LSU Doctoral Dissertations                                                    Graduate School

2010

# Land use, individual attributes, and travel behavior in Baton Rouge, Louisiana

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**LAND USE, INDIVIDUAL ATTRIBUTES, AND TRAVEL BEHAVIOR IN BATON ROUGE, LOUISIANA.**

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Geography and Anthropology

by
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August 2010

# Dedication

To my mom and dad, my husband Yuri, and my lovely girls Xenia and Julia.

# Acknowledgements

This dissertation would not have been made possible without the help, advice and support of many people. First, I would like to extend my profound thanks to my academic advisor, Prof. Fahui Wang, for his patience, professional advice, suggestions, and endless support offered from the very beginning of his working with me through the very end of this research. Thank you for leading me into an exciting world of transportation geography! I also wish to thank Prof. Chester Wilmot (Department of Civil and Environmental Engineering) who generously shared the data used for this study, offered time, help and personal friendship, I am greatly thankful. Prof. Lei Wang, who tirelessly advised me on writing, continuously encouraged me with my research, thank you for your interest, insightful suggestions, your support is very valuable to me. Prof. Barry Keim, thank you so much for stepping in at the very last minute, you have always believed in me.

I am also grateful to the Board of Regents, for the Economical Development Assistantship that supported my research financially during 2005-2009.

Particular thanks are extended to Prof. Patrick Hesp, Prof. Tony Lewis, Prof. William Rowe, other members of the Department of Geography and Anthropology for their support of my research.

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# Abstract

Although the interrelationship between land use and travel behavior was given more than scant attention in the past, urban planners are far from a solution to reduce commuting and travel by car. One of the reasons is that studies of this kind are often conducted at the aggregate scale limiting one's probabilities of making inferences of individual/household-level travel behavior. Using 1997 Baton Rouge Personal Transportation Survey (BRPTS) data this study attempts to overcome this limitation.

First, a multi-level modeling (MLM) approach is applied to investigate the geographical effect of a place and the role of population composition in accounting for place-to-place differentiation in commuting. The models examined the degree of association between several aspects of land use and travel behavior, considered alone and controlling for socio-economic factors. Results of the study indicate that land use remains significant even after accounting for socio-economic factors. Thus, spatial proximity of jobs determines commuting in a significant way.

Second, urban structure and its effect on commuting in the Baton Rouge region of Louisiana were examined. Job concentrations in the study area in 1990 and 2000 were defined and changes examined from 1990 to 2000. Commuting patterns both from the perspectives of monocentric and polycentric urban structures were investigated. Results indicate that the polycentric system contributes to a reduction in individual commuting times and distances in the study area.

Lastly, individual-level trip data for the Baton Rouge metropolitan area was used to examine the relationship between land use and trip chaining behavior. Specifically, land use measures were used to explain the likelihood of combining activities into multi-stop trip chains by residents of Baton Rouge region. In addition, the impact of travelers' employment status was also considered. Models of the ordinary logistic regression, and one accounting for correlation among individual observations were compared. In all models tested, inclusion of land use measures improved the model. Results indicate the significant land use impact on a traveler's decision regarding trip chaining. The study findings are consistent with the literature, however, they illustrate the difference that exists between by workers and non-workers.

# Introduction

"…research that enriches our understanding of how different elements of the built environment combine to shape travel behavior under different conditions is more imperative now than ever." (Cervero and Kockelman, 1997, p.219).

Traditionally, the transportation system in the USA has been considered very efficient, which offers extraordinary mobility (measured in terms of the ability to move efficiently between origins and destinations) and accessibility (measured as travel time or distance) to its population (U.S. DOT, 2001). Its tremendous role in the national economy is difficult to underestimate. There are more vehicles owned or available to U.S. households, with the mean number being 1.9 personal vehicles, than there are drivers in households; on average, households have 1.8 drivers (NHTS, 2004) (Table 1). According to the NHTS 2001 Highlights Report (2004), 92 percent of households use a vehicle on a regular basis. That is why the personal vehicle remains the prevalent transportation mode for both daily and long-distance trips; for the former, it contributes 87 percent of all daily trips (NHTS, 2004). However, there are also negative impacts of transportation on society.

**Table 1: Travelers' Characteristics.**

| Mean Number of Drivers, Vehicles, and Bicycles per Household | | |
|---|---|---|
| | Mean | SE |
| Drivers per household | 1.75 | 0.005 |
| Personal vehicles per household | 1.90 | 0.007 |
| Full-size bicycles per household | 0.86 | 0.009 |

Source: The 2001 National Household Travel Survey, household file, U.S. Department of Transportation.

Among the largest negative impacts is urban sprawl, a phenomenon characterized by the ever-increasing dependence on the automobile (Trancik, 1986). Many U.S. cities maintain a pattern of urban sprawl, with low-density suburbs necessitating long trips and wasteful use of land, energy, and other resources (Giuliano, 1995; Goulias, 2003). That people are choosing to live in less dense suburbs is correlated with an increase in income and is associated with greater automobile transportation and fossil fuel consumption (Pucher and Lefevre, 1996).

The increase in motorization leads in turn to another problem, environmental issues. According to Goulias (2003), transportation demand tends to grow along with consumers' desire to use larger, more comfortable and safer vehicles, which implies an increase in air pollution and consumption of energy. Transportation affects the environment during both the facility construction and operational stage (Goulias, 2003). Transportation is responsible for emissions of anthropogenic carbon dioxide ($CO_2$) which is believed to contribute to global climate change, as well as fuel combustion that causes greater morbidity, mortality, and damage to ecosystems. Communities are increasingly realizing the importance of such environmental effects of transportation on air, soil and water quality and land use as they affect life quality of all residents. The suggested solutions to these problems are seen in the implementation of fuel

efficiency and emission mandates, controlling and changing existing land uses which favor environment-friendly modes, managing transportation demand by utilizing carpooling, teleshopping and commuting, and making use of transportation information technology in the form of Intelligent Transportation Systems.

Yet another negative impact of transportation on society is congestion, defined as "waiting in line" (Downs, 2004, p.20), one of the widespread and severe problems of transport supply Ortuzar and Willumsen, 2006). It takes place when demand levels generated by the economic growth come close to the capacity of a facility and when travel time is much greater than the average time required to use this facility when demand is low. In other words, congestion begins when traffic changes from a high speed, free-flow conditions to a state with low speed and volume resulting in a delay to all other users (Ortuzar and Willumsen, 2006; Varaiya, 2005). According to NHTS 2001 report on travel trends, (2004) fifty percent of the U.S. adult population is to some extent severely worried about highway congestion (Table 2).

**Table 2: Travel-Related Characterisitcs of Individuals, 15 years Old and Older, in Percent.**

|  | Percent |
|---|---|
| Drivers | 88 |
| Used public transit in last 2 months | 17 |
| Biked in the last week | 8 |
| Have travel-affecting medical condition | 9 |
| Are somewhat to severely concerned about highway congestion | 50 |

Note: Percents do not total 100% since categories are not mutually exclusive. Source: The 2001 National Household Travel Survey, person file, U.S. Department of Transportation

An increase in income level results in greater households and individuals having more cars, as well as the growth of the proportion of multiple vehicle households, increase of commuting trip distances due to relocation of families to suburbs, the greater number and length of trips has been attributed to the fast growth of highway passenger travel reflected in a much amplified vehicle miles traveled (VMT) (Memmott, 2007). Population in Louisiana is forecast to experience a significant growth from 4.5 million in 2000 to 5.4 million in 2030, with an annual growth rate of 0.6 percent. Regarding employment, Louisiana economy is expected to gain over 900,000 jobs by the year 2030, with an annual increase of 1.1 percent.

**Table 3: Expected Growth of Population and Employment, Selected Areas.**

|  | Population | | Employment | |
|---|---|---|---|---|
|  | 2000 | 2030 | 2000 | 2030 |
| Arkansas | 2,673,400 | 3,645,132 | 1,508,746 | 2,218,439 |
| Louisiana | 4,468,976 | 5,437,145 | 2,416,492 | 3,345,073 |
| Mississippi | 2,844,658 | 3,672,795 | 1,512,021 | 2,139,201 |
| Texas | 20,851,820 | 32,035,969 | 12,164,883 | 19,376,875 |

Source: LA DOTD, 2003. http://www.dotd.louisiana.gov/study/pdf/LA_Poster.pdf

With the dramatic increase of population, employment, and, therefore, increased consumption of natural resources, such as gasoline, and natural gas, an urgent need arose to manage automobile travel in the U.S. cities. This also fits with the goals of the relatively new movement of Smart

Growth and New Urbanism. Advocates of this movement state that urban planning needs to be changed, for example, through appropriate land use policies such as a development of the traditional neighborhoods with mixing land use, greater density of population, more accessible, aesthetically-pleasant, and pedestrian-friendly streets, and other measures which might help to overcome the utter dependence on cars, change travel behavior and decrease the number of trips and single use of cars (Katz, 1994; McNally and Ryan,1993; Kulash,1990; Duany, Plater-Zyberk and Speck, 2000).

Therefore, the interaction between land use, transportation systems and travel behavior became a topic of much interest for many professionals (Krizek, 2003). Although recognizing the complexity of the link between urban form and travel behavior, land use has been shown to impact travel behavior (Boarnet, and Crane, 2001; van Wee, 2002). Travel behavior is studied in terms of commuting travel time and distance, vehicle miles traveled (VMT), vehicle ownership, mode choice, trip generation, trip length, while land use is often measured by population or employment density, mixes of uses (Frank, 1994; Frank and Pivo, 1994; Badoe and Miller, 2000; Zhang, 2005), neighborhood street design (Friedman, Gordon, and Peers, 1994; Cervero and Kockelman, 1997; Handy et al, 2005), and accessibility (Handy, 1992, 1993, 1994), among others.

However, the results of the numerous empirical studies on the impact of land-use policies on the transportation system and interaction between them are somewhat inconsistent (Badoe and Miller, 2000). For example, many findings indicate the relationship between vehicle ownership and land-use mix, urban densities, traditional neighborhood design schemes, while still other findings claim that land use impacts transportation, at best, not significantly (Giuliano, 1995).

The focus of this dissertation is an empirical investigation of travel behavior within the Baton Rouge region, Louisiana, measured by commuting length (in miles), commuting duration (in minutes), and the consolidation of several away-from-home activities into a single trip (trip chaining) as a function of urban land use. Specific objectives are to:

1. Examine the land use impact on commuting times and distances using multi-level modeling approach;
2. Examine the effect of monocentric (single employment center) and polycentric urban structure (multiple employment centers) on commuting within study area;
3. Investigate how land use impacts the trip chaining propensity among Baton Rouge employed and non-employed trip-makers.

Relationship between land use and travel behavior was analyzed by using individual-level 1997 Baton Rouge National Personal Transportation Survey data.

The following chapters (Chapters II to IV) represent three papers planned for a journal publication. They are related to one another by analyzing the interrelationship between land use and travel behavior in terms of the journey to work and car trips within the Baton Rouge area of Louisiana. This is accomplished by the papers investigating the objectives set above, respectively. The data that these chapters utilize have largely come from the same sources; at the same time, the methods and approaches used to analyze these data differ depending on the specific research purpose.

Chapter II investigates the geographical effect of a place and the role of population composition in accounting for place-to-place differentiation in commuting by using multi-level models. The models examine the degree of association between several aspects of land use and travel behavior, considered alone and controlling for socio-economic factors, both at neighborhood and individual levels.

Chapter III focuses on an examination of the employment structure within the Baton Rouge region of Louisiana and its effect on commuting patterns in the study area. It seeks to answer the question whether the polycentric system is more beneficial than the monocentric one to commuters in terms of saving travel time and distance by testing a "co-location theory". First, based on the notion of in-net commuting, we used the employment to resident workers (E/R) ratio as the main criterion to define job concentrations in the study area in 1990 and 2000 and we examined the changes from 1990 to 2000. Second, using the data of the 1997 Baton Rouge Personal Transportation Survey, we investigated the commuting patterns, both from the perspectives of the monocentric and polycentric urban structures.

Chapter IV aims to examine the relationship between land use and trip chaining behavior. Specifically, land use measures are used to explain the likelihood of combining activities into multi-stop trip chains by residents of Baton Rouge region. In addition, the chapter also considers the impact of travelers' gender and their employment status, namely workers and non-workers. Models of the ordinary logistic regression and the one accounting for the correlation of the individual observations are compared.

Chapter V discusses the results and conclusions reached by the preceding sections. This last chapter delineates the significance and contribution of the study. It further outlines the limitations of the research and provides some ideas for the future work. Chapter V is followed by the bibliography used for each of the chapters II through IV. The last entrance of this dissertation is the author's vita.

# Urban Land Uses, Individual Attributes and Travel Behavior: A Multilevel Modeling Approach

## Introduction

Commuting, an important component of our daily travels, is one of the major sources of congestion, delays (Levinson and Kumar, 1994) and air pollution in the United States (Sultana, 2002). Among various public policies for reducing personal travel needs, there is a growing interest in using land uses to alter travel behavior including commuting (Weber and Kwan, 2003). Land uses (e.g., industrial, residential, and commercial) have been found to determine the need to travel; and on the other side, travel also impacts spatial development (Wegener, 2004:127). The influence of the built environment on commuting is not only statistically significant but also practically important (Cao, Mokhtarian, and Handy, 2007; Handy et al., 2006). Density, land use form, and street design are common land use measures in studies on interrelationship between land use and transportation (Krizek, 2003).

First, residential (i.e., population) *density* has often been used to explain intraurban variation in commuting time or distance (Peng, 1997). In general, higher residential density areas are associated with a smaller number of trips undertaken and a lower percentage of car use (Pushkarev and Zupan, 1977; Smith, 1984; Cambridge Systematics, 1994; Krizek, 2003). Residential density and distance to the Central Business District (CBD) are found to significantly impact driving distance (Cheslow and Neeels, 1980). In higher population- and employment-density areas, the number of destinations/attractions within a fixed spatial range increases, and therefore people only need to travel a shorter distance to reach a destination (Schwanen and Mokhtarian, 2005). Increased densities also induce an increase in travel choices with better transit availability and improved walking conditions. Further, higher density areas are often associated with higher congestion levels and slow speeds for car drivers, and along with reduced parking options (e.g., higher parking fares and longer distance to a parking lot) make transit more attractive (Kockelman, 1997; Litman, 2008).

