</td>
<td>97.86</td>
</tr>
<tr>
<td>Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part-time</td>
<td>107.24</td>
<td>109.85</td>
<td>106.76</td>
<td>110.76</td>
<td>106.81</td>
<td>110.58</td>
<td>113.17</td>
<td>115.79</td>
<td>115.33</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>107.86</td>
<td>108.30</td>
<td>108.49</td>
<td>109.24</td>
<td>108.43</td>
<td>109.11</td>
<td>106.60</td>
<td>107.26</td>
<td>107.18</td>
</tr>
<tr>
<td>Female</td>
<td>90.46</td>
<td>89.93</td>
<td>89.70</td>
<td>88.80</td>
<td>89.78</td>
<td>88.95</td>
<td>92.00</td>
<td>94.19</td>
<td>91.29</td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>97.63</td>
<td>97.26</td>
<td>97.67</td>
<td>97.12</td>
<td>97.68</td>
<td>97.16</td>
<td>96.97</td>
<td>96.53</td>
<td>96.62</td>
</tr>
<tr>
<td>Female</td>
<td>105.68</td>
<td>107.92</td>
<td>105.02</td>
<td>108.50</td>
<td>105.09</td>
<td>108.56</td>
<td>111.15</td>
<td>113.46</td>
<td>113.04</td>
</tr>
<tr>
<td>Non-White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>126.31</td>
<td>126.14</td>
<td>127.05</td>
<td>126.28</td>
<td>126.58</td>
<td>125.84</td>
<td>122.08</td>
<td>123.34</td>
<td>122.79</td>
</tr>
<tr>
<td>Part-time</td>
<td>141.98</td>
<td>152.74</td>
<td>145.53</td>
<td>161.38</td>
<td>145.30</td>
<td>160.57</td>
<td>158.47</td>
<td>165.67</td>
<td>166.44</td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>105.46</td>
<td>105.89</td>
<td>105.93</td>
<td>106.66</td>
<td>105.90</td>
<td>106.57</td>
<td>104.31</td>
<td>104.74</td>
<td>104.71</td>
</tr>
<tr>
<td>Part-time</td>
<td>90.52</td>
<td>89.90</td>
<td>89.85</td>
<td>88.87</td>
<td>89.93</td>
<td>89.03</td>
<td>92.08</td>
<td>91.34</td>
<td>91.45</td>
</tr>
<tr>
<td>Non-White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>148.07</td>
<td>148.60</td>
<td>151.31</td>
<td>152.36</td>
<td>150.63</td>
<td>151.60</td>
<td>144.75</td>
<td>149.40</td>
<td>148.44</td>
</tr>
<tr>
<td>Part-time</td>
<td>88.81</td>
<td>90.92</td>
<td>85.58</td>
<td>86.80</td>
<td>85.61</td>
<td>86.85</td>
<td>89.73</td>
<td>87.02</td>
<td>86.97</td>
</tr>
<tr>
<td>White Full-time Male</td>
<td>105.66</td>
<td>105.55</td>
<td>106.34</td>
<td>106.31</td>
<td>106.28</td>
<td>106.23</td>
<td>103.58</td>
<td>103.87</td>
<td>103.86</td>
</tr>
<tr>
<td>White Full-time Female</td>
<td>89.82</td>
<td>89.11</td>
<td>89.05</td>
<td>87.75</td>
<td>89.11</td>
<td>87.92</td>
<td>90.71</td>
<td>91.44</td>
<td>91.61</td>
</tr>
<tr>
<td>White Part-time Male</td>
<td>135.61</td>
<td>142.97</td>
<td>135.65</td>
<td>146.10</td>
<td>135.49</td>
<td>145.35</td>
<td>144.65</td>
<td>150.05</td>
<td>149.02</td>
</tr>
<tr>
<td>White Part-time Female</td>
<td>93.35</td>
<td>93.64</td>
<td>92.62</td>
<td>93.47</td>
<td>92.78</td>
<td>93.57</td>
<td>97.77</td>
<td>99.03</td>
<td>98.84</td>
</tr>
<tr>
<td>Non-White Full-time Male</td>
<td>146.47</td>
<td>145.33</td>
<td>149.36</td>
<td>147.72</td>
<td>148.76</td>
<td>147.25</td>
<td>139.64</td>
<td>143.03</td>
<td>142.34</td>
</tr>
<tr>
<td>Non-White Full-time Female</td>
<td>89.21</td>
<td>90.83</td>
<td>86.00</td>
<td>86.84</td>
<td>85.75</td>
<td>86.60</td>
<td>89.78</td>
<td>87.12</td>
<td>86.80</td>
</tr>
<tr>
<td>Non-White Part-time Male</td>
<td>158.60</td>
<td>170.08</td>
<td>164.13</td>
<td>182.84</td>
<td>162.87</td>
<td>180.18</td>
<td>178.31</td>
<td>191.30</td>
<td>188.55</td>
</tr>
<tr>
<td>Non-White Part-time Female</td>
<td>83.82</td>
<td>92.08</td>
<td>80.35</td>
<td>86.30</td>
<td>83.81</td>
<td>90.94</td>
<td>89.02</td>
<td>85.80</td>
<td>89.09</td>
</tr>
</tbody>
</table>

Note: *italics* indicates that differences are statistically significant at p < 0.05
*Bold* indicates that differences are statistically significant at p < 0.01
activity duration at feasible opportunities. Raw values of average individual accessibility for each measure are shown in the first row. Since those values in each measure are so large and recorded in different units (for example, the number of parcels for $Num$, the square footage of parcels for $Area$, the minutes for $Act$ and $Dur$, and so on.), it is not so straightforward to undertake the interpretation and comparison between measures and among subgroups of the population. For easier comparison and visualization, accessibility values for each type of measure were standardized to a mean of 100 so that all measures are placed on a common scale. With such standardized accessibility values for each measure, interpersonal differences are examined with respect to race, employment status and gender. Less than 100 values of measure means lower accessibility than the average and more than 100 means higher accessibility compared to the average. If the interpersonal difference is statistically significant at the level of 0.01, the values are in bold while the values in italic represent the statistically significant difference among the subgroup populations at the level of 0.05.

Overall, the results demonstrate that accessibility differences among the subgroup populations become significant and well captured when activity duration is incorporated into the measure, as shown in Table 4.1b. Especially, when two types of temporal dimension (i.e. the business hour effect and the possible activity duration) are simultaneously taken into account, accessibility differences among subpopulation groups always become more strongly evident in all classifications of people with respect to race, employment status, and gender. When the possible activity duration within business
hours as well as the amount of opportunities is considered into the measure, differences among subpopulation groups by race, employment, and gender were always significant. Remarkably, the accessibility measures, AreaDur and WareaDur are not only conceptually more robust, but also more sensitive to differences between groups of people in different situations. Such findings suggest that more rigorous and inter-group difference-sensitive measures are achievable, on one hand, when possible activity duration with respect to the limited facility hours are explicitly take into account and, on the other hand, when both “how many (or large)” and “how long” accessibility properties are simultaneously taken into account. Specifically, when only the size (either number or area) of opportunities was measured, differences were not significant except with race and employment status. Even when maximum activity duration (Act) was incorporated into the measure, regardless of the combination with size factors, those measures could not capture accessibility differences between full-time workers and part-time workers. Employment status has been recognized as one of the most important factors which determine the level of access to urban opportunities. When the effect of business hours on activity duration was explicitly considered (Dur), differences in accessibility due to employment status by race was captured. Even when both size and activity duration based on the business hour are incorporated into the measure (AreaDur or WareaDur), interpersonal differences remain statistically significant for all types of subgroup-populations.

Regarding race, the results show that whites have lower accessibility than non-whites in terms of both spatial and temporal dimension of feasible opportunities. When activity
duration was considered, such a difference becomes statistically significant, as shown in Table 4.1b. However, we should ensure whether differences in other factors are not masking or enhancing a significant difference in average accessibility level. Differences in average accessibility by race may be influenced by factors such as employment status or gender and not by race alone. In the case of employment status, full-time workers tend to have lower accessibility values due to their longer work-hours compared to part-time workers. With gender, women have lower accessibility than men overall in terms of area and activity duration, regardless of consideration of business hours of opportunities. When a measure of the number of opportunities within space-time reach was used, women are seen to have slightly more opportunities than men. But the t-test result indicates that the gender difference in terms of the number, as well as the area or weighted area, of feasible opportunities is not statistically significant without activity duration components. In contrast, the measures with activity duration components (Act- and Dur-associated measure groups) show the existence of significant gender differences and identify the status of women as disadvantaged in access to urban opportunities compared to men.

As indicated in Table 4.1b, when race, employment status and gender are considered altogether, patterns of inter-subgroup differences in accessibility become complicated. The result of accessibility measures, for instance, WareaDur, shows that the relationship between race and accessibility is consistent with employment status, but inconsistent with gender. Non-white males are more accessible to urban opportunities than white males, regardless of employment status. By contrast, non-white female workers have lower
accessibility than white female workers regardless of employment status. Similarly, the relationship between employment status and accessibility was consistent with race, but not with gender. Part-time female workers for both races have lower accessibility than full-time non-white workers. As a result, even though non-white part-time workers are expected to have higher accessibility than whites and full-time workers, in fact non-white part-time female workers are the most disadvantaged.

This finding would imply that gender would be a more influential factor than race or employment status. Figure 4.1 clearly reveals that women have lower accessibility regardless of race and employment status. In addition, it shows that women do not follow the general pattern of accessibility variations along with their race and employment status, while men do. While non-white part-time female workers are expected to have higher accessibility than white part-time and even more than white full-time female workers, in fact, the former is found to have much lower accessibility than the latter. Since male workers follow the general expectation of accessibility level according to their race and employment status, non-white male part-time workers show the higher level of access to urban opportunities than both white and full-time male workers. Figure 4.1 reveals that the gender gap in accessibility becomes bigger for non-whites compared to whites, and for part-time workers compared to full-time workers. Non-white part-time female workers are not only the most disadvantaged in access to urban opportunities but also show the biggest gender gap among sub-population groups. It is evident from those
results that, owing to the greater influence of gender, the effect of race and employment status on individual accessibility becomes unstable and more complicated than expected.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Employment status</th>
<th>White</th>
<th>Non-White</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FullTime</td>
<td>1000000</td>
<td>1300000</td>
</tr>
<tr>
<td></td>
<td>PartTime</td>
<td>2000000</td>
<td>3200000</td>
</tr>
</tbody>
</table>

Figure 4.1: Gender differences in individual accessibility (\(WareaDur\)) by race and employment status.

In summary, lower accessibility level was shown for whites compared to non-whites, full-time workers to part-time workers, and women to men. Women, regardless of race and employment status, have lower accessibility than men. And also, when gender is combined with race and employment status, the accessibility pattern becomes more complicated and shows women do not follow the general pattern. The gender gap in accessibility intensifies when race is combined with gender. It shows that gender would be one of the most significant axes of ascribing to social inequality in access to urban opportunities. Due to small numbers of non-whites in the sample data, however, attention
only to gender without significant consideration of race will be given in the following chapters.

4.3 The significance of Including Temporal Availability into Accessibility Measure

In order to examine the significance of the inclusion of possible activity duration and temporal availability of feasible opportunities into the accessibility measure, the paired-samples T test procedure was employed (Table 4.2). This test computes the differences between the mean accessibility values for each pair of measures and tests whether the incorporation of such temporal dimension into the measure had an effect on the estimation of the level of accessibility. Since the significance value for change in every set of paired variables is close to 0, we can conclude that the average reduction of the estimated accessibility level is not due to chance variation, and can be attributed to the consideration of temporal dimension into the measure. In order words, this result shows that measures which explicitly take the temporal dimension into account significantly reduced the level of accessibility measure estimated. It therefore implies that existing accessibility measures, without such consideration of temporal availability of opportunities and possible activity duration, tend to significantly over-estimate the level of accessibility of individuals.

Table 4.2 shows the effect of the incorporation of the temporal dimension of feasible opportunities on the measure. Temporal dimension includes the temporal availability of opportunities due to limited opening hours and potential activity durations available within two consecutive fixed activities. The result reveals that the inclusion of
either activity duration and/or temporal availability of opportunities into the measure makes differences, and those differences are statistically significant. It implies that individual accessibility measures without proper consideration of temporal dimension would overestimate an individual's level of access to urban opportunities and makes the result less robust.

<table>
<thead>
<tr>
<th>a set of paired accessibility measures</th>
<th>Paired Differences</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Pair 1    Num - NumT</td>
<td>2726.50</td>
<td>4034.50</td>
</tr>
<tr>
<td>Pair 2    Area - AreaT</td>
<td>4186.73</td>
<td>5512.18</td>
</tr>
<tr>
<td>Pair 3    Warea - WareaT</td>
<td>4253.73</td>
<td>5681.16</td>
</tr>
<tr>
<td>Pair 4    Act - ActT</td>
<td>223295.02</td>
<td>396264.53</td>
</tr>
<tr>
<td>Pair 5    Area - AreaT</td>
<td>363326.17</td>
<td>623297.51</td>
</tr>
<tr>
<td>Pair 6    Warea - WareaT</td>
<td>366021.88</td>
<td>632354.83</td>
</tr>
<tr>
<td>Pair 7    Act - Dur</td>
<td>347334.44</td>
<td>849536.69</td>
</tr>
<tr>
<td>Pair 8    ActT - Dur</td>
<td>124039.42</td>
<td>709468.88</td>
</tr>
<tr>
<td>Pair 9    AreaAct - AreaDur</td>
<td>562521.90</td>
<td>1204478.84</td>
</tr>
<tr>
<td>Pair 10   AreaActT - AreaDur</td>
<td>199195.73</td>
<td>975756.24</td>
</tr>
<tr>
<td>Pair 11   WareaAct - WareaDur</td>
<td>567028.38</td>
<td>1243497.66</td>
</tr>
<tr>
<td>Pair 12   WareaActT - WareaDur</td>
<td>201006.49</td>
<td>1010870.21</td>
</tr>
</tbody>
</table>

Note: **Bold** indicates that differences are statistically significant at $p < 0.01$

Table 4.2: The effect of the temporal dimension incorporation into accessibility measure.

Due to the computational burden to calculate accessibility with different sets of factors included in the measure, only the difference made by the effect of temporal dimension was evaluated (as shown above in Table 4.2) and was found to be significant. If so, it can be inferred that there would be a much greater amount of overestimation in
the level of accessibility measured, compared to the results shown in the table, if the
measure did not include other factors such as minimum activity duration, delay times,
changes in travel times due to one-way streets in downtown areas and congestion hours.

In summary, with respect to the effect of activity duration and temporal
availability on the measure, this research reveals that there are significant differences
between each set of paired space-time accessibility measures. When the temporal
availability of feasible opportunities and further possible activity duration at each
opportunity are incorporated into the measure, the values of individual accessibility are
significantly reduced. This suggests that a more considerate and sophisticated treatment
of temporal dimension regarding the accessibility measure is vital for a more robust and
realistic estimation of individual accessibility levels.

4.4 Accessibility in Space and Time

The spatial and temporal characteristics of activity (and/or travel) patterns have
been widely explored, in an attempt to understand individuals’ experiences in an urban
environment (Kwan 1999b). Relatively, spatial and temporal aspects of accessibility still
remain largely unexplored. It is partly because of the greater difficulty in extracting the
information of individual accessibility compared to that of activity and travel, which is
usually readily available from the data set. It is also partly because of the intrinsic logic
of conventional measures for individual accessibility: the reduction of accessibility to the
proximity (or distance). According to the conventional measures, the location of homes
with respect to distance to the CBD and/or the urban opportunity density in the neighborhood directly determines the level of individual accessibility. Therefore, those living closer to the CBD or major urban centers would have higher access to urban opportunities. The over-reliance on the role of distance to accessibility, without consideration of individual characteristics and activity/travel behavior, has been criticized due to its failure in explaining, for example, the situation of low-income populations living in downtown areas and the differential accessibility of individuals within the same household. Recent empirical studies based on space-time accessibility measures revealed that the spatial patterns of individual accessibility levels do not simply follow that of proximity. Individual accessibility observed by space-time measures clearly showed little evidence supporting the importance of distance by demonstrating a more complicated relationship between proximity and accessibility than assumed. Space-time accessibility research argued that observed spatial patterns of individual accessibility suggest that individual characteristics and human behavior (activity and travel patterns) would be another significant dimension in determining the level of access. Spatial variations of individual accessibility properly measured in such a way could give more helpful insights on where the most disadvantaged are and how different population groups have different spatial patterns of accessibility given their own social, and space-time constraints. While the spatial pattern of individual accessibility and its implications have been rigorously examined by recent space-time accessibility research, no attempts have been made to study the temporal pattern of individual accessibility. It would be also interesting to take a look at temporal variations in accessibility as another way of understanding the urban
experiences of people. Temporal characteristics of accessibility by subpopulation groups allow the researcher to identify and assess who the most disadvantaged are, when people have less accessibility over times of the day, and to what extent.

