HOW FAR IS TOO FAR? SPATIAL AND SOCIO-DEMOGRAPHIC DETERMINANTS OF “LOCKED-IN” COMMUTING

DISSERTATION

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In the United States, people are traveling longer and farther to and from work. They are taking advantage of increasing highway capacity and variety in living and working locations to engage in increasingly inefficient commuting patterns. Commuting required by the spatial distribution of homes and jobs and people’s choices within these location choice sets are known to significantly impact observed work travel behavior. The part of observed commuting that is due to people’s choices and which potentially could be reduced if people swapped home and job locations is known as “excess commuting” and is the difference between the observed and required levels of work travel. Prior work defines the required level of work travel as the quantitative mismatch of all homes and jobs in a metropolitan area and explains the excess part as the effect of people’s socio-demographic characteristics and their housing and neighborhood preferences. These efforts do not adequately address the nature of the socio-spatial underlying required commuting.

It is understood that workers attempt to maximize their location utility within the spatial bounds, offered by urban form, embedded in socio-demographic processes. When making decisions where to live and work, people do not pick from all possible choices;
rather, their choice set is smaller and determined by factors such as: occupation; income; race; gender; transport mode; housing age, size and type preferences; access to environmental and leisure activities; school quality and safety concerns. This list shows that socio-demographic and preference factors constrain both home and workplace location choices. It is also clear that people make location decisions within an imperfect labor market suggesting that it is inappropriate to evaluate the efficiency of work trips against a baseline laden with assumptions of perfect competition and information.

The goals of this dissertation are accomplished by: (1) obtaining work trip flows disaggregated by occupation and income; and (2) developing a metric to track people’s location strategies relative to local and regional jobs. In order to evaluate the impact of socio-spatial mismatch on observed commuting behavior, an optimization model known as the transportation problem and a spatial interaction model are applied to commuting patterns in Wichita, Kansas and to a sample of U.S. cities. Results from Wichita indicate that the contribution of “locked-in” commuting to observed behavior varies among occupation-income groups. Moreover, empirical evidence from 25 U.S. cities suggests that the required commuting is a more significant contributor than previously thought. This research may benefit planning efforts aiming to reduce commuting through land use change.
DEDICATION

To Mom and Dad
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TABLE OF CONTENTS

Abstract ........................................................................................................................................ ii

Dedication ...................................................................................................................................... iv

Acknowledgments ..................................................................................................................... v

Vita ........................................................................................................................................... vi

List of Tables ............................................................................................................................. x

List of Figures ............................................................................................................................ xi

1. Introduction ............................................................................................................................ 1
   1.1 Background ......................................................................................................................... 1
   1.2 Problem statement .............................................................................................................. 4
   1.3 Research contributions ...................................................................................................... 6
   1.4 Dissertation outline .......................................................................................................... 8

2. Excess Commuting: Progress and Potential .................................................................... 9
   2.1 Introduction ......................................................................................................................... 9
   2.2 Modeling bounds on location mismatches ........................................................................ 12
      2.2.1 Density functions ......................................................................................................... 13
      2.2.2 Linear programming .................................................................................................... 14
   2.3 Uses of the excess commuting framework and its components ..................................... 15
      2.3.1 Predicting observed behavior ...................................................................................... 15
      2.3.2 Jobs-housing balance metrics ...................................................................................... 17
      2.3.3 Policy simulations ......................................................................................................... 19
   2.4 Location choice sets .......................................................................................................... 22
      2.4.1 Is occupation the only socio-demographic factor? ...................................................... 23
      2.4.2 What about site and situation? ..................................................................................... 26
2.5. Discussion and conclusion .......................................................................................... 28

3. Unraveling Distance and Access Considerations in Observed Location Behavior: an Excess Commuting Approach ........................................................................................... 31

3.1 Introduction ................................................................................................................. 31
3.2 Is access to the single local job the only location strategy? ......................................... 34
3.3 Measuring relative importance of location strategies .................................................. 36
   3.3.1 Observed behavior relative to the classical and revised theory .......................... 38
3.4 Data and analysis ........................................................................................................ 42
   3.4.1 Rationale .............................................................................................................. 42
   3.4.2 Data sources ........................................................................................................ 42
   3.4.3 Results ................................................................................................................ 43
3.5 Discussion and conclusion ......................................................................................... 48

4. Is the Journey-to-Work Explained by Urban and Social Structure? ............................. 51

4.1 Introduction ................................................................................................................. 51
4.2 Evolving definitions of required and excess commuting ............................................. 53
4.3 Redefining required and excess commuting ................................................................. 57
4.4 Data ............................................................................................................................. 61
   4.4.1 Estimating real work travel patterns by worker occupation and earnings .......... 62
   4.4.2 Commute benchmark estimates according to worker occupations and earnings ................................................................. 65
4.5 Application results ..................................................................................................... 66
4.6 Discussion and Conclusions ....................................................................................... 70

5. Income, Occupation and Commuting .......................................................................... 74

5.1 Introduction ................................................................................................................. 74
5.2 Spatial structure, commuting and location decisions .................................................. 76
5.3 Modeling real disaggregated work travel patterns ...................................................... 81
   5.3.1 Estimating work trips by occupation ............................................................... 82
   5.3.2 Estimating journey-to-work flow by occupation and income ........................... 82
5.4 Estimating work travel benchmarks ......................................................................... 83
   5.4.1 $T_{\text{min}}$ and $T_{\text{max}}$ ........................................................................................ 84
   5.4.2 $T_{\text{prop}}$ ............................................................................................................ 85
5.5 Analysis ....................................................................................................................... 86
   5.5.1 Study area ......................................................................................................... 86
   5.5.2 Results ............................................................................................................... 86
5.6 Summary and discussion ............................................................................................. 90
6. Conclusion .................................................................................................................... 94

6.1 Dissertation summary ....................................................................................... 95
6.2 Future directions ............................................................................................... 98

7. References................................................................................................................... 101
## LIST OF TABLES

Table 3.1 Various interpretations of commute benchmarks ............................................... 37
Table 3.2 Commuting metric value interpretations ............................................................. 41
Table 3.3 Regional commuting-analysis results. Cities where LS\(^+\) < 50% are highlighted. ........................................................................................................................................... 44
Table 4.1 Occupational classification scheme ................................................................. 63
Table 4.2 Overall regional commuting results for Wichita, Kansas (2000). ....................... 67
Table 5.1 Type and number of simultaneously worker characteristics used in estimates of average trip lengths. ........................................................................................................... 79
Table 5.2 Commute statistics by occupation type and earning groups for workers in Wichita, Kansas (2000) ........................................................................................................... 87
LIST OF FIGURES

Figure 3.1 Trip length curve in relation to land use configurations and access considerations ................................................................. 40
Figure 3.2 Location strategy (LS+) visualization for 2000 CTPP. ........................................ 47
Figure 4.1 Hamilton’s (1982) definition of required and excess commuting .................. 54
Figure 4.2 White’s (1988) definition of required and excess commuting ....................... 55
Figure 4.3 Commuting capacity extensions by Horner (2002) and Ma and Banister (2006). ................................................................. 57
Figure 4.4 Proposed redefinition of required, proportional, allowable and excess commuting. ................................................................. 60
Figure 4.5 Spatial Distribution of worker and job locations in Wichita, Kansas. .......... 70
CHAPTER 1

INTRODUCTION

1.1 Background

The journey-to-work is arguably the single most important recurring daily activity undertaken by households; for the vast majority of the population and for the foreseeable future, there is no other way to support the necessities and luxuries of everyday life. The work trip involves the need to use some form of transportation to overcome spatially separated residential and employment locations. Spatial separation between homes and jobs is a source of many urban problems, such as traffic congestion, air pollution, and inequality of access to suitable homes/jobs. Urban regions with good or poor proximity between home and job locations present different challenges to address negative externalities. The relationship between where people live and where they work motivates a considerable research effort in the urban literature.

Advances in transportation technology, which were made throughout the 19th and 20th centuries, have unleashed centrifugal forces that allowed people and jobs to escape the congestion of compact cities and settle in low-density suburban settings (Muller 2004;
Taaffe, Gauthier, and O'Kelly 1996). As decentralization continues unabated and the extent of the urban boundary is growing, the relationships between home and job locations are changing apace. The focus of commuting is no longer on the central core of the metropolitan area; rather, without an overwhelming employment attractor, commuting patterns exhibit unorganized tendencies, giving the result of long trip lengths. The national average journey-to-work distance in the U.S. has increased from 9 miles in 1975 to 13.4 miles in 2001 (Hanson 2004). The fastest growing commuting segment is the extreme work trip that takes ninety minutes one-way (Marion and Horner 2007). There were 34 million workers in 2000 who crossed county boundaries on the way to work spurred by the growth of intermetropolitan trips (8.3% of all trips in 2000) (Pisarski 2006).

Long work trips are problematic not only because they take time away from other activities, but also due to the overwhelming reliance on fossil-fuel-based automobiles that negatively impact the environment. In 2000, 88% of all work trips in the U.S. were made by private vehicles (Pisarski 2006). In the modern urban landscape, driving to work is a necessity because the separation between homes and jobs and low-density setting does not support the use of more environment-friendly modes such as transit, biking or walking. Spatial relationship between different land uses contributes to issues at the intersection of transportation and the environment and deserves research attention.
The shape of urban regions and internal structure of land-use are important in relation to environmental, urban service provision costs, and health problems. First, the spread of home and job locations, through increasing journey-to-work lengths and carbon-based automobile travel, is a major contributor to transportation emissions. The transportation sector is responsible for 33% of carbon dioxide emissions in the U.S (Brown, Southworth, and Sarzynski 2009). Carbon dioxide accounts for 95.4% of all transportation emissions and 84% of all greenhouse gas emissions (Brown, Southworth, and Sarzynski 2009; Greene 2004). Second, low-density landscapes increase the cost of providing basic services such as roads and transit, sewer, trash collection, street cleaning, emergency services, libraries, and child and elderly care (Burchell and Mukherji 2003; Carruthers and Ulfarsson 2003). More resources are needed to provide adequate levels of services to people spread out over vast expanses of land. Third, the use of the automobile, which is necessary due to poor home-job proximity, reduces the use of active transport modes such as cycling and walking and adds to insufficient physical exercise causing serious health problems such as obesity (Pucher 2004). In short, it is likely that management policies focused on land-use-based growth may help to alleviate many urban problems.

Improving the proximity between homes and jobs has been a planning goal since Howard’s garden cities idea in the early 20th century (Levine 1998) and continues today under the headings of jobs-housing balance, mixed-use development or smart growth (Cervero 1989, 1996b; Cervero and Duncan 2006; Ewing and Cervero 2001). The idea is
that improving the proximity between homes and jobs encourages shorter commutes and enhances the use of more active transport modes. The connection between land use and work trip patterns hinges on the substantial commute impact of land use, i.e. households make decisions where to live and work with some regard to separation between home and workplace sites. The operative word here is “some” because this assumption has attracted considerable attention and controversy. There is a difference of opinion on whether an active promotion of mixed-use development results in transportation benefits (Ewing and Cervero 2001; Giuliano 1991; Levine 1998; Sultana 2002). Partial evidence against the connection between changing land use and shorter work trips shows that the spatial distribution of homes and jobs does not explain observed work travel patterns well enough (Giuliano and Small 1993; Hamilton 1982). However, before any definitive conclusions are reached, it is important to measure the contribution of location choices to observed behavior. Advancing our understanding of the determinants of work travel patterns is crucial for policies aiming to improve urban quality of life.

1.2 Problem statement

It is well understood that the spatial distribution of homes and jobs, and workers’ socio-demographic profiles determine people’s location decisions and subsequently their journey-to-work length. What is less known is the relative importance of these constraints on workers’ location choices in general and on worker groups specifically. Theoretically, workers tend to minimize commutes within a subset of locations offered by urban form,
i.e. locations that are commensurate with their socio-demographic characteristics. These include occupation, income, race, gender, housing preferences, neighborhood amenities, household composition, and transport mode.

There is an extensive literature empirically testing the classic urban location trade-off between transportation costs (spatial constraints) and housing costs (socio-demographic constraints) (Giuliano and Small 1993; Hamburg et al. 1965; Horner 2002; Kim 1995; Ma and Banister 2006b; Watts 2009; Wheeler 1967b). There are, however, few studies that comprehensively and systematically investigate the determinants of location choices relative to urban form. When researchers do consider socio-demographic factors, they focus only on one of the work trip ends and in relation to an incomplete representation of urban form. It is understood, however, that workers attempt to maximize their utility, or find least-cost locations, within the spatial bounds embedded in socio-demographic processes (Wheeler 1967a).

There are four reasons to revisit the commute impact of land use. First, there is reason to believe that prior work fails to isolate the morphological and behavioral components of commuting due to an inadequate definition of behavioral commuting. Second, recent research provides new commute benchmarks that define the complete commuting scale of urban form and that make us look with suspicion at previous conclusions about the importance of work travel in how location decisions are made in relation to only one of the benchmarks. Third, commute benchmark metrics insufficiently capture socio-
demographic factors behind the housing cost component of the location trade-off. Fourth, previous modeling attempts do not capture socio-demographic constraints at the residential and employment ends of the work trip simultaneously.

1.3 Research contributions

It is reasonable that an empirical test of the classic urban location trade-off would compare observed and theoretical work travel patterns for worker groups with similar socio-demographic profiles. For instance, it is clear that plumbers and physicians do not pick from the same employment locations, while low and high income workers do not choose from the same residential sites. Unfortunately, prior work estimates purely distance-based theoretical commutes without much regard to worker heterogeneity and unsurprisingly commute length is deemed relatively unimportant in location choices. However, by partly attributing the deviation of observed work travel from the required commute to morphological constraints based on socio-demographic considerations, previous work has not fully isolated land use factors from commuting choices. The previously mentioned socio-demographic factors should be considered as contributors to the morphological component of observed commuting, because workers cannot be penalized for not making irrational decisions. Thus, I argue that the amount of commuting exceeding the required level is due to rational location choices with respect to the spatial pattern of homes and jobs commensurate with socio-demographic characteristics of households.
The spatial pattern of commensurate homes and jobs is benchmarked by three average trip lengths: minimum, proportional, and maximum. No previous research estimates the amount of behavioral commuting in relation to all three benchmarks for factors that constrain choices at the residential and employment ends of the work trips. In this work, I estimate these benchmarks for the worker population segmented by occupation and income, factors that are likely to have a combined constraining effect on location choices. Part of the paucity of work considering multiple constraining factors is due to limited dimensionality of the journey-to-work dataset available from the U.S. Census. I overcome this limitation by estimating trip lengths according to occupation and income using the information minimization method and a novel variation of the implicit data technique.

The potential benefits of this research appear to be a greater understanding of the effect of workers’ socio-demographic profiles on their residential and employment location choices as well as on commuting and job achievement outcomes. By detecting job achievement variations according to occupation and income in relation to urban form, this work makes connections to the spatial mismatch literature. Investigation of these and other issues, studied from the excess commuting perspective, may be expanded on the basis of the data extraction and modeling techniques presented in this research.
1.4 Dissertation outline

This dissertation is organized as follows. A critical review of the excess commuting framework, its uses, and socio-spatial determinants of observed and necessary commuting is presented in Chapter 2. Chapter 3 extends previous work by incorporating multiple representations of urban form and multiple location strategies. This way, distance and access considerations in location decisions are separated, thereby also providing an improved context for assessing the commute impact of land use. Chapter 4 incorporates two socio-economic factors in the empirical test of the urban location trade-off theory. I also propose an optimization model for assessing the contribution of necessary commuting to observed patterns incorporating social factors. Chapter 5 investigates the variations on location choice sets and mobility outcomes among worker groups under a level of detail that has rarely been achieved in this line of work. Finally, Chapter 6 provides conclusions and directions for future research.
CHAPTER 2

EXCESS COMMUTING: PROGRESS AND POTENTIAL

2.1 Introduction

Long distance travel in the U.S. is becoming an ordinary fixture of the urban landscape. Recent evidence shows that the amount of miles a person drives per vehicle, known as vehicle miles traveled (VMT), increased by approximately 67% between 1975 and 1999 (Giuliano 2004) and pertains to all trip purposes. Explosive growth in non-work trips means that work trips now comprise 16% of all travel, but they remain important because the transportation network is evaluated on the basis of its ability to handle peak work travel flow (Pisarski 2006). The rise in the U.S. average journey-to-work distance, from 9 miles in 1975 to 13.4 miles in 2001 (Hanson 2004), is partly propelled by growth in trips over 90 minutes each way, or extreme commuting (Marion and Horner 2007).