Secondly, *land use mix* or co-location of different land uses has been shown to affect travel behavior (Holtzclaw, 1994; Cervero and Gorham, 1995; Cervero, 1996; Schimek, 1996; Holtzclaw et al., 2002; Cervero and Duncan, 2002; Miller, 2003). An even balance in various land uses generally decreases the average commute distance and per capita vehicle travel (Litman, 2008). The underlying rationale is that proximity to various land uses reduces travel distances to every-day activities such as commuting to work, shopping, recreation and social networking. Land use mix can be measured as the number of employees in an area (Krizek, 2003), the ratio of jobs to residents in an area (Litman, 2008), the retail and service employment density around a person's residence (Boarnet and Sarmiento, 1996; Boarnet and Sarmiento, 1998), or a land use dissimilarity (mix) index (Kockelman, 1997).

*Street design and connectivity* are another perspective in examining the impacts of land use on transportation. Several studies have shown that the structural design of a neighborhood impacts the way residents travel (Bagley and Mokhtarian, 2002; van Wee and Maat, 2003; Schwanen and Mokhtarian, 2005; Lovejoy, 2006). Gridded streets, typical in traditional neighborhoods, tend to have a higher connectivity and shorten trips; and four-way intersections, also typical for

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traditional neighborhoods, generally slow traffic and generate more trips (Litman, 2008). Traditional neighborhoods also have better transit services and are friendlier for pedestrians, and thus produce fewer vehicle miles of travel (VMT) (McNally and Ryan, 1993).

However, some question the notion of interrelationship between land use and transportation by citing little or no evidence of the effect of density and urban design on travel behavior such as transit usage and vehicle miles traveled (VMT) (Peat, Marwick and Mitchell, 1975; Levinson and Kumar, 1993; Burby, 1974; Ewing et al., 1994; Friedman et al., 1994; Steiner, 1994; Crane, 1996; Handy, 1996a, 1996b; Boarnet and Crane, 2001). Others admit the role of densities on travel behavior, but emphasize that other confounding variables such as accessibility to opportunity sites, parking pricing and limitation, and congestion should also be included in order to obtain unbiased and consistent results (Green, 1993; Kockelman, 1997). Among the confounding variables, *socio-demographics* may play an even more important role in shaping travel behavior (Sultana 2005; Limtanakool, Dijst, and Schwanen, 2006; Cao, Mokhtarian, and Handy, 2007; Handy et al., 2006). Individual and household characteristics have been shown to exert a much stronger influence on individual accessibility than local urban environment such as land uses around an individual's home (Weber and Kwan, 2003). Similarly, micro-level personal and household attributes are more significant than urban form variables in explaining commute time (Schwanen, Dieleman, and Dijist, 2003). Demographic features of neighborhoods where individuals reside also help explain variation in their travel behavior (Boarnet and Sarmiento, 1998).

The debate over the land use impacts on travel behavior is far from reaching a consensus. Examining the relationship alone is insufficient in providing urban planners with a solution of journey to work reduction, particularly in an intraurban setting (Weber and Sultana, 2007). An aggregate scale such as census tract, block group or zip code area, employed by many studies, masks individual behavior, and leads to ambiguous findings (Boarnet and Sarmiento, 1998). This paper differs from the aforementioned studies in several aspects, and shreds new light on this important debate.

First and foremost, the combined effects of land use types and socio-demographics (including both individual and neighborhood attributes) on commuting are analyzed by a multilevel modeling approach. In addition, a localized job-housing balance ratio is computed to capture the degree of mixed land uses around each residential location, and its effect on commuting behavior is examined. Commuting is measured by both travel distance and time in order to capture the spatial separation of residence and workplace as well as road conditions.

The remainder of the paper is organized as follows. The next section discusses the study area and data sources, followed by a section on the selection and definition of variables, a section on analysis methods, and another section discussing the results. The paper is concluded with a brief summary and discussion of limitations.

## Study Area and Data

The study area consists of three parishes (East Baton Rouge, West Baton Rouge and Livingston), which form the core of Baton Rouge Metropolitan Area (excluding Ascension Parish on the south, which is mostly rural). Parish in Louisiana is equivalent to county elsewhere in the U.S.

The central city Baton Rouge is the capital city of Louisiana (Figure 1). We refer to it as the Baton Rouge region in the remainder of this paper. It encompasses a diverse range of land use types across urban, suburban, and rural settings.
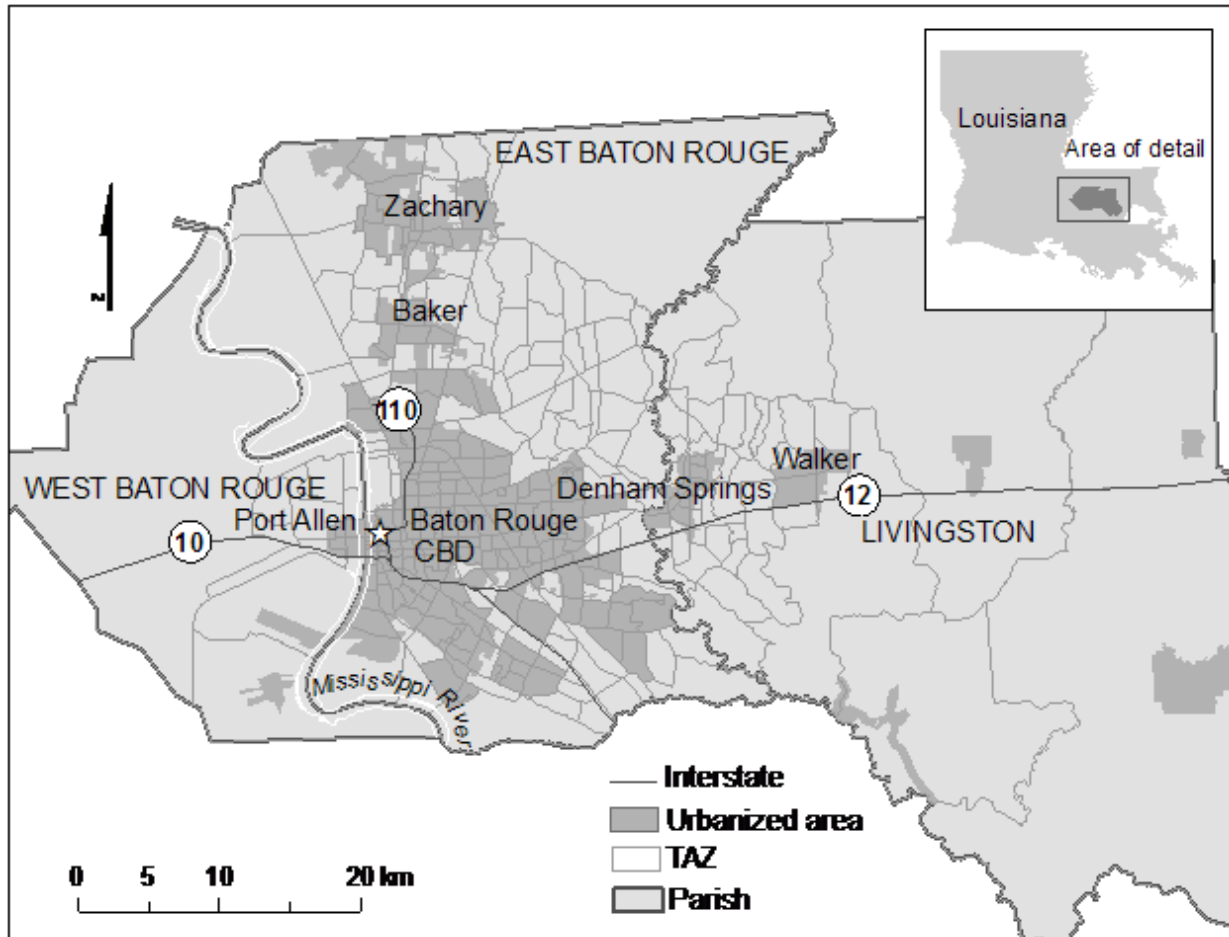


**Figure 1: Study Area.**

Detailed individual travel data were extracted from the 1997 Baton Rouge Personal Transportation Survey (BRPTS) database, collected by the Research Triangle Institute. The dataset has three files: household file, travel day file, and person file, which can be linked together. In addition to demographic and socioeconomic variables, the household file has geographic coordinates of household, and the person file has geographic coordinates of residence and workplace. The location information enables us to geocode each commuting trip's origin and destination, to identify land use where each household resides, and to associate with neighborhood attributes. The BRPTS sample originally included 1,395 surveyed households or 2,934 persons with reported travel day data. Those with missing residential or work locations were excluded from the travel data base for this study. The final travel data set provides detailed travel day data of 1,104 working individuals.

Table 4 shows the distributions of BRPTS respondents in various land uses and across socio-demographic categories. The respondents were predominantly white (76%), with 22% African-Americans and very few Asians and others (<1%). Males accounted for 45% of the respondents,

and females 55%. Table 4 also shows the distributions among various education attainments and at different stages of life cycle, while Table 5 reports household characteristics including household size, number of vehicles, drivers, and workers.

Another data source was the 2000 Census Transportation Planning Package (CTPP). The CTPP Parts 1 and 2 at the Traffic Analysis Zone (TAZ) level were used to define resident workers and employment, respectively. TAZs, defined on the basis of land use homogeneity and generally smaller than census tracts, were used in this research to represent neighborhoods. There were 250,516 jobs (employment) and 238,522 resident workers in the study area, and thus the average job to workers ratio (JWR) was 1.05, consistent with other metropolitan areas in the U.S. There were 377 TAZs in the study area. Table 6 reports basic statistics of variables at the neighborhood (TAZ) level. Table 7 reports all the variables used in the regression models (categories in *italics* represent a reference group). The next sections provide description and justification of the key variables' selection.

**Table 4: Distributions of the 1997 Baton Rouge Personal Transportation Survey Respondents.**

|  | No. respondents | % |
|---|---|---|
| Land Use Type: |  |  |
| agricultural | 139 | 12.59 |
| commercial/office | 107 | 9.69 |
| *low-density residential* | 721 | 65.31 |
| medium-density residential | 82 | 7.43 |
| high-density residential | 55 | 4.98 |
| Sex: |  |  |
| *male* | 497 | 45.02 |
| female | 607 | 54.98 |
| Education: |  |  |
| less than high school diploma | 75 | 6.82 |
| *high school diploma and some college* | 569 | 51.73 |
| Some degrees | 456 | 41.46 |
| Race: |  |  |
| *white* | 836 | 76.14 |
| African American | 245 | 22.31 |
| Asian and others | 17 | 1.55 |
| Life cycle: |  |  |
| households with no children | 429 | 38.85 |
| households with children < 16 yrs old | 514 | 46.56 |
| *households with children 16-18 yrs old* | 116 | 10.51 |
| retired | 45 | 4.08 |

Note: reference category in coding dummy variables in *italics*

**Table 5: Household Characteristics of 1997 Baton Rouge Personal Transportation Survey.**

| Household characteristics | Mean | Min | Max | St. Dev. |
|---|---|---|---|---|
| Vehicle count | 2 | 0 | 6 | 1 |
| Driver count | 2 | 0 | 5 | 1 |
| Household size | 3 | 1 | 8 | 1 |
| Worker count | 2 | 1 | 5 | 1 |

**Table 6: Basic Statistics of Variables of the Traffic Analysis Zone Within a Study Area.**

| TAZ characteristics, N=377 | Total | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|
| Resident workers | 238,522 | 632 | 661.10 | 0 | 3,905 |
| male | 125,311 | 332 | 357.50 | 0 | 2,245 |
| female | 113,218 | 300 | 300.30 | 0 | 1,655 |
| Population | 526,248 | 1,395 | 1427.10 | 0 | 9,630 |
| White | 332,468 | 881 | 1209.00 | 0 | 8,495 |
| AA | 175,256 | 464 | 771.00 | 0 | 6,035 |
| Asian | 8,978 | 24 | 66.00 | 0 | 780 |
| Households | 196,842 | 522 | 532.00 | 0 | 3,710 |
| Mean travel time (minutes) | | 22.8 | 9.28 | 0 | 75 |
| Mean travel time who drove alone | | 22.3 | 9.52 | 0 | 77.8 |
| Employed workers | 250,516 | 664 | 1001.00 | 0 | 8,980 |
| male | 129,124 | 342 | 499.50 | 0 | 3,585 |
| female | 121,326 | 322 | 546.90 | 0 | 5,395 |
| Jobs to Workers Ratio (JWR) | | 1.05 | 0.292 | 0.1 | 1.35 |

Source: Census 2000 CTPP Parts 1 and 2

**Table 7: Description of the Selected Variables.**

| Variables | Description |
|---|---|
| Roaddistmi | Commuting distance to work, miles |
| Roadtime | Commuting time to work, minutes |
| Agricultural | Agricultural land use |
| Comm./Office | Commercial/Office land use |
| *Resid. Low.* | *Low Density Residential land use* |
| Resid. Med. | Medium Density Residential land use |
| Resid. High | High Density Residential land use |
| JWR | Employment to Workers Ratio within 25 min. of travel catchment area |
| Sch345 | Living within 2 miles of a high-performing school catchment area |
| % minority | Percent of the minority population within TAZ |
| %below pov. | Percent of population below poverty level within TAZ |
| % SOV | Percent of workers who drove alone within TAZ |
| Income | Income level per individual household |
| Age | Age of a respondent |
| *Race, Wh* | *White* |
| Race, minority | African-American and Asian |
| *Gender, male* | *Male* |
| Gender, female | Female |
| <high school | Education: Less than GED or high school diploma |
| some college | Education: High school/some college |
| *degree* | *Education: Having a degree* |
| Life cycle: | |
| 1or2 adults, no children | Households consisting of 1 or more adults, no children |
| 1o2 adults, child.<16y.o. | Households consisting of 1 or more adults, children younger than 16 y.o. |
| *1o2 adults, child.16-18y.o.* | *Households consisting of 1 or more adults, children age 16-18y.o.* |
| Retired | Households consisting of 1 or more retired adults |
| *Usually drives, yes* | *Driving mode: Usually drives, yes* |
| Usually drives, no | Driving mode: Usually drives, no |
| *Job, full-time* | *Had a full-time job* |
| Job, part-time | Had a part-time job |
| Workers in household | Number of workers in a household |

## Selection and Definition of Variables

This study examines the combined effects of land uses and socio-demographics on commuting. The former are related to a respondent's location, and thus are also referred to as "spatial factors". The spatial factors include (1) land use type where a respondent resides, (2) land use mix captured by the JWR around the respondent's home, and (3) the respondent's proximity to a high-performing school. All spatial variables are defined on an individual basis. Socio-

demographic variables include both individual and neighborhood attributes. Individual attributes are extracted from the 1997 BRPTS, and neighborhood attributes are defined from the 2000 CTPP at the TAZ-level. The three-year time gap between the 1997 BRNPTS and the 2000 CTPP (mostly based on the 1999 yearend data) is considered acceptable to match them together. The zoning map showing a distribution of types of land use such as commercial, residential, industrial, etc. across the study area, have been published by the Baton Rouge City-Parish Planning Commission in 2004. Due to the relatively slow change of the urban built-up developed area (Mitchell and Rapkin, 1954: 15), and a stable temporal distribution of land uses (Wegener, 2004: 128), the gap of 7 years between the date of publication of land use data and the 1997 BRPTS survey, was considered non-significant. The following describes how the variables are selected and measured.