4.4.1 Accessibility Pattern in Geographic Space

The spatial pattern of individual accessibility, as indicated in Figure 4.2, reveals that individual accessibility does not vary directly along with distance from the CBD (and/or urban regional centers), or and is not directly determined by the spatial pattern of urban opportunities (as shown in Figure 4.3), in contrast to the general expectations of traditional accessibility measures such as gravity-type or cumulative-opportunity measures. In order to visualize spatial variations in individual accessibility, ArcView 3D analyst functions were used with the accessibility value of $W_{areaDur}$, creating a 3-dimensional continuous surface of accessibility. Values of the $W_{areaDur}$ accessibility measure were interpolated from points of individuals’ home locations. So, the surface height represents the deviation from the average values and basically reflects the level of accessibility of people residing in particular locations, rather than that of fixed places.
Figure 4.2: Spatial pattern of individual accessibility (W_AreaDur measure).
Figure 4.3: Spatial pattern of urban opportunity density.

Unlike the expectation of conventional accessibility measures, the spatial pattern of accessibility does not show any simple and clear relationship with the high concentrations of urban opportunities close to downtown Portland. Neither downtown areas nor major regional centers are the significant places for people with high accessibility. Even some areas close to downtown Portland inside the loop show low accessibility levels. What is interesting from the spatial pattern of accessibility is that
even more accessibility peaks as well as troughs are found at relatively peripheral areas rather than central areas. Additionally, such patterns do not show a noticeable association with the spatial pattern of urban opportunities.

The fact that the accessibility pattern is not directly determined by the spatial environment -- more specifically, the spatial location of an individual’s home within a city or the level of urban opportunities within residential areas -- indicates that people’s daily travel/activity characteristics, based on his/her own space-time constraints, also influence the accessibility pattern. In addition, the visualization of spatial variations of accessibility enables us easily and effectively to identify areas with the most disadvantage, to further analyze the affecting factors of low accessibility in particular areas, and to provide helpful insights to direct future policy to lessen such spatial inequality.

The result of this research supports the findings of previous space-time accessibility research on the relationship between accessibility and proximity (Weber and Kwan 2002; Weber 2003). As Weber (2003) used the same data set for the Portland individual accessibility, it would be interesting to compare the results of both in more detail. In order to demonstrate the spatial difference in the level of individual accessibility, spatial dimension of the feasible opportunities (i.e. the sum of weighted areas of FOSs within the space-time prism) was used by Weber. The comparison of spatial measure of individual accessibility, with the spatio-temporal measure demonstrated in this research, allows us to see to what extent the inclusion of temporal dimension into the measure makes different spatial patterns of accessibility. This research used the WareaDur
measure, which takes into account not only the weighted areas of FOSs, but also possible activity duration given the timing of activities and limited facility hours.

The spatial patterns of accessibility in downtown Portland, inside the loop, are almost identical in both findings. However, specific areas with relatively higher accessibility levels pointed out by Weber are quite different from those identified by this research, as shown in Figure 4.2. The individual accessibility surface for the weighted area measure by Weber showed that several distinctive accessibility peaks exist east of downtown Portland, within I-205, while people living west of downtown areas and in overall peripheral areas had lower accessibility levels. For this research, as the temporal as well as spatial dimension were considered -as indicated as $W_{\text{areaDur}}$-, higher accessibility areas are not found to be the same as shown by Weber’s measure. Both high peaks and low troughs of accessibility were found at peripheral areas (northern and eastern parts) and northwest of the downtown areas.

This clearly shows that the incorporation of activity duration, as well as other components - such as limited facility hours, minimum activity durations, delay times, transport network topology - would render spatial differences in the accessibility pattern, as well as the level of accessibility in the estimates as revealed in the previous section. This implies the individual accessibility obtained from the computation is very sensitive to the way in which the space-time prism and feasible opportunity sets are constructed, and to what dimension the measure itself takes into account. Taken together, it suggests that the conceptually and operationally sophisticated measure is prerequisite to a reliable result.
4.4.2 Accessibility Pattern in Time

Previous measures, whether conventional or space-time accessibility, have paid little, if any, attention to temporal variations of individual accessibility. For example, conventional measures (spatial measures such as gravity-type or cumulative-opportunity measures) implicitly assume a consistent level of accessibility regardless of time of day, emphasizing spatial proximity as the key factor in determining differential level of accessibility. Therefore, those measures ignore the fact that an individual would have temporally varying accessibility levels due to his/her everyday activity schedules and situations. Also, ignored is that even members in the same household would have different time schedules and thus could have different temporal pattern of accessibility due to different space-time fixities among individuals. Like conventional measures, previous space-time accessibility measures have not paid as much attention to temporal variation in the level of accessibility and its implications as to spatial aspects.

Figure 4.4 clearly shows that the level of accessibility varies by time of day. There are identifiable distinctive temporal patterns in accessibility: people have exclusively high accessibility around 6 pm (specifically, 5 pm to 7 pm) with the second peak at noon, either in terms of the total number of space-time prisms which could be made at a particular time of day (Figure 4.4a), or in terms of both size and duration possible from space-time prisms (Figure 4.4b).
Figure 4.4: Temporal pattern of individual accessibility: (a) the number of space-time prisms made, and (b) the level of accessibility of total population ($WareaDur$).
With regard to the number of space-time prisms occurred through time, two peaks dominate the temporal distribution of space-time prisms, as Figure 4.4a indicates. One is at noon and the other between 5 pm and 7 pm. When size and duration of space-time prisms are considered (Figure 4.4b), the latter became predominant, while the former became less visible due to its shorter duration of time windows. The rest of the day, people tend to have much lower average accessibility level.

Such a temporal pattern shows how society shapes the temporal rhythm of everyday life: when and how long people can participate in discretionary activities with how many choices is greatly determined by the way society organizes and constructs time, beyond mere individual decisions and situations. The result in Figure 4.4 clearly shows the typical temporal rhythm of Western society with the 9 am to 5 pm work-hours and the noon to 1 pm lunch break. Despite the recent introduction of flexibility in work-hours and a significant presence of part-time workers, the level of access to urban opportunities is still highly time-dependent, in general, and is temporally concentrated at a particular time of day—in the early evening. These findings shed light on the limitations of traditional measures which fail to recognize the fact that an individual’s accessibility level varies not only spatially but also temporally. Without recognition of how socially constrained individuals’ lives are in time, previous accessibility measures have ignored the fact that people could not access urban opportunities every time of day, and, therefore, the level of accessibility was assumed to be equal throughout the day. It is problematic in that the level of accessibility estimated by such a measure would likely be either overstated or
understated since the measure represents just one value, which masks actual fluctuations of individual accessibility over time.

Examining not only the size and possible duration of space-time prisms, but also the degree of interpersonal variations in the level of accessibility over time, would illuminate another dimension of individual accessibility with regard to quality of life. For example, even with the same level of accessibility on average, a person who has a high accessibility peak extremely concentrated on a certain point of time could be considered to have poorer access to opportunities, compared to a person with reasonably high and more temporally dispersed accessibility peaks during a day. It is because the latter would have more space-time flexibility to choose when to do discretionary activities and for how long, even with the same level of accessibility.

In this regard, Figure 4.5 provides a closer look at temporal patterns of accessibility by types of space-time measures, employment status and gender. First, Figure 4.5 shows that an overall similarity is found in temporal patterns in accessibility among the results of several space-time accessibility measures, even though slight differences exist. Comparison either between (a) and (c) or between (b) and (d) in Figure 4.5 reveals that particular patterns of temporal variation in accessibility for each type of employment status are identical, regardless whether accessibility is measured in terms of the number, area, or weighted area of feasible opportunities given business hours – $\text{NumT}$, $\text{AreaT}$, and $\text{WareaT}$, respectively (Figure 4.5 (a) or (b)), or in terms of both the size and duration – $\text{WareaDur}$- (Figure 4.5 (c) and (d)). In the same way, different measures
Figure 4.5: Temporal variations in accessibility by employment status (full-time (left) and part-time workers (right)) and by gender (e and f).
indicate a certain time of day for either relatively higher or lower accessibility. In this light, interpersonal differences in temporal variations of accessibility, by employment status and gender, are examined with the \textit{WareaDur} measure only.

It is clearly seen in Figure 4.5 that there are distinctive differences in temporal patterns by employment status and gender. What is interesting is that the overall trend of temporal variations in accessibility reflects the pattern of accessibility for \textit{full-time} workers, but not for part-time workers, and especially for the full-time employed \textit{men} compared to the female counterparts.

It is noticeable in Figure 4.5 that there are differences in the patterns of temporal variations of accessibility between full-time workers and part-time workers. Part-time workers are likely to be more flexible with time, and have more time for discretionary activities. So, as seen in Figure 4.5, part-time workers have quite a different temporal pattern in accessibility, compared to full-time workers with more stringent time fixities and less time for discretionary activities. Full-time workers have a distinctively high accessibility peak around 6 pm (specifically 5–7pm, after work) and a tiny peak around noon (the lunch break) (Figure 4.5 (a) and (c)). Such a pattern among full-time workers is more or less identical to that of the total population as shown in Figure 4.4.

By contrast, part-time workers have a consistent pattern of accessibility almost all day. High accessibility peaks for part-time workers show a more scattered pattern of accessibility, whereas those for full-time workers are more temporally concentrated at particular time of day. Dominance of a certain time of day for high level of accessibility
is less visible in the case of part-time workers. For part-time workers, strong midday peaks are present around 4 pm and 1 pm, along with the peak times as shown in the case of full-time workers (that is, 6-7pm).

It is noteworthy, however, that there are gender differences in temporal patterns of accessibility: women have slight different temporal patterns compared to men, whether employed full-time or part-time. The difference by gender is especially visible for part-time workers. In the case of full-time workers (as shown in Figure 4.5(e)), for both men and women, due to the presence of time fixity by their long work hours, a high accessibility peak stands out right after work. Thus, the difference between women and men would be negligible, since only a minute dissimilarity can be found in terms of the relative significance and timing of the next highest peak.

By contrast, part-time workers show a dramatically different temporal pattern of accessibility by gender. In the case of part-time employed men, their temporal pattern is, by and large, similar to that for total part-time workers as shown in Figure 4.5 (d), despite the slight difference in the relative importance of high accessibility peaks indicated. Overall, part-time male workers have high accessibility throughout the early afternoon (noon to 4 pm): more specifically, the highest accessibility around 4 pm, the second at 1 pm, and the third around 7 pm. Noticeably, female part-time workers, however, have exclusively different temporal pattern of accessibility compared to their male counterparts, both in terms of the timing of high accessibility peaks and the relative importance of a certain peak over others. In the case of female part-time workers, the
level of accessibility is exclusively high at late afternoon around 7-9 pm with a small peak at 1 pm.

It is interesting that female part-time workers - given their employment status, presumably time-flexible and time-rich compared to full-time workers- have a similar pattern with full-time workers (who have a strong time fixity during the day (9 am to 5 pm) and thus have flexible time only in the evening after work), rather than with part-time employed men. It would imply that part-time employed women, even though they have fewer work hours, might not be as free as presumed during the day. It might be because of a source of constraints which are relatively more imposed on women than on men: household and child-care responsibilities. Such responsibilities are disproportionately assigned to women, due to a socially perceived and constructed gender role.

In other words, unlike men, obligatory fixities required not only by paid work, but also by domestic work cause the limited temporality of women’s autonomy for discretionary activities during a day. It could be argued that, as a result, regardless of employment status, women are not only spatially entrapped but also temporally entrapped. That is, women’s “temporal entrapment” refers to the fact that women’s autonomy for discretionary activities is relatively more entrapped at certain time of day (particularly, in the evening) compared to men’s - as graphically indicated in a form of a dominant high-peak of accessibility around 5-7 pm compared to other times of day- regardless of employment status. The term suggested in this paper is devised from the idea of women’s “spatial entrapment” or “spatial containment” examined by previous gender studies and

The spatial entrapment thesis is widely used to highlight the fact that women’s heavy domestic responsibilities restrict their employment prospects and job-search area, and, in turn, spatially entrap women in their neighborhood of residence (Hanson and Pratt, 1995). That is, those spatially entrapped women, compared to men, face disadvantages in employment, especially: women are likely to be unemployed, or likely to work part-time, within a short commute distance -whether part-time or full-time- and with lower wages. Research based on the spatial entrapment thesis has revealed that urban/suburban wage differentials may exist only for certain kinds of workers who are more limited spatially in their commute, such as a particularly working mother in a suburb. By deliberately taking advantage of women’s spatially entrapped situation, firms in suburbs tend to give relatively lower wages to women compared to men with the same level of education and skill. In this regard, past research has been focused on the spatial dimension of women’s situation. Such findings imply that, through reducing the degree of spatial entrapment of women, the level of women’s access to urban opportunities (particularly, job opportunities) could be improved.

I would argue that highlighting the temporal dimension of women’s situations would be useful, as well as the spatial dimension. An examination of the temporal dimension of accessibility could give additional useful insights as to how, in what ways, and to what extent, women face, and thus could dismantle, disadvantages in access to urban opportunities (such as shopping, recreations, or jobs). In other words, the study on
temporal entrapment of women suggests another way to improve the level of access to urban opportunities: through reducing the degree of temporal entrapment of women. For example, through extending opening hours of daycare centers, a better level of access to opportunities could be accomplished, as well as through providing more daycare centers or jobs near their residence. Moreover, a comparison of the impacts of different strategies could guide which improvement strategy is more imperative and/or more efficient to improve the level and quality of access to urban opportunities of a particular segment of people.

4.5 Conclusions

This chapter has explored the results of space-time accessibility measures proposed and implemented in the previous chapter. The results of space-time measures were examined in terms of differences by types of measures, by subpopulation group (basically, with respect to race, employment status and gender), and in terms of spatial and temporal characteristics of accessibility. The findings in detail follow.

First, the differences in different types of space-time measures were examined. The results revealed that the significant inter-subgroup differences were visible when both size and duration factors were simultaneously taken into account. That is, $W_{area}Dur$ was found to be, not only conceptually reasonable, but also practically more robust and more sensitive in highlighting interpersonal differences.

Second, as argued in the previous chapter, it was imperative to incorporate temporal dimension into the accessibility measure to make the result by the measure
reliable and robust. There were significant differences between measures incorporating possible activity duration and temporal availability of opportunities into the measure and those that did not. The result implies that accessibility measures without consideration of the effect of temporal availability and reachability of feasible opportunities tend to overestimate the actual level of individual accessibility. In light of possible reduction effects by other factors considered in this paper (such as minimum activity time threshold, delay times, travel times under congestion or along one-way streets in CBD, and so on); without such consideration into the measure, resulting accessibility estimates would likely be overestimated. It would become problematic if the measure disproportionately overestimate certain groups of people, for instance, those who are likely to have most activities downtown and travel during peak hours, compared to other groups of people. Ill-measured results would misguide the evaluation of the disadvantaged, and, in turn, the establishment of efficient and effective policy decisions for the reduction in social inequality.

Third, when spatial and temporal patterns of accessibility were examined, it was clearly seen that the level of accessibility for individuals varies spatially and temporally. However, spatial variations in accessibility were not directly determined by spatial proximity and opportunity density as suggested by previous accessibility measures. It implies that spatial variations in individual accessibility are more likely a function of individual characteristics (i.e. activity-travel schedules and situations), rather than a function of the residence location and land use characteristics around them. Though little analysis has been made for temporal variations in individual accessibility by previous
research, not only spatial but also temporal dimension of accessibility could provide insightful findings as to how society constructs urban rhythms of peoples’ everyday lives and provide another dimension for urban policy makers to pay attention to effectively and efficiently improve the accessibility-disadvantaged. For certain population groups, temporal strategies (i.e. extension of facility opening hours such as a daycare center to allow them more time flexibility) would be more helpful than spatial strategies (i.e. more construction of urban opportunities such as daycare center).

Fourth, there were significant differences among subpopulation groups. Due to the length of work hours with rigid space-time constraints, full-time workers had less accessibility than part-time workers; whites had lower accessibility than nonwhites; women had lower accessibility than men. What was interesting is that when gender, race and employment status were combined, the differences among sub-population groups became more complicated, and women especially did not follow general trends expected by their race and employment status, while men did. For instance, even part-time employed women had lower accessibility than full-time employed men, whether whites or nonwhites. Another significant finding from the results is that, in addition to women’s lower accessibility in absolute terms, women’s temporal autonomy was strictly entrapped at only a particular time of day (in the late afternoon, specifically) regardless of employment status. To conceptualize this finding, a new term “temporal entrapment” of women was suggested in this research. This finding implies that the importance of gender-associated constraints should be fully recognized in determining how much and when people can access urban opportunities.
The findings from examining multi-dimensional characteristics of individual accessibility results in this chapter would suggest that urban policies should approach individual accessibility problems more carefully and thoughtfully. So far, the previous approach has been criticized due to its white, full-time worker, and male-oriented viewpoint. As a significant amount of research has suggested, in order to make policies realistic and effective, policy makers need to pay more attention to the situations of those who have been invisible and, therefore, poorly taken into account, such as women, part-time workers and non-whites. In addition, as there are significant spatial and temporal discrepancies in accessibility levels among population groups, it is also necessary to make the policy more geographic-intelligent and time-sensitive.