How far is too far? Researchers have for a long time contemplated this question about the relative importance of factors contributing to observed travel, i.e. those beyond a household’s control and those that are within its means to change. That is, some part of travel is required by the distribution of activities and another part is due to people’s choices to skip over the closest sites. The existing substantial literature gives us some
explanation of the differences in observed travel for different groups, trip purposes or modes (Crane 2007; Hanson 1982; Preston and McLafferty 1999; Redmond and Mokhtarian 2001), though there is less emphasis laid on understanding how constraints on location behavior produce necessary travel. At issue is whether or not “locked-in” travel is a substantial contributor to the total amount. The newly emerging literature on excess travel takes aim at establishing the bounds within which people make their choices. The recent focus on excess driving (Handy, Weston, and Mokhtarian 2005) and on excess non-work journeys (Horner and O'Kelly 2007) may be attributed to the long-standing interest in excess commuting.

Excess, or wasteful commuting as originally coined by Hamilton (1982) but dating back to Hamburg et al. (1965) and Wheeler (1967b), describes the amount of observed travel that is above the level required by the distribution of home and job locations. A large deviation between required and observed work travel is said to indicate a negligible contribution of necessary travel, ergo, people chose to travel longer. The initial emphasis was on free choice of all locations in a metropolitan area and researchers were slow to recognize how socio-economic and demographic constraints shape a households’ set of possible locations and consequently their required commute. Since a host of location mismatches are important in determining the household’s necessary work travel, it is imperative that we adopt a broader definition of commute bounds. Omitting factors such as income, house size or amenity access renders the excess commuting approach much less useful in addressing real world policy issues.
Growing out of their original use as a test of the classical urban location trade-off theory, the commute bounds have been used in a variety of ways, such as describing and improving jobs-housing balance to support land use policy that aims to reduce externalities and inequalities. The concern is that the results and policy suggestions of these studies may be misrepresented if the impacts of social and economic relations are not considered. I emphasize how location constraints vary by worker characteristics and preferences, and I also argue that as a strategic tool, excess commuting relies on the accurate modeling of differences in geographical barriers with respect to residential and employment choices. This review differs from Ma and Banister’s (2006a) recent effort, because my concern is with the question of what contextual factors explain the level of required commuting.

After a brief introduction to excess commuting (section 2.2), this chapter reviews different uses of this approach in section 2.3 to attract attention to the breadth of research questions to which it can contribute, to point out what has been learned about location choices and to identify potential research directions as this area of travel analysis remains understudied. Site and situation preferences are emphasized in sections 2.4.1 and 2.4.2, respectively. The chapter ends with conclusions and potential contributions.
2.2 Modeling bounds on location mismatches

Commuting happens because of location mismatch, that is, the spheres of home and work are spatially separated, requiring some minimum level of work travel for households to attain employment in order to sustain the necessities of life. If every household could live and work in the same geographical location, there would be no need for commuting, and the required and actual work trip distances would be zero. Location mismatch “pushes” workers to search for jobs outside of their home location and forces employers to “pull” employees from outside of their workplace site, but the issue at hand is the extent at which the observed commute exceeds the minimum pattern supported by the land use configuration.

Excess commuting is a construct to compare actual work trip lengths in a region with the minimum required commute. In the U.S., the actual commute length is calculated from data provided by the Census Bureau in the form of the Census Transportation Planning Package (CTPP). The required work travel level is defined as the minimum miles or minutes to connect the closest homes and jobs, which is simply a function of the actual spatial distribution of all homes and workplaces. Mathematically, excess commuting (EC) is found by:

\[
EC = \left( \frac{T_{\text{real}} - T_{\text{min}}}{T_{\text{real}}} \right) \times 100
\]

(2.1)

where \( T_{\text{real}} \) is the real observed commute and \( T_{\text{min}} \) is the minimum required commute.

Both are average trip lengths based on the number of workers (\( W \)), the travel costs (\( C_{ij} \))
between home \((i)\) and job \((j)\) sites, and either the actual work trip distribution, \(X_{ij}^{\text{real}}\),

\[
(T_{\text{real}}^{\text{real}} = \frac{1}{W} \sum_i \sum_j C_{ij} X_{ij}^{\text{real}}) \text{ or the minimum pattern, } X_{ij}^{\text{min}} \quad (T_{\text{min}}^{\text{min}} = \frac{1}{W} \sum_i \sum_j C_{ij} X_{ij}^{\text{min}}).
\]

Notice that the only unknown in equation (2.1) is \(T_{\text{min}}^{\text{min}}\) and the excess commuting literature provides two alternative ways of finding the minimum work travel level.

### 2.2.1. Density functions

Economists have used negative exponential density functions in two different ways to quantify \(T_{\text{min}}^{\text{min}}\). First, Hamilton (1982) proposed that \(T_{\text{min}}^{\text{min}}\) is the difference between the average distance from housing to the central business district (CBD) and the average distance from the employment location to the CBD. The average distances are found by integrating over the negative residential and employment exponential functions taking the CBD as the monocentric location of a given metropolitan area. Note that since an estimate of urban structure itself is used as input to an estimate of \(T_{\text{min}}^{\text{min}}\), there is a significant risk of error propagation if an inaccurate model of urban form is used.

Second, instead of assuming circular zones around the CBD, Song (1994, 1995) estimates the number of workers living in and the number of jobs for each census areal unit in a metropolitan area. These zonal counts are estimated using monocentric, polycentric, and dispersive residential and employment density functions. This test of urban structure estimates shows that error propagation is reduced with increasing accuracy of modeling.
actual home and job patterns (Song 1994, 1995). The estimated zonal counts are then used as an input to a linear program known as the transportation problem.

### 2.2.2. Linear programming

Geographers, regional scientists and planners have used the transportation problem, a deterministic utility location model, to estimate $T_{\text{min}}$. Researchers since White (1988) have adopted Hitchcock’s (1941) cost minimization assignment model, originally used in a logistics context, to construct a journey-to-work matrix ($X_{ij}^{\text{min}}$) of the shortest possible trip lengths that are consistent with the spatial distribution of residential and employment sites. Actual home and workplaces are aggregated into zones that form a division of the metropolitan area where each areal unit contains the total employment in zone $j$ ($D_j$) and total labor supply in zone $i$ ($O_i$). $O_i$ and $D_j$ are known in advance from CTPP data ($O_i = \sum_j X_{ij}^{\text{real}}$, $D_j = \sum_i X_{ij}^{\text{real}}$) or density function estimates. Since travel costs between every zonal pair are also known ($C_{ij}$), $T_{\text{min}}$ is found by the following:

$$T_{\text{min}} = \text{minimize} \, \frac{1}{W} \sum_i \sum_j C_{ij} X_{ij}^{\text{min}}$$

subject to:

$$\sum_j X_{ij}^{\text{min}} = O_i \quad \forall i$$

$$\sum_i X_{ij}^{\text{min}} = D_j \quad \forall j$$

$$X_{ij}^{\text{min}} \geq 0 \quad \forall i, j$$

14
In the resulting work travel matrix \( X_{ij}^{\min} \) workers are matched with jobs in the lowest possible travel cost (2.2) requiring that each worker is employed (2.3), and that each job is filled (2.4), while all flow is non-negative (2.5). In sum, the model provides an assessment of the level of location mismatch given the existing land use configuration.

2.3. Uses of the excess commuting framework and its components

2.3.1 Predicting observed behavior

The excess commuting literature originated as an empirical test of the cost-minimizing behavior of households (Hamburg et al. 1965; Hamilton 1982; Wheeler 1970) based on assumptions stemming from the classical urban location theory (Alonso 1964; Giuliano 2004; Herbert and Stevens 1960). The theory’s main feature proposes that all households trade-off housing and commuting utility when deciding where to live and work. The resulting location strategy maintains that it is most advantageous to live/work as close as possible to the job/home location. In the aggregate, the predicted commuting pattern is simply a function of the land use configuration, because households cannot exchange home/work locations to reduce travel costs of the urban system (Herbert and Stevens 1960; Wheaton 1974; Wilson and Senior 1974). Therefore, the observed pattern is equal to the predicted commute.

Most of the early research shows that the observed average trip length is poorly explained by the spatial pattern of homes and jobs. In most cases, excess commuting values are
greater than 50%, which means that urban structure explains less than 50% of real commuting patterns. Perhaps the weakest support for commute minimization behavior comes from those studies that use the monocentric model to estimate $T_{\text{min}}$. This work finds an average excess commuting value of 84.85%, ranging from 81.59% to 87.1% (Hamilton 1982; Merriman, Ohkawara, and Suzuki 1995; Small and Song 1992; Song 1995). However, these findings, unsurprisingly, are a rejection of people’s intent to minimize travel cost to the CBD and not travel cost to employment opportunities in general. Despite the use of the actual land use pattern or of dispersive density function estimates as inputs into the TP, results did not offer strong support for cost-minimization behavior holding spatial structure constant. In this case, the average excess commuting value was 64.77% with a range of 47.1-79.85% (Chen 2000; Giuliano and Small 1993; Hamilton 1989; Scott, Kanaroglou, and Anderson 1997; Small and Song 1992; Song 1995). The conclusion was reached that minimizing home-work separation is of little importance in household location choices, or in other words, necessary work travel is not a significant contributor to observed commuting. The relevance of commute reduction policy strategies was put into doubt because apparently households value other location factors more than they do the journey-to-work length.

Although required commuting seems to be a poor explanatory factor in real work travel, the impact of spatial constraints due to the land use configuration was not fully understood. The previously mentioned studies overestimated excess commuting because they did not place observed behavior in the context of the commuting capacity offered by
the land use. Having related real commuting to a lower and upper bound, more recent work finds a lower average excess commuting value of 32.97% with a range of 15.58%-67.2% (Horner 2002; Ma and Banister 2006b; Niedzielski 2006; O'Kelly and Lee 2005). The upper bound is $T_{\text{max}}$, the maximum allowable commute, and is found using the linear program in (2.3)-(2.5), though with a different objective:

$$T_{\text{max}} = \max \sum \sum C_{ij} X_{ij}^{\text{max}}$$  \hspace{1cm} (2.6)

where $X_{ij}^{\text{max}}$ is the highest possible cost trip distribution given the constraints in (2.3)-(2.5).

### 2.3.2. Jobs-housing balance metrics

Whereas the excess commuting metric is used to differentiate between necessary and choice-based work travel, minimum required commuting ($T_{\text{min}}$) itself is a direct indicator of the level of mismatch between home and work locations. Quite simply, if homes and jobs are well intermixed, creating a potential for short distance work trips, then the value of $T_{\text{min}}$ is lower than if the juxtaposition is poor (Giuliano and Small 1993; Horner 2002). Thus, planning for jobs-housing balance has become an important policy issue, because of potential benefits, such as reduced carbon footprints, lower costs of providing urban services, and less health problems (Atash 1996; Burchell and Mukherji 2003; Carruthers and Ulfarsson 2003; Cervero 1989). In an inter-regional comparison, Horner (2002) found that employed workers tend to have shorter commutes when they live in a city with a healthier home-job mix. This suggests the appropriate scale for the relevance of jobs-
housing balance is the local or neighborhood level, because metropolitan areas are balanced by definition due to their self-containment (Giuliano 1991; Peng 1997).

How cities are organized internally impacts households commuting outcomes. Several researchers have found that households living in housing-rich areas have very long work trips compared to those living in jobs-rich communities with very short commutes (Levinson 1998; Peng 1997; Sultana 2002; Wang 2001). Jobs-rich areas, on the other hand, import employees from longer distances and employers in housing-rich sites tend to fill jobs with local workers (Levinson 1998). Overall, Horner (2007) finds that households living in balanced areas within the city tend to travel shorter distances. However, the net outcome is dependent on how jobs-rich, balanced, and housing-rich areas are spatially related to each other.

For commute reduction policies, the regional configuration of homes and jobs is as important as the local proximity between them, because it is the attraction of employment clusters that has the greater impact on work travel patterns (O'Kelly and Lee 2005). Research by Horner (2007) in Tallahassee and Yang and Ferreira (2008) in Atlanta and Boston shows a positive relationship between the regional dispersal of employment opportunities and observed work travel. These researchers use excess commuting components to gauge the relationships between local and regional land-use configuration. Horner (2007) uses $T^{\text{max}}$ to measure the farthest distance between a specific home and job location, where a larger $T^{\text{max}}$ value indicates less-defined attractors due to the spread of
these locations on average (Horner 2002). Yang and Ferreira (2008) use a third metric known as the proportional commute, $T_{prop}$, which finds the regional average proximity from homes to multiple alternative job sites. Conceptually, it is a commute pattern where distance does not play a role in spatial decisions and the work trip distribution, $X_{ij}^{prop}$, is simply a proportional matching of regional homes and jobs. $T_{prop}$ is found by:

$$T_{prop} = \frac{1}{W} \sum_i \sum_j C_{ij} X_{ij}^{prop} \quad (2.7)$$

where $X_{ij}^{prop} = \frac{O_{ij} D_{ij}}{W}$. Larger $T_{prop}$ values indicate poorer multiple proximity or access, because these alternative opportunities are more dispersed.

### 2.3.3 Policy simulations

Implementing jobs-housing balance as a policy remains a controversial topic because the objectives and actual policy approach are still contested. Some researchers believe that jobs-housing balance policy may reduce the amount of commuting, congestion and pollution (Cervero 1989, 1991; Levinson 1998; Sultana 2002), though others are skeptical about the transportation benefits of land use change, pointing to the capacity-usurping principle at work in a similar fashion when transportation capacity is increased (Giuliano 1991; Levine 1998). Depending on the perceived benefits of jobs-housing balance, the goal of land-use-based policies is either to alleviate transportation or social problems. Notwithstanding the objective of jobs-housing balance policy, there is disagreement as to the role of government intervention in promoting home-work
proximity. Most researchers would agree that intervention is justified, but the
disagreement centers on whether the intervention should establish policies actively
promoting diverse land use patterns (Cervero 1989, 1991) or to end exclusionary land use
practices that distort the land market (Giuliano 1991, 1995; Levine 1998). It is not
surprising that the objective and policy approach to jobs-housing balance are contested,
given philosophical differences over social, economic and environmental issues (Shen
2000), but sustainable urban growth is dependent on a combination of land use and
transport pricing policies acting in concert (Cervero and Landis 1995).

Policies targeting local land-use mix (Cervero 1989; Horner 2004; Sultana 2002) and
regional balance (Schwanen, Dijst, and Dieleman 2004; Yang and Ferreira 2008) support
sustainable urban futures (Black 1996) and are often found in local and regional
government plans. Examples of promoting shorter work trips include encouraging
homeownership within the city of Baltimore (Yang 2008) or Chicago, and long-range
provisions for improving local imbalances such as in Southern California (Giuliano 1991;
Scott, Kanaroglou, and Anderson 1997; Wachs et al. 1993). To ensure London’s vitality,
the Mayor argues that the “best option – environmentally and economically – is to reduce
the distance between [home and work locations] and simply to reduce the need to travel
longer distances” (Greater London Authority, p. 29). Policy-makers need specific
planning recommendations to put into practice and the excess commuting framework
used in a prescriptive manner is perfectly poised to make important contributions to the
transport and land use planning initiatives.
Motivated by potential benefits, which land-use changes may bring, researchers have simulated the effect of such policies on commute lengths providing direct planning guidelines. The effects of alternative land-use configurations on actual commutes are investigated indirectly by gauging the impact on $T_{\text{min}}$. Scott and Getis (1998) exogenously determine changes to home and job locations in Los Angeles, though they do cannot guarantee an optimal land-use configuration. Merriman et al. (1995) used $T_{\text{min}}$ prescriptively by testing exogenous home-job distributions on regional commuting patterns in Tokyo. Unfortunately, since home-job configurations are set a priori in both cases, the alternative location scenarios are not guaranteed to result in the most effective inter-mixing of home-workplace sites.