**Land Use Type**

Land use data were from two sources. A detailed zoning map for the East Baton Rouge Parish in the PDF format was downloaded from the Baton Rouge City Planning Commission web site (BRCPRC, 2009). To construct the land use data in GIS, we first saved the PDF file as a tag image file, then imported it into ArcGIS and georeferenced it. The georeferenced raster file in a grid form was later converted into a shapefile by merging raster cells sharing the same land use types. For West Baton Rouge Parish and Livingston Parish that are mostly rural, no land use maps or GIS data sets similar to that of East Baton Rouge Parish were available for our study. The USGS 2001 data set from the Louisiana GIS Digital Map was used to identify land use categories for these two parishes. Similarly, we extracted the raster files representing land uses within parishes of West Baton Rouge and Livingston, and then converted them into shapefiles.

The BRCPC (2009) developed the following land use classification for the zoning map: industrial, recreation, transportation communication utilities, vacant, office, commercial, public/semi-public, low density residential, medium density residential, high density residential, and agricultural. Since no travel survey respondents in the BRNPTS data set resided within the first four land use groups, these categories were not considered by our study. The next three land use categories – office, commercial, and public/semi-public – were similar in terms of impact on travel behavior as all three are closely associated with employment location. In addition, there were only a small number of survey respondents from each of the three land uses. Therefore, office, commercial, and public/semi-public land uses were combined into one group: *commercial/office*. Three residential categories differ by land use intensity and have distinctively prevalent housing structure. *Low density residential* is generally dominated by single-family detached houses; *medium density residential* is characterized by smaller-lot single family houses, and *high density residential* is predominantly occupied by multi-family housing structures such as apartment complexes and condominiums (Homer et al, 2004). Outside urban areas, residential land types, agricultural (e.g., pasture/crops, cultivated crops, shrub/scrub, grassland) and sparsely populated forested areas were collapsed into a single category: *agricultural/rural*. In summary, there are five consolidated land use types used in the analysis: commercial/office, agricultural, low density residential, medium density residential and high density residential. The five land use types are different in terms of density, type of housing structure, as well as the type of economic activities taking place there.
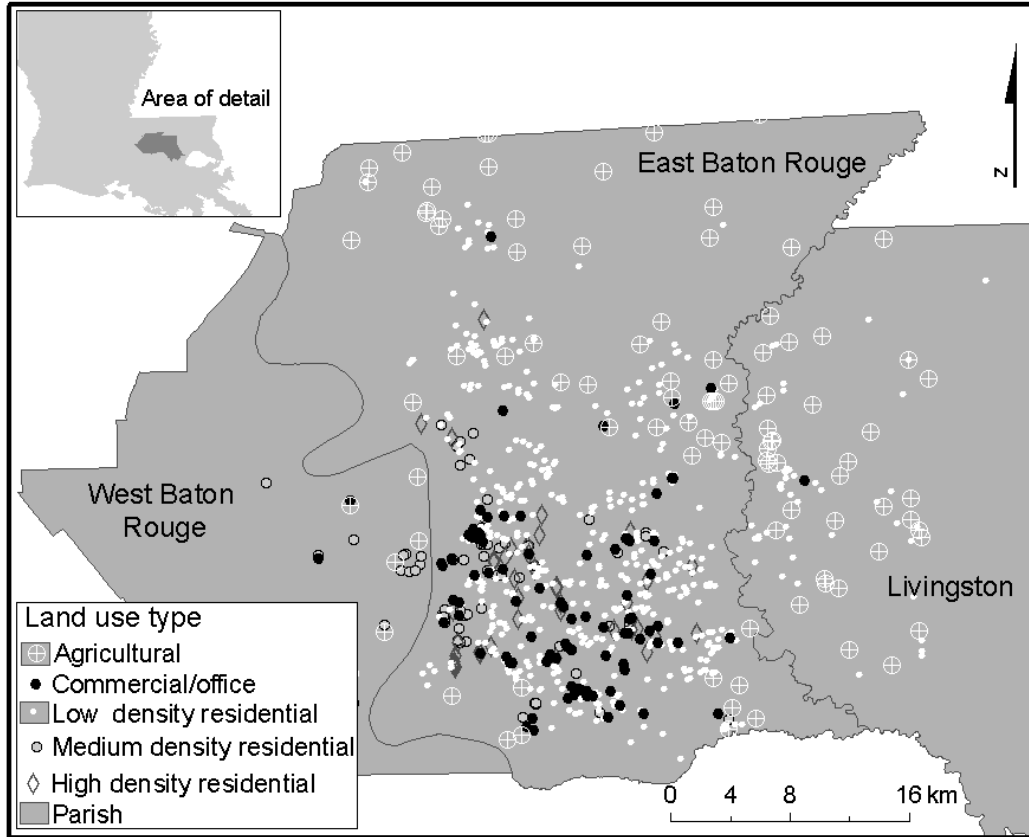
**Figure 2: Residencies by Land Use Type Within Study Area.**

Figure 2 shows the home locations of BRNPTS respondents superimposed on land use types. The map overlay operation enabled us to identify the corresponding land use for each respondent. Most of the households surveyed were in low-density residential areas (65.3%), followed by households in agricultural areas (12.6%), commercial/office (9.7%), medium-density residential (7.4%), and high-density residential (5%) (see Table 4).

Four dummy variables are sufficient to represent the five land use types. Given the largest number of respondents residing in the low-density residential areas, we code the low-density residential as the reference category (e.g., $x_1=x_2=x_3=x_4=0$), and the other four (comparison categories) such as:

    (1) Agricultural: $x_1=1$, $x_2=x_3=x_4=0$
    (2) Commercial/office: $x_1=0$, $x_2=1$, $x_3=x_4=0$
    (3) Medium-density residential: $x_1=x_2=0$, $x_3=1$, $x_4=0$
    (4) High-density residential: $x_1=x_2=x_3=0$, $x_4=1$

By doing so, the coefficient (and corresponding statistical significance) of $x_1$ in a regression model indicates the impact of agricultural land use on the dependent variable (i.e., commuting distance or time) with comparison to the low-density residential; the coefficient of $x_2$ indicates the impact of commercial/office land use on the dependent variable with comparison to the low-density residential, and so on. This explains why only the four comparison categories are listed

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in the Table 8 showing regression results. Similar interpretations apply to other dummy variables to be discussed below.

**Jobs to Workers Ratio (JWR)**

Many studies hypothesize that the job-housing balance ratio is an important determinant for commuting length (e.g., Cervero, 1989, 1996; Sultana, 2002). The jobs to workers ratio (JWR) is computed as a proxy to capture the degree of mixed land uses around a respondent's home as well as his/her job accessibility. A traditional measure is the number of jobs per resident worker within a geopolitical unit or a predefined arbitrary boundary. The JWR standardizes the job distribution in an area on the basis of workers residing in this area, and thus reflects the imbalance/inequality between jobs and resident workers (i.e., housing) in an area (Forstall and Green, 1997; Wang, 2000). An JWR higher than 1 in an area indicates that jobs outnumber resident workers and thus the area is relatively rich in job opportunities; and an JWR smaller than 1 implies an area relatively poor in jobs.

However, trips usually take place across geopolitical boundaries or analysis units. Sultana (2002) used a 7-mile radius from the centroid of each TAZ as a commuting catchment area. This study adopts the approach proposed by Wang and Minor (2002), which defines the JWR within a travel time range from a residential location, termed "catchment area." As the respondent's location changes, the catchment area moves (floats) around the location, but its range (e.g., 25-minute travel time) remains the same. Therefore, it is termed the "floating catchment area method". By using the CTPP 2000 parts 1 and 2 data, the JWR can be computed for each respondent. Since a worker spends an average of 20-22 minutes on commuting (US Department of Transportation, 2001), we set the catchment as 25-minute driving time. The JWR in the study area fluctuates between the values of 0.1 and 1.35 (Figure 3), with a higher value indicating a better job provision for workers residing there and also a better land use mix around the neighborhood.

**Proximity to a High-performing School**

Recent studies on travel behavior hypothesized that residential location choices are influenced by neighborhood characteristics (Giuliano and Small, 1991) including the quality schools (Fan et al, in press, p.7). Thus, commuting might be affected by proximity to quality schools. In the study area, all schools from elementary through high schools were given a score 1-5 according to their performance levels, with 5 indicating the highest-performing schools. Schools with scores 3-5 were considered high-performing schools. There were 30 high-performing schools out of total 197 schools in the study area (see Figure 5). Data on district school performance score were downloaded from the East Baton Rouge Parish School System website (http://www.ebrschools.org/explore.cfm/accreditation/). Only schools which existed in 1997 were used for the analysis.

If a respondent's home was within 2 miles from a high-performing school, the respondent was considered to be close to such a school; and otherwise if beyond 2 miles. A dummy variable Sch345 was coded such as Sch345 = 1 if within 2 miles of a high-performing school and 0 otherwise.
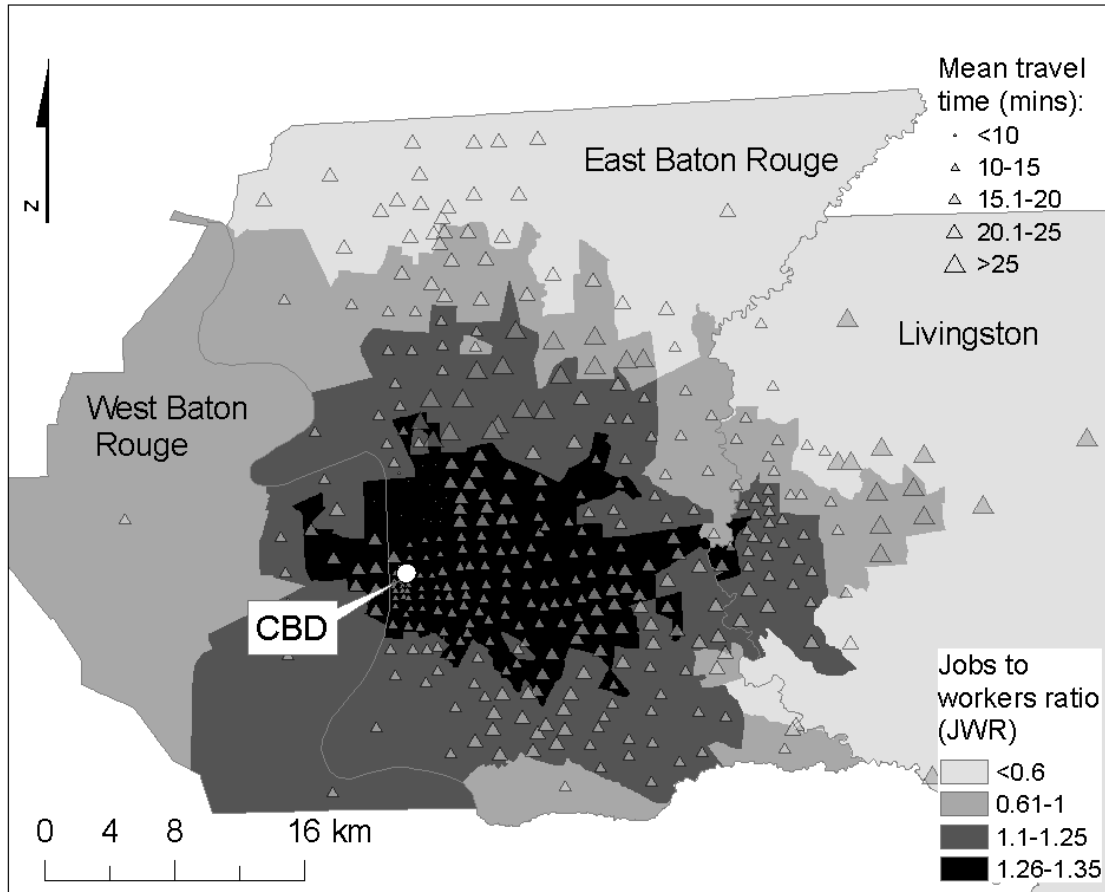
**Figure 3: Jobs to Workers Ratio (JWR) Within 25 of Travel from Residence and Mean Commuting Time, in minutes, for Those Who Drove Alone.**