In the next chapter, gender differences in individual accessibility will be further investigated. The next chapter will focus on gender but not on race. The importance of combining race to gender in explaining gender inequality has been recognized in previous research and this study. However, due to a relatively small sample size of non-whites, especially non-white women in the sample data used, gender will solely be considered in this research for statistically meaningful results and implications. Examining why women have lower and temporally entrapped accessibility compared to men, the way to effectively diminish gender gaps of quality of life as manifested in a form of accessibility will be suggested. To answer those questions, the following aspects will be examined: how women’s access to urban opportunity is lower than men’s, why and where. Then this study will examine the relationships between space-time accessibility and the factors
which have been utilized as key properties of accessibility by conventional accessibility measures. And this study will further discuss the importance of incorporating both the space-time dimension of constraints and opportunities into the measure and the characteristics of individuals and travel behaviors.
5.1 Introduction

The main purpose of this chapter is to further explore important elements which make a key difference in accessibility by gender. More specifically, a major focus in this chapter will be gender differences in influential determinants and contexts (in terms of location and travel/activity) which affect accessibility of people.

In the previous chapter, the existence of gender differences in individual accessibility was identified: the gender inequality in the levels of accessibility, and the spatial and temporal differences in variations of level of accessibility by gender. Women tend to have lower levels of access to urban opportunities regardless of their employment status. Despite the increasing belief about the more egalitarian status of current society, the result showed a persistent gender gap in everyday accessibility experiences in the urban environment. It was also interesting to note that individual accessibility levels
varied spatially, and the spatial pattern of women’s accessibility levels were not similar to that of men’s. Moreover, women, compared to men, showed the temporarily more restricted ability in access to urban opportunities. The occurrences of space-time autonomy for women were concentrated only at a particular time of day (in the early evening 5~7pm), even for part-time workers who are usually expected to be rather time-flexible throughout a day. In this research, individual accessibility based on the time geographic framework means “space-time autonomy” or “space-time feasibility.” The space-time autonomy could be evaluated not only in terms of the total amount of space-time autonomy during a day, but also in terms of its temporal distribution over time. In this regard, women’s strong temporal entrapment of the space-time feasibility in access to urban opportunities shed light on another dimension of women’s unequal accessibility experiences in their everyday lives.

Even though the dispersion of accessibility in time as well as in space matters, previous accessibility studies have overly focused on the level of accessibility between women and men. By doing so, those measures ignore the impact of the spatial and temporal distributions of space-time prisms or potential path areas on individual’s accessibility experiences. Even when two people have the same level of daily accessibility, if person A’s accessibility experiences are spatially and temporally more limited than person B’, person A’s space-time autonomy can be seen to be less than that of person B.

In this regard, beyond the detection of the existence of a gender gap in the level and the spatial-temporal distribution of individual accessibility, this chapter aims to
further explore the gendered aspects of individual accessibility, through attention to the factors and contexts determining the level of accessibility. More specifically, this chapter will focus on why and how women and men have different accessibility experiences, following the questions of whether, when, and where asked in the previous chapter. In other words, the gender differences in key determinants of individual accessibility, and the gendered situations in which people are likely to have space-time feasibility to access urban opportunities will be examined.

So, in the first phase of the analysis in this chapter, with respect to gender differences in major determinants, the critical examination on key factors, which have been recognized as important accessibility determinants by traditional measures, will be undertaken. Conventional measures include spatial measures (e.g. gravity-type measures, or cumulative opportunities measures), the length of work trip measures (especially in research focusing on job access), and temporal measures (time-budget measures). Each measure has emphasized a particular aspect of accessibility and thus utilized a particular factor exclusively in their formulation: (1) for spatial measures, the spatial centrality of people’s residential location within a city, and/or the spatial proximity to urban opportunities which were usually represented as the distance(s) to urban center(s) (i.e. the distance to the CBD in the city with the monocentric urban form, and the distances to multiple regional centers in the city with the polycentric urban form); (2) for commuting length measures, the travel distance or travel time between home to a workplace of an individual; and, (3) for temporal measures, the amount of work hours.
By looking at the relationships between results of the space-time accessibility measure and such factors, this study will examine whether and to what extent these factors explain individual accessibility and how influential determinants of individual accessibility are different between women and men. It is anticipated that the result would give some insights into complex relationships between factors and individual accessibility. This study not only attempts to uncover the gender bias of conventional measures in their concept and most likely in their outcomes as well, but also attempts to emphasize the importance of household responsibility constraints for women, as one of the key factors ignored in most past accessibility studies. Based on such analysis, this study will discuss that gender differences would come from more household work, which is likely to be imposed disproportionately on women, and, therefore, individual accessibility measure with no consideration of such gender-role constraints would be problematic in understanding and assessing gendered accessibility experiences in everyday lives.

The second phase of analysis in this chapter will be devoted to illuminate the gender distinct contexts of experiencing accessibility or space-time autonomy – that is, situations with respect to travel types (either linked or unlinked) and locations from/to which travels are made. More specifically, an effort to address which travel situations and at which locations people are likely to become capable to participate in discretionary activities, and how often and how much, will be made in order to unravel additional dimensions of gender differences of accessibility. Many studies have argued that conventional measures
are difficult to use as individual accessibility measures, due to their unrealistic
travel/activity behavioral understandings. However, little has been empirically examined
regarding how the reflection of complex, diverse, and gender-distinct characteristics of
travel/activity behaviors into the measure is critical to evaluate individual accessibility, or
how women and men differ in terms of the situations and locations in which particular
urban opportunities become accessible and meaningful to them. Such attempts to identify
further detailed pictures of gendered accessibility experiences, beyond the women’s
lower level of accessibility, would provide richer and more comprehensive insights on
the multiple ways in which women are less accessible to urban opportunities.

Since little has been examined regarding a range of gendered dimensions of
accessibility, this chapter attempts to unveil various aspects of gender differences in the
individual accessibility experience. In the following section (5.2), gender difference in
critical determinants of individual accessibility will be analyzed. Then, Section 5.3 will
examine gender differences in travel/location contexts of individual accessibility
occurrences. Many studies have stressed the importance of multi-stop and multi-purpose
trips in everyday life experiences (Arentze et al., 1994; Hanson, 1980a, 1980b, Hanson,
1982), and, therefore, pointed out one of the critical weak points of previous accessibility
measures, since those measures cannot capture such behavioral characteristics in their
formulation. However, no study has empirically examined and stressed the importance of
the incorporation of such complex travel possibilities into the accessibility measure, and
further possible gender differences in travel/location situations in which the levels of
accessibility are primarily determined. This chapter will try to answer a number of
questions: in which travel contexts, and around which locations, are urban opportunities accessible; and, whether there are gender differences in situational and locational characteristics in terms of composition, frequency and average size of space-time prism made.

5.2 Significant Determinants of Accessibility by Gender

One of the crucial problems of conventional spatial measures is that they expect individuals within the same household to have the same level of accessibility, regardless of gender, employment status, or car availability. This is because of their exclusive emphasis of spatial factors and single origin assumption: they assume that the relative position of home within the city solely determines the level of accessibility. Therefore, the results from such conventional measures, governed by the spatial proximity between home and potential urban opportunities, fail to expose interpersonal differences in accessibility. In this regard, particularly, those measures have been criticized for their gender-blindness, since there is no room in their framework to account for women’s quite different life situations and how they shape accessibility experience. Although the measure itself does not provide any information of gender differences in accessibility, the gender differential sensitivity of individual accessibility to each factor might still be interesting to examine. Accessibility of certain groups of people would be more sensitive to spatial proximity than others, for example. In addition, each factor would not be equally influential in determining accessibility of individuals belonging to a particular
population group. Indeed, major determinants of accessibility would vary depending on the particular everyday life experiences of individuals in diverse situations.

In this light, stepwise regression analysis is utilized in an attempt to identify the most meaningful factors by gender. With a dependent variable, the level of individual accessibility (\textit{WareaDur}), six independent variables were used for the analysis: the distance to the CBD (\textit{CBD\_DMILE}), the distance to the nearest urban center (\textit{NEARCENT}), the weighted areas of opportunities within the 10-minute distance from home (\textit{WAREA10T}), the commuting distance (\textit{MILES}), the weekly work hours (\textit{WORKHRSW}), and the household work hours during a day (\textit{HHDHRS}). In addition to factors commonly used from previous conventional measures, the variable of household work hours (\textit{HHDHRS}) is especially added in the analysis to examine gender differential determinants most important in determining accessibility levels, since a significant amount of studies on gender have suggested that gender difference in accessibility would mainly result from the disproportionate division of domestic work. Past studies pointed out that household-related work hours would be another important source of temporal constraints (and also spatial, as people need to be at home or at certain places for a task) limiting space-time feasibility to access urban opportunities, and would be a critical determinant rendering gender inequality in access to urban opportunities, since household responsibilities are often considered as gender-role constraints. A lot of evidence has shown that household responsibilities have a tendency to be more heavily allocated to women than their spouses even with the same employment status, which, in turn, gives
women a time-poor situation and time budget problem in gaining access to urban opportunities.

The regression result in Table 5.1 shows the best fitting model for each population group (total, men, and women). It shows clearly the gender differences in influential variables selected through the stepwise selection criteria. For women, three variables are selected as the most influential factors explaining individual accessibility: the urban opportunity density (WAREA10T), household work hours (HHDHRS), and paid-work hours (WORKHRSW) – listed in an order of importance as indicated by the values of beta, yet almost equally important. The same variables with the same order of significance were extracted for the total population. By contrast, for men, only the employment status variable (WORKHRSW) was selected.

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficients</th>
<th>t</th>
<th>R²</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Beta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>(Constant)</td>
<td>2763453.12</td>
<td>4.29**</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>WAREA10T</td>
<td>235.88</td>
<td>0.18</td>
<td>2.66**</td>
</tr>
<tr>
<td></td>
<td>HHDHOUR</td>
<td>-3907.49</td>
<td>-0.17</td>
<td>-2.60**</td>
</tr>
<tr>
<td></td>
<td>WORKHRSW</td>
<td>-33037.21</td>
<td>-0.17</td>
<td>-2.48**</td>
</tr>
<tr>
<td>MEN</td>
<td>(Constant)</td>
<td>4044049.93</td>
<td>3.67**</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>WORKHRSW</td>
<td>-52378.16</td>
<td>-0.20</td>
<td>-2.13*</td>
</tr>
<tr>
<td>WOMEN</td>
<td>(Constant)</td>
<td>2400818.39</td>
<td>3.53**</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>WAREA10T</td>
<td>339.96</td>
<td>0.29</td>
<td>3.31**</td>
</tr>
<tr>
<td></td>
<td>HHDHOUR</td>
<td>-4811.25</td>
<td>-0.27</td>
<td>-3.01**</td>
</tr>
<tr>
<td></td>
<td>WORKHRSW</td>
<td>-33050.78</td>
<td>-0.19</td>
<td>-2.17*</td>
</tr>
</tbody>
</table>

(Note: ** indicates the variable is significant at the 0.01 level (2-tailed).
* indicates the variable is significant at the 0.05 level (2-tailed).
The variable, HHDHOUR, indicates the amount of household-associated work hours during a day.

Table 5.1: Gendered determinants significant to individual accessibility
What is surprising is that unlike the past studies’ emphasis on the importance of distance affecting accessibility, all the distance measures to urban opportunities (distance to major urban opportunity centers or distance to workplace) do not appear on the outcomes regardless of gender. That is, neither the distance to major urban centers -- either CBD or any center nearest to home— or the distance to workplace was not found to be critical in shaping individual accessibility. The position of home within the city or spatial proximity to urban opportunities are not seen to be as influential as the local urban opportunity density within reach \((WAREA10T)\) and temporal constraints \((WORKHRSW\) or \(HHDHRS)\).

The first notable gender difference in influential determinants on accessibility is the difference in the number of factors selected. This would imply that, for men, access to urban opportunities are determined exclusively by the time constraint governed by their employment status \((WORKHRSW)\), while, for women, it is determined by the interplay of several space-time constraints. Unlike men, not only temporal, but also spatial constraints \((WAREA10T)\), are influential to women’s access to urban opportunities. In addition, temporal constraints affecting accessibility originate from two different sources: one from employment status, and the other mainly from marital status and socially required gender role \((HHDHOUR)\). Women’s access to urban opportunities is determined more sensitively by the availability of urban opportunities near home and the amount of household work, as well as the amount of work hours, when compared to men’s.
Second, the relative importance of those constraints on accessibility for men and women is also worthy of attention. For men, work hours could be the direct indicator of their level of access to urban opportunities. Meanwhile, for women, work hours seem to be the least influential determinant compared to the influence of local opportunity density and household responsibilities. Additionally, it would not be correct to use one of three determinants solely as a direct indicator for women, because of the interplay among three factors, which are almost equally as important. The two additional factors critical in explaining women’s accessibility – the level of nearby urban opportunity density and the amount of household work hours -- would imply women are more home-oriented or spatially entrapped around home and would consider the continuing gender inequality in allocation of household work.

5. 3 Travel/Location Contexts of Accessibility

Despite the significant amount of findings on increasing and widespread multi-stop-multi-purpose linked travel patterns, the majority of individual accessibility research still tends to be strongly based on single-reference and home-based accessibility measures. Although, to overcome this problem, space-time measures have been recently suggested, no studies have yet tried an analysis with concrete and empirical evidence in an attempt to explicitly unveil the problem of conventional behavioral assumptions. Therefore, the relationship between travel patterns/locations and individual accessibility will be examined in this section, and its gender differences will be further analyzed.
5.3.1 The significance of linked trips and “other” locations

Table 5.2 shows the composition of individual accessibility values by type of travel and locations where space-time prisms are made. It clearly shows that conventional accessibility measures, based on a single reference location and unlinked trip assumptions, are problematic to evaluate individual accessibility. Regardless of gender and employment status, multi-reference location-based accessibility values predominantly contribute to the overall accessibility level of people (81.7% on average). Accessibility values based on a single-reference location only count 18% for the total population, and 24.6 % for part-time employed men at most.

Home has been considered as a reference point for conventional measures. In this light, when the importance of home is examined, the results suggest that such an assumption would render accessibility values measured by previous methods seriously unreliable. Strikingly, home is the least influential location of origin in shaping the level of individual accessibility (14.8%). Indeed, the most influential origin for accessibility is found to be the workplace (69.1%), followed by other locations (16.1%). On the other hand, when people return home, their substantial space-time autonomy leads home to be the important destination with which accessibility values are made (75.6%). However, this case includes both single-reference and multi-reference location-based accessibility values – that is, a home-based destination consists of ‘home to home’, ‘workplace to home’, and ‘other place to home.’
### Table 5.2: Composition of accessibility values by each type of travel/location