It is possible to simulate optimal distributions of residences and workplaces through extensions on linear programs such as in equations (2.2)-(2.5) that allow land-use changes to be determined endogenously. Horner and Murray (2003) use an extended $T_{\text{min}}$ model to physically move homes and jobs to achieve healthier balance. They find that in Atlanta, Georgia, the greatest reduction in $T_{\text{min}}$ occurs when homes are recentralized, though clearly not a very likely scenario. In contrast to physical changes in urban form, Horner (2008) asks how additional new homes and jobs may be added to the current fixed distribution in Tallahassee, Florida, to achieve a greater proximity between labor supply and demand. The idea is that targeted incremental changes are much more politically practical and palatable.
2.4. Location choice sets

Studies reviewed in the previous section greatly advance the policy-relevance of the excess commuting framework by investigating the importance of commuting cost in location decisions, measuring the location mismatch level or detailing which specific parts of a region should be targeted for labor supply and demand changes. However, the narrow focus on homogenous households in these studies, for the most part, is a misrepresentation of location mismatch, and may be part of the reason, along with methodological uncertainties, why excess commuting work has “…rarely been used to support real-world policy…” (Ma and Banister, 2006a, 763). Since the contribution of excess commuting is the contextualization of observed choices, a rethinking of the basic concepts is a matter for renewed debate about what constitutes “real” excess commuting. The key question is this: are location choice sets the result of a general location mismatch? Or are they due to socio-spatial mismatch when worker characteristics are taken into account? The former implies that people’s spatial context for selecting locations is independent of their constraints and preferences while the latter implies that there is a systematic variation in location choice sets with household characteristics affecting commuting outcomes. The policy-relevance of the excess commuting framework is likely to be increased when location mismatch is conceptualized as resulting from social constraints embedded within spatial constraints.
Socio-spatial mismatches have been used to explain excess commuting but there is reason to believe that they contribute to necessary work travel. Despite well-known constraints on household location choices (Ma and Banister 2006a; Mills 1998), the excess commuting literature for the most part focuses on homogeneous households with few exceptions. There is a vast urban geography literature that investigates differences in mobility and summarizes the explanations behind variations under three groupings: socio-economic-demographic, site and situation. Put another way, these household characteristics are factors in selecting residential and employment locations and it seems reasonable that these characteristics also lead to constrained location choice sets or options, which are different among households. Location choice sets, subsets of all possible locations in the region, define the spatial decision-making space for households and are limited by factors such as occupation, income, race, gender, housing amenities or access to recreation among others. The implication is whether current definitions of required/allowable and excess commuting appropriately capture the spatial decision-making process and the constraints on it.

2.4.1 Is occupation the only socio-demographic factor?

In the excess commuting literature, there are exceptions to homogeneity constraints seen in several papers examining the impact of occupation on location choice sets (Bill, Mitchell, and Watts 2008; Giuliano and Small 1993; Horner 2002; Ma and Banister 2006b; O'Kelly and Lee 2005; Watts 2009; Wheeler 1967a). Researchers find a tendency for actual work trip lengths to be positively associated with occupation status, though this
association is less clear with the minimum commute. This suggests that the contribution of “locked-in” commuting varies by occupation, and, moreover, it also varies for the same occupations by region (O’Kelly and Lee 2005). More research is needed to understand the impact of geographical context, occupation definitions and aggregations on location choices and outcomes. Although occupation is an important agent of influence on where people work and subsequently on the commute length (Cubukgil and Miller 1982), occupation does not exhaust the determinants of location choice sets and yet it is the single most studied worker characteristic in the literature (40% of all papers).

By focusing mostly on occupation, other factors impacting residential location have been omitted. Though rarely studied (Hamburg et al. 1965), income rather than occupation is clearly a more relevant factor in deciding where to live. It has been assumed that occupation is a good proxy for income (Giuliano and Small 1993), but wage variations do exist within each occupation which determine affordable housing locations (Cervero 1996; Manning 2003; O’Kelly and Mikelbank 2002). Transportation mode influences residential and employment outcomes as well as location options (Taylor and Ong 1995). Whether people choose or are constrained to use transit, it is clear that location choices for this group are dictated by the public transport network. Unfortunately, this factor has received little attention in excess commuting work (Hamburg et al. 1965; Horner and Mefford 2007). Housing options are also affected by housing tenure. Differences in location choices and outcomes are related to home ownership or renter status, because this is associated with income and spatial distribution of owner or renter housing.
(Punpuing 1993). It is not surprising that Cropper and Gordon (1991) and Kim (1995) find owners to have a more constrained choice set.

There is an extensive literature wherein the impact of demographic factors - such as gender and race - is examined with regard to observed work travel (general overviews include Hanson and Pratt 1988; Holzer 1991; Preston and McLafferty 1999). Evidence from the spatial entrapment literature suggests that women have shorter commutes because of household responsibilities, such as caring for children and other housework duties (Johnston-Anumonwo 1992; McLafferty and Preston 1997; Prashker, Shiftan, and Hershkovitch-Sarusi 2008; Turner and Niemeier 1997). Spatial mismatch research shows that whites travel longer to work than blacks after controlling for earning and location amenity differentials (Gabriel and Rosenthal 1996; Wheeler 1968; Zax 1990). It is also known that the interaction of both socio-economic and demographic factors results in commuting outcomes that deviate from these generalities. For instance, black women using transit travel longer to work than white women and minority men (Johnston-Anumonwo 1997; McLafferty and Preston 1997). It is evident that the interaction of demography and commuting outcomes is nuanced, but the question remains how the outcomes are related to the underlying home and work separation and how this relationship varies across racial/gender groups. Women may travel shorter distances to work, but is required commuting also lower for them? Are jobs and housing better balanced for women than men and what does that mean for constrained work trips? It is clear that future research should explore the relationship between jobs-housing balance
and commuting for racial and gender groups to enrich the spatial entrapment and mismatch debates before any definitive conclusions may be reached.

2.4.2 What about site and situation?

Socio-economic and demographic characteristics are not the only factors associated with the size and shape of location choice sets. Site and situation are equally important factors (Kim and Morrow-Jones 2005; Rouwendal and Meijer 2001; Schwanen and Mokhtarian 2004), but their omission may underestimate the impact of location mismatch on observed commuting (Cropper and Gordon 1991; Ng 2008). There is considerable evidence in the literature that residential location decisions are influenced by people’s preferences for housing and neighborhood amenities (Alperovich 1980; Kim and Morrow-Jones 2005; Ng 2008; Rouwendal and Meijer 2001; Schwanen and Mokhtarian 2004). Data constraints may have played a role in these factors not appearing in past efforts at estimating “locked-in” commuting, but site and situation variables may be captured using geographic information systems (GIS) techniques (Kim, Horner, and Marans 2005).

Residential location choices are constrained by housing amenities. These include housing characteristics such as age, value, and type (Kim and Morrow-Jones 2005; Schwanen and Mokhtarian 2004), and life cycle stage and household composition factors such as the size of the household and age of its members. Homes further away from the central core of the metropolitan area that are newer, cheaper, and larger (Giuliano 1995; Wachs et al. 2004).
1993) may be more attractive to families with children who may prefer more living space and larger lot sizes that those with fewer or no children. Single-worker households or those without children are less likely to be influenced by site characteristics valuing job access more (Kim 1995; Kim, Horner, and Marans 2005).

Neighborhood amenity preferences produce large differences in location decisions among households (Alperovich 1980; Ng 2008; Rouwendal and Meijer 2001). Relative location choices reflect household lifestyle preferences based on their life cycle stage which evolves over time (Krizek and Waddell 2002). One of the key features underlying spatial decisions is density because it is a surrogate of urban conditions (Levinson and Kumar 1997). Higher density areas, usually closer to the region core, offer positive externalities such as more opportunities of all kinds within the same distance as compared to lower density areas. Younger or unmarried households are more likely to prefer heterogeneous activities and people more prevalent in urban places as opposed to couples with children preferring settings that are less dense, less urban, more homogeneous with better natural environment access (Kim, Horner, and Marans 2005; Schwanen and Mokhtarian 2004). Furthermore, advantages of less dense locations perceived by households with children relate to the health and development benefits of less pollution (Cummins and Jackson 2001), better school quality (Kim and Morrow-Jones 2005; Merriman and Hellerstein 1994) and less crime (Kim and Morrow-Jones 2005; Morrow-Jones and Kim 2009).
Most research on location choices focuses on the home end of the work trip, but characteristics at the work end of the commute are also important in observed and theoretical outcomes. It is well-known that the work trip is influenced by wage, economic sector and density differences as well as occupation types (Manning 2003; Merriman and Hellerstein 1994). Within their location options, however, workers may choose to travel longer to access higher wages or in anticipation of switching to better paying jobs in the future due to better information access (Crane 1996). Those location options, however, may be limited by workplace preferences. Recent research shows that “local amenities, leisure opportunities, and opportunities to socialize” (Shearmur 2006, p. 355), associated with the workplace, contribute to decision-making over and above socio-economic and demographic factors. Workplace preferences may be important influences on location sets in addition to residential preferences (Shearmur 2006).

2.5. Discussion and conclusion

Work travel in excess of that required by urban structure is problematic because of its detrimental impact on sustainable urban growth (Horner 2004). The central question that this chapter has probed is how the impact of urban structure or “locked-in” commuting on observed outcomes should be measured and has motivated debate on this issue by reviewing methodological and contextual contributors. This chapter has shown that while three benchmarks of urban structure are being used to capture bounds on location options, the complexities behind what constitutes these bounds have received considerably less attention.
The excess commuting framework is discussed with respect to research on factors determining residential and employment location decisions. Analysis of these topics shows that observed location behavior and resulting commuting outcomes are influenced by three dimensions – socio-economic-demographic, site, and situation – and this chapter argues that they be taken into account in estimates of theoretical commutes. When people search for locations to live and work they limit their potential sites based on who they are, what type of dwelling they want and the amenities they want to be close to. The implication is that neglecting this heterogeneity underestimates the impact of location choice sets and may prematurely undersell the potential benefits of land-use strategies for urban policy and planning. More research is clearly needed to understand the differential impact of urban structure on different households so that policy efforts may be better informed.

Apart from broader questions raised with regard to what constitutes location mismatch, this chapter demonstrates the flexibility of the excess commuting approach. Originally, used as a test of the maximum utility location theory, the actual-theoretical commute comparison or the benchmarks themselves have the potential to contribute to contemporary debates surrounding spatial mismatch and commute reduction policies. With excess commuting it is possible to investigate whether spatial entrapment or mismatch persists after controlling for location choice sets. Recent methodological contributions by O’Kelly and Lee (2005), Niedzielski (2006) and Horner (2007) allows
these sorts of questions to be analyzed at a local scale overcoming the very aggregate intra-metropolitan comparison prevalent in the literature. Extensions on the basic model may provide guidance to policy makers how best to reduce commutes with the least land-use change effort. Ultimately, the success of investigation along these and other research avenues is dependent on more accurate measurements of “locked-in” commuting. There is still scope to work within the bounds of current data limitations, but “greater efforts can be made to improve data collection” (Cubukgil and Miller 1982, p. 252) and incorporate other sources. In this last regard, the use of geographic information systems (GIS) holds promise for substantial contributions to commute-related research (Kim, Horner, and Marans 2005).
CHAPTER 3

UNRAVELING DISTANCE AND ACCESS CONSIDERATIONS IN OBSERVED LOCATION BEHAVIOR: AN EXCESS COMMUTING APPROACH

3.1 Introduction

The commute impact of land use remains an important topic for research, not least because of the contribution of journey-to-work lengths to a city’s carbon footprint (Brown, Southworth, and Sarzynski 2009) or because of the higher costs of providing basic services to sprawling cities (Burchell and Mukherji 2003; Carruthers and Ulfarsson 2003). Central to any debate on commute length explanations is the classic urban location theory, which proposes that location choices are based on extracting the greatest benefit from transportation and housing costs (Alonso 1964). An intriguing way to test this theory is to compare actual commuting with the theoretical pattern using the monocentric model or linear programming. Small and Song (1992) argued convincingly that the optimization approach is more suited to the task, because it is based on the actual home-job distribution.

The assertiveness of the title of Small and Song’s paper (“Wasteful commuting - a resolution”; 1992) implies thoroughly worked out concepts and methodology. Despite
this, however, issues in this framework, known as excess commuting, are far from resolved. Small and Song (1992) only established the difference between testing the ability of density functions to explain real commuting and testing the behavioral assumptions of the classic urban location trade-off. To perform the latter, Small and Song (1992) use the actual home-job distribution pattern as an input into the minimum required commute ($T_{\text{min}}$) model, a special type of linear program. The $T_{\text{min}}$ model reflects the transport costs of urban location theory and, when compared with actual commuting, it is used to make conclusions about the commute minimization assumption in the standard theory (Hamilton, 1989). Based on results implying that 66.3% of real commuting is excess, Giuliano and Small (1993) conclude that work travel is not important in workers spatial choices because the “…behavioral assumption of cost minimization in the standard model is inadequate to explain commuting” (p. 1486).

Giuliano and Small’s (1993) findings, however, could be misleading if $T_{\text{min}}$ inadequately represents urban structure and people’s location strategies. To the extent that perfect competition and information assumptions hold, then $T_{\text{min}}$ is sufficient as a baseline for commute importance conclusions. The actual-minimum comparison, however, ignores market imperfections that might interfere with the goal of economizing on distance. Thus, it is not possible to distinguish whether Giuliano and Small’s (1993) findings are a rejection of commute distance minimization or of the more fundamental assumption of commuting behavior whereby urban workers economize on access to jobs. It might not be surprising to challenge the assumption of commute minimization, though the rejection of
urban structure as a key determinant in residential/employment location challenges the validity of location theory.

If land use policies to reduce cities’ carbon footprints, service provision costs, or social inequality are to be effective, we need to understand the impact of urban structure on location and commute decisions. This can only be accomplished if we go beyond the single representation of urban form and location strategy to incorporate multiple perspectives. Despite recent developments, including the proportionally matched commute ($T^{\text{prop}}$) (Yang 2005) and the maximum allowable commute ($T^{\text{max}}$) (Horner 2002), a unified framework has not been proposed and the debates on commute importance in location decisions have not been updated. The first purpose of this chapter is to combine the different benchmarks and strategies to provide a complete commuting scale with a new baseline against which to draw conclusions about the importance of work travel in people’s spatial decision-making process. If, even after controlling for other benchmarks, empirical evidence would show a significant difference between minimum and actual average trip lengths, it may be because people prefer multiple opportunity access (Crane 1996; Giuliano 1989). The second purpose is, therefore, to examine empirically the following question: what type of location strategy better explains workers observed aggregate journey-to-work pattern? By combining distance and access considerations, a new context for understanding aggregate observed work travel behavior is proposed.
3.2 Is access to the single local job the only location strategy?

Commuting is the outcome of what choices households make about where to live and work. Idealistically, these choices are governed by the existence of direct compensation between the length of the commute and consumption of living space. Each household is able to freely exchange longer (shorter) work trips for more (less) living space in the urban location market with three components: labor, housing, and transportation (Rouwendal and Nijkamp 2004). Some households travel longer between home and work because it is simply not possible for equidistant commuting by each household given land use constraints. In the equilibrium, however, the disutility of longer trips is offset by more space or higher remuneration. The urban location market is cleared because each household extracts the same utility or benefit from the chosen locations and as a result is indifferent to work travel distance (Alonso 1964; Giuliano 2004; Rouwendal and Nijkamp 2004).

Assuming that people are free to exchange home and job locations and that they have a preference for shorter commuting distance, classic urban location theory predicts that the aggregate commuting pattern for all households in a given urban area is as short as possible given the constraints of the land use configuration. The shortest average trip length, $T^{\text{min}}$, represents classical theory with all the assumptions that come with it: perfect competition and information. In other words, $T^{\text{min}}$ reflects people’s behavior embedded within perfectly functioning and completely transparent labor and housing markets without uncertainty in regard to future outcomes. Empirical evidence, however, shows
that the deviation between $T_{\text{min}}$ and real observed commuting ($T_{\text{obs}}$) is significant, thereby it is concluded that household’s commute and access considerations are weak in their spatial choices (Giuliano and Small 1993; Hamilton 1989; Small and Song 1992). The deviation, known as excess commuting (EC) was originally expressed mathematically as:

$$EC = \frac{T_{\text{obs}} - T_{\text{min}}}{T_{\text{obs}}} \times 100.$$  

(3.1)

Note that by comparing $T_{\text{obs}}$ against $T_{\text{min}}$, the impact of urban structure on observed location choices is misestimated, because the framework in (3.1) misrepresents the actual commuting range of a metropolitan area and the cost-access relationship.

The point at which we begin to better understand the context for observed behavior is when we realize that commute distance and location access are separate considerations in deciding where to live and work. The classical theory, as represented by $T_{\text{min}}$, assumes there is no difference between minimizing distance and maximizing access, but this may not be an accurate reflection of reality. If access is defined the standard way, i.e. as location advantage with respect to the distribution of employment opportunities, then being close to the single local job may not exhaust all types of location strategies. Extensions to the classical theory provide alternative explanations of observed behavior that suggest location access is multi-dimensional.