The relationship between JWR and commuting time (for those who drove alone) is evident from Figure 3, and further illustrated in Figure 4. In other words, more than 20 percent of variation in commuting time across 1,104 commuters is explainable by the JWR alone.
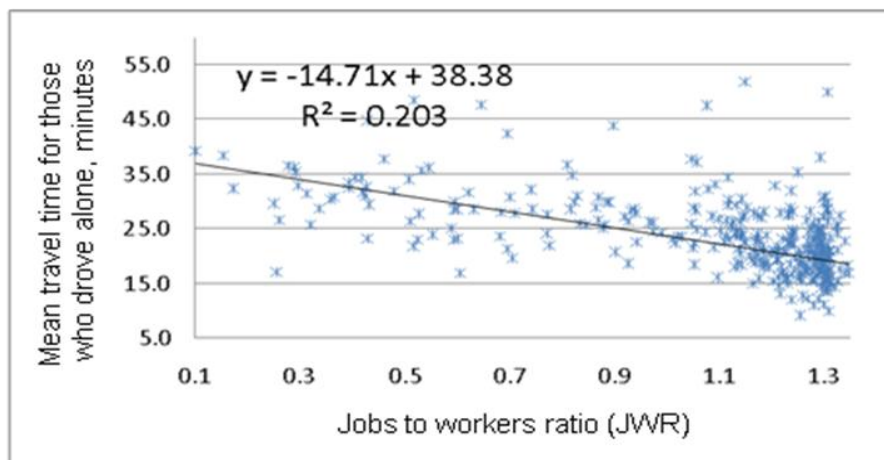


**Figure 4: Relationship between Jobs to Workers Ratio and Mean Commuting Time, in Minutes, for Those Who Drove Alone.**

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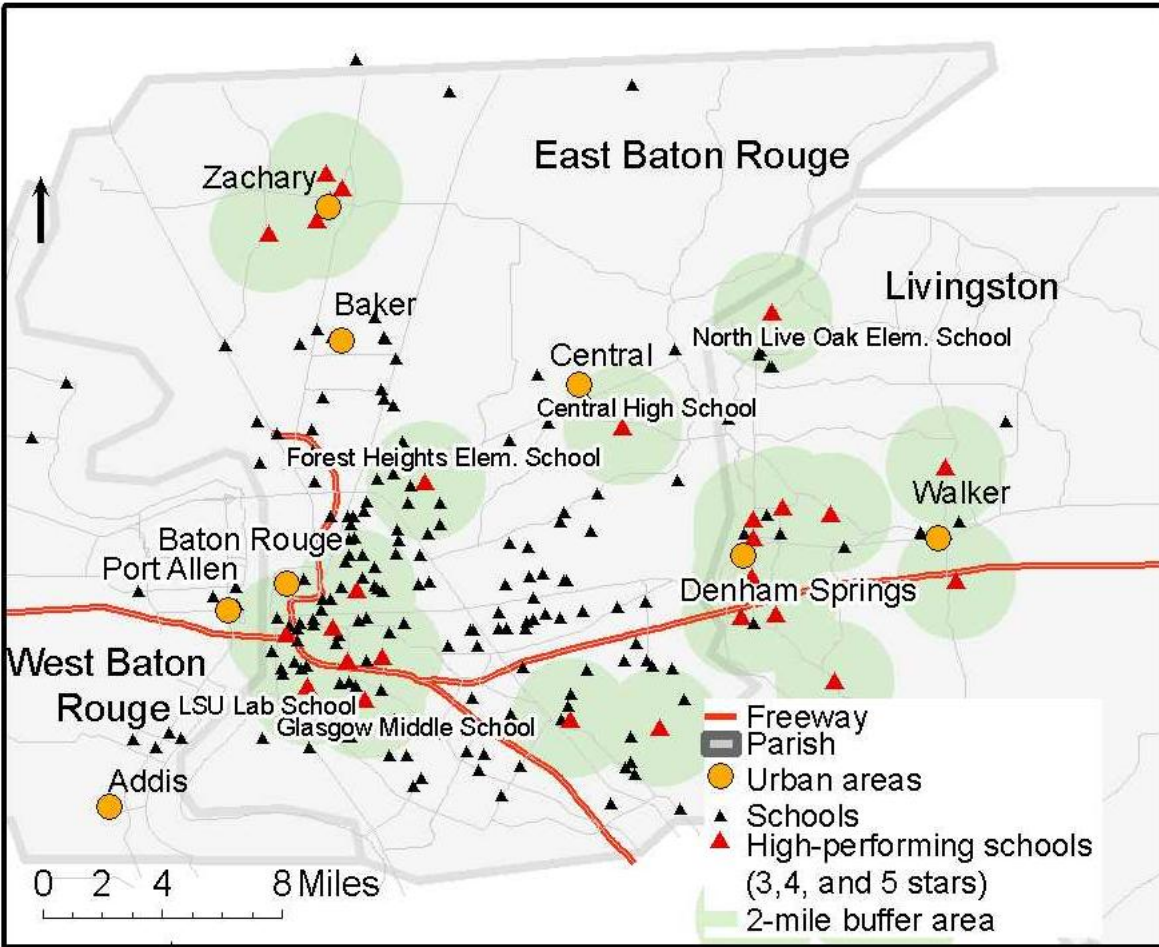
**Figure 5: High-performing Schools in the Study Area.**

**Neighborhood Socio-Economic Attributes**

There are a wide range of demographic and socioeconomic variables available from the CTPP at the TAZ level. Many of the variables are correlated. To mitigate the effect of multicollinearity in the regression models, we considered various variables commonly used in ecological studies of commuting patterns (e.g., Wang, 2001) such as ethnic composition, female-headed household ratio, mean income, poverty rate, home ownership rate, educational attainment, etc., but retained only two variables: percentage of non-white minority population and percentage of population below poverty. Minority populations, in particular African-Americans (also the dominant minority in the study area), are frequently cited to experience longer commutes than their white counterparts (e.g., Ellwood, 1986; Kasarda, 1995; O'Regan and Quigle, 1998). Percentage of population below the poverty level is considered by many researchers as another major indicator of socioeconomic structure in a neighborhood that affects commuting behavior (e.g., Krieger et al, 2003). We also add a new variable, namely "percentage of workers commuting to work in single-occupancy vehicles (SOV)". This variable is used to capture a neighborhood's dependence on automobiles and dominance of drove-alone commuters. Commuters by SOV have greater mobility and tend to travel longer (Weber and Kwan, 2003).

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**Individual Socio-Economic Variables**

Socio-economic and demographic variables at the individual level came from the 1997 Baton Rouge Personal Transportation Survey (BRNPTS). Based on the literature review, we select the variables that may influence commuting behavior and are also available from the BRNPTS. Specifically, the following variables are selected:

- Income: household income,
- Age: respondent's age,
- Race: defined as a dummy variable (=0 for white and 1 for any non-white minority),
- Gender: defined as a dummy variable (=0 for male and 1 for female),
- Education: two dummy variables used to define three categories ($E_1=E_2=0$ for one with any degree as the reference category, $E_1=1$ and $E_2=0$ for one with less than high school diploma, and $E_1=0$ and $E_2=1$ for one with a high school diploma or some college),
- Life cycle: three dummy variables used to define four categories ($L_1=L_2=L_3=0$ for households with children 16-18 years old as the reference category, $L_1=1$ and $L_2=L_3=0$ for households with no children, $L_2=1$ and $L_1=L_3=0$ for households with children younger than 16 years old, and $L_3=1$ and $L_1=L_2=0$ for households with one or more retired adults),
- Driving mode: defined as a dummy variable (=0 for "usually drives" and 1 otherwise),
- Job status: defined as a dummy variable (=0 for full-time and 1 for part-time), and
- Workers in household: number of workers in a household.

## Selection and Definition of Variables

As discussed previously, many previous studies on travel behavior used aggregated data in geographical areas, and thus masked individual behavior and might result in ecological fallacy (Robinson, 1950). One the other side, working individual-level data alone without considering the context, in which such individual behavior takes place, may lead to atomistic fallacy (Alker, 1969), and fail to account for the variability between places (Jones and Duncan, 1996). A multi-level modeling approach is needed to account for the hierarchical structure of the data (i.e., since individuals were nested within TAZs, those within the same TAZ were more similar than those across TAZs). By specifying individual commuters nested within TAZs, multi-level models isolate the relationship of neighborhoods from individual commuting (Singer, 1998; Weber and Kwan, 2003). Variables defined in the previous section belong to two levels:

- Neighborhood (TAZ) level: three neighborhood socioeconomic attributes (% minority, % below poverty, and % SOV commuters), and
- Individual level: spatial factors (land use type where a respondent resides, EWR around the respondent's home, and the respondent's proximity to a high-performing school) all individual socio-demographic variables extracted from the BRNPTS.

The specific model formulation used in this study is a 2-level intercepts as outcomes model. Such a model assumes that the effects of individual-level variables are fixed across TAZ areas and that TAZs vary as a function of TAZ-level socio-economic variables. To estimate the impacts of various sets of variables on commuting, the independent variables were entered into the models in blocks (Table 8). Model 1 examined the effect of land use only, and thus included land use types, JWR, and proximity to a high-performing school. Model 2 added three

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neighborhood variables such as minority population, population below poverty, and commuters by single-occupancy vehicles (SOV), all measured in percentage. Model 3 added individual-level attributes such as income, age, gender, race, education, life cycle stage, transportation mode, part-time or full-time work status, and number of workers in household. All models were estimated by the SAS software, and more specifically PROC MIXED.

Note that in Table 8, as explained previously for the dummy variable coding for land use types, the reference category for any dummy variable is absent and the comparison category (categories) is listed. For example, the negative coefficient for the dummy variable Sch345 (and statistically significant) in models 1a and 1b indicates that one living within 2 miles from a high-performing school (i.e., the comparison category) tended to commute less. In models 3a and 3b, the dummy variables for educational attainment indicate that those with less than a high school diploma (with a negative coefficient and statistically significant) tended to commute in shorter ranges than those with some degree (i.e., the reference category), and there was no significant difference between those with a high school diploma or some college (with a corresponding negative coefficient but not statistically significant) and those with some degree.

## Results and Discussion

In Table 2, among the land use types, all models reveal that only residents in the medium-density residential areas came out significant, with comparison to residents in low-density residential areas, in influencing commuting time (not distance). The results are consistent across all models. One may group residents in agricultural and low-density residential areas together (both in low-density areas with similar housing structure), and group residents in commercial/office and high-density residential together (both occupied by a disproportionally high percentage of disadvantaged population groups). The former is referred to as "low-density residents", and the latter "high-density residents". As some literature (e.g., Wang, 2003) suggested, high-density residents might not be able to take advantage of their physical proximity to job concentration areas and convert that into shorter commuting trips because of possible spatial mismatch. This makes the medium-density residents the lonely category that experience shorter commuting time.

In all models, the JWR stood out as highly significant for both commuting time and distance. The negative coefficient indicates that a higher JWR value (i.e., job-richer areas) was associated with shorter commuting trips. This once again provides convincing evidence that job-housing imbalance is a major contributor to long commute, and the effect remains significant while controlling for confounding variables. The negative and statistically significant coefficient of Sch345 in models 1a-2b is counterintuitive to the expectation. The individuals whose household location is within good-quality school catchment area, appear to commute shorter than those who do not live close to the high-performing schools.

Among the individual attributes in models 3a and 3b, the following variables were statistically significant and consistent in models on both commuting time and distance:
   (1) Female workers were found to commute less, consistent with the finding in most studies, because they tended to share more domestic and childcare duties and chose to work closer to home.

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(2) Those with less than a high school diploma had shorter commuting trips (i.e., almost 6 minutes less and 4 miles shorter) than other with some degrees. This least educated group may only find entry-level jobs with minimum pay, and thus afford to take jobs close to their homes.

(3) Workers from households with no children tended to commute less. One plausible explanation is that their residential choice was not confined to traditional family-oriented neighborhoods, instead choosing to live in the apartment complexes or condominium-type places, which typically are located closer to a road, and thus helped them live closer to workplace.

(4) Those who did not usually drive commuted more, as might be the case when using a different transportation mode (either walking or by public transportation), or by being vanpool passengers.

(5) Part-time workers commuted less than their full-time worker counterparts. Similarly to people with minimal education, part-time workers tended to find jobs close to their homes.

(6) Having additional workers in a household seemed to cut back commuting in both time and distance. It is contradictory to the popular "multi-worker household theory" that household with more than one worker tend to commute more because of the difficulty of optimizing individuals' commuting between different workplaces (Hamilton, 1982:1047). However, a recent study on Atlanta by Sultana (2005) found that the average commute of dual-earner households was either not significantly different, and even shorter than that of the single-earner households, while both household types experienced longer commutes due to the lack of affordable housing near employment.

## Conclusions

The debate over the land use impacts on commuting is far from being settled. Examining the relationship alone is insufficient without considering other confounding factors such as socio-demographic attributes of commuters. Many studies used aggregate data at the census tract, block group or zip code area level, and masked individual behavior. This research uses a multilevel modeling approach to examine the combined effects of land use types and socio-demographics (including both individual and neighborhood attributes) on commuting.

This research suggests that different land use measures are useful in explaining commuting patterns, and socio-demographic characteristics of individuals play a role at least as important in influencing commuting behavior. Our results lend further support to the notion that job-housing balance plays a crucial role in determining commute lengths. Individual attributes such as gender, educational attainment, presence of children at home, job status (part-time or full-time) and number of workers in household, influence commute behavior. Most of the findings are consistent with the literature, but we also have some surprising observations.

The study has several limitations that we hope to address in future work. First concerns the freshness of the 1997 Baton Rouge Personal Transportation Survey (BRPTS) database. Surveys of this kind are usually conducted every 10 years at the national level, but much less frequently for medium-size metropolitan areas such as Baton Rouge. Secondly, there are various ways to measure land use, and also many socio-demographic variables at both the individual and

neighborhood levels, which may also affect commuting behavior. Our selection and definition of variables certainly have room to improve. Finally, there is obvious value to replicate and expand the research to include other study areas and across time need, which will help us improve our understanding of commuting patterns.