<table>
<thead>
<tr>
<th>Percentage of accessibility values</th>
<th>Gender</th>
<th>Employment Status</th>
<th>Men</th>
<th>Women</th>
<th>Full-time</th>
<th>Part-time</th>
<th>Men</th>
<th>Women</th>
<th>Full-time</th>
<th>Part-time</th>
<th>Men</th>
<th>Women</th>
<th>Full-time</th>
<th>Part-time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Number of reference points</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>18.3</td>
<td>16.9</td>
<td>20.3</td>
<td>17.5</td>
<td>23.4</td>
<td>16.0</td>
<td>24.6</td>
<td>19.8</td>
<td>22.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two</td>
<td>81.7</td>
<td>83.1</td>
<td>79.7</td>
<td>82.5</td>
<td>76.6</td>
<td>84.0</td>
<td>75.4</td>
<td>80.2</td>
<td>77.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Origin location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>14.8</td>
<td>15.2</td>
<td>14.3</td>
<td>12.3</td>
<td>29.8</td>
<td>13.6</td>
<td>29.1</td>
<td>10.3</td>
<td>30.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>69.1</td>
<td>69.4</td>
<td>68.7</td>
<td>73.6</td>
<td>41.9</td>
<td>72.1</td>
<td>45.8</td>
<td>75.9</td>
<td>39.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>16.1</td>
<td>15.4</td>
<td>17.1</td>
<td>14.1</td>
<td>28.3</td>
<td>14.3</td>
<td>25.2</td>
<td>13.8</td>
<td>30.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Destination Location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>75.6</td>
<td>75.2</td>
<td>76.0</td>
<td>76.9</td>
<td>67.4</td>
<td>77.1</td>
<td>58.6</td>
<td>76.5</td>
<td>73.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>17.7</td>
<td>19.3</td>
<td>15.4</td>
<td>16.5</td>
<td>24.9</td>
<td>17.3</td>
<td>36.4</td>
<td>15.2</td>
<td>16.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>6.8</td>
<td>5.5</td>
<td>8.5</td>
<td>6.6</td>
<td>7.7</td>
<td>5.6</td>
<td>5.0</td>
<td>8.2</td>
<td>9.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Origin-Destination Location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Home</td>
<td>9.1</td>
<td>8.2</td>
<td>10.4</td>
<td>7.7</td>
<td>17.5</td>
<td>7.4</td>
<td>15.1</td>
<td>8.2</td>
<td>19.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Work</td>
<td>4.8</td>
<td>6.4</td>
<td>2.4</td>
<td>4.0</td>
<td>9.1</td>
<td>5.6</td>
<td>13.8</td>
<td>1.6</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Other</td>
<td>0.9</td>
<td>0.5</td>
<td>1.5</td>
<td>0.6</td>
<td>3.1</td>
<td>0.6</td>
<td>0.2</td>
<td>0.5</td>
<td>5.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work - Home</td>
<td>56.5</td>
<td>58.5</td>
<td>53.7</td>
<td>60.1</td>
<td>34.7</td>
<td>61.0</td>
<td>36.4</td>
<td>58.7</td>
<td>33.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work - Work</td>
<td>8.9</td>
<td>8.4</td>
<td>9.7</td>
<td>9.6</td>
<td>5.2</td>
<td>8.5</td>
<td>8.1</td>
<td>11.3</td>
<td>3.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work - Other</td>
<td>3.7</td>
<td>2.5</td>
<td>5.3</td>
<td>3.9</td>
<td>2.1</td>
<td>2.7</td>
<td>1.3</td>
<td>5.9</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other - Home</td>
<td>10.0</td>
<td>8.6</td>
<td>11.9</td>
<td>9.1</td>
<td>15.2</td>
<td>8.8</td>
<td>7.0</td>
<td>9.7</td>
<td>21.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other - Work</td>
<td>4.0</td>
<td>4.4</td>
<td>3.3</td>
<td>2.9</td>
<td>10.6</td>
<td>3.3</td>
<td>14.6</td>
<td>2.3</td>
<td>7.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other - Other</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.7</td>
<td>0.1</td>
<td>1.4</td>
<td>0.3</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other A - Other B</td>
<td>1.9</td>
<td>2.2</td>
<td>1.5</td>
<td>1.9</td>
<td>1.8</td>
<td>2.2</td>
<td>2.2</td>
<td>1.5</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As multi-reference location-based accessibility values largely explain the total accessibility levels of individuals, this study examines in detail how much each type of travel/location context contributes in shaping the accessibility level. Accessibility values contributed by *home-to-home* trips, which conventional measures usually assume to be a typical trip pattern with a typical reference location, are just 9.1% of the total. The second
most widely used location by conventional measures would be the workplace. It also counts merely 8.9%. Another type of single-referenced accessibility value could be possible from the trip with other place as both origin and destination, but again its contribution to total accessibility level is also negligible -- only 0.3%. The results clearly show that, in fact, people have the largest space-time flexibility on the journey to home from work. Workplace-home trip based accessibility values count as 56.5% of individual accessibility values of the total.

Such findings suggest that urban opportunities feasible to an individual are not confined just to those near home. The results as indicated by Table 5.2 clearly show the home-to-home accessibility values are very small -- only 9.1%, whereas other travel and locational situations count more than 90%. Yet, urban opportunities considerably far away from home could contribute more to the accessibility level than those close to home, since people’s accessibilities are mostly affected by various meaningful nodes other than home, and is based on the strong tendency of linked-trips where the origin and destination are not the same. Particularly, the overwhelming significance of the workplace-to-home journey based accessibility implies that urban opportunities even distant from home but close to either the location of workplace or the routes on the way home are accessible and important to individuals, as well as those close to home.

This finding, however, does not mean the workplace is a better place as a reference point to evaluate individual accessibility, nor does not suggest that the
workplace and home should be considered as two reference points in determining individual accessibility. Rather, the suggestion is that accessibility research should explicitly recognize the importance of various locations and situations on individual accessibility, and, even further, the different significance of each type of location and travel among subpopulation groups. For example, part-time workers have a relatively lower significance of workplace (41.9% vs. 73.6% for full-time workers and 69.1% for the total population) and a relatively increased significance of home and other places (29.8% compared to full-time workers’ 12.3% and the total population’s 14.8%; 28.3% vs. 14.1% and 16.1%, respectively). Especially, for women who are employed part-time, each location is almost equally important in forming their accessibility: 39.1% from work, 20% from other places (by type of origins in Table 5.2). By contrast, full-time employed women show stronger dependency on workplace-based accessibility than any other group, which might be because they do not have time other than the lunch break and right after work due to the additional source of obligatory activities in the evening (i.e. picking up children or carrying out household responsibilities). Such gender differences will be further detailed in the later part of this section.

In general, however, the overall pattern of the limited contribution of single-referenced and home-based situations into the overall accessibility level does not change much along with gender and employment status. In any subpopulation group, the single-referenced type explains no more than 25% of total accessibility values; and, either the
home to any locations or the home-to-home cases contribute to a trivial extent -- no more than 30.3% and 19.3%, respectively, as indicated in Table 5.2.

Those findings are confirmed with the further analyses of accessibility composition by type of travel and location generating space-time prisms. The relative contribution of each situation with respect to the travel type and location as origin and destination reflects two dimensions: the frequency each situation occurs and the average level of accessibility each situation establishes, as shown in Table 5.3 and 5.4 respectively. A great contribution of a certain type of situation to the total individual accessibility might be achieved with its occurrence many times a day though average size of accessibility itself is small. It might also be possible with a huge amount of space-time autonomy, even if the situation occurs just once a day.

In this light, the effort to examine how often and how large each situation contributes to total accessibility and whether findings from those are different from that of the composition of accessibility values was made. Particularly, one question, which is in what situation people are most likely to have space-time autonomy, is answered by examining the percentage of numbers of space-time prisms made by each type of travel/location, as shown in Table 5.3. Another question, which is in what situation individual accessibility is large or small on average, is also explored by examining average accessibility values by each travel/location context, standardized by total average and subgroup average. Standardized average accessibility by the total allows comparison and contrast of values across population groups. So, which subgroup of the population, or
<table>
<thead>
<tr>
<th>Percentage of accessibility values</th>
<th>Gender</th>
<th>Employment Status</th>
<th>Men</th>
<th>Women</th>
<th>Full-time</th>
<th>Part-time</th>
<th>Men</th>
<th>Women</th>
<th>Full-time</th>
<th>Part-time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Number of reference points</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>18.3</td>
<td>16.9</td>
<td>20.3</td>
<td>17.5</td>
<td>23.4</td>
<td>16.0</td>
<td>24.6</td>
<td>19.8</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>Two</td>
<td>81.7</td>
<td>83.1</td>
<td>79.7</td>
<td>82.5</td>
<td>76.6</td>
<td>84.0</td>
<td>75.4</td>
<td>80.2</td>
<td>77.5</td>
<td></td>
</tr>
<tr>
<td>Origin location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>14.8</td>
<td>15.2</td>
<td>14.3</td>
<td>12.3</td>
<td>29.8</td>
<td>13.6</td>
<td>29.1</td>
<td>10.3</td>
<td>30.3</td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>69.1</td>
<td>69.4</td>
<td>68.7</td>
<td>73.6</td>
<td>41.9</td>
<td>72.1</td>
<td>45.8</td>
<td>75.9</td>
<td>39.1</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>16.1</td>
<td>15.4</td>
<td>17.1</td>
<td>14.1</td>
<td>28.3</td>
<td>14.3</td>
<td>25.2</td>
<td>13.8</td>
<td>30.5</td>
<td></td>
</tr>
<tr>
<td>Destination Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>75.6</td>
<td>75.2</td>
<td>76.0</td>
<td>76.9</td>
<td>67.4</td>
<td>77.1</td>
<td>58.6</td>
<td>76.5</td>
<td>73.9</td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>17.7</td>
<td>19.3</td>
<td>15.4</td>
<td>16.5</td>
<td>24.9</td>
<td>17.3</td>
<td>36.4</td>
<td>15.2</td>
<td>16.4</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>6.8</td>
<td>5.5</td>
<td>8.5</td>
<td>6.6</td>
<td>7.7</td>
<td>5.6</td>
<td>5.0</td>
<td>8.2</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Origin-Destination Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Home</td>
<td>9.1</td>
<td>8.2</td>
<td>10.4</td>
<td>7.7</td>
<td>17.5</td>
<td>7.4</td>
<td>15.1</td>
<td>8.2</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>Home - Work</td>
<td>4.8</td>
<td>6.4</td>
<td>2.4</td>
<td>4.0</td>
<td>9.1</td>
<td>5.6</td>
<td>13.8</td>
<td>1.6</td>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>Home - Other</td>
<td>0.9</td>
<td>0.5</td>
<td>1.5</td>
<td>0.6</td>
<td>3.1</td>
<td>0.6</td>
<td>0.2</td>
<td>0.5</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Work - Home</td>
<td>56.5</td>
<td>58.5</td>
<td>53.7</td>
<td>60.1</td>
<td>34.7</td>
<td>61.0</td>
<td>36.4</td>
<td>58.7</td>
<td>33.4</td>
<td></td>
</tr>
<tr>
<td>Work - Work</td>
<td>8.9</td>
<td>8.4</td>
<td>9.7</td>
<td>9.6</td>
<td>5.2</td>
<td>8.5</td>
<td>8.1</td>
<td>11.3</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Work - Other</td>
<td>3.7</td>
<td>2.5</td>
<td>5.3</td>
<td>3.9</td>
<td>2.1</td>
<td>2.7</td>
<td>1.3</td>
<td>5.9</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Other - Home</td>
<td>10.0</td>
<td>8.6</td>
<td>11.9</td>
<td>9.1</td>
<td>15.2</td>
<td>8.8</td>
<td>7.0</td>
<td>9.7</td>
<td>21.2</td>
<td></td>
</tr>
<tr>
<td>Other - Work</td>
<td>4.0</td>
<td>4.4</td>
<td>3.3</td>
<td>2.9</td>
<td>10.6</td>
<td>3.3</td>
<td>14.6</td>
<td>2.3</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>Other - Other</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.7</td>
<td>0.1</td>
<td>1.4</td>
<td>0.3</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Other A - Other B</td>
<td>1.9</td>
<td>2.2</td>
<td>1.5</td>
<td>1.9</td>
<td>1.8</td>
<td>2.2</td>
<td>2.2</td>
<td>1.5</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2: Composition of accessibility values by each type of travel/location

As multi-reference location-based accessibility values largely explain the total accessibility levels of individuals, this study examines in detail how much each type of travel/location context contributes in shaping the accessibility level. Accessibility values contributed by *home-to-home* trips, which conventional measures usually assume to be a typical trip pattern with a typical reference location, are just 9.1% of the total. The second
<table>
<thead>
<tr>
<th></th>
<th>Mean accessibility values standardized by total population</th>
<th>Mean accessibility values standardized by subpopulation group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>108.8</td>
</tr>
<tr>
<td>Number of reference points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two</td>
<td>123.8</td>
<td>135.1</td>
</tr>
<tr>
<td>Origin location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>110.6</td>
<td>123.8</td>
</tr>
<tr>
<td>Destination Location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>78.1</td>
<td>82.2</td>
</tr>
<tr>
<td>Origin-Destination Location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Home</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home - Other</td>
<td>44.5</td>
<td>39.3</td>
</tr>
<tr>
<td>Work - Home</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work - Work</td>
<td>44.8</td>
<td>44.6</td>
</tr>
<tr>
<td>Work - Other</td>
<td>86.1</td>
<td>72.1</td>
</tr>
<tr>
<td>Other - Home</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other - Work</td>
<td>114.1</td>
<td>113.8</td>
</tr>
<tr>
<td>Other - Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other A - Other B</td>
<td>100.5</td>
<td>140.6</td>
</tr>
</tbody>
</table>

Table 5.4: Average level of space-time accessibility by each travel/location type.
With both frequencies and average sizes of accessibility values (in Table 5.3 and 5.4), the findings from the percentage of accessibility values (as shown in Table 5.2) are consistent. With one location focus, space-time prisms are less likely to be made (no more than 35.2%) and tend to be much below average (almost half of the total average). The similar pattern is found for the home origin situation in general and the home-to-home situation in particular. Overall, home-based space-prisms were not made as often as workplace-based ones and their average size is a lot smaller than that from workplace or other places, as well. Especially, home as both origin and destination does not play a major role in forming accessibility of individuals as it counts only 13.7% and as its size is significantly low compared to both total and subpopulation average regardless of gender and employment status.

This implies that individual accessibility measures based on the framework of the single-reference with home as origin tend to highly overvalue urban opportunities nearby, and seriously undervalue those far away but still accessible due to the interconnectedness and interdependence of travels/activities people carry out given their activity schedules and space-time constraints. Therefore, conventional measures are problematic in examining individual accessibilities, since these measures have used home, which all potential trips must start from and/or return to. By doing so, conventional measures would be likely to result in a strongly biased, and thus unreliable, outcome by paying exclusive attention to urban opportunities close to the home only. Therefore, these measures become doubtful in their ability to capture the real picture of individual accessibility and its interpersonal differences by leaving a greater, and important, portion
of actual individual accessibility -- that is, the greater possibility of space-time autonomy or feasibility from various locations other than home and on the way from/to another location – unexplained.

5.3.2. Gendered travel/location contexts of accessibility

Now, the center of attention moves more toward gender differences in contexts where space-time feasibility most often occurs. The relative importance of each travel situation and each location in contributing to individual accessibility is visually represented in Figure 5.1. The circle represents three types of locations: home, workplace, and other (which are further separated to distinguish the linked trip situation from the unlinked one). The arrow represents the travel situation at each location, which allows us to differentiate its contribution to accessibility by types (linked or unlinked) and directions of trips (i.e. journey from home to workplace vs. that from workplace to home), without difficulty. The width of each arrow represents the percentage of accessibility values possible at each situation – the thicker the arrow, the larger portion of total accessibility of a particular population group a particular situation holds, and vice versa (the values are drawn from the results in Table 5.2). The color of the arrows reflects the average accessibility level people have in each situation. Such values were standardized by an average accessibility value of each subpopulation group (as shown in the right-hand section of Table 5.4): the value above 100 means a larger accessibility level in a particular travel and locational situation than the level people would get on
average, and vice versa. For higher than average, dark red is assigned, and for lower than average, dark blue is assigned. That is, red for the highest accessibility level and pink for the medium-high compared to average, whereas blue for the lowest and purple for medium-low, comparing to the mean accessibility value of a particular population group. This way of visualization helps to easily identify and compare significant axes of locations and travel situations among subpopulation groups. In addition, the numbers on the arrow represent correspondingly the percentage of accessibility values, frequencies, and average sizes: the percentage of accessibility values are derived from Table 5.2; the frequencies are from Table 5.3; and, the averages sizes of accessibility are from Table 5.4 (particularly, the right-hand section).

From Figure 5.1, several different patterns can be identified between men and women in showing the relative importance of particular travel/location situations, in terms of the share, frequency, and average size of accessibility.

For full-time workers, there seems to be fewer significant gender differences in the relative importance of certain types of locations and trip patterns on individual accessibility than in the case of part-time workers. Women and men, employed full-time, show a very similar pattern with respect to the composition and frequency of accessibility levels by each situation. One of the obvious similarities for them would be the primary role the journey home after work plays in determining accessibility levels. Women employed full-time have similar patterns with their male counterparts, in large part due to the huge amount of space-time fixities from their employment status.
Figure 5.1: Significance of each type of travels and locations on individual accessibility by gender and by employment status

(1) The thickness of arrow represents the percentage of each type-based accessibilities; (2) the color of arrow represents the average of accessibility values standardized by each subgroup’s average (red for the highest, pink for the medium-high, blue for the lowest, and purple for medium-low, compared to average); and, (3) the numbers on the arrow represent the percentage of accessibility values, frequencies, and average sizes, respectively.
Their space-time autonomy and feasible opportunities are, to the largest extent, obtainable in between a workplace and a home, especially in the situation of the journey to home after work. This situation is seen to be the most significant in shaping the level of accessibility of full-time workers regardless of gender: it explains 61.0% for men and 58.7% for women. The importance of the journey from work to home for full-time workers is also observed in terms of numbers of space-time prisms made (see Table 5.3, and also the first numerical value in each parenthesis in Figure 5.1). Most people are the most likely to have the space-time feasibility to urban opportunities in this situation (43.4% for men and 40.9% for women). Moreover, the average size of accessibility feasible from this situation is much higher than average to both men and women who work full-time (139 for men and 143.4 for women). In combination with the contributions of home-based and workplace-based unlinked trips and that of home-to-work trips – 7.4%, 8.5%, and 5.6% for men, and 8.2%, 11.3%, and 1.6% for women-- the journey to home from work, the most significant trip situation for accessibility, makes urban opportunities near and in between the home and the workplace the most accessible than any others. In other words, urban opportunities with two locational axes, home and workplace, are, by and large, accessible and meaningful to full-time workers as the sum of accessibility values from these trips counts more than 70% of individual accessibility.