Researchers have revised classical location theory by suggesting that many factors are rational contributors to longer work trip lengths. The revised theory is based on the understanding that labor and housing markets are imperfect (Giuliano 1989; Rouwendal
and Nijkamp 2004). In the real and imperfect world, information barriers preclude full knowledge of all job vacancies and all available workers, employment instability and uncertainty increase households expectation about future job changes, and job and housing searches as well as the actual relocation require substantial monetary and time expenditures (Crane 1996; Giuliano 1989; Rouwendal and Nijkamp 2004; van Ommeren, Rietveld, and Nijkamp 1997). Because people are rational, they may engage in longer commutes by maximizing access to multiple job sites to decrease the duration of unemployment or increase wages (Giuliano 1989; Rouwendal and Nijkamp 2004). If markets are imperfect and minimum distance-maximum access considerations might diverge, then it may not be reasonable to compare $T_{\text{obs}}$ with $T_{\text{min}}$. Since multiple access may involve longer commutes, there is a need for “…developing models that aim to capture more relevant aspects of the reality of urban life…” (Rouwendal and Nijkamp 2004, p. 293).

3.3 Measuring relative importance of location strategies

Incorporating multiple perspectives extends the usefulness of the excess commuting framework in several ways. First, $T_{\text{min}}$ along with $T_{\text{prop}}$ and $T_{\text{max}}$ are the three benchmarks that represent the commuting range of a metropolitan area. Whereas $T_{\text{prop}}$ is the proportional average trip length where distance does not play a role in location choices\(^1\) (Hamburg et al. 1965; Yang 2005; Yang and Ferreira 2008), $T_{\text{max}}$ is the maximum trip

\(^1\) See page 366 of Yang and Ferreira (2008) for the formulation
length demarcating the upper bound on the commuting possible in a region. Second, it may be possible to distinguish between commute and access considerations in location decisions. The latter is a more fundamental assumption of the urban location theory, because it represents a multiple perspective on the commute impact of land use where commute minimization is only one type of commute economy. A multiple perspective is achieved by the integration of cost (Evans 1973), access (Yang and Ferreira 2008) and entropy (Wilson 1974; Wilson and Senior 1974) interpretations of the three average trip lengths (Table 3.1). The extremes of the cost-access relationship provide a way to incorporate a “…more flexible form of household utility with respect to transport costs…” (Giuliano, 1991, p. 154) and labor market conditions (Crane 1996; Rouwendal 1998), whereby a household’s valuation of transport costs may be based on their utility associated with proximity or access to different configurations of opportunities.

<table>
<thead>
<tr>
<th>Land-use configuration benchmark</th>
<th>Cost objective</th>
<th>Access objective</th>
<th>Labor market condition</th>
<th>Trip length</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{min}}$</td>
<td>Minimize</td>
<td>Maximize to single local job</td>
<td>Stable and certain</td>
<td>Short</td>
</tr>
<tr>
<td>$T_{\text{prop}}$</td>
<td>No preference</td>
<td>Maximize to multiple regional jobs</td>
<td>Instable and uncertain</td>
<td>Medium</td>
</tr>
<tr>
<td>$T_{\text{max}}$</td>
<td>Maximize</td>
<td>Maximize to single regional job</td>
<td>Stable and certain</td>
<td>Long</td>
</tr>
</tbody>
</table>

Table 3.1 Various interpretations of commute benchmarks

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2 See pages 551 and 552 of Horner (2002) for the formulation
Third, a null hypothesis may be introduced to evaluate observed work trip lengths. Since $T^{\text{prop}}$ captures the most likely location and commuting behavior if households (employers) have no information on possible employment (worker) locations, it is an appropriate baseline against which to infer the importance of land-use on people’s spatial choices. $T^{\text{min}}$ is an inappropriate baseline, because it is laden with restrictive behavioral assumptions and constraints that assume households make choices in reference to the always known least cost pattern. Fourth, it may be possible to identify the relative importance of location strategies in explaining observed commuting patterns. We may investigate the complexity and multi-dimensionality of the spatial decision narrative: how are trip length and job access important? Is proximity to a nearer job site or proximity to farther alternative employment options more important in aggregate observed behavior?

### 3.3.1 Observed behavior relative to the classical and revised theory

Although the excess commuting literature provides a metric to evaluate the deviation of observed behavior from the optimal pattern assumed by the classical location theory, a new metric is needed to capture the cost-access relationship under the revised theory. Recognizing the deficiency in the original excess commuting metric (equation 3.1), Horner (2002) evaluated observed behavior ($T^{\text{obs}}$) in relation to the full commuting range ($T^{\text{min}}$-$T^{\text{max}}$) using a normalized version of excess commuting:

$$NEC = \frac{T^{\text{obs}} - T^{\text{min}}}{T^{\text{max}} - T^{\text{min}}} \times 100 .$$

(3.2)
An improvement over the original metric, NEC reduces overestimation bias inherent in
the EC value and allows for an accurate inter-regional comparative analysis (Horner
2002). The issue is, of course, that observed outcomes are still related to classical theory
assumptions and the solution is to replace $T^{\text{max}}$ in equation (3.2) with $T^{\text{prop}}$. This simple
switch of the upper bound in the denominator is unsatisfactory, because the numerator
remains unchanged, indicating that the comparison is still being made in reference to
$T^{\text{min}}$. To account for what I believe to be an incorrect way to view the relative importance
of location strategies on commuting outcomes, the numerator needs to reflect the change
in the baseline condition. However, if $T^{\text{prop}}$ is the new base, the denominator should
reflect whether observed behavior is in the distance sensitive or insensitive range.

What this suggests is that evaluating observed behavior is a two-step process. First, the
position of $T^{\text{obs}}$ relative to $T^{\text{prop}}$ indicates whether land use has a positive ($T^{\text{obs}} < T^{\text{prop}}$) or
negative ($T^{\text{obs}} > T^{\text{prop}}$) impact on decisions and provides an answer to the question
whether distance is important in the location selection process. Second, the position of
$T^{\text{obs}}$ relative to the distance sensitive ($T^{\text{min}}-T^{\text{prop}}$) or insensitive ($T^{\text{prop}}-T^{\text{max}}$) range captures
the trade-off between distance and access importance. If $T^{\text{obs}} < T^{\text{prop}}$, then the location
strategy (LS) metric becomes:

$$LS^+ = \frac{T^{\text{prop}} - T^{\text{obs}}}{T^{\text{prop}} - T^{\text{min}}} \times 100.$$  

Otherwise, if $T^{\text{obs}} > T^{\text{prop}}$ then the metric becomes:

$$LS^- = \frac{T^{\text{prop}} - T^{\text{obs}}}{T^{\text{max}} - T^{\text{prop}}} \times 100.$$  

39
In this case, the negative sign in front of this value indicates the negative impact.

The advantage of using $LS^+$ and $LS^-$ is that it is now possible to evaluate each point on the trip length curve in terms of cost and access considerations (Figure 3.1). If observed patterns fall at B (D) on average, households would neither be maximizing access to the specific local (regional) job site or alternative workplaces. Moreover, local (regional) single job access is the overriding household concern in the AB (DE) range, whereas regional multiple job access dominates location decisions in the BC (CD) range.

Figure 3.1 Trip length curve in relation to land use configurations and access considerations
Table 3.2 provides a comparison of values and their meanings for the NEC, \(LS^+\) and \(LS^-\) measures. Whereas smaller (larger) \(LS^+ / LS^-\) values capture increasing influence of multiple (single) access considerations, larger NEC values show decreasing (increasing) influence of single local (regional) access. With the \(LS^+ / LS^-\) metrics, the 50% division separates access considerations because it represents the point at which access is at a minimum (point B or point D in Figure 3.1), though this hard and fast rule is not applicable to NEC. If \(LS^+ (LS^-) > 50\%\), then households prefer short (long) distances and access to the specific local (regional) job, whereas \(LS^- (LS^+ < 50\%\) indicates preference for access to multiple regional jobs and importance (unimportance) of distance leading to medium-short (-long) trip lengths.

<table>
<thead>
<tr>
<th>Metric Value</th>
<th>NEC interpretation</th>
<th>(LS^-) interpretation</th>
<th>(LS^+) interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50%</td>
<td>More efficient: distance is more important</td>
<td>More efficient: multiple regional access is more important; medium-short trip lengths</td>
<td>Less efficient: multiple regional access is more important; medium-long trip lengths</td>
</tr>
<tr>
<td>&gt; 50%</td>
<td>Less efficient: distance is less important</td>
<td>Most efficient: single local access is more important; short trip lengths</td>
<td>Least efficient: single regional access is more important; long trip lengths</td>
</tr>
</tbody>
</table>

Table 3.2 Commuting metric value interpretations
3.4 Data and analysis

3.4.1 Rationale

The review and discussion of issues and limitations of the excess commuting literature in this and the previous chapter underscore the need for continuing research in multiple directions. Extensions of the excess commuting framework as an explanatory context for observed behavior include: socio-economic, site and situation considerations; individual’s location objectives; policy-relevant simulations; and the trade-off between the classical and revised theory. Addressing all these issues at once is beyond the scope of this or any single chapter, and the focus here is to empirically examine the relative importance of location strategies which has been overlooked by excess commuting work. By examining the variation in the cost-access trade-off for a sample of U.S. cities, this work lays the contextual foundation for future research addressing the previously identified research questions. At this point, it is necessary to have a theoretically grounded evaluation of the commute impact of land use so that we are prepared to understand other pertinent issues within this context.

3.4.2 Data sources

The aggregate relationship between cost and access considerations is explored for a set of 25 cities that have been used in a comparative framework in other related studies (Horner 2002; O'Kelly and Niedzielski 2008). The necessary data consists of home and workplace locations as well as the flows between them and were extracted from the 2000 Census
Transportation Planning Package (CTPP) of the U.S. Census. Part 3 of the CTPP contains aggregate journey-to-work flows for each city and the origin and destination totals from each matrix provide the number of workers and jobs in each individual census unit such as traffic analysis zones (TAZ) or block groups (BG). Transport costs between TAZ or BG centroids were calculated using Euclidean distance. Within each zone, travel costs were set equal to a variable fraction of the radius of a circle circumscribing each areal unit (Frost, Linneker, and Spence 1998; O'Kelly and Lee 2005). The mathematical formulation of each benchmark is shown in many related papers and is not repeated here (see Horner 2002; Yang 2005).

3.4.3 Results

Results of the inter-regional location strategy analysis are reported in Table 3.3. Both NEC and LS\(^+\) are shown along with the components of these statistics: \(T^{\text{min}}\), \(T^{\text{obs}}\), \(T^{\text{prop}}\), and \(T^{\text{max}}\). In the first step of evaluating observed behavior, the comparison of \(T^{\text{obs}}\) and \(T^{\text{prop}}\) is of prime importance. Since \(T^{\text{obs}} < T^{\text{prop}}\) for all cities, all location strategy metric values are positive (LS\(^+\)). This outcome means that households value journey-to-work distance and it is important in their decision-making process. The commute impact of land use is positive, because households consider journey-to-work distance when deciding where to live and work.
Table 3.3 Regional commuting-analysis results. Cities where LS + < 50% are highlighted.

<table>
<thead>
<tr>
<th>City</th>
<th>Number of work trips</th>
<th>$T_{min}$</th>
<th>$T_{obs}$</th>
<th>$T_{prop}$</th>
<th>$T_{max}$</th>
<th>NEC</th>
<th>LS +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta</td>
<td>2 089 224</td>
<td>4.80</td>
<td>11.11</td>
<td>26.92</td>
<td>36.21</td>
<td>20.08</td>
<td>71.48</td>
</tr>
<tr>
<td>Baltimore</td>
<td>1 719 426</td>
<td>3.02</td>
<td>8.57</td>
<td>26.83</td>
<td>38.20</td>
<td>15.77</td>
<td>76.70</td>
</tr>
<tr>
<td>Boise</td>
<td>225 029</td>
<td>3.65</td>
<td>7.53</td>
<td>14.72</td>
<td>19.46</td>
<td>24.55</td>
<td>64.95</td>
</tr>
<tr>
<td>Boston</td>
<td>1 352 039</td>
<td>2.30</td>
<td>6.59</td>
<td>14.00</td>
<td>18.49</td>
<td>26.45</td>
<td>63.39</td>
</tr>
<tr>
<td>Charlotte</td>
<td>383 007</td>
<td>3.10</td>
<td>7.32</td>
<td>11.74</td>
<td>15.85</td>
<td>33.16</td>
<td>51.09</td>
</tr>
<tr>
<td>Cincinnati</td>
<td>1 235 483</td>
<td>2.76</td>
<td>7.99</td>
<td>28.29</td>
<td>41.04</td>
<td>13.67</td>
<td>79.50</td>
</tr>
<tr>
<td>Cleveland</td>
<td>1 593 963</td>
<td>2.79</td>
<td>8.20</td>
<td>30.06</td>
<td>42.43</td>
<td>13.65</td>
<td>80.16</td>
</tr>
<tr>
<td>Columbus</td>
<td>749 453</td>
<td>2.86</td>
<td>7.95</td>
<td>15.90</td>
<td>21.21</td>
<td>27.74</td>
<td>60.97</td>
</tr>
<tr>
<td>Denver</td>
<td>1 287 318</td>
<td>2.73</td>
<td>8.15</td>
<td>19.33</td>
<td>25.88</td>
<td>23.41</td>
<td>67.35</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>615 903</td>
<td>2.98</td>
<td>7.22</td>
<td>10.59</td>
<td>13.65</td>
<td>39.70</td>
<td>44.31</td>
</tr>
<tr>
<td>Memphis</td>
<td>436 780</td>
<td>2.78</td>
<td>7.79</td>
<td>10.82</td>
<td>15.09</td>
<td>40.72</td>
<td>37.65</td>
</tr>
<tr>
<td>Miami</td>
<td>804 753</td>
<td>3.18</td>
<td>7.49</td>
<td>11.64</td>
<td>16.17</td>
<td>33.23</td>
<td>49.01</td>
</tr>
<tr>
<td>Milwaukee</td>
<td>859 278</td>
<td>2.23</td>
<td>7.69</td>
<td>19.81</td>
<td>26.67</td>
<td>22.35</td>
<td>68.92</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>1 672 921</td>
<td>4.28</td>
<td>9.67</td>
<td>23.48</td>
<td>30.61</td>
<td>20.48</td>
<td>71.92</td>
</tr>
<tr>
<td>Omaha</td>
<td>345 553</td>
<td>2.04</td>
<td>5.78</td>
<td>9.28</td>
<td>12.57</td>
<td>35.51</td>
<td>48.32</td>
</tr>
<tr>
<td>Phoenix</td>
<td>1 475 527</td>
<td>5.47</td>
<td>11.25</td>
<td>23.34</td>
<td>30.53</td>
<td>23.05</td>
<td>67.68</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>1 036 214</td>
<td>3.10</td>
<td>8.30</td>
<td>22.91</td>
<td>30.37</td>
<td>19.06</td>
<td>73.76</td>
</tr>
<tr>
<td>Portland</td>
<td>680 222</td>
<td>2.37</td>
<td>6.36</td>
<td>11.36</td>
<td>15.57</td>
<td>30.26</td>
<td>55.59</td>
</tr>
<tr>
<td>Rochester</td>
<td>529 134</td>
<td>4.34</td>
<td>8.73</td>
<td>21.45</td>
<td>27.82</td>
<td>18.70</td>
<td>74.34</td>
</tr>
<tr>
<td>Sacramento</td>
<td>783 094</td>
<td>3.23</td>
<td>8.55</td>
<td>20.96</td>
<td>27.75</td>
<td>21.69</td>
<td>70.00</td>
</tr>
<tr>
<td>Saint Louis</td>
<td>1 136 720</td>
<td>3.74</td>
<td>9.33</td>
<td>18.97</td>
<td>25.70</td>
<td>25.43</td>
<td>63.32</td>
</tr>
<tr>
<td>San Antonio</td>
<td>655 030</td>
<td>2.58</td>
<td>8.01</td>
<td>13.36</td>
<td>18.17</td>
<td>34.80</td>
<td>49.68</td>
</tr>
<tr>
<td>San Diego</td>
<td>1 238 100</td>
<td>3.05</td>
<td>9.49</td>
<td>18.66</td>
<td>26.33</td>
<td>27.66</td>
<td>58.74</td>
</tr>
<tr>
<td>Seattle</td>
<td>1 796 708</td>
<td>3.93</td>
<td>9.24</td>
<td>28.21</td>
<td>38.22</td>
<td>15.50</td>
<td>78.11</td>
</tr>
<tr>
<td>Wichita</td>
<td>301 542</td>
<td>3.00</td>
<td>7.39</td>
<td>19.80</td>
<td>24.97</td>
<td>19.96</td>
<td>73.89</td>
</tr>
</tbody>
</table>

Given that the sign of the LS + metric indicates that land use is important in location choices, the magnitude of the metric values provide empirical evidence on the relative importance of distance or access in these spatial decisions. Values in the last column of Table 3.3 indicate, for the most part, that aggregate observed behavior is further away from proportional commuting and closer to minimum work travel. We can infer that while households and employers do not have perfect information about the locations of the other groups, they are not completely lacking this spatial knowledge. To understand the importance of these findings, note that despite all other constraints on their decisions,
such as imperfect information, relocation costs or access to non-work activities, households make good spatial choices from the sustainable transport perspective. That is, given all the possible location and commuting options offered by urban form, households travel less than they otherwise could have. Note that the NEC values suggest that observed commutes are also close to the minimum patterns.