**Table 8: Multi-level Model Coefficients for Commuting Time and Distance.**

| | Model 1 | | | | Model 2 | | | | Model 3 | | | |
| | Time | | Distance | | Time | | Distance | | Time | | Distance | |
| | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | 26.95 | | 18.36 | | 24.79 | | 17.28 | | 30.81 | | 22.7 | |
| Agricultural | -1.65 | -1.42 | -0.73 | -0.71 | -1.7 | -1.46 | -0.79 | -0.76 | -0.77 | -0.63 | 0.15 | 0.14 |
| Comm./Office | -1.92 | -1.7 | -1.39 | -1.4 | -1.83 | -1.62 | -1.34 | -1.34 | -2.02 | -1.63 | -1.33 | -1.21 |
| Resid. Med. | -3.42 | -2.7 ** | -1.98 | -1.77 | -3.1 | -2.38* | -1.78 | -1.55 | -2.82 | -1.97* | -1.84 | -1.45 |
| Resid. High | -1.16 | -0.76 | -0.41 | -0.3 | -1.16 | -0.76 | -0.41 | -0.3 | -1.05 | -0.63 | -0.39 | -0.27 |
| JWR | -10.76 | -7.41*** | -7.78 | -6.14*** | -10.22 | -6.75*** | -7.41 | -5.6*** | -9.33 | -5.68*** | -6.6 | -4.65*** |
| Sch34 | -1.59 | -2.36* | -1.41 | -2.4* | -1.61 | -2.34* | -1.44 | -2.38* | -1.23 | -1.65 | -1.07 | -1.66 |
| % minority | | | | | -0.02 | -1.34 | -0.01 | -1.34 | -0.01 | -0.68 | -0.002 | -0.14 |
| % below pov. | | | | | 0.04 | 0.96 | 0.03 | 0.96 | 0.04 | 0.93 | 0.04 | 0.97 |
| % SOV | | | | | 0.02 | 0.5 | 0.009 | 0.5 | 0.006 | 0.15 | -0.002 | -0.06 |
| Income | | | | | | | | | 0.000003 | 1.67 | 0.000003 | 1.97* |
| Age | | | | | | | | | -0.02 | -0.65 | -0.04 | -1.6 |
| Race, minority | | | | | | | | | -0.05 | -0.04 | -0.05 | -0.04 |
| Sex, female | | | | | | | | | -1.55 | -2.16* | -1.68 | -2.62* |
| Education: | | | | | | | | | | | | |
| <high school | | | | | | | | | -5.64 | -3.65*** | -4.26 | -3.1*** |
| some college | | | | | | | | | -1.04 | -1.3 | -0.83 | -1.17 |
| Life cycle: | | | | | | | | | | | | |
| 1or2 adults, no children | | | | | | | | | -3.56 | -2.55* | -2.59 | -2.1* |
| 1o2 adults, children <16y.o. | | | | | | | | | -2.49 | -1.89 | -2.04 | -1.75 |
| Retired | | | | | | | | | -2.09 | -0.91 | 1.57 | 0.78 |
| Usually drives, no | | | | | | | | | 3.74 | 2.52* | 3.41 | 2.58* |
| Job, part time | | | | | | | | | -2.35 | -2.34* | -2.42 | -2.69** |
| Workers in household | | | | | | | | | -1.1 | -2.24* | -0.94 | -2.17* |

*-significant at 0.05 level, ***-significant at 0.01 level, ****-significant at 0.001 level

# Urban Structure and Commuting Patterns in Baton Rouge MSA

## Introduction

According to the classic economic monocentric urban model, a city has a single, most accessible center, where all jobs are located and land prices are the highest. Households living close to a CBD travel shorter distances to their workplaces than others in the urban area. However, innovations in transportation, communication, and employment suburbanization, among other reasons, have resulted in a polycentric urban form in many cities (Gordon, et al, 1998; Ingram, 1998). Within polycentric models, some studies claim that peripheral cities appear more dominant than traditional downtowns urban cores (Dear, 2005). Others, although recognizing the polycentric trend of spatial job distribution, argue that the CBD maintains its role as a major employment center (Greene, 2008). The spatial distribution of activities, including employment, dictates travel patterns, especially those related to the journey to work. Studying urban structure is, therefore, crucial for understanding commuting trends.

Polycentric structure affects commuting by distributing the direction of commuting flows: while in a centralized city all workers travel into the central city, with decentralized employment it is the suburbs that attract commuters (Levine, 1992). Land use decentralization and associated with that polycentrism have been theorized to reduce commuting by car mainly due to a closer location to the employment centers (co-location theory) and due to reduced congestion which typically intensifies within the monocentric concentration of activities (Gordon and Wong, 1985; Gordon et al., 1989a, 1989b; Gordon, et al., 1991; Gordon, and Richardson, 1996; Ingram, 1998).

A lack of research regarding analysis of intraurban commuting and land use patterns in small- to medium-sized metropolitan areas within the U.S. southern region (Ladd and Wheaton, 1991; Horner, 2004a, 2007), motivated this research. Therefore, the objective of this study is twofold. First, urban form within the medium-sized Baton Rouge region was observed for two time periods, 1990 and 2000, to determine any change during this period. Second, to understand the impact of metropolitan structure on commuter travel we investigated the commuting patterns under the monocentric and polycentric assumptions.

Most commuting research utilizes a single measure of the spatial separation between home and work locations. The single measure is time and it is used because travel time is directly available from the travel data (Sultana and Weber, 2007). However, distances indicate commute lengths more consistently (Wang, 2000; Sultana and Weber, 2007). To accommodate this need to explore commuting from the multiple perspectives, both measures of the spatial separation reflected by the time and distance traveled were incorporated into the study.

Unfortunately, research on the influence of land use on travel behavior of individuals often relies on aggregate data (Weber and Kwan, 2002). Therefore, for our second objective, the commuting consequence of job decentralization were examined indicated by the commuting times and distances from the disaggregate individual-level 1997 Baton Rouge Personal Transportation Survey (BRPTS).

## Literature Review

To find employment areas, a thorough literature review on job concentration identification was implemented to search for techniques used in the big and medium-sized MSA areas in the past. Numerous studies identify employment concentrations as part of their analysis (Gordon and Wong, 1985; Gordon et al., 1989a, 1989b; Gordon, et al., 1991; Gordon, and Richardson, 1996; Schwanen, Dieleman and Dijst, 2003; Sultana, 2000; Shearmur, 2006; Shearmur et al., 2007; Horner, 2007).

Job density was frequently used as the main criteria to locate employment centers (Forstall and Green, 1997; McMillen, 2001; Lee, 2007). Job density values which vary from 500 to 2000 per center (Zhou and Kockelman, 2006; Cervero, 1989) or 7 to 10 jobs per acre were used (Cervero and Wu, 1997; Guiliano and Small, 1991). This approach was criticized for defining job density merely on land area, rather than expressing it as the true relationship between job distribution and workers residing in the area (Forstall and Green, 1997). Jobs-to-resident workers ratio (JWR) was suggested as a job concentration criterion with an emphasis on net in-commuting as 'the most significant characteristic of a worker concentration" (Forstall and Green, 1997). There are caveats associated with the methods above. First, the cutoff value of 10 employees per acre applied to identify job concentrations in the big metropolitan area might be inappropriate in smaller metropolitan areas. Second, areas such as airports where most of jobs are located in a small part might not be recognized as major centers if job density is used as a main criterion to identify job concentrations; such places typically have a much lower job density (Forstall and Green, 1997). Lastly, an application of the JWR approach toward large areal units such as census tracts can erroneously indicate the entire area as an employment center while in fact most of jobs might be concentrated within a small portion of the entire area.

Parallel to studies on employment subcenters, there has been a growing body of research studying the effects of polycentrism on commuting patterns. The following section briefly reviews literature addressing the commuting impact of changing urban structure.

There are two arguments in the literature on the effect of the polycentric structure on travel. The first argument deals with the change of urban structure towards polycentrism over time and its impact on commuting patterns. In fact, commuters are thought to not benefit in terms of saving travel time as jobs move to the suburbs. A study focused on the effect that job decentralization has on the average commute in the San Francisco Bay area, and demonstrated that on average a one-way commuting distance grew by 12 per cent and travel time by 5 per cent to reach the sub-centers in 1990 compared to 1980 (Cervero and Wu, 1998). However, the identified job concentrations accounted for less than half of all jobs in the area, therefore, the total effect of job decentralization on average commute is hard to define (Anas, 1998).

The second argument is that, in contrast, people commute less to multiple centers than to the monocenter in a CBD. Studies of this kind consider one point in time, however. There is empirical evidence that overtime households relocate closer to workplaces and shorten commuting distances caused by job suburbanization (Crane and Chatman, 2004; Sultana and Weber, 2007). In an Atlanta-based study, Sultana (2000) has empirically shown that people working in subcenters, on average, have shorter commuting times than those working in the

central city. However, it should be noted that there is more difference between distances than there is a difference between times in monocentric and polycentric urban structures. This has the following important implications: as the cities grow outward, the overall commuting between homes and work places may grow too (Crane and Chatman, 2004), however, the time spent travelling to job locations may not be very much different for the monocentric and polycentric settings, principally due to the better roads with more capacities and faster speeds (Sultana and Weber, 2007).

Contrary results were obtained by France- and Netherlands-based studies of the consequences of the employment decentralization. There it was found that the average commute is longer in a decentralized spatial structure. This may be partly explained by spatial planning policies in those countries as well as cultural factors such a greater attachment to the place of residence and the regulated nature of housing provision resulting in reduced household mobility (Clark and Dieleman, 1996; Schwanen et al, 2003; Aguilera, 2005). Aguilera (2005) used distance to measure commuting, and found that the majority of people who live close to job concentrations, in fact, work outside their sub-center and, therefore, experience longer commutes. Although it is not clear whether the same conclusion would be made if commuting times were used instead of distance since commuting to suburban employment centers typically experiences less congestion.

A large corpus of the theoretical and empirical research found that socio-economic variables such as income, home ownership, racial membership, transportation mode, time leaving for work, among others, influence in a significant way the length of the working trips (Handy, 1996; Sultana, 2005; Limtanakool, Dijst, and Schwanen, 2006, Sultana and Weber, 2007).
Other explanations regarding improving commuting include residential self-selection or time-lags, among others (Handy, Cao, and Mokhtarian, 2005; Sarzynski et al., 2006).


## Study Area and Data

The study area for this research is a part of the Baton Rouge MSA, Louisiana. It completely covers the Baton Rouge urbanized area which is one of the fastest growing areas in the South. It lies along the eastern banks of the Mississippi River and is located within the Capital Region Planning Commission district, which is its designated Metropolitan Planning Organization (MPO). Boundaries of the Baton Rouge urbanized area provide, therefore, effective boundaries for the current study (Figure 1). Its area is 3,567 square kilometers (455 square miles). The study area consists of the parishes of East and West Baton Rouge, and urban clusters within Livingston Parish, and is referred to as the Baton Rouge region elsewhere in the study. It encompasses a diverse range of land use types across urban, suburban, and rural settings.

In 2000, 526,248 people lived within the study area. There is almost twice as many White population as African-Americans in the study area (63% vs. 33%). There are 238,522 workers in total, with males comprising 52% of all resident workers. The average jobs to resident workers ratio (JWR), defined before, is 1.05 which is consistent with other metropolitan areas.

To analyze daily travel patterns in the United States self-reported data is ordinarily taken from travel surveys (Murakami and Wagner, 1999). Accordingly, the first source used in this study is the disaggregate Baton Rouge Personal Transportation Survey (BRPTS) carried out in 1997. The

BRPTS sample originally included 1,395 surveyed households or and 3,069 persons, of whom 2,934 persons reported travel-day data. Those with missing residential or work locations were excluded from the travel data base. The final travel data set provides detailed and disaggregate information on 1,104 individuals whose work and home locations were geographically referenced, therefore, allowing for the detailed match of the land use characteristics. Ethnically, they are predominantly White (76 %), followed by African-Americans (22 %), Asians (<1%), and Others (<1 %). 45 % of the respondents are male, and 55 % are female.

To define job concentrations within the study area we used the Census 2000 Transportation Planning Package (CTPP) parts 1, and 2 at the Traffic Analysis Zone (TAZ) level. For the identification of job locations in 1990, the urban element of CTPP 1990 for TAZs was used.

## Identification of the Employment Centers

Preliminary identification of the employment centers began with obtaining and subsequently geocoding major employers (those employing in excess of 1,000 workers) for the study area available from the local area chamber (BRAC, 2009). Addresses for the geocoding were retrieved from the Yellow Pages for the area studied. Then, to find work places, employment data from the US Census CTPP 2000 part 3 was used. We decided to use Traffic Analysis Zones (TAZs) as the smallest spatial components for which employment data were available from the CTPP 2000.

This study builds upon the concept of jobs-to-resident workers ratio (JWR) stressing the importance of a net in-commuting to determine job concentrations (Forstall and Green, 1997). A higher value of JWR computed within each TAZ indicates a better job provision for workers residing within this TAZ, and therefore, higher access to jobs.

The following criteria were set for an area/s to qualify as an employment concentration: first, the zones forming a job center should be contiguous, second, an JWR within an area itself should be of 1.0 and greater, and third, the total number of jobs per single TAZ should represent a peak in employment for the surrounding zones. A value of 750 jobs per TAZ was chosen as the threshold value to qualify an area as an employment concentration based on a review of employment data for the study area. Contiguous zones with a total employment of at least 10,000 jobs were given the status of a job center, and subcenters were defined as those areas with lower employment.

Layers of zone properties were superimposed on each other and used in the decision to assign an area a status of an employment center or a subcenter. Individual knowledge of the region also helped us identify employment concentrations (Weber and Kwan, 2002). Finally, job concentrations were identified and given names reflecting an economic activity taking place or by the name of nearby roads (Table 9). They stretch from the north-west to the south-east of the study area, roughly following the main road network structure. Figure 6 illustrates these employment centers. The locations of major employers have been geocoded and are superimposed on the TAZs as also shown in Figure 6.