In spite of such a common characteristic with respect to trips and locations key to individual accessibility, several differences between full-time men and women are also noticeable. Full-time working women have a much smaller space-time feasibility in the home to work trip situation, when compared to their male counterparts, not only in terms
of accessibility values (5.6% for men vs. 1.6% for women), but also in terms of frequency (5.4% vs. 3.8%) and average level of accessibility at each occurrence (102.9% shown in red vs. 42.4% shown in blue). With the greater importance of the trip home right after work, women enjoy a larger amount of space-time feasibility compared to the group average of the work to other place and the other place to home travel situations -- although its share is low as the frequency is small -- whereas they do not with the other places or travel situations, as clearly shown by color of arrow in Figure 5.1. Unlike women, men have more diversified travel directional and locational significances, regarding each situation’s contribution to the individual accessibility level: instead of the workplace to other place trip, the opposite directional trip makes the large accessibility above average. It is noteworthy that unlike women, even the home to work trip situation and the linked trip among different places other than home and workplace lead to above average accessibility for men.

Those findings reveal that full-time working women’s accessibility is more tightly constrained by time and space, compared to men with the same employment status: space-time autonomy for discretionary activities are possible only after work, as implied by the share and average amount of accessibility in forms of the work to other place and the other place to home, as well as the work to home, situations. Especially, the relative freedom on the journey to work for men stands out against the very low space-time autonomy of women in the same situation which might imply the existence of other tasks to be carried out (e.g. drop-off children to daycare centers or schools).
Like full-time workers, the work to home trip situation takes the biggest share of individual accessibility for part-time workers in general, regardless of gender – 36.4% for men and 33.4% for women -- and also has considerable rank with respect to percentage of frequency and average level. However, the significance is not so dominant for part-time workers as for full-time workers. A more decentralized pattern can be identified from part-time workers. It may be mainly because their lighter space-time constraints for work (i.e. less work hours at the workplace and thus a lower level of locational fixity). Contrary to the exclusive importance of the workplace as a trip origin for full-time workers, and the total population in general, the workplace’s relative importance for part-time workers is reduced by approximately 30% and home and other place became very important both as origins and destinations. Such a pattern of decreasing importance of workplace and increasing importance of home and other place does not change with the percent of numbers of space-time prisms made. This implies that for part-time workers, urban opportunities close to places other than home (and/or workplace) are greatly meaningful and accessible, even if they are located far away from home and/or workplace. Therefore, without the appropriate consideration of this situation in the formulation, accessibility measures would likely underestimate the value of urban opportunities distant from major residential and employment centers in contributing to people’s accessibility.

In addition, part-time workers tend to have a comparatively higher portion of the single reference travel pattern, in which origin and destination locations are identical for two consecutive fixed activities. Those results are, in part, due to the rising importance of
the home-to-home journey for both men and women employed part-time. Its share rises up to 15.1% for men and 19.3% for women, and so do its frequencies -- up to 22.6% for men and 26.3% for women. It is clear that home-to-home trip-based accessibility is the most important for part-time working women.

Above all, the most significant gender difference among part-time workers could be found with regard to the location and orientation of travels; specifically, women’s more home-centered and home-oriented characteristics of accessibility.

The first observation from the results is that, for women, home is a more significant location in assessing peoples’ level of access to urban opportunities for women than for men. With three nodes -- home, workplace, and other places, men still give a much greater priority to workplace as a most influential origin than do women (29.1%: 45.8%: 25.3% vs. 30.3%: 39.1%: 30.5%, in an order of home, workplace, and other place). Men also have decreasing importance of home as destination, as in the cases of full-time and total population, and increasing importance of workplace. Contrary to the case of men, part-time women still present greater (73.9% vs. 58.6% for part-time men), and more slightly decreasing (-2% vs. -20% for part-time men compared to values of total and full-time), importance of home as destination, but smaller, and even decreasing, importance of workplace (vs. 16.4% with 2% decrease vs. 36.4% with 10% increase compared to total and full-time for men).

The second observation with regard to gender difference is associated with women’s more home-oriented travel situations which set up most space-time autonomy...
people would have during a day. With regard to the proportion of each situation of travel and location, the journeys of workplace-to-home (33.4%), other place-to-home (21.2%), and home-to-home (19.3%) are found to be the most significant for part-time women. In contrast to the case of part-time women, men show a general tendency toward dual destinations: workplace is an almost equally influential destination to home. In addition to the journeys home — that is, from the workplace (36.4%) and from home (15.1%) — journeys toward the workplace — that is, from home (13.8%) and from another place (14.6%) is apparent. Unlike women, the journey from another place to home is less significant for men compared to women. Although part-time workers would seemingly have more time and less spatial fixity because of less paid-work hours, women tend to have less diverged and dispersed travel and location patterns in shaping individual accessibility. The strong orientation toward, and greater importance of, home for women would suggest women’s accessibility would be more responsive to the availability of urban opportunities around home than for men employed part-time.

5.4 Conclusions

This chapter has examined the gender differences in determinants of accessibility along with a critical examination of conventional measures, and the gender differences in contexts where people are situated to be able to participate in discretionary activities. From the results, several valuable findings were made:

First, any single factor from conventional measures could not satisfactorily explain the totality of individual experiences in access to urban opportunities.
Individuals’ levels of accessibility may be shaped through rather complex processes where even multiple constraints themselves, either spatial or temporal, affect, and are affected by, each other.

Second, women’s lower levels of accessibility than men is regardless of employment status was largely due to additional constraints: household responsibilities. Compared to men, the level of availability of urban opportunities near home was found to be crucial in determining women’s accessibility levels.

Third, people tend to enjoy the space-time autonomy in the work-to-home travel situation, and, as a result, have the workplace and home as the most central locations of accessibility, as an origin and a destination, respectively. Such a dominance of linked trip-based accessibility experiences suggests that conventional measures with the single-reference and unlinked trip assumptions would be doubtful in properly assessing individual accessibility. Such measures tend to undervalue the importance of urban opportunities around locations other than home in shaping accessibility levels. Additionally, past studies stressed that women’s lower accessibility would be closely associated with women’s highly complex, multi-purpose travel behaviors with a slower transport mode than men who are likely to make single-purpose trips at higher cost and using superior modes of transport. However, even when transport mode is controlled in the analysis (only car drivers were analyzed in this study), gender differences are still found. Moreover, both men and women showed more multi-purpose trip-based accessibility patterns. This may imply that men’s higher accessibility does not necessarily stem from single purpose trip situations.
Fourth, most noteworthy is the fact that women tend to be more home-oriented in the travel context and home-centered in the location context, when compared to men. Also, the importance of other locations for women is higher than men. Such gender differences were more explicit between part-time workers with more non-work activities, while full-time workers did not show great differences since their everyday life is strongly governed by long work hours.

The home as a relatively more influential location for women gives a clue why local urban opportunities around home and household work hours (as well as work hours) appeared to be significant determinants of accessibility for women in the regression analysis, which was not the case for men. Women have more household-associated work than men, and, thus, are more often required to be at home. Therefore, women’s tendency to be attached to home renders their accessibility more sensitive to the availability of local urban opportunities around home.
CHAPTER 6

GENDER ROLES, ACCESSIBILITY, AND GENDERED SPATIALITY:
A COMPARISON OF MARRIED DUAL-EARNER COUPLES
BY PARENTAL STATUS

6.1 Introduction

As shown in Chapter 5, there are gender differences in terms of key determinants of accessibility, and in terms of the location/travel contexts where space-time autonomy for discretionary activities occurs. Whereas men’s accessibility experience is primarily governed by their employment status (i.e. work hours), it is not so for women. Unlike men, the level of women’s daily accessibility is determined largely by gender roles (i.e. household work hours) and the local context (i.e. the amount of urban opportunities within a limited distance from home), in addition to employment status. These findings would imply that women and men are differently situated in society. Socially constructed expectations on gender have real effects on how women and men live their lives in general, and experience accessibility in space and time, in particular. When location/travel contexts -- where space-time prisms (that is, accessibility) are made -- are examined, women’s accessibility experiences are found to be more home-oriented and more home-centered. Whereas for men, the workplace-to-home travel contexts and the
workplace-to-workplace travel contexts are predominant, for women, however, these contexts are less important than others. Rather, women’s space-time prisms mainly occur in the home-to-home and the other (that is, non-work out-of-home)-to-home travel contexts. While Chapter 5 examined such gender differences in accessibility experiences in travel/location contexts, among women and men with different employment status, this chapter will pay attention to the gender differences among husbands and wives in different parental status. Specifically, Chapter 6 will further explore whether and how so-called socially-constructed gender roles influence individuals’ accessibility experiences in their everyday lives, through the analysis of dual-earner couples. Such analysis will give us a more detailed picture which will help us to understand how gender roles shape everyday experiences of men and women differently, even though each member of a couple lives in the same household with the same socio-demographic situation.

Furthermore, this chapter attempts to investigate how individual accessibility experience takes a form of gendered spatiality. Gendered spatiality has been predominantly examined in terms of activity space (i.e. revealed travel distance from home to activities) (Dijst and Vidakovic, 2000). In this chapter, an alternative way of examining gendered spatiality will be suggested, with a critical examination of activity space. In other words, gendered spatiality will be examined in terms of accessibility space (possible activity space).

While conventional indicators explaining gendered spatiality have concentrated their interests on the actual spatial extent (spatial extent of activity space) of travels, the
analysis in this chapter will pay attention to the possible spatial extent of travels (spatial extent of accessibility space) as well. Conventionally, gendered spatiality has been identified through measuring travel distances from home to activity locations (discretionary activities or workplaces), travel distances between activities, and level of travels for, and participation in, non-work out-of-home activities. These widely used indicators are based on the assumption that women’s circumstances of spatial entrapment (or spatial containment) and being home-attached would be exposed in a form of shorter and closer-to-home travels and less out-of-home activity than men. The applicability and usefulness of these indicators to grasp gendered spatiality will be critically examined in this chapter. Besides these methods, this chapter will employ another way of detecting gendered spatiality. Some previous conventional studies have been overly concentrated on the spatial extent of actual activity space, which could be a product of either individuals’ choice or constraints. The spatial extent of possible accessibility space given space-time constraints, which women and men might face in a different way, can help to enhance our understanding of gendered spatiality.

In the examination of gendered spatiality, taking into consideration accessibility spaces can help to enhance not only our understanding of gendered spatiality, but also of activity space per se.

Therefore, the purpose of this chapter is to understand how gender roles, household responsibilities, and accessibility affect and are affected by one another through the analysis of husbands and wives within the same households; and whether and
how those factors result in gendered spatiality in terms of activity space and accessibility space. In Section 6.2, after looking at general characteristics of households of dual-earner couples selected in this chapter, the importance of gender roles in shaping household responsibilities and accessibility will be examined. Then, the remaining sections will focus on how such gender role constraints differentiate accessibility experiences, more specifically in terms of spatiality, between husbands and wives in different parental status. Section 6.3 will analyze gendered spatiality through the analysis of activity space to examine women’s home-attached and spatially entrapped characteristics (through the measure of travel distances from home and the amount of in-home and out-of-home activities). In Section 6.4, then, gendered spatiality by accessibility space will also be taken into account. Conclusions and discussion will follow after the relationship between the spatial dimension of accessibility experiences and revealed activity/travel behaviors is examined in Section 6.5,

### 6.2 Household responsibilities as Gender-role Constraints

Unlike the previous chapters, a total number of 271 dual-earner married couples in Portland – therefore, 542 individuals within the 271 households where both husbands and wives are present in the data set – are further selected from the data set used in Chapter 4 and 5. Such a sample selection for the analysis in Chapter 6 was needed in order to examine how gender roles render accessibility experiences in everyday lives that are different between husbands and wives even within the same households. Therefore,
gender differences in accessibility and household responsibilities (domestic work and childcare) will be examined using the data set of the 542 individuals (271 dual-earner couples’ households) who reported having cars available for trips throughout a day. In addition, to examine the effect of childcare-associated gender roles, couples with children under 18 years old are classified as mothers and fathers in this study. The sample data set is composed of 124 households with a dual-earner couple with children and 147 households without children. Besides, this sample data includes only Whites in order to control the effect of race. The residential location of these households is shown in Figure 6.1.

Figure 6.1: Residential location of households with dual-earner couples in sample.
Household characteristics of dual-earner couples in Portland in the subsample are shown in Table 6.1. In the subsample, the number of households with children is slightly less than that those without children. Most couples in parenthood tend to have one or two children. The predominant type of employment status is full-time, for both husbands and wives. Specifically, households where couples are both employed full-time are the largest group in the sample data (FF: 74.2%), followed by those with full-time employed husbands and part-time employed wives (FP: 19.6%). However, gender difference is found in terms of the proportion of part-time employment, which is found to be much higher for wives (21%), compared to husbands (6.3%). Moreover, in the case of couples with children, the percent of part-time employed wives is much larger than that of wives with no children (26.6 % vs. 16.3%), while it is not the case for husbands (5.6% vs. 6.8%). So, the presence of children significantly affects wives’ employment status but not husbands’. It can be also seen from the fact that the percentage of couples with full-time working husbands and part-time working wives with children increases, compared to couples without children, while that for the couples with both employed full-time (FF) decreases. Thus, it can be said that the impact of parental status on employment status would be gender-dependent. It would imply that what leads women to be part-time workers may not be roles defined by the change of life stage (i.e. marriage, children), but rather gender roles socially defined for them as married women (wives and mothers), as indicated by the difference in changes in the percent of part-time employment by gender and parental status.
### Household characteristics with dual-earner couples

<table>
<thead>
<tr>
<th></th>
<th># of households</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL</strong></td>
<td>271</td>
<td>(100.0)</td>
</tr>
<tr>
<td><strong>Parental status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No children</td>
<td>147</td>
<td>(54.2)</td>
</tr>
<tr>
<td>Children under 18</td>
<td>124</td>
<td>(45.8)</td>
</tr>
<tr>
<td>children under 12</td>
<td>64</td>
<td>(23.6)</td>
</tr>
<tr>
<td>children under 6</td>
<td>30</td>
<td>(11.1)</td>
</tr>
<tr>
<td><strong>Number of children</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>49</td>
<td>(18.1)</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>(18.8)</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>(6.3)</td>
</tr>
<tr>
<td>4+</td>
<td>7</td>
<td>(2.6)</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Husband, Full-time</td>
<td>254</td>
<td>(93.7)</td>
</tr>
<tr>
<td>Husband, Part-time</td>
<td>17</td>
<td>(6.3)</td>
</tr>
<tr>
<td>Wife, Full-time</td>
<td>214</td>
<td>(79.0)</td>
</tr>
<tr>
<td>Wife, Part-time</td>
<td>57</td>
<td>(21.0)</td>
</tr>
</tbody>
</table>

#### Households with No Children

147 (100.0)

| Employment status of husbands and wives * | FF | (74.2) |
| FF                                      | 201|       |
| FP                                      | 53 | (19.6) |
| PF                                      | 13 | (4.8)  |
| PP                                      | 4  | (1.5)  |

#### Households with Children

124 (100.0)

| Employment status of husbands and wives * | FF | (68.5) |
| FF                                      | 85 |       |
| FP                                      | 32 | (25.8) |
| PF                                      | 6 | (4.8)  |
| PP                                      | 1 | (0.8)  |

* Employment status of each household is indicated in an order of husband and wife. F and P represent full-time workers and part-time workers, respectively.

Table 6.1: Household characteristics of dual-earner couples in sample.
It is generally believed that marriage and parenthood increase one’s physical and psychological burdens in terms of household responsibilities (such as household maintenance and childcare). Along with paid-work hours at workplaces, the additional obligatory work hours for the home restrict individuals’ discretionary time, and, in turn, their accessibility to urban opportunities. Traditional gender role expectations are changing slightly, but still continuing in society. Obligatory activities associated with household-associated work are likely to be undertaken by wives more disproportionately than their husbands, regardless of women’s employment status. In this regard, gender role constraints (household work hours) play a significant role in producing a gender gap in terms of the quality of life in general, and in terms of accessibility to urban opportunities specifically. Therefore, the level of accessibility is likely to be gender-dependent, as women are disproportionately heavily-laden with household responsibilities.

If accessibility is not significantly determined by gender roles, a husband and a wife in the very same conditions (the location of home within the urban environment and the presence of children) would be expected to have the same level of access to urban opportunities. Then, the difference in employment status would be the only significant factor making a difference. In this light, as there are 40 more part-time employed wives than part-time employed husbands in the sample (Table 6.1), thus, more households can be assumed to have couples where a wife enjoys better access than a husband. However, this is not the case in reality. As shown in Figure 6.2(a), in more households, wives have lower accessibility than husbands, instead of better access. More specifically, while, due
to a higher percentage of part-time working women than men among couples in the subsample, wives’ higher accessibility than husbands’ (led by wives’ shorter work hours at a workplace) might be generally expected. However, the actual level of wives’ accessibility is found to be lower in most cases of the households investigated.