Analysis of observed behavior based on NEC is undoubtedly useful, because it identifies the portion of the commuting capacity that is actually used, but the benefit of using the location strategy approach and \(LS^+\) metric is to uncover the cost-access relationship in household spatial decisions. \(LS^+\) metric values range from 37.65% (Memphis) to 80.16% (Cleveland). However, \(T_{obs}\) is at least 50% further away from \(T_{prop}\) for twenty out of twenty-five cities in the sample. This finding suggests that there is a convergence between minimizing commutes and maximizing access to the specific local job in terms of aggregate household behavior. On the other hand, access or proximity to multiple employment opportunities seems to be more important for household choices in Las Vegas, Memphis, Miami, Omaha, and San Antonio. In the case of the latter three cities, the \(LS^+\) value of almost 50% suggests that household value access to the local and regional jobs almost equally. For workers in Las Vegas and Memphis, their spatial choices are dominated by multiple job site access considerations.

The variation in \(LS^+\) metric values is mapped in Figure 3.2. A pattern is noticeable when rust-belt and sun-belt cities are compared. Four of five cities with the highest value are
Midwestern and northeastern cities (Cleveland, Cincinnati, Baltimore, and Rochester). Conversely, four of five cities with the lowest value are sun-belt cities (San Antonio, Miami, Las Vegas, and Memphis). This pattern may be partially explained by city size measured by the number of work trips. Even though there are about the same number of cities above and below the one million work trip mark, seven out of ten cities with $LS^+ > 70\%$ have more than 1 million trips and 5 have more than 1.5 million trips. This suggests that the larger the city, the stronger the tendency for aggregate household location choices to be better explained by preference for single local access, although this relationship is not absolute (correlation coefficient between city size and $LS^+$ is 0.571). Clearly, single access tendency is much stronger in places like Seattle and Baltimore than Portland and Columbus. Conversely, single access preference is weaker in large cities such as San Diego and Boston and stronger in smaller places such as Wichita and Rochester.

Controlling for the city size effect, notice that workers in similarly sized places have decidedly different access considerations. For example, San Diego and Cincinnati have about the same number of work trips (1,238,100 and 1,235,483, respectively), but single job site access is not the overriding concern for San Diegan households as it is for
Figure 3.2 Location strategy (LS+) visualization for 2000 CTPP.
residents of Cincinnati. This is true for at least two other similarly sized city pairs, Saint Louis (1,136,720) and Pittsburgh (1,036,214) as well as Miami (804,753) and Sacramento (783,094). Households in Pittsburgh value single local access much more than their counterparts in Saint Louis. The contrast is more pronounced when comparing Miami and Sacramento, because households in the former city locate within equal distance of single and multiple job access as opposed to a clear preference for the local job in the latter. These examples illustrate that even though the preference for single access is stronger in larger cities, local context may play a role in the variation of location strategies. For instance, the response to local conditions in Las Vegas and Rochester is not identical.

3.5 Discussion and conclusion

The intent of the research in this chapter is to connect the classical and revised urban location theories in the study of explanations behind variations in observed location and commuting behavior. These two literatures are linked by the theoretical association of special types of average commutes with expected behavior under fully perfect and imperfect functioning market conditions. The combination provides the context necessary to unravel the trade-off between cost and access consideration in the household spatial decision-making process and is useful in assessing the relative household preference for different types of location strategies.
The added value of this research may be seen when the relative access preferences are placed in the context of land-use-based commute reduction policies. Researchers argue that negative externalities associated with journey-to-work distances may be alleviated by promoting better spatial mix between home and workplace locations. This includes both local level efforts such as mixed-use developments as well regional approaches to limit sprawl and promote location clustering. The goal is to reduce distance to both single and multiple opportunity access (lower $T^{\text{min}}$ and $T^{\text{prop}}$ values) so that irrespective of local economic conditions households would not have to travel longer than they otherwise would need in a less favorable location setting. Correlation analysis between observed behavior and each of the theoretical work trips supports previous studies on the influence of urban form on location choices. Spearman correlations between $T^{\text{obs}}$ and $T^{\text{min}}$ ($0.707 P = 0.000$), $T^{\text{obs}}$ and $T^{\text{prop}}$ ($0.712 P = 0.000$), and $T^{\text{min}}$ and $T^{\text{prop}}$ ($0.440 P = 0.028$) suggest that combined local and regional access has positive influence on household observed choices. The next step for researchers is to simulate different urban form types that lead to commute reductions based on changes in $T^{\text{min}}$ and $T^{\text{prop}}$. Recent development may hold promise for improving a region’s jobs-housing balance (Horner 2008; Horner and Murray 2003).

This research provides for new directions. This chapter focuses on establishing the links between the classical and revised theories and as such it has not been able to provide insight into how the cost-access trade-off varies for households located in different parts of the city and for workers with different socio-economic characteristics. Intraurban
comparative research may consider how the relative importance of location strategies differs across places within the city using the spatial disaggregation approach found in the work of Niedzielski (2006) and Horner (2007). Testing for this direct linkage is important in light of the discussion above about the policy initiative aiming for commute reductions. A subregional perspective takes on added meaning when location inequalities are considered for different socio-economic groups. Researchers may begin to unravel differences in cost-access considerations for groups based on occupation, gender and race/ethnicity among others. Tracking whether differences exist in location strategies is important for informed land-use policies and O’Kelly and Lee (2005) offer such an approach for disaggregating commuting data.
CHAPTER 4

IS THE JOURNEY-TO-WORK EXPLAINED BY URBAN AND SOCIAL STRUCTURE?

4.1 Introduction

Commuting, as a regular and predictable pattern of people’s need to overcome the spatial separation between homes and jobs, is an unavoidable consequence of the set-up of modern metropolitan areas. The journey-to-work is an outcome of people’s location decisions about where to live and work within the possibilities offered by the spatial distribution of homes and jobs. One of the explanations behind people’s spatial decision making process has been Alonso’s (1964) location trade-off theory. Classic urban location theory maintains that people may choose between more living space with longer commutes or less living space with shorter commutes based on an auction process of individuals outbidding each other for locations based on their utility preferences. People’s maximization of location utility leads to observable aggregate commuting patterns which are the focus of many empirical tests of Alonso-type theories.
One way to test the trade-off theory empirically is by using the excess commuting framework. Originating from work by Hamburg et al. (1965), Wheeler (1967b), and Hamilton (1982), the excess commuting approach compares the aggregate real work travel pattern with a theoretical pattern that is required by the spatial arrangement of homes and jobs. In a seminal paper, Giuliano and Small (1993) seemingly find that the real pattern in Los Angeles exceeds the prediction by 66.3%, appearing to suggest that only 33.7% of real commuting is explained by land-use. Consequently, it seems that people do not minimize commutes and that jobs-housing balance has little impact on work travel, implying that land-use-based commute reduction policies would have very limited effect.

As noted in the previous chapter, however, results and conclusions based only on the spatial structure should be treated with caution. Current models, purporting to test Alonso’s trade-off theory empirically, assume that people choose from all location options in a metropolitan area. Yet, this focus on spatial imbalance or mismatch in urban structure in excess commuting ignores social structure – the other component of the trade-off theory – i.e. socio-economic characteristics, demographics and other factors contribute to constrained location choices. When investigating the commute impact of land, variations in location choice sets due to social factors have to be taken into account to avoid misleading results.
Studies examining the impact of socio-economic and demographic factors on observed location and commuting behavior provide evidence that people have constraints on their location choices (Gobillon, Selod, and Zenou 2007; Preston and McLafferty 1999). I argue that spatial and social structures, as the two components of urban structure, contribute to bounds on location choices and commuting, because not all homes and jobs are possible choices for every worker. Previous studies have usually incorporated one characteristic, such as occupation (Horner 2002; Manning 2003; O'Kelly and Lee 2005), race (Horner and Mefford 2007; Wheeler 1970), or gender (Buliung and Kanaroglou 2002; Horner 2002), though never for the complete location choice set. I point out that a disconnect exists between the theoretical assumptions and the modeling techniques. First, I redefine what is meant by required and excess commuting to examine how much real commuting is due to choice and necessity. Then, I compute all three commuting range components (required, proportional and allowable) using two socio-economic characteristics and data from Wichita, Kansas. The remainder of this chapter reviews current definitions of components of the commuting scale, proposes new definitions, provides an empirical analysis of the commute impact of land use and ends in a discussion and conclusion.

4.2 Evolving definitions of required and excess commuting

The metropolitan spatial arrangement of homes and jobs offers many location choices and urban researchers in the Alonso tradition suggest that people choose sites with some regard to commuting distance (Giuliano 2004; Ng 2008; Small and Song 1992; Wheeler
and housing preferences, driven by socio-economic and demographic characteristics (Herbert and Stevens 1960; Wheaton 1974). Hamilton (1982) proposed to test the standard urban location theory using urban form represented by the monocentric model. However, by assuming that residential and employment exponential density gradients decrease from a central point, Hamilton’s (1982) minimum required commute definition forces people to make inward commutes along identical radial roads (Figure 4.1). Because of these unrealistic and irrational assumptions about household location decisions (White 1988), the required commute was underestimated and the excess commute overestimated. In Hamilton’s (1982) definition, outward/circumferential commuting and the transportation network along with other factors are deemed to cause

![Figure 4.1 Hamilton’s (1982) definition of required and excess commuting.](image-url)
excess commuting. This is unreasonable, because people make decisions in relation to real urban form and transportation networks (Small and Song 1992; White 1988).

Critical of Hamilton’s representation of urban form, White (1988) used real home and job locations aggregated into zones and distances between every zonal pair as input into a linear program known as the transportation problem to calculate the minimum required commute. By arguing that urban form encapsulates real (aggregate) locations and transport networks, White (1988) separated morphology based on quantitative factors from behavior based on qualitative factors (Figure 4.2). These less strict definitions maintain that the amount of commuting above the minimum is based on socio-economic

![Diagram](image)

**Figure 4.2** White’s (1988) definition of required and excess commuting.
and demographic characteristics interfering with optimal location choices. This quantitative-qualitative divide has remained unchallenged with Ma and Banister (2006b) recently arguing that qualitative factors result in longer work trips. Instead, recent studies have challenged the limited one-dimensional view of urban form established by White (1988) and others following her lead.

Horner (2002) and Ma and Banister (2006b) have shown that more accurate and reliable estimates of excess commuting are attainable when real commuting is compared against the commuting range between minimum and maximum offered by urban form (Figure 4.3). Although Hamilton (1982) and White (1988) defined the required commute as the shortest possible work travel pattern, Figures 4.1 and 4.2 respectively, in practical terms their definition of the excess commuting (EC) metric,

$$EC = \frac{T_{\text{obs}} - T_{\text{min}}}{T_{\text{obs}}}$$

(4.1)

means that the lower bound is zero and the upper bound is the real commute (note the commuting range in Figures 4.1 and 4.2 depicted as a black box). By establishing the commuting range based on the true minimum as the lower bound and the true maximum as the upper bound and the resulting normalized version of the metric,

$$NEC = \frac{T_{\text{obs}} - T_{\text{min}}}{T_{\text{max}} - T_{\text{min}}}$$

(4.2)

Horner (2002) found that normalized excess commuting (NEC) values are lower than the original excess commute values. The bounds on commuting provide accurate spatial context for real work travel patterns by removing bias due to the incomplete geographical representation of spatial structure.
### 4.3 Redefining required and excess commuting

Notwithstanding the stated research agenda, excess commuting models have not adequately represented standard urban economic theory because they control for commuting costs, but not the housing component of the location trade-off. Although most of urban research has moved beyond equating urban structure with a simple numerical

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**Figure 4.3** Commuting capacity extensions by Horner (2002) and Ma and Banister (2006).
imbalance of all homes and jobs, the excess commuting literature has lagged behind. However, urban structure has a second component, namely social structure, which is the spatial differentiation of locations due to socio-economic and demographic factors. The issue is that social factors have been considered as the explanation behind the existence of excess commuting rather than contributing to location imbalance. However, if “[m]ismatches occur when prices or other characteristics make housing in the area unsuitable for the workers who hold jobs there” (Giuliano and Small 1993, p. 1486), is it reasonable to assume that required commuting is a simple numerical imbalance? This location mismatch assumes workers are homogenous, but are all locations possible choices for all workers?

Research on real commuting outcomes and location preferences suggests that constraints on spatial choices and decisions vary among different population groups. Urban researchers understand that people’s socio-economic and demographic characteristics such as occupation, income, household structure, race, gender, availability and number of automobiles among others influence where people can live and work (Fernandez 2008; Gabriel and Rosenthal 1996; Preston and McLafferty 1999). Because location constraints vary between population groups, it is clear that every worker cannot swap homes and jobs with just any other worker. Since “…each household minimizes its housing plus commuting cost, with housing held constant” (Small and Song 1992, p. 890), the implication is that models of commuting bounds have to take into account the spatial distribution of various population groups because
“…different status groups will attempt to maximize the utility of their income within a level of residential space-preference. For each quantity of residential space, a least-cost location is possible for each income level” (Wheeler 1967a, p. 510).

For example, consider a graduate student in a one-worker household with a $1,500 monthly wage with no children and no car and a physician in a two-worker household earning $8,000 monthly with two children and two cars. Clearly, it is unreasonable to assume that the student and physician can swap home and job locations. Moreover, it is also unreasonable in the case of this physician and another physician with the same characteristics except for having no children. Socio-demographic differences result in different location constraints implying a limitation on the amount of possible home and jobs exchanges. Thus, while White (1988) criticized Hamilton’s (1982) definition for forcing people to make irrational spatial decisions, it is also unreasonable to expect people to live in homes and take jobs that are unsuitable for them.

Because the debate over excess commuting has confused what constitutes required and excess commuting, new definitions of these commuting range components are needed to move the methodology in line with the research agenda (Figure 4.4). Since the real commute (B) is an outcome of a complex spatial decision making process due to socio-economic and demographic factors, the true minimum required commute (A2) and true maximum allowable commute (D2) incorporate worker heterogeneity for accurate predictions. Thus, excess commuting should only be that part of real commuting that may
Figure 4.4  Proposed redefinition of required, proportional, allowable and excess commuting.
be reduced by swapping commensurate homes/jobs within location constraints of each population group. By adopting broader definitions of required and allowable commuting that embed the importance of distance within socio-economic relations, I redefine Horner’s (2002) normalized excess commuting (NEC) metric as:

\[
NEC = \frac{T_{obs} - T_{min}}{T_{max} - T_{min}}
\]  \hspace{1cm} (4.3)

and the location strategy (LS+) metric proposed in the previous chapter as

\[
LS^+ = \left( \frac{T_{prop} - T_{obs}}{T_{prop} - T_{min}} \right) \times 100
\]  \hspace{1cm} (4.4)

where: \(T_{min}\) = heterogeneous minimum average required commute (A2), \(T_{obs}\) = observed average commute (B), \(T_{prop}\) = heterogeneous proportional average commute (C), and \(T_{max}\) = heterogeneous maximum average allowable commute (D2).

### 4.4 Data

Ideally, a detailed data set would be available that provides worker flows disaggregated by all the socio-economic factors listed above. In the absence of detailed data, the next best option is to use work flows from the Census Transportation Planning Package (CTPP) produced by the U.S. Census. The aggregate number of workers traveling between residential and employment zones in a study area is contained in Part 3 of the CTPP. More detailed data is contained in Parts 1 and 2, which provide the number of people living and working in each zone, respectively. However, the dimensionality of data in Parts 1 and 2 is limited, because, at best, the outflows and inflows are segmented
by two characteristics. This study uses occupation types and worker earnings to compute heterogeneous required, proportional and allowable average work trip lengths.