Because our data fall between two Census periods, we decided to study the urban structure for 1990 and 2000. Therefore, employment centers and subcenters for the study area were identified

for the year 1990 using the set of the same criteria as for 2000. The numerous discussions of the downtown revitalization with the subsequent development of the different revitalization projects such as a downtown pedestrian mall, civic center, entertainment and gaming places, among others, have started since the late 1950s serving the purpose to attract residents and businesses back into the CBD area, and therefore, to augment the monocentric urban system (Wheeler, 1994). We tested the hypothesis that polycentric urban structure is more favorable to journey-to-work travel, both spatially and temporally, then the monocentric system, using the medium-sized metro area of Baton Rouge, Louisiana, as a test area.
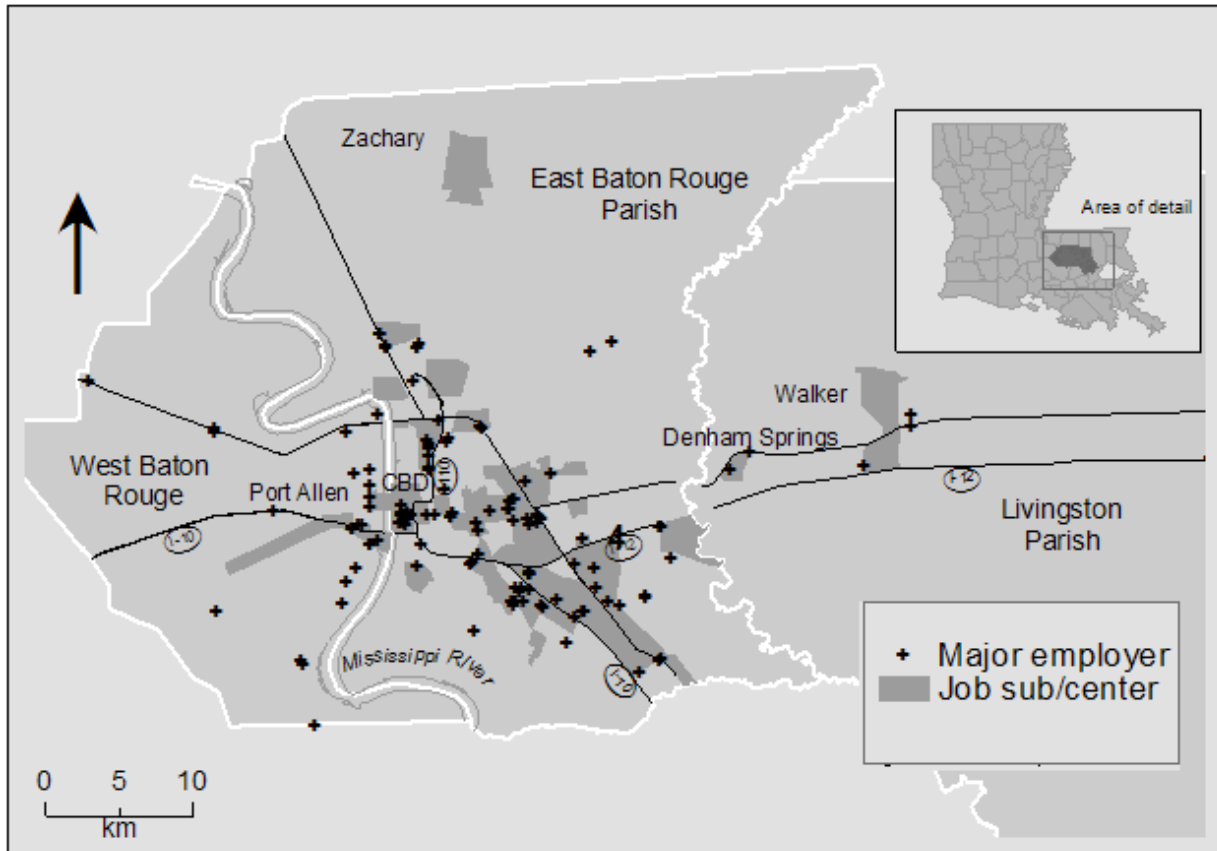


**Figure 6: Employment Sub/centers and the Major Employers in 2000**

**1990-2000 Employment Concentrations**

Based on total jobs and employment to resident workers ratio (E/R) criteria, we identified 20 job concentrations composed of contiguous TAZs within the Baton Rouge region for the year of 2000, some of them being of regional importance (like the CBD, Louisiana State University, Baton Rouge Metropolitan Ryan Field Airport), while others are only of or local importance. Figure 7 illustrates location of these centers within the study area for both 1990 and 2000. In 2000 the job centers rank from 1 to 20 according to total jobs, with the center 1 being the largest, while job centers rank from 1 to 14 in 1990 (Figure 7). In 1990, the 14 identified employment locations contained 60.4 % of all the jobs found within the Baton Rouge region with the CBD certainly standing out as the largest employment center. In 2000, the identified job locations contained 67.1% of all employment.
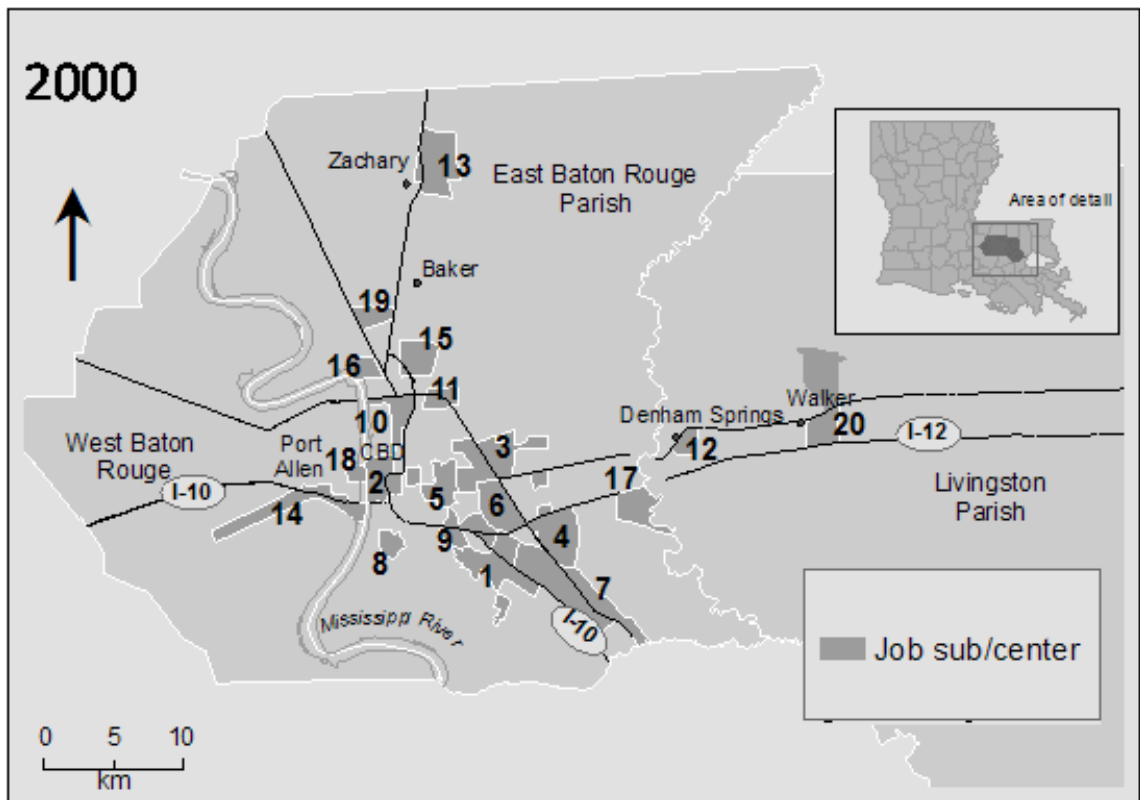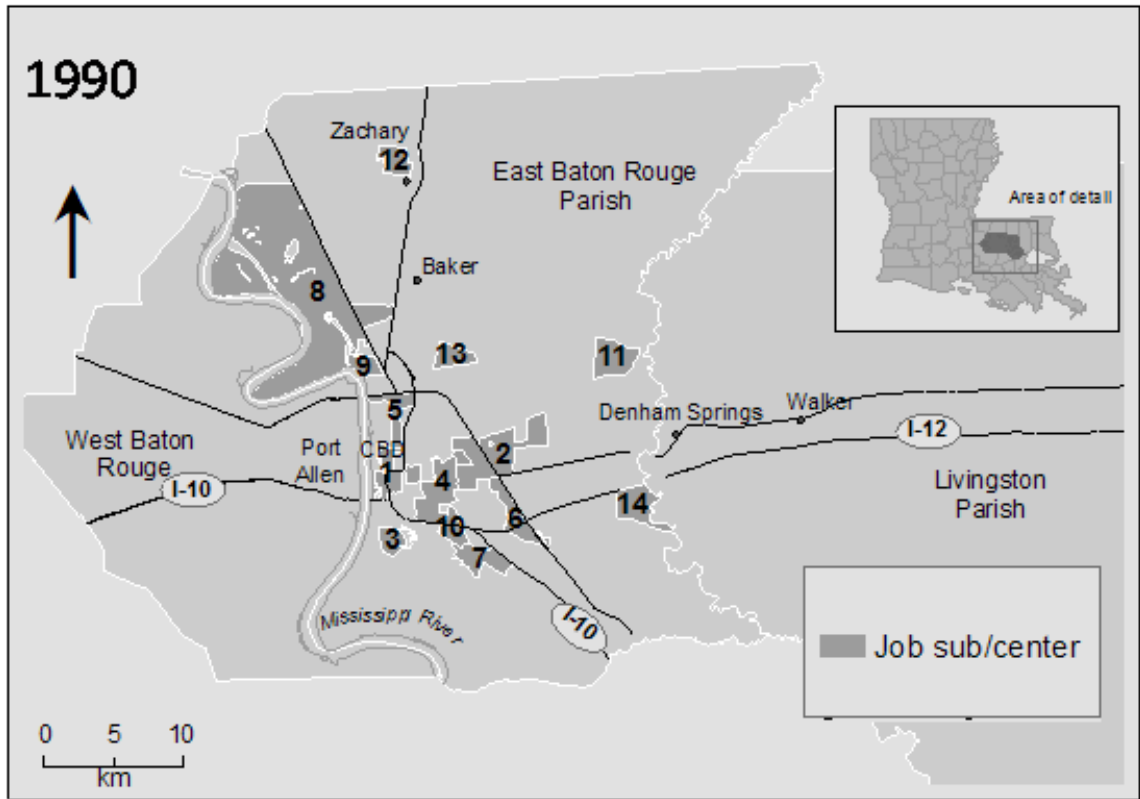
**Figure 7: Employment Subcenters in 1990 and 2000.**
Note: center numbers can be found in Table 9.

A plot of employment density distribution reveals a decrease in job density in the Baton Rouge CBD area in 2000 in contrast to 1990 (a broken line against a solid line in Figure 8(a)). In absolute magnitude, a significant employment increase in the centers other than the CBD occurred between 1990 and 2000. Peaks in Figure 8 (b) reveal the location of these centers, and thus, confirm the existing and growing polycentric urban structure within the Baton Rouge region.
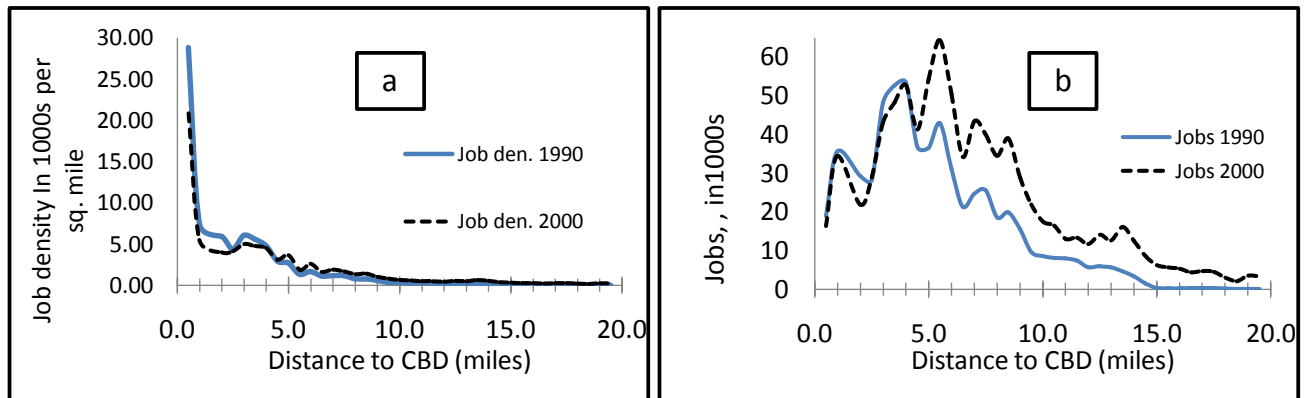


**Figure 8: Distribution of a) Employment Density (per Square Mile) and b) Employment (per Square Mile) Within Baton Rouge Region in 1990 and 2000**

Table 9 provides a detailed description of these employment concentrations for 2000 and 1990. In 2000, 20 percent of population and workers and two thirds of all employment (67%) was concentrated in the employment concentrations. The E/R of each TAZ fluctuates between 1.28 and 14.1 within the Baton Rouge region reflecting that at least 28% of all employees are in-commuting from other areas. Among these job concentrations 8 were defined as job centers (as there were at least 10,000 jobs in total), and others as subcenters.
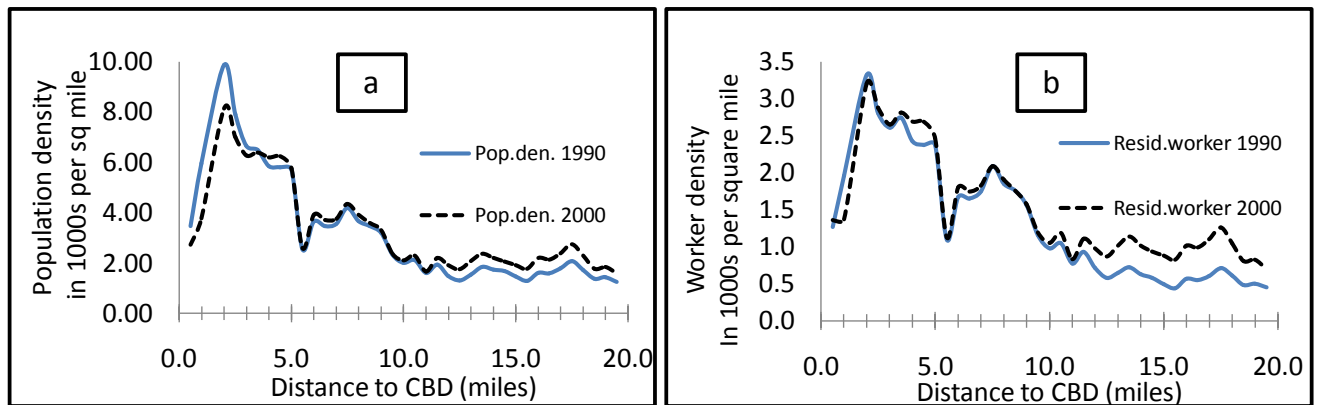


**Figure 9: Distribution of a) Population Density (per Square Mile) and b) Resident Worker Density (per Square Mile) Within Baton Rouge Region in 1990 and 2000**

Figure 9 (a) demonstrates that between 1990 and 2000, population migrated away from the central area to outer areas. At the same time, the number of resident workers remained almost the same within the central area, but grew in the outer areas (Figure 9b).