The missing link between the level of accessibility and the composition of employment status within households is gender role-induced, unequally distributed, household responsibilities by gender. That is, inequitably allocated household responsibilities to married women are another important axis shaping gender differences of individuals’ daily accessibility experiences.

The gender division of labor within the household in terms of daily household work hours spent by husbands and wives is shown in Figure 6.2(b). This gives some indications of the current status of changes in gender roles and gender relations within the household. Households where women are primarily responsible for most household tasks are still a typical type of household, as the number of households is the largest when wives spend more time on household work than their spouses. The percentage of women’s longer household work durations than those of men is especially high among couples with children. Interestingly, the biggest group of households with couples without children is shown to share the household work burden equally. It might indicate that parental status is a stronger factor than marital status.
Figure 6.2: The number of households (a) by types of gender difference in daily accessibility ($\text{WareaDur}$); (b) by types of gender division of labor within household in terms of daily household work hours.
Therefore, wives’ relatively shorter paid-work hours do not directly represent more space-time autonomy and thus higher accessibility. Contrary to general expectations, wives’ longer household-work hours tend to counteract the possibility of better accessibility experience with shorter paid-work hours. As a result, more wives are found to experience lower, not higher, accessibility than their spouses.

Additionally, Table 6.2 also shows that dual-earner couples experience significantly unequal division of labor within households in terms of the number and the duration (both total and average) of household-associated work. Married women spend 23.2 minutes more time on household work than their spouses; such a time difference is statistically significant. Also, wives have to carry out more household-associated activities throughout a day, and their average work duration required is longer than their husbands’.

It is noteworthy that the presence of children significantly intensifies the unequal division of labor within household by gender. Interestingly, the gender difference in household responsibilities is negligible and even becomes statistically insignificant among dual-earner couples without children. Another notable finding from the result is that the effect of parental status on household responsibilities is quite gender-biased. Overall, couples with children spend a longer time on more household work than those without children. However, the amount of the increase, and its significance, in household work burden by parental status is clearly different by gender. For example, women with children carry out more household-associated activities than those without children (1.4
activities during a day vs. 0.5), and spend about 40 minutes more on those tasks (78.2 minutes vs. 34.4 minutes). Unlike women, men with children, however, do not experience a large increase in either total or average household work duration or frequency of household work, compared to men without children.

<table>
<thead>
<tr>
<th>Total</th>
<th>Total household work duration during a day</th>
<th>Number of household works</th>
<th>Average household work duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Husbands</td>
<td>Wives</td>
<td>Husbands</td>
</tr>
<tr>
<td>(N = 271)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>31.24</td>
<td>54.44</td>
<td>0.61</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>63.53</td>
<td>89.98</td>
<td>0.96</td>
</tr>
<tr>
<td>Mean Difference</td>
<td>-23.20**</td>
<td>-0.31**</td>
<td>-9.99**</td>
</tr>
<tr>
<td>Couples without children (n = 147)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>26.91</td>
<td>34.43</td>
<td>0.42</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>63.2</td>
<td>64.37</td>
<td>0.79</td>
</tr>
<tr>
<td>Mean Difference</td>
<td>-7.52</td>
<td>-0.1</td>
<td></td>
</tr>
<tr>
<td>Couples with children (n = 124)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>36.37</td>
<td>78.17</td>
<td>0.83</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>63.79</td>
<td>108.67</td>
<td>1.09</td>
</tr>
<tr>
<td>Mean Difference</td>
<td>-41.80**</td>
<td>-0.56**</td>
<td>-15.69**</td>
</tr>
</tbody>
</table>

** : Mean difference by gender is statistically significant at the 0.01 level (2-tailed)
**Bold**: Mean difference by parental status is statistically significant at the 0.01 level (2-tailed).

Table 6.2: Difference in household responsibilities between dual-earner couples by gender and parental status.
In summary, it is found that wives encounter significantly heavier household responsibilities than their spouses. Gender difference in terms of the division of labor within households are found to be significant among couples with children, not among couples without children. Couples without children tend to show the moderately equal division of labor within households. In this regard, for dual-earner couples, marital status itself might not be a crucial factor as much as parental status in shaping gendered division of household labor. Moreover, the intensification of household responsibilities by a change in parental status is found to be much greater for women, compared to men. Household responsibilities can be considered as gender role constraints. Gender difference in the frequency and duration of household work would make women stay longer at home and travel more from/to home, which renders the spatial characteristics of women’s accessibility home-centered and home-oriented.

6.3 Gendered Spatiality in terms of Activity Space

There have been considerable studies on women’s limited spatiality as compared to men’s (Tivers 1985; Palm and Pred 1978; Pickup 1884; Cichocki 1980, England 1988; Handson and Pratt 1995). Women are often considered as “spatial entrapped” or “home attached.” Gendered spatiality has been largely studied in terms of activity space. Using different measures, gender difference in the use or usability of space has been identified. To demonstrate such gendered spatiality, travel distance to activities from home, or the level of out-of-home activities have often been utilized as useful indicators. These
methods are based on assumptions of either women’s preference (choice) for shorter travels, their limited mobility (lack of access to cars), or their space-time constraints which stem from gender roles. Basically, previous studies have found women travel shorter distances, travel to activities close to home, participate in less out-of-home activities, and spend more time at home), which are evidence of gendered spatiality – as pointed out by the well-known “spatial entrapment,” “spatial containment,” or “home-attached” thesis on women’s situation.

6.3.1 Participation in out-of-home activities

One of the forms of gendered spatiality which previous studies often pointed out is women’s higher likelihood of staying at home for household work activities and their lower level of participation in out-of-home discretionary activities as a result. Are women really home attached? One of the limitations of previous studies on women’s home attachment is that analyses tend to draw conclusions simply from one side of the findings. In other words, when women’s higher level of in-home household fixed activities are empirically identified, it is often thought that their level of out-of-home flexible activities can be straightforwardly elicited. Or, it is generally assumed that the empirical evidence of women’s fewer out-of-home flexible activities may represent women’s heavier household responsibilities. There are few studies which examine women’s home attachment through considering both sides of women’s activity patterns, in-home and out-of-home simultaneously.
Another limitation of previous studies is that in-home activities have often been ignored as a location choice for flexible activities and improperly assumed as a mere location constraint for fixed activities. Despite the fact that home is also a center of a wide variety of activities, all in-home activities are often treated as if they were a single type—obligatory in nature, especially in a form of a household-serving activity.

Alternatively, although a lot of out-of-home, non-work activities do in fact include obligatory activities, all out-of-home activities are often regarded as an indicator of an individual’s level of freedom from space-time constraint.

Table 6.3 shows gender differences in the number of activities by location and by activity fixity type. Basically, married women tend to perform a greater number of activities during the day than married men (1,874 vs. 1,773), which is reasonably consistent regardless of activity locations and their parental status. Regarding activity fixity, the number of flexible activities undertaken during a day by a person is greater than that of fixed activities, for either women or men, with or without children.

What is surprising from the results is that unlike general expectations, wives undertook more out-of-home activities than husbands. Previous studies strongly believed that the greater the number of out-of-home activities, then, the better access to urban opportunities. According to these studies, due to heavier household responsibilities, women would have fewer out-of-home activities. However, this study shows that out-of-home activities are largely made up of fixed activities, not flexible activities, whereas in-
home activities are largely made up of flexible activities, not fixed activities. Gender difference in the percent of fixed activities among out-of home activities is negligible (64.6% for husbands vs. 64.4% for wives), which is consistent regardless of parental status. However, parental status tends to increase the percent of fixed out-of-home activities, regardless of gender.

<table>
<thead>
<tr>
<th># of activities performed during a day by location by fixity type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Husbands</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Subtotal</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>(%)</td>
</tr>
<tr>
<td>out-of-home</td>
</tr>
<tr>
<td>(%)</td>
</tr>
<tr>
<td>in-home</td>
</tr>
<tr>
<td>(%)</td>
</tr>
</tbody>
</table>

Parental status

<table>
<thead>
<tr>
<th>No child</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Husbands</td>
<td>Flexible activities (%)</td>
<td>Flexible activities (%)</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>961</td>
<td>377 (39.2)</td>
</tr>
<tr>
<td>(%)</td>
<td>(100)</td>
<td>(100)</td>
</tr>
<tr>
<td>out-of-home</td>
<td>482</td>
<td>301 (62.4)</td>
</tr>
<tr>
<td>(%)</td>
<td>(50.2)</td>
<td>(79.8)</td>
</tr>
<tr>
<td>in-home</td>
<td>479</td>
<td>76 (15.9)</td>
</tr>
<tr>
<td>(%)</td>
<td>(49.8)</td>
<td>(20.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Child</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Husbands</td>
<td>Flexible activities (%)</td>
<td>Flexible activities (%)</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>812</td>
<td>345 (42.5)</td>
</tr>
<tr>
<td>(%)</td>
<td>(100)</td>
<td>(100)</td>
</tr>
<tr>
<td>out-of-home</td>
<td>405</td>
<td>272 (67.2)</td>
</tr>
<tr>
<td>(%)</td>
<td>(49.9)</td>
<td>(78.8)</td>
</tr>
<tr>
<td>in-home</td>
<td>407</td>
<td>73 (17.9)</td>
</tr>
<tr>
<td>(%)</td>
<td>(50.1)</td>
<td>(21.2)</td>
</tr>
</tbody>
</table>

Table 6.3: Gender differences in number of activities by location by fixity type
On the other hand, in-home activities are more likely to be flexible in nature, for both husbands and wives, regardless of parental status. Contrary to the case of out-of-home activities, there are gender differences in composition of fixity type for in-home activities -- the percentage of flexible activities among in-home activities is higher for men than women. In the case of men 83.2% of in-home activities are flexible, in the case of women only 76.8% are flexible.

Parental status leads to the increase in ratio of fixed activities to flexible activities for both men and women (but, more sharply for women than for men). The increase in the relative importance of fixed activities is found in terms of in-home activities as well as out-of-home activities regardless of gender. In particular, women with children experience a dramatically increased percent of fixed activities among in-home activities (19.2% for women without children, vs. 27.51% for women with children), while men do not (15.8% vs. 17.94%).

These findings imply that gender roles generate more fixed activities at home onto women. Hence, the results suggest that gender expectations of parental status, rather than gender itself, makes people stay at home in general, and makes women more home-attached in particular. Parental status requires more household-associated obligatory activities, which forces people to be at home more. Since the share of household responsibilities within a household is still gender-imbalanced, women’s relatively heavier household responsibilities compared to men’s lead women to perform more obligatory activities at home.
At the same time, what needs attention is the fact that gender roles also make wives with children carry out more out-of-home household tasks, as shown in Table 6.4. Women undertake more household-related fixed activities than men regardless of their parental status. For both men and women, most in-home fixed activities (approximately 60~70%) are household-related regardless of their parental status. However, it is worthy of note that women and men with children encounter a lot of household tasks which need to be accomplished out of home. Especially, women with children have approximately twice the number of household-associated activities than men, not only in home but also out of home. In addition, in terms of the number of activities, women with young children are not necessarily home attached, as the higher proportion of household work is undertaken out of home (52.6%) rather than in home (47.4%).

Hence, home should not be interpreted as simply a place for household responsibilities. In fact, home is also chosen for flexible activities by those who have enough time to participate in out-of-home activities. The percentage of those staying at home is quite gender-indifferent, and most in-home activities are flexible, not fixed. It should not be ignored that people stay at home, not just because they have no choice (which has been overemphasized by previous studies), but also because they want. Therefore, unawareness of the fact that the majority of out-of-home activities are fixed and that the majority of in-home activities are flexible would mislead interpretation of the gender difference in number of out-of-home activities. In this light, it calls for a critical re-examination of women’s home-attachment. Gender role-associated household
responsibilities oblige women not only travel to, and stay at, home, but also travel to
locations other than home.

<table>
<thead>
<tr>
<th>Activity purpose</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>subtotal (%)</td>
<td>out-of-home (%)</td>
</tr>
<tr>
<td>Total</td>
<td>722 (100)</td>
<td>573 (100)</td>
</tr>
<tr>
<td>Household</td>
<td>202 (28.0)</td>
<td>104 (18.2)</td>
</tr>
<tr>
<td>(%)</td>
<td>(100)</td>
<td>(51.5)</td>
</tr>
<tr>
<td>Work</td>
<td>496 (68.7)</td>
<td>449 (78.4)</td>
</tr>
<tr>
<td>Personal</td>
<td>24 (3.3)</td>
<td>20 (3.5)</td>
</tr>
</tbody>
</table>

Table 6.4: Gender differences in number of fixed activities by location by activity purpose.

Staying at home itself could be for two different types of activities, either
obligatory (spatially and/or temporally fixed) or discretionary (spatially and/or
temporally flexible). Therefore, home as a location for activities could be both a constraint and a choice. More in-home activities do not necessarily mean less ability to get out of the home. In addition, participating in more out-of-home activities (particularly, out-of-home non-work activities) does not necessarily mean higher access to urban opportunities. That is, out-of-home activity locations could also be both constraints and choices. In this regard, it is necessary to look at a more detailed picture of gender differences (especially in couples with children), specifically whether out-of-home activities and in-home activities are either flexible or fixed in nature.

6.3.2 The spatial extent of activity space

Past studies generally show that, owing to women’s higher level of spatial and temporal fixity constraints which mainly stems from their dual roles, women have certain characteristics of travel behavior such as shorter travels in general, travels closer to home or to workplaces, shorter journey-to-work distances compared to men, and therefore their activity spaces are expected to be much smaller and closer to home than men.

The results indicated by Table 6.5 tell that such expectations are not always justified. First of all, gender difference in travel times itself is turned out to be not statistically significant at all. Travel times from one activity to the next are not gender-dependent. Therefore, the finding in this analysis is against the assumption regarding
women’s shorter travel behavior. It implies that gendered spatiality is not necessarily characterized by women’s short travel distances.

<table>
<thead>
<tr>
<th>Travel distances between (in minutes)</th>
<th>Couples with No Children</th>
<th>Couples with Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Husbands</td>
<td>Wives</td>
</tr>
<tr>
<td>Activity - activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.4</td>
<td>10.7</td>
</tr>
<tr>
<td>Home - activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Flexible activities</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>- Fixed activities</td>
<td>14.3</td>
<td>11.0</td>
</tr>
<tr>
<td>(Home – Work)</td>
<td>22.6</td>
<td>19.6</td>
</tr>
<tr>
<td>- Total activities</td>
<td>8.5</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Bold**: Mean difference by Gender is statistically significant at the 0.01 level (2-tailed).

**: Mean difference by Parental Status is statistically significant at the 0.01 level (2-tailed)

*: Mean difference by Parental Status is statistically significant at the 0.05 level (2-tailed)

(Note: all the travel times above are network-based, free-flow speed based (FreeFlow). However, travel times for Home-Work are exceptionally congested-flow speed based (CongFlow).)

Table 6.5: The spatial extent of activity space with respect to distances traveled.

What about women’s spatiality in terms of the extent of activity space? The spatial extent of activity space is generally considered as the travel distance from home to activities. Travel distance from home to work is also often used.

It is surprising that the activity space in terms of average travel times from home to all flexible activity locations does not vary either by gender or by parental status.
Discretionary activities were undertaken within a 5-minute travel distance on average, for both women or men, and with or without children. Similarly, the spatial extent for fixed activities is not statistically different between men and women.

Additionally, the examination of travel distances from home by activity purpose (as shown in Figure 6.3) clearly corroborates the idea that it is questionable that women are likely to travel shorter distances and engage in activities closer to home than men, which in turn results in women’ spatially bound experience. Travel distances to all the types of activities except the workplace do not show that women significantly travel shorter distances from home than men. In most cases, the differences in distance are negligible, and for some activities such as shopping, personal services or appointments, women were found to travel even further than men.

Women’s activity space from home to all activities, on the other hand, is found to be smaller with a statistical significance (Table 6.5). Such gender differences in the spatial extent of all activities from home are true only for women and men with children. Another interesting gender difference found in such activity spaces is that for wives, parental status renders activity space significantly smaller (8.0 for women without children \( \rightarrow \) 6.5 minutes for women with children), while for men, it makes no difference at all (8.5 \( \rightarrow \) 8.5 minutes).

The spatial extent of activity space from home to workplace is the only type which shows statistically significant gender differences not only between couples with children, but also between couples without children. However, like the case of the home-
all activities activity space, the change in parental status significantly further restricts the spatial extent of the activity space from/to the workplace only for women, not for men.

Figure 6.3: Travel distances by activity purpose by gender and parental status
(Note: Travel times are based on free flow speeds for all activities)
In short, it seems that travel distances imply no necessary relationship to gendered spatiality. Women’s shorter travels or closer-to-home travels are found to be statistically insignificant, in general. Women’s spatial entrapment is not readily identifiable through the examination of activity spaces, either. Gender differences in a form of compactness and home-centeredness of activity spaces are found to be statistically insignificant in most cases. Thus, it suggests that outcomes from conventional methods would need to be critically reexamined with caution.