4.4.1 Estimating real work travel patterns by worker occupation and earnings

Since Part 3 of the CTPP provides aggregate worker flows, two steps are needed to estimate the real work travel pattern disaggregated by worker occupations and earnings ($X_{ijk}$). In the first step, the twenty four occupational groups defined in the 2000 CTPP are aggregated into four occupations types (as shown in Table 4.1): (1) managerial and professional, (2) sales, (3) service, and (4) craft. Aggregation into fewer groups is necessary in order to have a consistent classification scheme that will allow comparisons with data from the 1990 and 2010 censuses in future research.

Actual work trip distribution disaggregated by occupation ($X_{ijo}$) is obtained using the information-minimizing (IM) model subject to the conditions that the total number of trips of occupation type $o$ leaving an origin and ending in a destination matches the labor supply ($S_{io}$) and demand ($D_{jo}$) and that the total number of all trips of type $o$ ($X_{ijo}$) equals the observed total from Part 3. The IM model fills in the missing real disaggregated flows by staying true to known data ($X_{ij} > 0$) and remaining “…non-committal with respect to the missing data [(X$_{ij} = 0$)]…” (O'Kelly and Lee 2005, p. 2239) and the details of the procedure are provided in section 4.1 and the appendix of their paper. Another advantage of the IM model is that it accounts for differences in geographic extent of the CTPP data sets. The IM model uses an extra origin and destination to account for
<table>
<thead>
<tr>
<th>CTPP 2000 Occupations (24)</th>
<th>New Occupational Groups (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management occupations</td>
<td>Managerial and Professional</td>
</tr>
<tr>
<td>Farmers and farm managers</td>
<td></td>
</tr>
<tr>
<td>Business and financial operations specialists</td>
<td></td>
</tr>
<tr>
<td>Computer and mathematical</td>
<td></td>
</tr>
<tr>
<td>Architecture and engineering</td>
<td></td>
</tr>
<tr>
<td>Life, physical and social science</td>
<td></td>
</tr>
<tr>
<td>Community and social service</td>
<td></td>
</tr>
<tr>
<td>Legal</td>
<td></td>
</tr>
<tr>
<td>Education, training and library</td>
<td></td>
</tr>
<tr>
<td>Arts, design, entertainment, sports and media</td>
<td></td>
</tr>
<tr>
<td>Healthcare practitioners and technicians</td>
<td></td>
</tr>
<tr>
<td>Sales and related</td>
<td></td>
</tr>
<tr>
<td>Office and administrative support</td>
<td></td>
</tr>
<tr>
<td>Healthcare support</td>
<td></td>
</tr>
<tr>
<td>Protective service</td>
<td></td>
</tr>
<tr>
<td>Food preparation and serving related</td>
<td></td>
</tr>
<tr>
<td>Building and grounds cleaning and maintenance</td>
<td>Service</td>
</tr>
<tr>
<td>Personal care and service</td>
<td></td>
</tr>
<tr>
<td>Farming, fishing, and forestry</td>
<td></td>
</tr>
<tr>
<td>Construction and excavation</td>
<td></td>
</tr>
<tr>
<td>Installation, maintenance and repairs</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td></td>
</tr>
<tr>
<td>Transportation and material moving</td>
<td>Craft</td>
</tr>
<tr>
<td>Armed Forces</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1 Occupational classification scheme

differences between Parts 1 and 2 (include workers living/working beyond study area) and Part 3 (only workers living/working within study area boundary). However, the analysis in this chapter uses $X_{ijk}$ flows in the core study area ($n \times m$ matrices) to generate the disaggregated origin ($S_{ik}$) and destination ($D_{jk}$) totals as input for the required, proportional, and allowable models.
However, occupational segmentation is only the first step toward more accurate estimates of commuting bounds, because of large variations within each occupational group. The 2000 census classifies people of all skill levels in the same occupational category (U.S. Census Bureau 2003), though the skill variation implies wage variation which in turn results in different location constraints for workers within the same occupational group. Therefore, the worker flows by occupation ($X_{ijo}$) are further disaggregated by six earning groups: (1) less than $15,000, (2) \$15,000 - \$30,000, (3) \$30,000 - \$45,000, (4) \$45,000 - \$60,000, (5) \$60,000 - \$75,000, and (6) greater than \$75,000. The use of twenty four occupation-earning combinations creates commensurate home-work pairings which are meant to control for social structure by making sure only workers with similar housing and job preferences may exchange residential and employment locations. The second step produces twenty four work travel matrices, one for each occupation-earning group ($X_{ijk}$). The $X_{ijk}$ matrices allow for the estimation of the overall real commute:

$$T^{obs} = \frac{1}{W} \sum_{i} \sum_{j} \sum_{k} X_{ijk}.$$  

(4.5)

where $W =$ total number of workers in the study area, $n =$ number of origin zones, $m =$ number of destination zones, and all other notation as previously defined. In addition, each of the twenty four matrices provides origin and destination totals as input for the required, random and allowable commute models.
4.4.2 Commute benchmark estimates according to worker occupations and earnings

Since only one index, \( k \), representing each occupation-earnings combination, and only the core \( n \times m \) matrices are used, only two constraint types are needed to ensure worker supply and employment demand is met for the \( k \text{th} \) matrix in the following the disaggregate versions of the transportation problem that minimize (4.6) or maximize (4.7) average work travel costs:

Minimize \[ T_{\min} = \frac{1}{W} \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{K} C_{ij} X_{ijk} \] \hspace{1cm} (4.6)

or

Maximize \[ T_{\max} = \frac{1}{W} \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{K} C_{ij} X_{ijk} \] \hspace{1cm} (4.7)

subject to:

\[ \sum_{j=1}^{n} X_{ijk} = S_{ik} \hspace{1cm} \forall j, k \] \hspace{1cm} (4.8)

\[ \sum_{i=1}^{m} X_{ijk} = D_{jk} \hspace{1cm} \forall i, k \] \hspace{1cm} (4.9)

\[ X_{ijk} \geq 0 \hspace{1cm} \forall i, j, k \] \hspace{1cm} (4.10)

where all notation is as previously defined. When matching commensurate homes and jobs in the model, constraints (4.8) guarantee that the number of workers of occupation-earning type \( k \) living in zone \( i \) is equal to the real numbers for each group and constraints (4.9) ensure that the number of workers of occupation-earning type \( k \) working in zone \( j \)
matches the real employment opportunities for each group. Constraints (4.10) maintain non-negativity requirements for each group.

In practice, the proportional commute occurs when workers match homes and jobs without regard to their locations. Any home or job is just as likely as any other, where the most probable set of worker flows is a simple proportional distribution based on a zonal pair’s share of the metropolitan areas labor force of type $k$. The proportionally matched commute ($T^{\text{prop}}$) may be estimated as follows:

\[
T^{\text{prop}} = \frac{1}{W} \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{K} C_{ij} X_{ijk} 
\]

(4.11)

where:

\[
X_{ijk} = \frac{S_{ik} D_{jk}}{W_k}, \quad \forall i, j, k,
\]

(4.12)

$W_k = \text{number of workers of type } k$, and all notation as previously defined.

### 4.5 Application results

Wichita, Kansas, U.S.A., appearing in many commuting-related studies (Horner 2002; O'Kelly and Lee 2005; O'Kelly and Niedzielski 2008, 2009), is used as the study area to investigate workers commute behavior. There are 300,521 people who live and work in the five county Wichita Metropolitan Statistical Area which is composed of 559 Traffic Analysis Zones (TAZ). A geographical information system (GIS) is used to calculate Euclidean distances ($C_{ij}$) between TAZ centroids. To account for work trips within zones,
intra-zonal distances \((C_{ii})\) are set equal to a variable fraction (refer to O'Kelly and Lee 2005) of the radius of a circle circumscribing each zone (Frost, Linneker, and Spence 1998). For comparative purposes, application results for four models are presented in Table 4.2.

Context for the estimated real average commute of 7.38 miles is provided by the three components of the commuting scale. Not surprising given more accurate methods of modeling real location choice sets in this research, the \(T_{\text{min}}\) value increases as the level of disaggregation increases from no disaggregation \((k=1)\), through disaggregation by one characteristic \((k=4\) or \(k=6)\) to disaggregation by two characteristics \((k=24)\). \(T_{\text{min}}\) is 2.99 miles for \(k=1\), 3.14 miles at \(k=4\) or 3.23 miles for \(k=6\), increasing to 3.38 miles for twenty four occupation-earning groups. Between each disaggregation level, \(T_{\text{min}}\) increases by 5.01\% \((k=1\) to \(k=4)\) or 8.03\% \((k=1\) to \(k=6)\), and 7.64\% \((k=4\) to \(k=24)\) or 4.64\% \((k=6\) to \(k=24)\).

<table>
<thead>
<tr>
<th>Model</th>
<th>(T_{\text{min}}) (miles)</th>
<th>(T_{\text{obs}}) (miles)</th>
<th>(T_{\text{prop}}) (miles)</th>
<th>(T_{\text{max}}) (miles)</th>
<th>NEC (%)</th>
<th>LS(^+) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate ((k=1))</td>
<td>2.99</td>
<td>7.38</td>
<td>19.86</td>
<td>25.00</td>
<td>19.93</td>
<td>73.99</td>
</tr>
<tr>
<td>Occupations ((k=4))</td>
<td>3.14</td>
<td>7.38</td>
<td>19.83</td>
<td>24.96</td>
<td>19.45</td>
<td>74.58</td>
</tr>
<tr>
<td>Earning groups ((k=6))</td>
<td>3.23</td>
<td>7.38</td>
<td>19.39</td>
<td>24.90</td>
<td>19.14</td>
<td>74.34</td>
</tr>
<tr>
<td>Occupation-Earning groups ((k=24))</td>
<td>3.38</td>
<td>7.38</td>
<td>19.34</td>
<td>24.84</td>
<td>18.62</td>
<td>74.96</td>
</tr>
</tbody>
</table>

Table 4.2 Overall regional commuting results for Wichita, Kansas (2000).
to $k=24$). Overall, the $T_{\text{min}}$ value for the occupation-earning model is higher than the aggregate by 13.04%. Conversely, the $T_{\text{prop}}$ and $T_{\text{max}}$ values decrease with increasing disaggregation though this change is smaller. The decrease in $T_{\text{prop}}$ and $T_{\text{max}}$ values from the aggregate to the most disaggregate model is 2.62% and 0.48%, respectively.

Higher $T_{\text{min}}$ and lower $T_{\text{prop}}/T_{\text{max}}$ values indicate that location choice sets are more constrained than the simple numerical imbalance. When real commuting is compared against fewer location choices, the commuting metric values decrease. The contribution of location choice sets to observed commuting is actually higher when social factors are included. NEC value of 18.62% shows that 81.38% of real commuting is explained by urban structure compared to 19.93% and 80.07% by spatial structure alone. This is because the $T_{\text{min}}$ value increase rate is higher than the $T_{\text{prop}}/T_{\text{max}}$ value decrease rates. The high contribution of urban structure seen as the composition of numerical imbalance and social mismatch ($T_{\text{min}}$) to the actual work trip length ($T_{\text{obs}}$) suggests that the local intermixing of commensurate homes and jobs is poor in the Wichita metropolitan area.

Commuting patterns may also be explored in terms of worker’s location strategies. The NEC results only indicate that workers in Wichita use relatively little commuting capacity. The contextual perspective introduced in the previous chapter provides several insights. Workers in Wichita value proximity between homes and jobs making location decisions with some regard to commute distance after controlling for worker occupations and earnings. Furthermore, the $LS^+$ metric tells us whether people are minimizing
distance to fewer but closer job sites or to more but distant job opportunity clusters. In Wichita, the LS\(^+\) value (74.96\%) suggests that workers prefer to be close to the smaller local array of job sites. In other words, longer distance commutes to a wider variety of jobs are much less attractive.

The results are consistent with expectations about commuting patterns in a city like Wichita that has well-defined residential and employment areas. This is shown in the stability of \(T_{prop}\) values after disaggregation (Table 4.2) and in Figure 4.5, which shows the ratio of the number of workers living in and the number of jobs in a zone. The majority of jobs are concentrated in the downtown and four clusters on the central city perimeter, while most homes are located in the city and the southeastern suburbs. Wichita has a relatively favorable compact set-up, and it would be very surprising if commuting patterns were not significantly influenced by the land use pattern. Thus, while workers in Wichita are efficient in their behavioral choices, they would probably not be ranked highly compared to workers making smart location decisions in a city with a much less favorable inter-mixing of homes and jobs (i.e. a dispersed urban form).
4.6 Discussion and Conclusions

The framework deployed in this chapter seeks to make some fundamental contributions to debates on urban form and location decisions. Much of the analysis to date investigating the importance of commute distances on location decisions has not fully incorporated Alonso’s trade-off theory, despite this goal in the stated research agenda. Unfortunately, by not controlling for social structure, previous studies have not stayed true to the spirit of Alonso’s insight about the housing-commuting cost trade-off. People
minimize commutes to the extent that their housing preferences are satisfied. Thus, one contribution of this chapter is to argue that the research question behind excess commuting should not be about modeling spatial separation of all homes and jobs, but rather spatial separation of homes and jobs that are commensurate based on socio-economic and demographic characteristics.

The fact is that previous studies have not controlled for social structure while seeking to explain the journey-to-work by urban structure. Without holding social structure constant by including socio-economic and demographic characteristics in the modeling techniques, the effect of urban structure is underestimated. This is because the frequently cited causes of excess commuting such as job heterogeneity, 2-worker households, housing and neighborhood characteristics, and transport mode (Giuliano and Small 1993; Ma and Banister 2006b; Manning 2003) actually impose constraints on people’s location decisions and should be incorporated into the definition of required commuting. If in reality, the number of commensurate home-job locations is reduced because workers cannot select from some home and job locations due to the factors listed above, then the modeling approach cannot penalize them for not making irrational and improbable decisions. Thus, the improved excess commuting framework proposed in this chapter argues that quantitative (spatial imbalance) and qualitative (spatial mismatch) factors contribute to required commuting and the part that is excess is due only to people’s rational location behavior set within realistic bounds.
Results for Wichita, Kansas indicate that more realistic representations of real commuting increase the value of required commuting by 13.04% leading to a decrease in the efficiency and behavior metrics by 6.57% and 3.73%, respectively. Though these may be relatively small reductions, it is important to remember that only two worker characteristics are used to control for real social structure that is much more complex. Furthermore, despite improvement over previous attempts, the groupings of occupations and earnings in this chapter still do not adequately reflect commensurate home-job interchanges. Finer differentiation of occupation and earning types and further disaggregation incorporating housing preferences, neighborhood characteristics, race and gender among others will likely result in more accurate estimates of the commute impact of land use. People’s rational choices within commensurate location options may provide support for the relevance of commute length in the spatial decision making process. Further exploration of this issue is needed.

It is not at all clear whether more or less excess commuting will be found with greater worker segmentation. First, there are many behavioral factors that do not contribute to required or necessary commuting. Workers may not choose the shortest distance commute possible because they may prefer the more distant home based on better access to school, environmental, recreational or leisure activities, housing architectural style, or social network. Second, the broader context for location decisions and consequently commute lengths incorporates both a distance and access perspective. The labor market is
not perfect, which means there will always be some workers minimizing proximity
toward a larger selection of jobs than toward the local job location.