Comparison of spatial distribution of job concentrations, as well as population and job density between these two time periods reveals a relative overall stability of urban structure (Figures 7,8, and 9). Multicenter employment distribution within the Baton Rouge region, a relatively small metro area, confirms the polycentric urban structure that is characteristic of many larger U.S. metropolitan areas.

## Examining Impacts of Urban Structure on Commuting Patterns

This research utilized both times and distances as two distinct measures of spatial separation between home and work locations (Wang, 2000; Sultana and Weber, 2007). The role of job concentrations in affecting commuting outcomes was investigated taking both monocentric and polycentric assumptions of urban structure. The idea of a possible revitalization of a significant part of employment in downtown area motivated a "what-if" approach.

### Commuting and Monocentric vs. Polycentric Structure – Hypothetic Scenario

We tested the co-location hypothesis that a polycentric urban structure is conducive to shorter commutes vs. a monocentric structure, both in terms of time and distance. To test this hypothesis we proceeded in two steps. First, the commuting consequences of hypothetically concentrating employment at either the CBD or at employment centers were estimated. In a monocentric urban structure case, all the residents kept the same home locations, but their work places were assigned to the Baton Rouge CBD. The advantage of having the geographic coordinates for the places of residence within the Baton Rouge region contained in the data let us compute the commuting free-flow times (in minutes) and distances (in miles) using the real-world road network. To get more realistic results, the road type and varying travel speeds in different urban settings was taken into account (Luo and Wang, 2003). The detailed explanation of the computation process for the travel times and distances within the GIS environment is beyond the scope of the study and can be found in Wang (2006). The polycentric scenario was investigated likewise using existing home locations and assuming workers worked at the nearest identified employment centers. The simulated monocentric commuting times and distances were compared to the simulated polycentric travel times and distances.

An investigation of the commuting impacts of the urban structure supports the co-location theory as the experiment clearly demonstrated that monocentric structure does not contribute to a reduction in commuting. A paired t-test of means of the simulated commuting times and distances vs. the true times and distances resulted in significant differences. Workers commuting into the Central Business District where all the jobs are concentrated need to travel longer distances and spend more time commuting. For example, according to the experiment, the monocentric commuting distances were almost 2 miles longer (significant at less than 0.001 level) than distances required to reach multiple job concentrations. Similar results were obtained for the travel times, which were also longer for the monocentric conditions. Table 10 provides the paired t-test of means results of the experiment.

**Table 9: 2000 and 1990 Employment Concentrations (Ranked According to Number of Jobs).**

| 2000 | | | | | | 1990 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Center (rank) | Name | Jobs | Workers | Pop. | E/R | Center (rank) | Name | Jobs | Workers | Pop. | E/R |
| 1 | Essen Medical | 24675 | 4925 | 9550 | 5.01 | 7 | Essen Medical | 6949 | 2017 | 2312 | 3.45 |
| 2 | CBD | 23905 | 1693 | 3733 | 14.1 | 1 | CBD | 24740 | 3727 | 5083 | 6.64 |
| 3 | Cortana Mall Plaza | 20540 | 6225 | 14595 | 3.3 | 2 | Cortana Mall Plaza | 21498 | 11312 | 14422 | 1.90 |
| 4 | Harrells/S.Sherwood Commercial | 14370 | 8165 | 14340 | 1.76 | n/a | n/a | n/a | n/a | n/a | n/a |
| 5 | Florida Blvd Medical | 13555 | 4665 | 12540 | 2.91 | 4 | Florida Blvd Medical | 14526 | 12561 | 15911 | 1.16 |
| 6 | Hammond Aire Plaza | 12950 | 3245 | 5930 | 3.99 | 6 | Hammond Aire Plaza | 6975 | 4513 | 5432 | 1.55 |
| 7 | Siegen/Industriplex Commercial | 12740 | 4905 | 9130 | 2.6 | n/a | n/a | n/a | n/a | n/a | n/a |
| 8 | Louisiana State University | 11425 | 3330 | 7325 | 3.43 | 3 | Louisiana State University | 16479 | 6106 | 6228 | 2.70 |
| 9 | Corporate Blvd Commercial | 8940 | 3030 | 5620 | 2.95 | 10 | Corporate Blvd Commercial | 4625 | 2173 | 2616 | 2.13 |
| 10 | Industrial 1 | 8165 | 665 | 1755 | 12.3 | 5 | Industrial 1 | 13375 | 1360 | 2088 | 9.83 |
| 11 | EKL Memorial Hospital | 2575 | 2085 | 5625 | 1.24 | n/a | n/a | n/a | n/a | n/a | n/a |
| 12 | Denham Springs downtown | 2360 | 655 | 1685 | 3.6 | n/a | n/a | n/a | n/a | n/a | n/a |
| 13 | Zachary downtown | 2180 | 820 | 2155 | 2.66 | 12 | Zachary downtown | 930 | 791 | 1120 | 1.18 |
| 14 | Industrial WBRP | 1880 | 160 | 325 | 11.8 | n/a | n/a | n/a | n/a | n/a | n/a |
| 15 | BR Metro Ryan Field Airport | 1800 | 340 | 3165 | 5.29 | 13 | BR Metro Ryan Field Airport | 823 | 675 | 925 | 1.22 |
| 16 | Southern University | 1690 | 660 | 2820 | 2.56 | 9 | Southern University | 3002 | 2628 | 2832 | 1.14 |
| 17 | O'Neal medical | 1295 | 1010 | 2195 | 1.28 | 14 | O'Neal medical | 783 | 710 | 1079 | 1.10 |
| 18 | Port Allen downtown | 1190 | 475 | 1220 | 2.51 | n/a | n/a | n/a | n/a | n/a | n/a |
| 19 | Industrial 2 | 1005 | 60 | 170 | 16.8 | 8 | Industrial 2 | 3794 | 300 | 385 | 12.7 |
| 20 | Walker downtown | 800 | 555 | 1220 | 1.44 | n/a | n/a | n/a | n/a | n/a | n/a |
| | | | | | | 11 | Central | 1175 | 714 | 1023 | 1.65 |
| Total in centers | | 168,040 (67.1%) | 47,668 (19.9%) | 105,098 (19.9%) | 3.53 | | | 119,674 (58%) | 49,587 (24%) | 61,456 (13%) | 2 |
| Total within study area | | 250,516 | 238,522 | 526,248 | 1.05 | | | 207,464 | 206,357 | 470,050 | 1.01 |

**Commuting and Monocentric vs. Polycentric Structure – Observed Data**

For the second step, we compared the observed commuting times (in minutes) and distances (in miles) as reported by the survey respondents who work within the Central Business District (CBD) (the monocentric commutes) with those who work in all other employment concentrations (the polycentric commutes). The relative spatial stability of the job subcenters between 1990 and 2000, as well as temporal proximity of data to 2000, allowed us to use the boundaries for the employment concentrations for the year 2000. Accordingly, for the second step, to determine whether real data support the findings from the experiment, we tested the data empirically using the self-reported commuting times and distances to work contained in the BRPTS survey. For this purpose, the workers working within the Central Business District (CBD) as well as other employment concentrations were identified. The former were defined as the "monocentric group", while the latter workers
were defined as the "polycentric group".

**Table 10: T-test of the Mean Commuting Times and Distances (Monocentric- and Polycentric-Simulated).**

|                               | Polycentric (Job centers) | Monocentric (CBD) |          |
| ----------------------------- | ------------------------- | ----------------- | -------- |
| Measure of spatial separation | Mean                      | Mean              | t Stat   |
| Distance, miles               | 8                         | 9.85              | 8.87 *** |
| N                             | 1104                      | 1104              |          |
| Time, minutes                 | 12.96                     | 14.15             | 4.38***  |
| N                             | 1104                      | 1104              |          |

*-significant at 0.05 level of significance, ***-significant at 0.001 level of significance

To check whether observed data follow the theoretical expectations, reported distances and time to work were examined among the CBD workers and those employed at other work destinations. Empirical data from the survey support the findings of the experiment above. Within the survey data, 107 respondents worked in the CBD, and 503 worked in the other 19 centers, making a total of 610 workers who worked in employment centers. The remaining 497 workers worked elsewhere outside of the identified job concentrations. Table 11 reports the findings from the empirical analysis together with the statistical results of the t-test.

A t-test of means conducted to determine whether commuting lengths were different between the commuters to the CBD and to the multiple job concentrations showed that commuting to multiple job concentrations results in significantly shorter times and distances (Table 11). For example, 610 workers identified from the 1997 Baton Rouge survey that commuted to 20 employment centers and subcenters (including the CBD as one of the job centers), generally traveled about two miles less and spent about 1 minute less time on their journey to work than did 107 commuters working just in the CBD area (Table 11). The numbers of 2 miles and 1 minute may seem minor; however, with commuting being a vital activity for the American households (Hanson and Pratt, 1988; Horner, 2004b), these numbers multiplied by the number of working days in a year and years over which the impact is being measured, can translate into

much bigger numbers which could otherwise be spent with a family or other activities (Clark and Wang, 2005).

**Table 11: T-test of the Mean Commuting Times and Distances (Observed).**

|                              | Polycentric (Job centers) | Monocentric (CBD) |        |
| ---------------------------- | ------------------------- | ----------------- | ------ |
| Measure of spatial separation | Mean                      | Mean              | t Stat |
| Distance, miles              | 8.41                      | 9.73              | -2.11** |
| N                            | 503                       | 107               |        |
| Time, minutes                | 18.36                     | 21.43             | -2.49** |
| N                            | 503                       | 107               |        |

*-significant at 0.05 level of significance, **-significant at 0.01 level of significance

Figures 9 and 10 visualize the mean travel time and the observed time, respectively, for each TAZ in 2000 and as reported by the respondents to a work place. Generally individuals benefit from living closer to job-rich places as is demonstrated by the lower commuting times (which are less than 20 minutes), while those living farther away spend longer time.

Commuting in the Baton Rouge region was visualized by plotting mean travel times and distances as a function of distance from the CBD under the monocentric (shown in a solid line) and polycentric expectations (shown in a broken line) (Figures 11 and 12). In monocentric conditions the commuting times and distances increase with the distance from the CBD almost linearly, which is expected, while under the polycentric conditions there are many highs and lows observed in the commuting times and distances. This step-wise spatial pattern provides an important evidence of the polycentric nature of the study area by revealing the presence of other than the CBD employment concentrations, close proximity to these places results in saving both times and distances. For example, both Figures 12a and Figure 11a show that the job concentrations can be found at the distance of 6, 10, 13, and 17 miles from the Baton Rouge CBD.

Both the simulation experiment (Figure 11a) and empirical testing (Figure 11b) show graphically that on average the travel distances to work places are lower for the polycentric system. Monocentric distances and times seem to be shorter only within a distance of 4 miles from the Baton Rouge downtown. Figure 12 shows the travel time patterns which are strikingly similar to these revealed by the distances. Again, generally, commuters spend more time travelling to the CBD than they do to the multiple job concentrations both within the monocentric experimental setting (Figure 12a) and when tested empirically (Figure 12b). However, it should be noted that polycentric times more closely follow the monocentric times than do the distances (Figure 12b vs. Figure 11b).