Then, can the fact that women’s activity spaces, especially from home to flexible or discretionary activities, are not necessarily smaller compared to those of men be interpreted as evidence of the attenuation of gender inequalities stemming from gender role constraints? In other words, can we draw a conclusion of the equitable gender division of labor within households, simply from an observation of no gender difference in actual activity space? This question will be answered in remaining sections with the examination of accessibility space.

6.4 Gendered Spatiality in terms of Accessibility Space

The literature on gendered spatiality concentrates on activity space (often in terms of actual travel distance or actual activity location choice). Accessibility space, or possible activity space, has received less attention. How long, when, and where people travel do not take place in a vacuum (therefore as a form of unconditional choice), but
rather in a constrained situation in space and time. In this regard, it is worthwhile to examine gendered spatiality using accessibility space.

In order to identify gendered spatiality, two elements of accessibility space are explored: the average size of accessibility space, and the positional characteristics of accessibility spaces. Gendered spatiality can be manifested as a form of the compactness in size, and the spatial containment to a certain place.

Figure 6.4 demonstrates possible ways in which women face spatial entrapment regarding accessibility experiences. Women may be spatially entrapped due to a smaller time budget and therefore have a smaller accessibility space as a result compared to men, as depicted in Figure 6.4 (A). Or women may be spatially entrapped due to tighter space-
time fixities which limits accessibility spaces to those near home, while men have more extensive and diverse accessibility spaces, and therefore their locational choice set is much larger, as can be seen in Figure 6.4 (B). Whether gendered spatiality is manifested in a certain characteristic of accessibility space or in a combined form of these two will be examined.

6.4.1 Gendered Spatiality by average size of accessibility space

When average size of accessibility space by gender and parental status is examined, the results in Table 6.6 show that, regardless of parental status, there are no significant gender differences in the size of accessibility space. The finding is consistent across a variety of accessibility measures. In contrast to general expectations again, such an insignificant difference by gender in the spatial extent of possible activity space would indicate that individual accessibility spaces of women are not necessarily smaller than those of men. Therefore, the examination of gender differences in average size of accessibility space in this section does not support existing arguments on women’s limited spatiality. Further it implies that women’s lower space-time accessibility during a day, due to heavier household responsibilities than men, does not necessarily take a form of smaller size of accessibility space on average.
**Significance in Difference**

**Average Size of Accessibility Spaces by Gender**

<table>
<thead>
<tr>
<th></th>
<th>Husbands</th>
<th>Wives</th>
<th>p</th>
<th>p (Men)</th>
<th>p (Women)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUM</td>
<td>12230.3</td>
<td>12225.1</td>
<td>0.993</td>
<td>0.731</td>
<td>0.118</td>
</tr>
<tr>
<td>NUMT</td>
<td>10582.2</td>
<td>10471.7</td>
<td>0.831</td>
<td>0.521</td>
<td>0.379</td>
</tr>
<tr>
<td>AREA</td>
<td>14729.7</td>
<td>14309.5</td>
<td>0.577</td>
<td>0.631</td>
<td>0.073</td>
</tr>
<tr>
<td>AREAT</td>
<td>12092.5</td>
<td>11606.7</td>
<td>0.462</td>
<td>0.469</td>
<td>0.333</td>
</tr>
<tr>
<td>WAREA</td>
<td>15510.7</td>
<td>15114.8</td>
<td>0.611</td>
<td>0.676</td>
<td>0.079</td>
</tr>
<tr>
<td>Wareat</td>
<td>12835.9</td>
<td>12375.2</td>
<td>0.503</td>
<td>0.504</td>
<td>0.341</td>
</tr>
</tbody>
</table>

**Households with No Children**

<table>
<thead>
<tr>
<th></th>
<th>NUM</th>
<th>NUMT</th>
<th>AREA</th>
<th>AREAT</th>
<th>WAREA</th>
<th>Wareat</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUM</td>
<td>12108.7</td>
<td>12763.1</td>
<td>0.378</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NUMT</td>
<td>10372.0</td>
<td>10751.3</td>
<td>0.583</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AREA</td>
<td>14502.0</td>
<td>15138.9</td>
<td>0.531</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AREAT</td>
<td>11789.3</td>
<td>11997.8</td>
<td>0.814</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAREA</td>
<td>15305.4</td>
<td>15956.1</td>
<td>0.535</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wareat</td>
<td>12544.2</td>
<td>12775.8</td>
<td>0.802</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Households with Children**

<table>
<thead>
<tr>
<th></th>
<th>NUM</th>
<th>NUMT</th>
<th>AREA</th>
<th>AREAT</th>
<th>WAREA</th>
<th>Wareat</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUM</td>
<td>12391.5</td>
<td>11556.1</td>
<td>0.326</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NUMT</td>
<td>10860.8</td>
<td>10124.0</td>
<td>0.346</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AREA</td>
<td>15031.5</td>
<td>13278.4</td>
<td>0.117</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AREAT</td>
<td>12494.4</td>
<td>11120.5</td>
<td>0.166</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAREA</td>
<td>15782.7</td>
<td>14068.8</td>
<td>0.140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wareat</td>
<td>13222.7</td>
<td>11877.3</td>
<td>0.193</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.6: Gender differences in average size of accessibility space

### 6.4.2 Gendered Spatiality by Average Distance from home to PPAs

Whereas gendered spatiality is not established with respect to the average size of accessibility spaces, the results in Table 6.7, however, point out the existence of gendered spatiality, which takes a form of more locationally constrained characteristics of women, compared to men. Specifically, women’s accessibility spaces are more likely than men is
to be close to home, as shown in terms of the average distance from home to origin locations of PPAs (or space-time prisms). Gender differences are found statistically significant between couples with children, but not between couples without children. Furthermore, women’s daily accessibility space becomes further spatially limited to home by having children, while the change in parental status does not significantly affect the spatial extent of men’s daily accessibility space in location.

<table>
<thead>
<tr>
<th>GENDER</th>
<th>Average distance from home to PPAs (in minutes)</th>
<th>Significance in Difference ($p$) by Gender</th>
<th>Significance in Difference ($p$) by Parental Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>14.8</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>12.1</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Husbands with No Children</td>
<td>14.7</td>
<td>0.465</td>
<td>0.927</td>
</tr>
<tr>
<td>Wives with No Children</td>
<td>13.9 **</td>
<td>0.465</td>
<td>0.000</td>
</tr>
<tr>
<td>Husbands with Children</td>
<td>14.9</td>
<td>0.000</td>
<td>0.927</td>
</tr>
<tr>
<td>Wives with Children</td>
<td>10.1 **</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**Bold**: Mean difference by Gender is statistically significant at the 0.01 level (2-tailed).

****: Mean difference by Parental Status is statistically significant at the 0.01 level (2-tailed)

Table 6.7: Average distance from home to PPAs by gender and parental status

Although women tend to be confined within more limited spatial boundaries compared to men, the more home-centeredness of women’s accessibility spaces is not because of smaller accessibility spaces on average due to a smaller time budget than men
is. It is rather because of the location-confined nature of accessibility spaces due to space-time rigidity which makes women need to be at home and travel to child-caring activity locations which are usually nearby.

6.5 Understanding spatio-temporal context of accessibility space

It is crucial to examine situations where space-time prisms are made, in order to understand home-centeredness of daily accessibility spaces of women. Such an effort will be accompanied with the attempt to examine how household responsibilities and fixed activity distributions in space and time are associated with characteristics of accessibility spaces in space and time. It is expected to provide some useful insights to interpret revealed activity patterns in a more appropriate manner by linking accessibility space to activity space.

6.5.1 Temporal pattern of fixed activities by gender

In the previous section, we found that women have a greater level of fixity constraints as they shoulder heavier household responsibilities than men in addition to paid work. Figure 6.5 demonstrates how fixed activities are temporally distributed throughout a day, clearly showing that women’s heavier fixity is mainly due to household work in addition to paid work, and that gender differences become more distinct when dual-earner couples have children.
Figure 6.5: Spatio-temporal pattern of fixed activities by gender by activity purpose: the occurrences of fixed activities in space and time, unweighted.
Women with children encounter more household work than men with children, and furthermore their household work burden takes place not only in the morning and in the evening like men, but also during the daytime. In particular, in the late afternoon or in the early evening, women with children are found to carry out a great number of household-related obligatory activities.

6.5.2 Spatio-temporal patterns of fixed activities by gender

Since our point of interest is on gendered spatiality, it is worthwhile to note how household and other types of fixed activities are located in space as well as in time. Figures 6.5 and Figure 6.6 show spatio-temporal patterns of fixed activities by gender and by activity purpose. Figure 6.6 demonstrates that, whereas couples with no children do not have significant gender differences in fixed activity patterns in space and time, couples with children show gender difference in spatio-temporal patterns of fixed activities. Working mothers have not only more in-home activities throughout a day, but also a lot more out-of-home household-work activities than men. Such out-of-home household-serving activity locations are mainly within 5~10 travel time distances from home and are located much closer to home than workplaces locations overall. In addition, workplaces for wives with children are much closer than those for husbands with children, while no dramatic difference is found for couples with no children, as pointed out in the previous section on activity space. On the other hand, other types of fixed activities (personal appointments and school) are minimal regardless of gender and
parental status and also do not show distinctive gender differences in location in space and time.

Figure 6.6: Spatio-temporal pattern of fixed activities by gender by activity purpose: the occurrences of fixed activities in space and time, weighted by activity duration.
When each fixed activity is weighted by activity duration as shown in Figure 6.6, the relatively small size of circles, which represents out-of-home household work activities, implies that these activities include mainly picking up and dropping off children, which is spatially and temporally fixed with a great level of rigidity.

6.5.3 Spatio-temporal pattern of accessibility experience by gender

With detailed understanding of underlying space-time constraints, which shapes accessibility experiences, gendered spatiality manifested by women’s more home-centeredness in daily accessibility space becomes more interpretable.

Figure 6.7 shows the gender differences in the occurrences of accessibility spaces in space and time. It provides a clear difference by gender and parental status. In couples without children, husbands and wives do not show any noticeable differences in patterns. Two major types of accessibility space formation are the midday lunch break and the evening after-work time periods. In the case of couples with children, husbands have similar patterns to couples without children, in that the relative importance of work-to-home after work and work-to-work during midday is quite visible. On the contrary, such importance is dramatically reduced, and even becomes very minimal in the case of women with children. Working mothers show significantly distinctive patterns of accessibility space in space and time, contrasted to those without children or men with children. During the midday, the relative importance of other places increases (more dramatically in the evening), and work-to-home accessibility becomes far less important.
Figure 6.7: Spatio-temporal pattern of accessibility experiences by gender by location context: the occurrences of accessibility in space and time, weighted by the level of accessibility (\(\text{WareaDur}\)).
for working mothers. Instead, home-centered accessibility spaces and the other-to-home accessibility spaces become predominant types, which renders women more sensitive than men to urban opportunities close to home. Given the high proportion of out-of-home household work among non-work out-of-home fixed activities (that is, other activities) as identified in the previous section, the other-to-home accessibility space is basically equivalent to the child-serving location to home accessibility space. The higher level of space-time rigidity for the evening household activities renders women inaccessible to urban opportunities near workplaces and along the journey from work to home. It only allows women to have access to urban opportunities after they arrive at daycare centers or at home to accomplish household-serving and child-serving activities. This prevents women’s accessibility spaces to extend farther away. Whether the workplace is farther away from or closer to home, it does not critically influence women’s spatial experience of accessibility spaces, since their major type of accessibility space is the household-serving location to home, not workplace-to-home.

The findings so far suggest that women’s spatial entrapment or tendency to be home-attached should be understood within broader and more complex but interlinked contexts of their activity, mobility, and accessibility. Like men, most travels by women are not home-based. Even travel distances or times by women are not necessarily shorter than men is. The reason women have activities relatively more at, and much closer to, home is the very women’s gender-role constraints and their associated accessibility experience, which is home-centered or home-oriented accessibility spaces.
6.6 Understanding activity space through understanding of accessibility space

The examination of accessibility space in space and time reveals that while men have more space-time autonomy to participate in discretionary activities after work, women do not. In other words, husbands can reach urban opportunities not only close to home but also far away and close to the workplace. However, wives with children are not very accessible to urban opportunities located far from home. The more household-work activities in and out-of-home and more importantly associated timing constraints (e.g. the pick-up children from daycare center) limit women’s possible activity space to just near home, because women become free only after picking up children at the daycare center which is likely to be much closer to home than workplaces, or even after coming back home and finishing household-serving activities at home after work.

The presence of a considerable amount of out-of-home household-serving and child-serving activities and travels, especially in the evening (or after work), for working mothers, results in the decrease of the relative importance of work-to-home accessibility spaces, as indicated in the previous section.

The findings on activity/travel contexts where accessibility spaces (PPAs) are made during a day indicate that, for husbands, the workplace is a relatively more important focal point for urban opportunities, since accessibility spaces are mainly constructed in between the work-to-home fixed activity pairs and the work-to-work fixed activity pairs. By contrast, working mothers have home as a relatively more important focal point compared to the workplace. Their accessibility space is made mainly in the
home-to-home fixed activity context, while the relative importance of work-to-home accessibility space is a lot lower, compared to men or women without children.

The home-centeredness of possible activity spaces, however, should be distinguished from revealed patterns of home-centeredness of activities/travels. Being accessible to opportunities only around the home needs to be distinguished from actual participation in activities near home. Distance does not inherently imply anything. People might want to choose opportunities close to home for a variety of reasons, even though they can access opportunities at very remote places. Therefore, the shorter or longer distance cannot be a direct and inherently meaningful indicator. In considering the factor of distance, we can just describe individuals’ spatiality in some sense, but cannot fully explain or understand it. What matters is the situation. The activity space or travel distance should be understood in terms of whether people either choose or are constrained to be at/near home. For some, being at home is a choice since home could be a place of comfort and relaxation, and going to nearby locations even with a large enough time budget may be rational, since longer activity times can be enjoyed.

Figure 6.8 illustrates the possible relationships between accessibility spaces and activity spaces. Small activity space can be derived either because of the small accessibility space (Figure 6.8 (A)), or because of the choice of activity locations within a shorter travel distance even when a large accessibility space is allowed (Figure 6.8 (C)).
Therefore, we should keep in mind that the same outcomes can be generated by different situations. Such classification helps our understanding of why women and men have similar spatial extent of activity spaces despite their gap in accessibility space experiences. In the case of men, their alternative activity space could have taken the type (B) – large activity space due to large accessibility space, which in turn would clearly render gendered spatiality, but it was not revealed in reality. On the contrary, in the case

Figure 6.8: Possible relationship between accessibility space and activity space
of women, they have no choice but to have a small activity space because their possible activity space itself is very limited. Linking accessibility space to activity space provides not only appropriate interpretation of the nature of revealed activity/travel patterns, but also the detection of its gendered spatiality which would be invisible otherwise.

6.7 Conclusions

The examination of the relationship between gender, household responsibility and gendered spatiality leads to several conclusions. First, the result agrees with general expectations regarding the relationship between gender, household responsibility, and accessibility. The presence of children results in the increase of women’s household work responsibility in terms of average and total work hours during a day and the number of activities undertaken, which in turn leads to women’s smaller daily accessibility to urban opportunities.

When the focus is moved to gendered spatiality, the results, however, do not follow general expectations. One would expect that women would have shorter and/or closer to home travel behaviors or less out-of-home activities and more in-home activities due to a heavier household work burden than men. However, the way the household responsibility is linked to gendered spatiality is not as straightforward as previous researches has often assumed. Despite women’s more household responsibilities, their activity spaces are not necessarily smaller than those of men. Average travel distances
from one location to another are not different between husbands and wives whether they have children or not. Furthermore, the average activity space from home to either fixed or flexible activities does not show any gender difference. However, the average travel distances from home to workplaces show gender difference – women’s workplaces are located closer to home than men’s. Given the findings in this chapter, it is hard to tell that women have smaller, or more home-centered, activity spaces than men.

Furthermore, when gendered spatiality is examined in terms of the percent of in-home and out-of-home activities, the results again point out that conventional assumptions on gendered spatiality (and therefore indicators based on them) need to be reexamined. The dichotomic assumption that home is mainly the location for obligatory activities, since women are usually attached to home for household work, and out-of-home is mainly the location for discretionary activities, is problematic. Usually more out-of-home activities are believed to be an indicator of better access to urban opportunities. However, results show that the ratio of out-of-home and in-home activities is not different by gender and, even more, women have more out-of-home activities (either discretionary or obligatory) than men. Interestingly, the results also show that most of in-home activities are in fact discretionary, while most of out-of-home activities are obligatory. What should noted here is that temporal autonomy may not be directly captured in the form of the number of out-of-home activities. It should not be ignored that more than 80% of flexible activities are undertaken in home instead of out-of-home for men, and more than 60% of fixed activities are undertaken out of home instead of in-
home for women. Therefore, the implication of the findings is that the rigid dualistic assumptions on location need to be reconsidered. Home is not only a place of constraint for obligatory household work but also a place of choice for relaxation and amusement. On the other hand, out-of-home is not necessarily a place of choice but also a place of constraint. Even though it is true that women with heavier household responsibilities have more in-home obligatory activities, it does not directly result in women’s smaller out-of-home activities. Rather, women have more out-of-home obligatory activities as well as more out-of-home discretionary activities.