Future research directions are plentiful. For a more sophisticated understanding of the
effect of urban and social structure on commutes, a more refined and detailed approach to
worker segmentation is needed. Geographical context should be taken into account by
performing a comparative analysis across multiple metropolitan areas and multiple scales
to uncover the variation in socio-spatial mismatch. Furthermore, comparative research
over time could determine whether workers have changed their location strategies and
subsequently their commuting outcomes. Lastly, there are possible policy implications
about the effectiveness of jobs-housing balance strategies on reducing commutes
stemming from this research which need to be thoroughly worked out.
CHAPTER 5

INCOME, OCCUPATION AND COMMUTING

5.1 Introduction

Researchers recognize that spatial and aspatial factors are the key determinants of employment achievement outcomes (Kain 1968; Preston and McLafferty 1999; Shen 2000). Job attainment may be constrained by people’s residential location relative to employment sites and by their socio-demographic profile. After having compared observed commutes among worker groups, the spatial mismatch and entrapment literatures find that race and gender contribute significantly to variations in mobility. For example, commute times tend to be longer for racial minorities (Gabriel and Rosenthal 1996; McLafferty and Preston 1997) and transit users (Kawabata and Shen 2007; Taylor and Ong 1995), but shorter for females (Johnston-Anumonwo 1997; McLafferty and Preston 1997). Location plays a crucial role in labor market achievement as well. Certain groups (minority, low income) enjoy good absolute location, or job-housing balance, but their relative location, or job accessibility, is substantially worse (Shen 1998, 2000; Wang 2003).
A critical issue for informed policy decisions is how employment achievement outcomes, i.e. observed work trip lengths, relate to the job attainment opportunity range, offered by the underlying spatial distribution of homes and jobs. The excess commuting literature attempts to quantify this relationship (Hamilton, 1989; Small and Song, 1992; White, 1988), but the limitation of previous work is the lack of knowledge about how the land use configuration, i.e. location choice sets, varies for workers with different socio-demographic profiles and preferences. Homogeneity assumptions are problematic, because although the locations of homes and jobs may be relatively well interspersed in sprawling U.S. metropolitan areas, these proximate opportunities may not be commensurate. Housing affordability, income, occupation, race, and gender among other worker characteristics may have significant impact on the possible home (work) location choices next to the available supply of jobs (homes) (Cervero 1996; Cubukgil and Miller 1982; Preston and McLafferty 1999; Sultana 2002; Wheeler 1970). For example, lower status workers may not have the qualifications to work at the plentiful higher-skilled jobs near their homes or they may not have the financial resources to afford plentiful housing opportunities near jobs requiring skills they possess. This very important but unexplored issue deserves research attention because of its direct relevance to the land use policy debates surrounding ways of reducing transportation externalities and employment access inequalities.

The intent in this chapter is to understand how opportunity range (mobility range) and search range (mobility outcomes) vary among worker groups under a level of detail that
has rarely been achieved in this line of work. This chapter explores the variation in location choice sets for occupation-income worker groups, as measured by three commute benchmarks (minimum, proportional, maximum), using the excess commuting framework applied to the Census Transportation Planning Package (CTPP) 2000 data for Wichita, Kansas, U.S.A. Occupation and income are chosen as they likely have a combined constraining effect on people’s location choices due to housing affordability and job skills mismatch.

The review of past efforts at disaggregating excess commuting in section 2 is followed by the explanation of techniques used to extract work trips according to occupation and income in section 3. The fourth section is devoted to modeling frameworks that quantify disaggregated commute benchmarks. Section 5 opens up with a brief introduction to the study area and gives the reader a recapitulation of the findings. A summary and discussion are provided in the last section.

### 5.2 Spatial structure, commuting and location decisions

Most households, if not all, would argue that their current residential and employment locations are optimal, given their preferences and household circumstances. The change of home/job locations to shorten the commute seems inconceivable due to the complexities of the household spatial decision-making process. However, if carefully considered, the process of choosing locations involves multiple possibilities. Households choose locations from the opportunity range offered by the spatial distribution of
residences and workplaces. If the local home-work separation is large, workers must commute long required distances ($T^{\text{min}}$) to work; similarly the required commute is shorter if local locations are closer to each other. Conversely, spatial separation between home and job sites may limit or extend the ability to attain opportunities. Horner and Mefford (2007) argue that spatial choices may be limited if location alternatives (as measured by the proportional, $T^{\text{prop}}$, or maximum, $T^{\text{max}}$, commutes) are closer than if they are further apart. This is because a shorter $T^{\text{prop}}$ or $T^{\text{max}}$ implies that opportunity and commuting choices are less diverse. Therefore, a larger opportunity range defined as the difference between $T^{\text{min}}$ and $T^{\text{max}}$ (or $T^{\text{prop}}$) is indicative of spatial advantage and privilege (Horner and Mefford 2007).

The spatial juxtaposition of homes with respect to job sites is clearly important in providing the setting for location and commuting decisions, but just as socio-demographic characteristics shape commuting outcomes, they also shape location choice sets. The existing extensive literature explores differences in observed commuting outcomes among worker groups. Thus, longer work trips are typically associated with whites (Fernandez 2008; Gabriel and Rosenthal 1996), men (Crane 2007; Turner and Niemeier 1997), automobiles (distance)/transit (time) (Taylor and Ong 1995), higher status occupations (Cubukgil and Miller 1982; Wheeler 1967a), and higher income workers (Hamburg et al. 1965; Wang 2003). The question remains about how the underlying spatial structure varies for these worker groups. Which groups have smaller (larger) opportunity ranges, and, therefore, possess location (dis)advantage and how does
observed commuting relate to the range? Clearly the answer depends on modeling the opportunity range offered by the spatial distribution of commensurate residences and workplaces.

The comparison of feasible residential and employment locations has largely been ignored in the excess commuting literature. In the early development stage of the framework, little attention was paid to heterogeneity because the focus was on establishing appropriate methodology (the Hamilton (1982; 1989), White (1988) and Small and Song (1992) debates). Since then, the methodology has been refined to incorporate $T^{\text{prop}}$ and $T^{\text{max}}$ as well as worker characteristics. Despite these improvements, past research has rarely explored location choice sets for more than one worker characteristic (Table 5.1). Occupation is the most frequently used characteristic, though rarely simultaneously considered with other factors (Horner 2002; Manning 2003). Despite extensive research on the impact of gender and race on observed commuting, little empirical research has been done on location choice sets and opportunity range and how they relate to commuting patterns. Horner and Mefford (2007) explore opportunity ranges for worker groups stratified by race and transport mode. They find that minorities have smaller ranges and, thus, less diverse options, than whites. Considering the significant individual effect of income and its combined impact with occupation, the dearth of empirical work using these characteristics is surprising.
<table>
<thead>
<tr>
<th>Type of characteristics</th>
<th>Number of characteristics used simultaneously</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Occupation types</td>
<td>Wheeler (1967a)(^1)</td>
</tr>
<tr>
<td></td>
<td>Wheeler (1967b)(^1)</td>
</tr>
<tr>
<td></td>
<td>Wheeler (1970)(^1)</td>
</tr>
<tr>
<td></td>
<td>Giuliano &amp; Small (1993)(^1)</td>
</tr>
<tr>
<td></td>
<td>O’Kelly &amp; Lee (2005)(^2)</td>
</tr>
<tr>
<td></td>
<td>Ma &amp; Banister (2006)(^2)</td>
</tr>
<tr>
<td></td>
<td>Bill et al (2008)(^0)</td>
</tr>
<tr>
<td></td>
<td>Watts (2009)(^2)</td>
</tr>
<tr>
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<td>Wheeler (1970)(^1)</td>
</tr>
<tr>
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<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>Wheeler (1970)(^1)</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
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</tr>
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<td></td>
</tr>
<tr>
<td>Income</td>
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</tr>
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</tr>
<tr>
<td>Housing tenure</td>
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<td></td>
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</table>

Note: 0 – \(T_{\text{obs}}\) and all three benchmarks calculated; 1 – \(T_{\text{min}}\) and \(T_{\text{obs}}\) calculated only; 2 – \(T_{\text{min}}, T_{\text{obs}},\) and \(T_{\text{max}}\) calculated only; 3 – \(T_{\text{min}}\) and \(T_{\text{max}}\) calculated only; 4 – \(T_{\text{min}}, T_{\text{obs}},\) and \(T_{\text{prop}}\) calculated only; 5 – \(T_{\text{min}}\) calculated only.

Table 5.1 Type and number of simultaneously worker characteristics used in estimates of average trip lengths.

One shortcoming of prior work on variation in the observed commuting and its associated range is that it does not simultaneously deal with occupation types and income that likely have a combined constraining effect on worker choices. In the studies to date, the influence of occupation and income has been treated separately and all but one focus on job skills partly because they are used as a proxy for worker earnings. In general, the occupation-based studies suggest that higher skilled workers tend to have longer
observed commutes that tend to be under predicted by commuting bounds (Bill, Mitchell, and Watts 2008; O'Kelly and Lee 2005; Watts 2009; Wheeler 1967a). Admittedly, these studies provide useful insights on the influence of occupation on commuting outcomes, yet they disregard the substantial income variation within each occupation type (Manning 2003). Variation in take home pay implies variation in home purchasing power which in turn suggests variation in the range of location possibilities and in commuting behavior. By controlling for occupations and income, a more realistic model of location constraints is possible because it would account for factors conditioning residential and workplace location choices.

Income is one of the primary determinants of worker’s residential location and work trip lengths. According to the trade-off between longer commutes/cheaper housing and shorter work trips/expensive housing, as seen in the classical urban location theory (Alonso 1964), higher income groups live further away from job locations because they can afford higher commuting costs that allow them to realize their living preferences for more housing and space. Lower income groups reduce their commuting expense by consuming less housing and space closer to the workplace (Roberto 2008). In relation to the mostly monocentric structure of post-war U.S. cities, the links between income, location choice and commuting outcomes were relatively straightforward. Indeed, the single study of the effect of income on commuting behavior empirically confirmed this positive relationship between observed/excess commuting and income (Hamburg et al. 1965). However, in recent work on accessibility patterns, Wang (2003) finds a non-linear
relationship between income and observed commuting. With contrasting findings and with the decentralization of U.S. cities over the past several decades, questions about the relationship between characteristics, such as occupation and income, and observed patterns and opportunity ranges need to be addressed to improve our understanding of how commuting options are shaped by the commensurate home/job spatial arrangement.

5.3 Modeling real disaggregated work travel patterns

Limited dimensionality of journey-to-work data available in the U.S. Census Transportation Planning Package (CTPP) is partly the reason for the paucity of a deeply segmented excess commuting analysis. For each metropolitan statistical area (MSA), the CTPP data set consists of three parts: disaggregated outflows (Part 1) and inflows (Part 2) with a geographical extent larger than the study area, and a matrix of aggregate trips with starting and ending locations within region (Part 3). At best, Parts 1 and 2 are segmented by two worker characteristics simultaneously. Thus, researchers need to estimate observed disaggregated work trip distributions with balanced total worker sums. The preferred solution is to use the information-minimizing (IM) method to model work trips segmented by two factors (see O’Kelly and Lee 2005), but outflows and inflows disaggregated by occupation and income simultaneously are simply not available in the CTPP. As a result, in this research the IM method is supplemented with an implicit data technique to derive work trips by occupation and income.
5.3.1 Estimating work trips by occupation

CTPP Parts 1 and 2 provide the number of workers residing in zones $i$ by occupation $k$ ($O_{ik}$) and the number of jobs in zones $j$ by occupation $k$ ($D_{jk}$), respectively. Although the 2000 CTPP defines 24 occupation groups, this research aggregates occupations into 4 groups as shown in Table 4.1: (1) management and professional; (2) sales; (3) service; and (4) craft. To devise the unknown number of workers of occupation type $k$ traveling from zone $i$ to zone $j$ ($X_{ijk}$), an iterative algorithm is provided to guide the distribution of estimated actual work trip using as much known information and as little unknown information (refer to O'Kelly and Lee (2005) for details). For the purpose of this research, the core matrices of inflows and outflows ($m \times n$) are used as input data into the stratification of work trips by occupation and income ($X_{ijw}$) and then into the derivation of commuting benchmarks.

5.3.2 Estimating journey-to-work flow by occupation and income

Estimating work trips by occupation and income criteria is possible with the use of implicit data contained in journey-to-work matrices, such as $X_{ij}$ (from Part 3) or $X_{ijk}$ (from the first disaggregation step). Originally, Horner (2002) used the implicit data technique to restrict interaction to those home-job pairs where flow actually took place forcing procedures modeling the commute benchmarks to stay true to “commuters’ original intent and behavior” (Horner 2002, p. 559) as expressed in the real work travel pattern. A similar constrained analysis may be adapted to disaggregate occupation work
trips (X_{ijk}) by income. Note that Part 1 (Part 2) also records outflows (inflows) by average earnings for the residents (workers) of each zone i, E_i (j, E_j). Cells in the occupation work travel matrices, X_{ijk}, represent zonal interactions for workers with a given average level of earnings at the origin and destination end of the work trip.

Define Y_{ij} as a matrix where the ith element is equal to (E_i + E_j)/2. Define e as an index of earning groups and let I_{ije} correspond to a binary matrix where the ith element of: I_{ij1} is equal to 1 if Y_{ij} \leq $15,000 and 0 otherwise; I_{ij2} is equal to 1 if $15,000 < Y_{ij} \leq $30,000 and 0 otherwise; I_{ij3} is equal to 1 if $30,000 < Y_{ij} \leq $45,000 and 0 otherwise; I_{ij4} is equal to 1 if $45,000 < Y_{ij} \leq $60,000 and 0 otherwise; I_{ij5} is equal to 1 if $60,000 < Y_{ij} \leq $75,000 and 0 otherwise; and I_{ij6} is equal to 1 if Y_{ij} > $75,000 and 0 otherwise. Given I_{ije}, define w as an index of occupation-earning groups and let X_{ijw} correspond to a matrix where the ith element is equal to X_{ijk} \cdot I_{ije} for each k and e combination. The result of this procedure is the derivation of journey-to-work matrices for each of the 24 worker occupation-earning groups. The row and column sums from these matrices are used as inputs to the optimization problems and the spatial interaction model that generate the three commuting benchmarks.

5.4 Estimating work travel benchmarks

As previously discussed, the combined effect of occupation and income status weigh heavily into residential and employment location choices (Alonso 1964; Wang 2003; Wheeler 1967a). As a result, both factors are considered in the analysis of commuting
range \((C_{\text{range}})\) and location strategy \((LS^+)\) of each occupation-earning worker group. 

\(C_{\text{range}}\), the difference between the minimum and maximum amount of travel in a region, is given by:

\[
C_{\text{range}} = T_{\text{max}} - T_{\text{min}},
\]

and \(LS^+\), the relative influence of local (regional) access, is given by:

\[
LS^+ = \frac{T_{\text{prop}} - T_{\text{obs}}}{T_{\text{prop}} - T_{\text{min}}} \times 100,
\]

where: \(T_{\text{obs}}\) = observed commute; \(T_{\text{min}}\) = minimum required commute; \(T_{\text{prop}}\) = proportionally matched commute; and \(T_{\text{max}}\) = maximum allowable commute. Of the three unknowns in equations (5.1) and (5.2) – \(T_{\text{min}}\), \(T_{\text{prop}}\), and \(T_{\text{max}}\) – the predominant method of estimating \(T_{\text{min}}\) and \(T_{\text{max}}\) is the linear program known as the transportation problem (Hamburg et al. 1965; Wheeler 1967b; White 1988), whereas the \(T_{\text{prop}}\) is approximated using a spatial interaction model (SIM).

### 5.4.1 \(T_{\text{min}}\) and \(T_{\text{max}}\)

The TP finds the optimal commuting pattern for the lower or upper bound depending on the objective, given fixed home and work locations, extending the seminal work of Hitchcock (1941):

Minimize

\[
T_{\text{min}} = \frac{1}{T} \sum_{j=1}^{m} \sum_{i=1}^{n} \sum_{w=1}^{W} C_{ij} X_{ijw}
\]

or

Maximize

\[
T_{\text{max}} = \frac{1}{T} \sum_{j=1}^{m} \sum_{i=1}^{n} \sum_{w=1}^{W} C_{ij} X_{ijw}
\]
\[ \sum_{j=1}^{n} X_{ijw} = O_{iw} \quad \forall j, w \]  \hspace{1cm} (5.4)

\[ \sum_{i=1}^{m} X_{ijw} = D_{wj} \quad \forall i, w \]  \hspace{1cm} (5.5)

\[ X_{ijw} \geq 0 \quad \forall i, j, w, \]  \hspace{1cm} (5.6)

where: \( i \) = index of residential zones; \( n \) = number of residential zones; \( j \) = index of employment zones; \( m \) = number of work zones; \( w \) = index of occupation-earning groups; \( W \) = number of worker groups; \( C_{ij} \) = travel costs between zones; \( O_{iw} \) = number of workers of type \( w \) living in zone \( i \); \( D_{wj} \) = number of workers of type \( w \) employed in zone \( j \); \( X_{ijw} \) = number of workers of type \( w \) traveling from home location \( i \) to work location \( j \); and \( T \) = total number of workers. By minimizing (5.3a) or maximizing (5.3b) average travel costs, the TP provides bounds on commuting choices. These are the best or worst trip distributions possible within the population distribution defined by constraints (5.4) and (5.5) guarantying that all workers of type \( w \) find jobs and that all jobs of type \( w \) are filled, respectively. Constraints (5.6) restrict the decision variables to non-negative values.