Therefore, measures on gendered spatiality in terms of the frequency of out-of-home or in terms of the distance of activities from home do not strongly support previous findings on women’s more home-attached situation and more home-centeredness. Actual activity space does not vary by gender. The result implies that household responsibility does not necessarily structure gendered spatiality of activity space. Revealed patterns of short travel distances would actually be the outcome of either constraints individuals face, or their choices. Likewise, staying at home can be either a result of one’s spatial fixity or a result of one’s choice. The primary question of gendered spatiality is who has more autonomy reaching and being at a certain place.

In this regard, gendered spatiality is examined in terms of possible activity space given to individuals, that is, accessibility space. When the average size of accessibility
space is compared between men and women, the results find no significant difference. The spatial extent of women’s possible activity space is not smaller than men’s.

Rather, the results suggest that gendered spatiality can be captured by where and when accessibility spaces are made, instead of by size, by gender. Accessibility spaces for women with children are found to be more home-centered than other groups of people. The results indicate that working mothers are spatially restricted to areas closer to home in terms of possible activity spaces. In the case of husbands, the most salient type of accessibility spaces occurs in the workplace-to-home travel context, which is made after work in the evening, and the next is the accessibility space in the context of the excursion from/to the workplace, during the lunch break. That is, their possible activity space is extended to places around workplaces, which is even significantly farther away from home compared to women’s. In other words, husbands have spatial autonomy to choose their activity locations in between home and work. On the other hand, wives with children are more likely than husbands to have another space-time constraint after work. Unlike their husbands, wives with children cannot enjoy their space-time autonomy right after work (in time) and on the way home from work (in space). Working mothers must take trips to serve the household after work, such as picking up children and must also perform household maintaining activities at home. So, their accessibility space is only made on the way home from another location, which is much closer to the workplace, or after coming back home. In this way, women’s possible activity space becomes more home-centered compared to men’s.
In conclusion, the analysis of the spatio-temporal context of accessibility space makes gendered spatiality visible. More household responsibilities throughout a day and, even more, the time constraint of picking up children at the daycare centers after work leads women’s possible activity space to be more home-centered. However, such gendered spatiality associated with household responsibility is not easily discernible, when actual activity space based on revealed activity/travel patterns is simply analyzed. It is because the revealed activity spaces can be not only an outcome of constraint but also an outcome of choice. No significant gender difference in the spatial extent of fixed and flexible activity spaces from home or in the number of out-of-home discretionary activities suggests that conventional methods on gendered spatiality call for critical examination of the activity/location assumptions they are based on, and more careful interpretation of the results.

Women’s activities are more likely than men is to take place near home and daycare centers, and/or in between them, whereas men have more freedom to make trips further away from home and participate in activities in broader areas. However, when actual travel distances and location choice was examined, no significant difference was found between men and women. It is because men, despite their large space-time autonomy, decide to stay at home for their discretionary activities and choose activities near home instead of in remote areas. In contrast, women have no choice but to travel a short distance within limited areas around home, due to the very nature of the spatial-temporal fixity they face. That is, even if women and men are differently situated,
outcomes are not statistically significant. Women’s activity space is limited by spatial-temporal constraints. However, in the case of men, their activity space is determined by their preference of home as a discretionary activity location, and/or short travels to nearby out-of-home activity locations, as well as by the land use characteristics of accessibility spaces.

Therefore, the findings in this chapter suggest that behavioral outcomes should be understood with an explicit awareness of constraints individuals face. In addition, behavioral outcomes should not be treated as a straightforward expression of the level of constraints. It is problematic to expect that behavioral outcomes directly mirror the level of constraints. It is also problematic to suppose that the level of constraints can be straightforwardly elicited from revealed behavioral outcomes.
CHAPTER 7

CONCLUSIONS

7.1 Summary and Major Findings

Two important questions this dissertation has attempted to answer are (1) are the proposed space-time accessibility measures better in identifying gender differences in accessibility?; and (2) do gender roles lead to different accessibility experiences for men and women, and how?

This chapter reviews and expounds findings presented in earlier chapters. This study had two main goals. First, the usefulness of a new measure of space-time accessibility was evaluated. Past space-time accessibility measures did not fully take account temporal dimensions of feasible opportunities within a space-time prism, as well as realistic travel behaviors. The result shows that exclusion of temporal dimensions tends to significantly overestimate an individuals’ accessibility level. Even more, the results showed that gender differences in the level of accessibility became significant only when temporal dimension was taken into account in the measure. This suggest that
the exclusion of temporal dimension would greatly overestimate women’s accessibility level to a greater extent, compared to men’s, thus masking gender differences in accessibility. Women were seen to have lower access than men when both spatial and temporal dimensions were considered, which was not captured when only spatial dimension was considered.

The second goal was to investigate the way women and men face different accessibility experiences. The study of when, where, and in what activity/travel context accessibility takes place for women and men gives an idea that women’s heavier household responsibilities mean their space-time constraints are different from men’s. This, in turn, makes the location and timing of women’s accessibility more strict, contrary to men’s comparatively more diverse options. In addition, it makes the spatial extent of women’s accessibility spaces more restricted compared to men’s. For example, part-time employed women, despite fewer work hours and thus presumably a greater amount of, and more flexible, time than those who work full-time, can not take an advantage significantly in either higher level of accessibility or a more diverse temporal pattern of accessibility than full-time workers; whereas part-time employed men do enjoy considerably better and more time-flexible accessibility.

Furthermore, while most accessibility occurs in the work-to-home context, especially for full time workers (more than 60% of daily accessibility) due to their rigid time schedule, the relative significance of work-to-home accessibility decreased for part-time workers to approximately 30% and, instead, diverse locations and activity contexts
became important. Again, gender differences exist in significant accessibility contexts: women’s accessibility experience was more home-oriented and home-centered, which was less evident in the case of men’s. In addition to the work-to-home context, two other predominant contexts for part-time employed women were the other-to-home and home-to-home ones; each of them takes 20% of individual’s daily accessibility. This implies that previous measures based on a single reference (e.g. home) or just the home and work link considerations are not sufficient reveal the way women and men experience accessibilities. For men, home and workplace are two pivotal locations, around and along which their accessibility spaces are mainly made. However, for women, another pivotal locational axis, non-home non-work activity locations, is identified, which is mainly associated with household responsibilities.

In other words, women and men do experience accessibility differently in space and time. It can be concluded that the use of a single-reference point in accessibility measure (especially, home) is problematic. Moreover, the universal use of the home-to-work axis is also problematic. For women, part-time employed with children, childcare-associated activity locations are more influential. Therefore, women are accessible to urban opportunities around home and the childcare center or school, whereas men have more extensive accessibility space since their major axis of accessibility is work-to-home. These findings suggest that gendered importance of location and timing and accessibility context in travel/activity sequences needs to be explicitly acknowledged for better understanding of the gender gap in access to urban opportunities.
Regarding the household responsibility hypothesis associated with gender role constraints, the findings showed that children affects wives’ accessibility experiences more than husbands’: in a form of a lower accessibility level, a shorter journey to work, more spatially constrained accessibility space around home due to the relatively greater importance of the other-to-home and the home-to-home accessibility contexts. While there was no gender gap in household responsibility found between married women and men with no children, as measures in number, total duration, and average duration of household work, the heavier household responsibility of married women with children, compared to married men with children, was identified. Other interesting findings are the spatial and temporal patterns of household work. Women encountered not only in-home obligatory activities but also more out-of-home obligatory activities than men and most of the out-of-home fixed activities are household work-related (e.g. picking up and dropping off children). This might be associated with the findings of the temporal entrapment pattern of part-time women’s accessibility. Even when part-time employed, working mothers’ non-work hours in the afternoon were not spent for their individual discretionary activities, rather for other family members. Chauffeuring children from/to daycare centers/schools or after-school activities inhibit working mothers in their own space-time autonomy, while part-time working men were shown to enjoy their open time window during the afternoon. In this way, women became temporally entrapped to a particular time of day (evening) even when their employment status presumably allowed more flexibility in space and time.
Along with temporal entrapment, women’s spatial entrapment to a particular location was examined. The results of analysis on the spatial extent of accessibility space from home showed that the presence of children made a significant gender difference between dual-earner couples, but no difference between married women and men with no children. A gender gap in the impact of children existed as well: the presence of children affects wives’ spatial extent of accessibility spaces, but not husbands. It might be because women’s accessibility is mainly between the home and other places (especially, day care centers or schools) which are much closer to home compared to the workplace, in addition to the fact that even women’s workplaces tend to be closer to home than men’s. Most of “other” belongs in the category of “household work.” This suggests another spatial node for women which significantly characterizes women’s accessibility spaces in addition to home and workplace: the childcare center or schools of children. Furthermore, such a location seems to be a more dominant reference point in shaping their accessibility than the workplace. Such gender difference in accessibility experiences explains why the level of availability of urban opportunities close to home is found to be one of the important determinants of accessibility for women, but not for men. Paid work hours are the only determinant significant to men’s accessibility, while household work hours and neighborhood opportunity density are also important factors to women’s.

In summary, gender roles lead to different accessibility experiences for women and men. The need to coordinate multiple roles of spouse, parent, and worker affects women’s accessibility more than men’s. Gender roles require women to perform more
household labor, including house maintenance chores and childcare. Wives do a larger share of the household work (in terms of the number and duration of housework activities), which results in less and more fragmented discretionary time (therefore, a lower accessibility level). Further, a heavier household responsibility confines the spatial extent of women’s accessibility spaces to near the home and daycare center (therefore, a less extensive accessibility space from home). Additionally, household responsibilities (especially, meal preparation, childcare, and chauffeuring) postpones the timing of women’s accessibility to the evening (after picking-up children at childcare or school, or the housework at home after work), while it does not affect men’s as much.

Therefore, gender roles lead women and men to face different accessibility experiences. Combining multiple roles (as wives, mothers, and workers) causes women to have lower accessibility. What is more, women’s accessibility to urban opportunities is characterized as spatially and temporally more entrapped. The major axis of women’s accessibility spaces is created between the home and daycare center (or school), whereas men enjoy more extensive accessibility spaces between home and workplaces due to their relative freedom from the space-time fixities caused by household work. Women’s accessibility, regardless of employment status, takes place mostly at a certain time of day, especially in the evening, whereas men’s accessibility greatly depends their employment status and thus can occur in a more diverse time of day.
Therefore, the major characteristics of gender differences in accessibility can be summarized as follows: (1) women’s accessibility level is lower than men’s; (2) women’s space-time autonomy is spatially and temporally entrapped, compared to men in similar conditions; (3) the major axis of accessibility spaces are gendered -- working mothers’ accessibility spaces are along home and out-of-home non-work locations (usually associated with children’s activities), and along home and work, while married men’s accessibility spaces are primarily along the home and work axis. And, whereas the relative importance of workplace and work hours is found in shaping men’s accessibility, women have more home-oriented accessibility spaces and the relative importance of household work hours and associated locations were distinctive; and (4) Gender roles constrain women’s accessibility more severely in space and time than men’s. More specifically, children render more gendered experiences of married women and men. This indicates that child-care responsibilities are still perceived as more feminine rather than gender-neutral or masculine, and in turn fragments women’s time and limits their mobility to more restricted areas in space.

7.2 Future research directions

Several areas still call for research. First, more sophisticated treatment of urban opportunities is needed. In other words, urban opportunities need to be further differentiated with respect to the cognitive aspects of urban opportunities such as familiarity, preference, security/fear and so on, as done by Kwan and Hong (1998). Also,
we need to explicitly acknowledge gender differences in meaningful urban opportunities by type and location. So far, urban opportunities have been treated as if they are gender-neutral. However, a considerable body of research has found that women and men value urban opportunities differently because of the occupational segregation by gender, the spatial segregation of industry, and the existence of feminine/masculine urban services.

Second, more sophisticated treatment of free time is also needed in measuring individual accessibility. It requires the explicit awareness of women’s multitasking (Bittman and Wajcman, 2000), and the existence of gender difference in quality of free time (e.g. the contamination of free time by the presence of children (Mattingly and Bianchi, 2003; Davies, 2001, Sayer, 2005).

Third, most previous studies on space-time accessibility have only considered the physical world and urban opportunities within the physical world and transportation as mobility. Since new information technology (IT), telecommunications and widespread internet use have changed lives profoundly and a significant amount of cyberspace opportunities extend choices for activities and substitute the need to move over space, devising ways to incorporating cyber-spatial opportunities and the impact of new IT into accessibility measures is needed (Bimber, 2000; Busy, 2000; Golob and Regan, 2001; Kwan, 2001).

In addition, since implementing the geocomputational algorithm in a GIS environment is still daunting and time-consuming, future research should seek to develop more efficient algorithms that deploy the power of massively parallel computing, to
ultimately allow the incorporation of even more detail of the urban environment and the examination of interpersonal differences in accessibility using large data sets.

Further, space-time accessibility research has largely focused on automobile users to date because of data limitations. However, as the accessibility of individuals of marginalized or disadvantaged social groups is of particular concern, it is imperative to develop operational methods to also allow the study of non-automobile users and/or a joint travel mode.
GLOSSARY

*Act*: the maximum activity participation time regardless of facility opening hours

*ActT*: the maximum activity duration of opportunities that are reachable within their opening hours

*Area*: the sum of area of opportunities that are reachable within their opening hours

*Area*: the sum of area of urban opportunities within PPAs. a function of the attractiveness of the FOS. used as one of space-time accessibility indicators.

*CBD_DMILE*: the distance to the CBD,

*Dur*: the possible activity duration with respect to facility opening hours

Dynamic delay times: times spent during travel associated with traffic lights, turns, and traffic accidents

FOS: the feasible opportunity set. That is, urban opportunities within the space-time prism

*HHDDHRS*: the household work hours during a day.

*MAX*: the maximum travel time threshold

*MILES*: the commuting distance in miles,

*NEARCENT*: the distance to the nearest urban center in minutes,

*Num*: the total number of urban opportunities within the PPA. a function of the attractiveness of opportunities. used as one of space-time accessibility indicators.

*NumT*: the number of opportunities that are reachable within their opening hours

PPA: the potential path area. That is, areas within reach given an individual’s time budget and space-time fixity constraints.
Static delay times: times required for looking for a parking space, walking from/to opportunities before/after parking, or waiting for buses

$T$: this suffix represents measures incorporating the effect of the temporal availability of opportunity (i.e. reachable and non-reachable).

$W\text{Area}$: the sum of weighted area of opportunities that are reachable within their opening hours

$\text{Warea}$: the sum of weighted area of urban opportunities by their building height.

$WAREA10T$: the weighted areas of opportunities within the 10-minute distance from home,

$\text{WareaDur}$: the sum of opportunities weighted by their areas and possible activity duration.

$\text{WORKHRSW}$: the weekly paid-work hours


Blumen, O., 1994, Gender differences in the journey to work, Urban Geography, 15:3, 223-245.


Hanson, S., 1980a, Spatial diversification and multipurpose travel - implications for choice theory, *Geographical Analysis*, 12: (3) 245-251.

Hanson, S., 1980b, The importance of the multipurpose journey to work in urban travel behavior, *Transportation*, 9: (3) 229-248.


Hanson, S., and Hanson, P., 1980, Gender and urban activity patterns in Uppsala, Sweden, *Geographical Review*, 70, 291-299.

Hanson, S., and Hanson, P., 1981, The impact of married women’s employment on household travel patterns: A Swedish example, *Transportation*, 10, 165-183.


Hanson, S., and Pratt, G., 1990, Geographic perspectives on the occupational segregation of women, National Geographic Research, 6(4), 376-399.


Kwan, M.P., 1999a, Gender and individual access to urban opportunities: A study using space-time measures, *Professional Geographer*, 51: 2, 210-227.

Kwan, M.P., 1999b, Gender, the home-work link, and space-time patterns of non-employment activities, *Economic Geography*, 75(4): 370-394.


Nishii, K., and Kondo, K., 1992, Trip linkages of urban railway commuters under time-space constraints: some empirical observations, Transportation Research B, 26, 33-44.


Patton, 1976, The effect of accessibility on residential density, special report 7, Department of Civil Engineering, University of Melbourne, Melbourne;

Pickup, L., 1984, Women’s gender-role and its influence on their travel behaviour, Built Environment, 10, 61-68.


Turner T, and Niemeier D., 1997, Travel to work and household responsibility: new evidence, *Transportation*, 24: (4) 397-419.