### 5.4.2 \( T^{\text{prop}} \)

As opposed to the distance sensitive (\( T^{\text{min}} \)) and insensitive (\( T^{\text{max}} \)) work travel patterns, \( T^{\text{prop}} \) identifies the trip distribution where distance has no impact on location decisions and is found using the following equation:

\[ T^{\text{prop}} = \frac{1}{T} \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{w=1}^{W} C_{ij} X_{ijw} \]  \hspace{1cm} (5.7)
where:

\[ X_{ijw} = \frac{O_{rw} D_{jw}}{\sum_j D_{jw}} \quad \forall i, j, w, \]  

(5.8)

and all notation as previously defined. The \( T^{\text{prop}} \) pattern is a set of work trips based on a simple proportional distribution of a zonal pairs share of employees and employers of the total regional labor market. As a result, it reflects the regional home-work relationship (Hamburg et al. 1965; Yang and Ferreira 2008).

5.5 Analysis

5.5.1 Study area

Table 5.2 reports the four average trip lengths and the two metrics for each of the twenty-four subgroups of 300,521 workers in the five-county Wichita, MSA which appears in many commuting-related studies (Horner 2002; O'Kelly and Lee 2005; O'Kelly and Niedzielski 2008, 2009). GIS is used to manage data and calculate distances between and within 559 zones. Impedances between zones, \( C_{ij} \), are straight-line distances, while a variable fraction of the radius of a circle circumscribing each zone serves as travel costs within zones, \( C_{ii} \) (Frost, Linneker, and Spence 1998; O'Kelly and Lee 2005).

5.5.2 Results

The observed average commute (\( T^{\text{obs}} \)) measures mobility or the actual traveling distance workers overcome between home and workplaces. Differences in mobility outcomes
reflect variation in job achievement ability (Wang 2003). By holding earnings constant and focusing on the four occupation groups, the findings tend to support previous observations about the variation in trip lengths according to job skills (Bill, Mitchell, and Watts 2008; O'Kelly and Lee 2005; Wheeler 1967a). Higher-skilled workers and those

<table>
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<tr>
<th>Occupational Groups</th>
<th>Metrics</th>
<th>Earning Groups (in thousand $)</th>
<th>Occupation Group Totals</th>
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<td>15 - 30</td>
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<td></td>
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<td></td>
<td>(LS^+)</td>
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<tr>
<td></td>
<td>(LS^+)</td>
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</tr>
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</table>

Note: \(T_{\text{max}}, T_{\text{prop}}, T_{\text{obs}}, T_{\text{min}}, \) and \(C_{\text{range}}\) are in miles; \(LS^+\) is in %.

Table 5.2 Commute statistics by occupation type and earning groups for workers in Wichita, Kansas (2000).
working in trade and craft occupations have longer distance commutes on average than their counterparts in occupations considered as lower-skilled (sales, services). In fact, craft workers travel, on average, almost 2 miles more to work than sales workers. If occupation is a good proxy for income, then examining job skills variations in commuting would suggest that the higher remuneration of higher skilled workers results in their higher mobility due to fewer constraints on their job achievement abilities.

The classic urban location model suggests that more affluent workers are more mobile than those less affluent because the marginal savings in living space outweighs the marginal increase in travel costs for the wealthier. When holding occupations constant, the linear relationship between income and mobility is only partly explained by the empirical findings. In fact, the relationship is non-linear as observed commutes increase (from a low of 2.14 miles) with increasing income reaching a peak for the $30,000-$45,000 group (8.40 miles) and then decreasing to 4.63 miles for the most affluent. The result seemingly suggest that financial situations constrain lower-income workers into shorter commutes but provide the means for higher-income workers to reduce their work travel (Wang 2003). Differences among occupation-earning groups reveal significant contrasts with patterns suggested by variations in job skills but not income. After controlling for both occupation types and income, the analysis suggests that there is no clear mobility pattern by job skills. On the other hand, mobility is highest among middle
income groups, lower for higher income groups, and lowest for lower earners with few exceptions (high income sales and service workers).

From Table 5.3, the commuting range \( (C^{\text{range}}) \) is lowest for sales workers earning more than $75,000 (0 miles) and highest for management and professional workers earning less than $15,000 (54.99 miles). Range values decrease steadily as a function of increasing income and decreasing job skills. The largest ranges are found for lower income and higher skilled workers and the lowest ranges are detected for higher income and lower skilled. This finding suggests that home-work location sets for higher income workers in Wichita are much more spatial clustered, compared with lower income workers. It seems that the less affluent face more flexible and dispersed home-work interactions.

From a sustainability perspective, larger opportunity ranges may be viewed negatively because they represent increased home-work dispersion. However, from a spatial mismatch perspective larger opportunity ranges may be viewed positively because they represent job achievement possibilities (Horner and Mefford 2007; Wang 2003). Opportunity range represents potential, not actual home-work interactions. By analyzing observed behavior in relation to the opportunity range, it is possible to assess workers’ search range for home and job locations. An open question remains as to the relationship among opportunity range, higher mobility, and search range. The results suggest that a larger opportunity range does not necessarily translate into higher mobility and a larger search range. Lower income workers have the largest opportunity ranges, but are the least
mobile ($T^{obs}$) and have the shortest search range being drawn to the single local job as measured by NEC and LS$^+$. Interestingly, search range increases as a function of increasing income to the middle income rate ($45,000-$60,000) and then decreases. Middle-wage earners work farthest from their local job preferring proximity to a wider assortment of potential jobs than any other group (42.60%-63.49%). In fact, all groups, with varying degree, exhibit convergence between shorter trip distances and access to the local job except management and professional, service, and craft workers in the $45,000-$60,000 income bracket (58.16%-63.49% LS$^+$ range for these groups).

5.6 Summary and discussion

Previous attempts at modeling real constraints on worker’s location choices in the excess commuting tradition have not comprehensively addressed the issues of urban form and socio-demographic profiles. In fact, no previous research incorporates all three benchmarks with factors constraining choices at the residential and employment ends of the work trips. In this work, the worker population is segmented by occupation and income that likely have a combined constraining effect on location choices. Part of the paucity of work considering multiple constraining factors is due to limited dimensionality of the journey-to-work dataset available from the U.S. Census. To overcome this limitation, trip lengths according to occupation and income are devised using the information minimization method and the implicit data technique. The results presented in this chapter have to be treated with caution, however, because the two disaggregation steps produce estimates of and not real observed work trip distributions. Furthermore, the
implicit data technique is based on average earnings and may hide the true variation in excess commuting components for occupation-income worker groups. The unexpected occurrence of workers in the management and professional category making less than $15,000 is likely an artifact of the disaggregation technique. This study should be treated as an exploratory analysis into deep segmentation. Development of better methods is clearly needed.

This exploratory study raises several important questions in regard to understanding the extent of location choices and how observed commutes relate to them. The results indicate that opportunity range decreases as a function of income, due mostly to the significant drop in $T^{\text{max}}$. Does this indicate that higher income workers have less diverse and alternative commuting options that lower income workers? How do these results relate to Horner and Mefford’s (2007) study in Atlanta who find that opportunity range is smaller for minorities and larger for whites. Would higher income minorities have location disadvantage with respect lower income whites? Apart from these substantive questions, a few important analytical and empirical issues emerge when comparing both studies. Are the results in this chapter mostly artifacts of the data set or are they driven by real location options and commuting behavior? Are the results unique to Wichita or are these patterns repeated in other U.S. metropolitan areas?

The pattern of opportunity range by income may be explained by the fact that higher-paying jobs are much less ubiquitous. If there are fewer high-income opportunities, then
it stands to reason that they would be spatially constrained and have smaller opportunity ranges. This may not be an indication of disadvantage, but rather of the fact that location alternatives are limited for the wealthy, because there are only a small number of employment and residential locations that meet their requirements. Thus, one fruitful research direction is to merge the analysis of income and racial groups to track the opportunity range for these combined groups. More broadly, the conceptualization of mobility range as an indicator of spatial (dis)advantage may need to be expanded. The comparative level of benchmarks used in the calculation of mobility range in combination of the range extent may provide important insights. Further theoretical and empirical work is clearly needed.

Another issue is the relationship between observed commuting and the opportunity range. As the opportunity range is decreasing as a function income, the observed average work trips are longest for middle income, shorter for higher income and shortest for lower income workers. What role do financial constraints play in this pattern? Perhaps low-wage workers are less mobile because their financial resources force them to work locally as they cannot afford housing closer to better paying jobs or the recurring costs of commuting. Middle-income workers, however, may possess enough financial clout to absorb longer distance commuting costs but may not afford more expensive housing closer to their workplace. The relatively short distances of higher-income workers may be counterintuitive from the standpoint of classical urban location theory, which suggests these workers are most flexible in their location choices. Does high income allow
workers to afford long distances from peripheral residential sites or to afford expensive housing closer to their workplace? These sorts of questions that may be taken for granted need to be answered considering the changing landscape of U.S. metropolitan areas.

Perhaps the patterns identified in this study are due to the unique spatial structure of Wichita, Kansas. The small opportunity range found for higher-income workers may simply be due to the close proximity of home and workplaces for these households. The location constraints due to their high income status may just as easily translate into a large opportunity range if their homes and jobs were located at opposite ends of a metropolitan area. On the other hand, the opportunity range for lower-income workers could be smaller if their homes and jobs were proximate to each other. Clearly an inter-regional comparison is needed to isolate the impact of spatial structure on opportunity range variations.
CHAPTER 6

CONCLUSION

At some point in life, everyone is faced with the decision of having to choose a location to live and to work. Location opportunities offered by the metropolitan area both enable and define possible options available for each household. In the normal course of events, each household scans all locations in the region and focuses on locations in those sections of the city that match its expectations: Is this position suitable for my job skills? Is this workplace close to a wide range of other jobs in case I lose this one? Can I afford to buy a house or do I need to rent an apartment? What size house or apartment can I afford to live in, bearing in mind my own income? Is this house or apartment big enough for my family? Is there a yard for my children to play in? What types of entertainment, recreational, and leisure activities are close by? Are there parks and playgrounds close by? What is the quality of the local school?

Over time, these socio-economic, demographic, site and situation factors have received considerable attention in the urban geography literature. This is not surprising; given the relationship between location choices and travel, and the impact this relationship has on the sustainability of urban growth. It is surprising, however, that these social factors have received relatively little attention in that part of the literature which is concerned with the
estimation of location choice sets in relation to home and job sites associated with commuting. Thus, the purpose of this dissertation is twofold. First, by exposing the pertinent characteristics of socio-spatial mismatch, this dissertation attempts to examine the definitions of location choice sets and of excess commuting. Second, this thesis attempts to evaluate the contribution of “locked-in” commuting to observed work travel patterns and to assess the variation in location choice sets and commuting outcomes for different socio-economic households. A more detailed break-down of the contributions of this work is presented in the remainder of this dissertation.

6.1 Dissertation summary

This dissertation addresses the challenge of modeling household location choice sets. Chapter 2 provides a general understanding of the modeling techniques that estimate location options and of the different uses of these models in support of commuting-related research. Following this is the exposition of three types of factors that determine observed location and commuting behavior. Thereafter, I propose that socio-economic-demographic, site and situation factors are key determinants of the shape and size of location choice sets. With this in mind, an enquiry is made into how socio-demographic characteristics (income, occupation, race, gender, and transport mode), housing attributes (value, age, and size), and neighborhood amenities (density, access to environmental and leisure activities, school quality and crime rates) combine to make an impact on household choices. I suggest that these factors reduce the metropolitan locations from which people pick their actual homes and workplace. My particular concern is that
models omitting these factors misrepresent location choice sets and consequently may provide misleading conclusions and policy recommendations.

In Chapter 3, I claim that the single representation of urban form and location strategy is an incomplete perspective on location decisions. The existing approach for evaluating observed behavior is to compare it with the behavioral outcome assuming people are solely focused on optimizing their journey-to-work patterns. This type of theoretical behavior is measured by the minimum required commute and represents classical location theory. The assumptions behind the classical theory, however, are unreasonable because it maintains that workers/employers have perfect information about job openings/worker availability and that there is no uncertainty in regard to future employment. At the other extreme is the revised location theory, measured by the proportionally matched commute, which assumes that the labor market functions in a highly imperfect way. This chapter argues that the proportional commute is the appropriate baseline to assess observed behavior because it is the null hypothesis of commuting. With no information to guide their location choices, household commuting patterns will be apportioned randomly.

Chapter 3 proposes a new metric to answer the following question: what type of a location strategy better explains workers’ observed aggregate journey-to-work pattern? The new context combining the classical and revised theories is applied to the commuting patterns of households in 25 metropolitan areas in the U.S. The results indicate that
observed average work trips are further away from the proportional commuting and closer to the minimum work travel. The implication is that while households and employers do not have perfect information about the locations of other groups, they are not completely lacking this spatial knowledge. In fact, the observed patterns are at least 50% further away from the proportional commute for twenty out of twenty-five cities in the sample. This means that households in these twenty cities, in varying degrees, value access to the single local job rather than multiple regional jobs.

Chapter 4 argues that urban and social structures contribute to bounds on location choices and commuting, because not all homes and jobs are possible choices for every worker. It points out that there is a disconnect between the theoretical assumptions and the modeling techniques. Since the socio-economic and demographic characteristics are one type of factors that limit location choices, it is important to address these constraints in the modeling techniques. A redefinition of the required and excess commuting is presented and incorporated into the models that quantify location choice sets. Using data from Wichita, Kansas, disaggregated at a more detailed level than in previous studies, it is found that accounting for socio-spatial mismatch better explains observed commuting than simple location mismatch used in previous work.

In addressing the socio-spatial mismatch, the main challenge is the estimation of observed commuting. A comprehensive data source that provides deeply segmented work trip flows is not available, because at best the work travel data provided by the U.S.
Census is stratified by two worker characteristics. Unfortunately, occupation and income are not in these sets, and so work travel stratified by these two characteristics is obtained through an implicit data technique.

Chapter 5 incorporates socio-economic constraints in the modeling of location choices sets and assesses observed behavior in the context of multiple location strategy perspectives. Occupation and income are used to capture socio-demographic constraints at the residential and employment ends of the work trip simultaneously. These socio-economic factors contribute to required commuting because they control for job skill and housing affordability mismatches. Inclusion of both factors is also useful to test the assumption prevalent in previous studies that occupation is a good proxy of income. Based on the stratified analysis in Wichita, Kansas, it is found that occupation is not a good proxy of income (and vice versa) because it is earnings that drive the variations in observed behavior and location choice sets of occupation-income groups. Lower and higher income workers across all occupation types tend to work locally, because financial resources prohibit long distance commuting or allow for short distance work trips, respectively. Middle income workers are able to afford the recurring costs of travel but are priced out of local housing.

6.2 Future directions

The study of the commute impact of land use is intricate because the spatial decision making process is quite complex. Due to time and resources constraints, this dissertation
is able to address only a small number of issues pertaining to research at the intersection of transportation and land use. It is hoped that the ideas presented in this thesis may serve as a foundation for future ideas.

The attempt in this dissertation is to accurately measure the location choice sets faced by households when making location decisions. The use of two socio-economic characteristics is a rather coarse segmentation of households. Further work is needed to capture pertinent demographic, site and situation factors limiting location options. Beyond this, however, there are two research directions of prime interest. First, armed with improved techniques to measure the relationship between home and job locations, it is imperative to more thoroughly investigate the question of whether a better balance between homes and jobs encourages shorter commutes. The existing evidence partially supports the claim that mixed-use landscape promotes shorter commutes. Thus, the second research direction is to investigate whether and how land use may be changed to reduce commutes without degrading worker’s current quality of life.

There are still methodological questions that have not been fully worked out in the existing literature. Despite the ideas presented in this dissertation, location choice sets may still be misrepresented. The extent of location choice sets may be overestimated because the system-wide minimizing objective forces workers in some parts of the city to actually commute longer than their observed pattern. Moreover, the current models of the lower and upper bounds on location choice sets, including the expanded ones in this
thesis, assume that workers tend to minimize their commutes on the basis of achieving a system optimum. This optimized travel pattern may not be commensurate with individual decision-making strategies. New formulations should be explored to model realistic behaviors. Another possible research vein is to investigate the effect of data definitions and aggregations on excess commuting results. Currently, the impact of different ways of defining and aggregating occupations, income etc. on commuting metrics is unknown.

Finally, this dissertation focuses on the relationship between commuting outcomes and location choice sets for one city in one time period at a regional scale. Extending the analysis herein to the top 100 U.S. metropolitan areas for census data in 1990, 2000 and 2010 across regional and local scales would provide the empirical foundation for the exploration of numerous commuting-related questions. Some of the potential questions waiting to be investigated are: how labor achievement and opportunity range vary among racial and income groups living in different sections of the city, how this compares across different geographical contexts and how this is changing over time.
REFERENCES