## Conclusion

Two objectives were achieved within this paper. First, we investigated the urban structure of the Baton Rouge metropolitan region in terms of job concentration area using the criteria of in-net
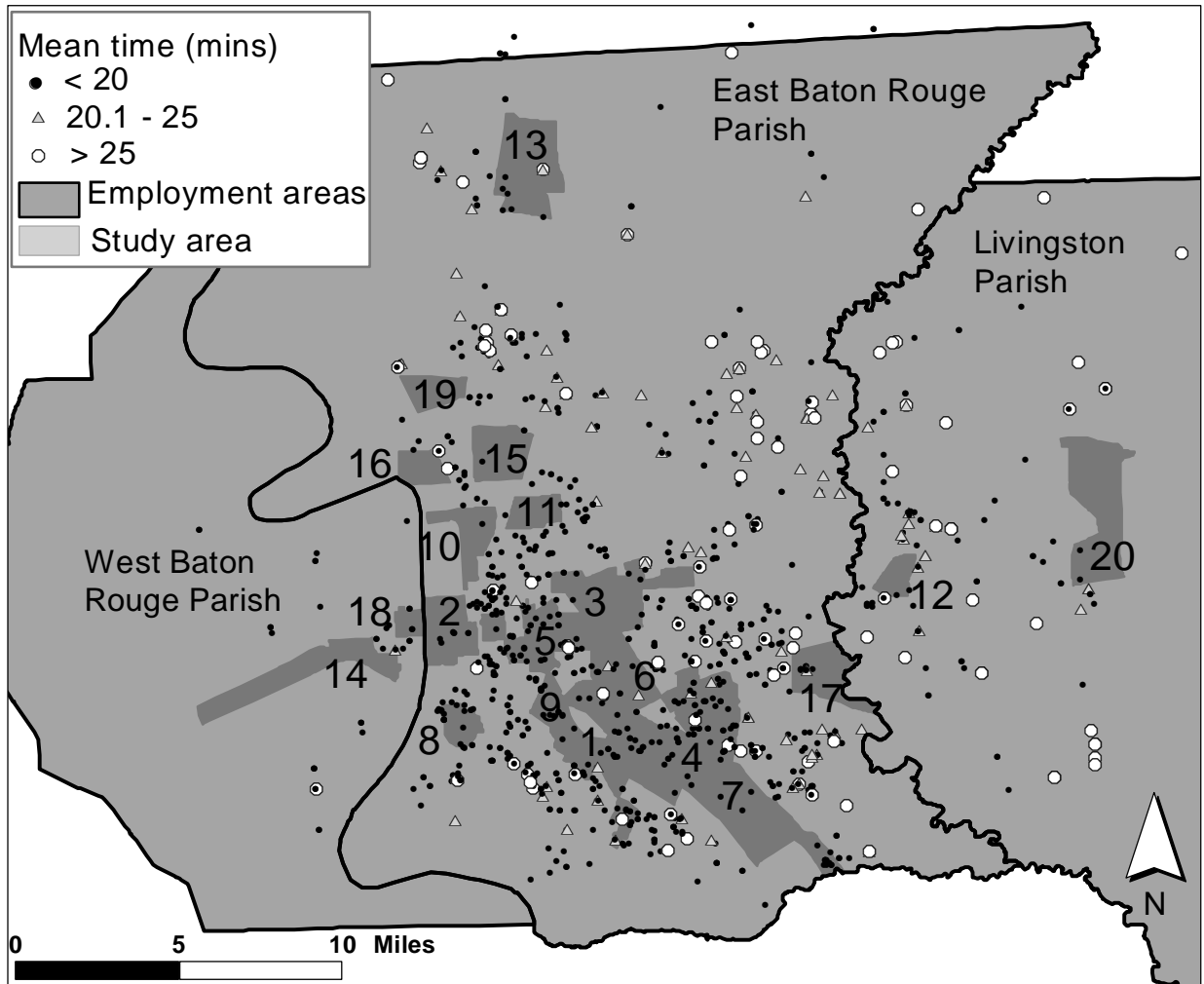
**Figure 10: 1997 Baton Rouge Transportation Survey Respondents' Observed Commuting Times and Employment Centers Locations.**
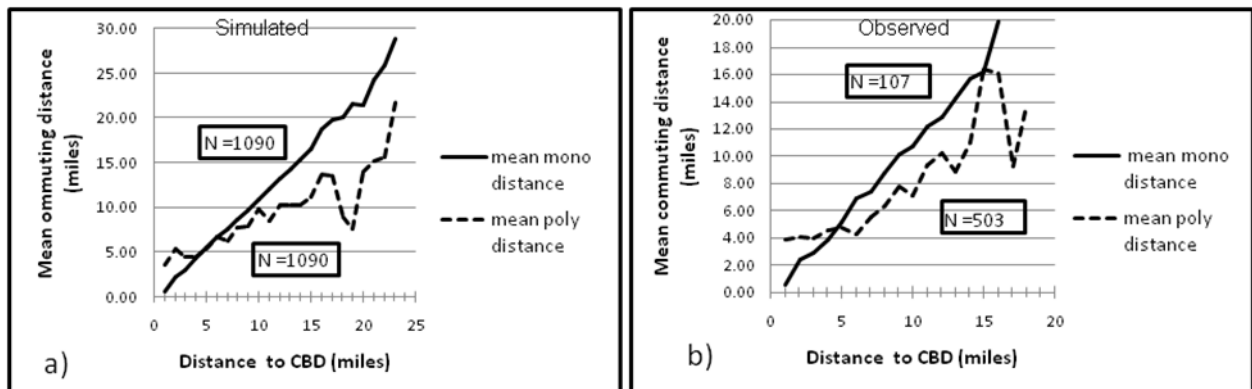


**Figure 11: Monocentric and Polycentric Commuting Distances.**

Note: Monocentric (in solid line) and polycentric (in broken line) commuting distances: a) computer-simulated distances with all workers having their jobs at the CBD vs. simulated polycentric distances; b) observed travel distances of workers commuting to CBD vs. those to other job concentrations.

commuting, total employment, and contiguity of the zones, for 2000 and1990. Our findings indicate that being relatively small, the Baton Rouge region is best described as polycentric as many other contemporary U.S. metropolitan areas. 20 job concentrations were identified, among which 8 were defined as job centers and the other as the subcenters.
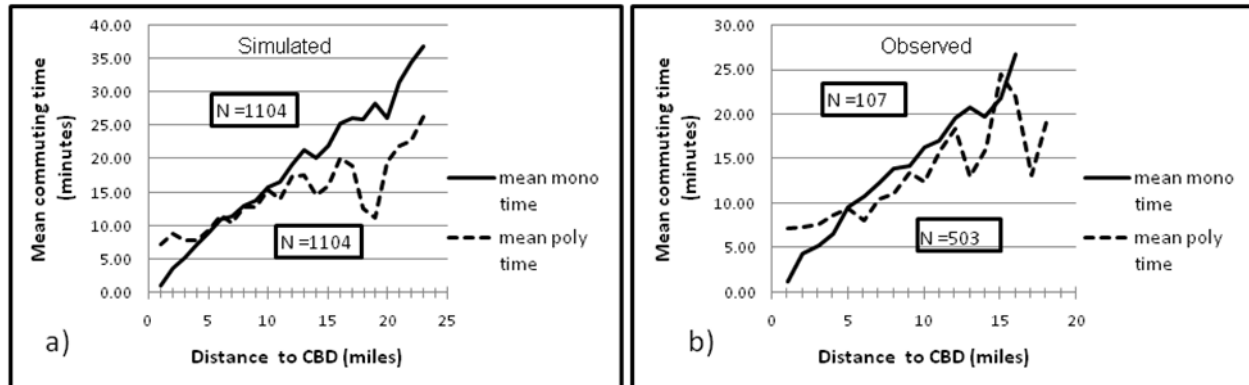


**Figure 12:  Monocentric and Polycentric Commuting Times.**
Note: Monocentric (in solid line) and polycentric (in broken line) commuting times: a) computer-simulated monocentric times (solid line) and polycentric times; b) real travel times of workers commuting to CBD vs. those of all job centers.

The second objective of the study focused on the investigation of the commuting impacts of the urban structure. Specifically, the co-location hypothesis was tested according to which homes are located closer to employment centers. Two measures of the spatial separation between home and work reflected by the time and distance traveled, as indicated by the previous research, were investigated in the study. Conflicting findings on the effects of job decentralization on the journey-to-work was claimed due to use of the averages from the large metropolitan-wide data (Cervero and Wu, 1996). To avoid this problem, the disaggregate data that was obtained from the 1997 Baton Rouge Personal Transportation Survey (BRPTS) was used for the analysis. In turn, spatial patterns of commuting times and distances both provide evidence of the polycentric urban structure of the Baton Rouge region by demonstrating dips in the commuting times and distances within proximity to other than CBD job concentrations.

We conducted a simulation exercise with the purpose of determining commuting times and distances under the assumption of monocentric job structure. Accordingly, all persons were assigned the new work place – the Baton Rouge CBD. Using the road network we computed the monocentric-simulated times and distances. Likewise, times and distances were computed for the polycentric urban structure using the locations of the identified job sub/centers for the year 2000. The commuting behavior measures under the monocentric assumptions were compared to polycentric ones. To verify and enhance results from the experiment, the real times and distances to work taken from the travel data were analyzed next.

A paired t-test of means of the monocentric commuting times and distances vs. the polycentric times and distances, both simulated and observed, resulted in significant differences in both measures of the commuting lengths. Under the assumption of a monocentric urban structure, the travel times and distances required for workers to reach a single center (i.e., the CBD) were longer than for the decentralized structure. This finding is consistent with other research

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concluding that job suburbanization is associated with shorter commuting distances (Crane and Chatman, 2004).

Additionally, the travel times patterns were found strikingly similar to these revealed by the distances. This trend of the similar behavior between travel times and mileage although representing distinct commuting measures were also found by Sultana and Weber (2007) in their Alabama-based study of two midsize southeastern metropolitan areas.

Keeping in line with the co-location theory, our findings indicate that the polycentric system appears to reduce the commuting lengths measured both by the distance and time. However, it should be noted that there is more difference between distances than there is a difference between times in monocentric and polycentric urban structures which can be explained by faster speeds (Sultana and Weber, 2007). However, as the objective of the study did not include an explanation of the variation in the commuting lengths, such variables were not considered. We realize this limitation of the study while the incorporation of the variables of this nature may even have a greater influence on commuting than the urban structure.

# Land Use Impacts on Trip Chaining Propensity of Workers and Non-workers: Evidence from Baton Rouge Region, Louisiana

## Introduction

Overall travel by automobile has grown in the U.S. since such data were first reported by the Nationwide Personal Transportation Survey (NPTS) in 1969. According to the National Household Travel Survey (NHTS), the time spent in a car by the Americans increased by 10% while the number of miles traveled remained about the same from 1995 to 2001 (NHTS, 2004). A similar trend was observed for commuting during 1995-2001, indicating slower commute speeds and greater congestion. Other travel-related problems such as travel delays, environmental impacts and traffic accidents call for public policies conducive to a reduction in car dependence, trip frequency, and overall vehicle miles (VMT) and hours traveled (VHT).

A trip is defined as a single one-way link of travel between an origin and a destination, which forms the most basic measure of personal travel, represented as a record in the travel day file. A sequence of a set of trips, e.g., traveling from home to a store, and then to place of work, generates a tour that begins at home and ends at work. *Trip chaining* can be defined as combining several away-from-home activities (i.e., making several stops) as a part of a tour into one trip. Trip chaining, among others, has been suggested to have the effect of alleviating some of the aforementioned travel-related problems. By chaining trips, the total travel time required for carrying out the set of such activities may be reduced (Goulias and Kitamura, 1989; Greenwald and McNally, 2008). Trip chaining as an outcome of travel behavior may also reduce the total number of trips, total vehicle miles and hours traveled (VMT and VHT), and share of trips made in cold start mode (Lee et al., 2002; Johnston, 2004).

*Work status* is a crucial factor for explaining travel demand and trip chaining in particular (McGuckin and Murakami, 1999). Most studies focus on trip chaining patterns of workers who add non-work activities to commuting trips (Kondo and Kitamura, 1987; Strathman et al, 1993; Downs, 1992; McGuckin and Murakami, 1999; Chu, 2003). Others examined non-work activities represented by separate trip chains originated from home (Nishii, et al, 1988). Much less is on non-workers, who also make chained trips from home not related to work (e.g., Misra and Bhat, 2000; Bhat and Misra, 2001). Non-commuting trips, made by employed and non-employed alike, are an important element of a trip chain, and have been found to grow faster than do the work trips (Gordon et al., 1988; Richardson and Gordon, 1989). However, workers and non-workers may differ significantly when it comes to trip chaining (Bianco and Lawson, 1996; Misra and Bhat, 2000). This makes the understanding of both workers' and non-workers' travel behavior crucial for the successful development and application of relevant travel management programs aimed at reduction of trips, distance and time traveled, and improving air quality, etc.

Researchers on trip chaining behavior also consider various *demographic and socioeconomic characteristics* such as (1) gender (e.g., Golob, 1986; McGuckin and Murakami,1999; McGuckin et al., 2005), (2) age of a trip maker and presence of children in the household (Bhat and Zhao,

2002; McGuckin, et al, 2005), (3) income (Golob, 1986; Bhat, 1997; Yalamanchili et al., 1999; Wallace et al., 2000), (4) number of vehicles per worker (Bhat, 1997), (5) household composition (e.g., Yalamanchili et al., 1999; Wallace et al., 2000; Bricka, 2008), and (6) life cycle stage and household structure (Golob, 1986; Strathman et al., 1994a; McGuckin and Murakami, 1999; Misra and Bhat, 2000; McGuckin et al., 2005). Factors affecting the trip chaining decision also include time duration of an activity, distance between home and non-work activity locations, distance between home and work location, density of opportunities (Nishii, et al, 1988), time of day (Downs, 1992; Strathman et al., 1993), and others (Kondo and Kitamura, 1987; Abdelghany and Mahmassani, 2003).

Other studies examine the relationship between *land use* and trip consolidating. Factors found to impact the propensity of trip chaining include residential density (McGuckin and Murakami, 1999), accessibility (Golob, 2000; Krizek, 2003), and mixed land use and urban design (Greenwald and McNally, 2008). More dense areas are found to generate more trips (Hanson, 1982); in contrast, a larger average parcel size, typical for low-density residential areas, reduces the number of trip chains by automobile (Greenwald and McNally, 2008). Ample shopping opportunities within proximity to residents, often in areas with mixed land uses, cut back the average trip lengths of several sequentially connected trip segments (Hanson, 1982). Higher employment densities, particularly retail and services, were found related to increased trip chaining (Adler and Ben-Akiva, 1979; Bhat, 1997). An increase in accessibility to jobs and other activities improves the likelihood of trip chaining and leads to fewer vehicle miles traveled (Krizek, 2003). These empirical studies imply great potential for public policy by adjusting urban land uses to alter travelers behavior in commute stop-making tendency (Chu, 2003).

Two shortfalls from the literature reviewed above are noticed. One is lack of analysis of combined impacts of land use and individual attributes, including different effects by work status and by gender. Another is the primitive measure of mixed land uses, which has been identified as an important factor in shaping travel behavior in general and trip chaining in particular.

Contributions of this study can be summarized in three aspects:
We examine the integrated effects of land use types and individual attributes on trip chaining.
A localized job-housing balance ratio is computed to capture the degree of mixed land uses around each residential location, and its effect on trip chaining is analyzed.
We analyze the effects of these factors by work status and by gender in order to capture possible distinctive patterns between worker and non-worker and between man and woman.
This research uses a Personal Transportation Survey dataset for the Baton Rouge metropolitan area, Louisiana, in 1997 to analyze the issues. The remainder of the paper is organized as follows. The next section discusses the study area and data sources, followed by methods for defining key variables. The next section presents the analysis results, with another section interpreting the results. The paper is concluded with a brief summary and suggestions for the future research.

## Study Area and Data Sources

The study area consists of three parishes (East Baton Rouge, West Baton Rouge and Livingston), which form the core of Baton Rouge Metropolitan Area (excluding Ascension Parish on the south, which is mostly rural). The central city Baton Rouge is the capital city of Louisiana

(Figure 1). We refer to it as the Baton Rouge region elsewhere in the paper. It encompasses a diverse range of land use types across urban, suburban, and rural settings.
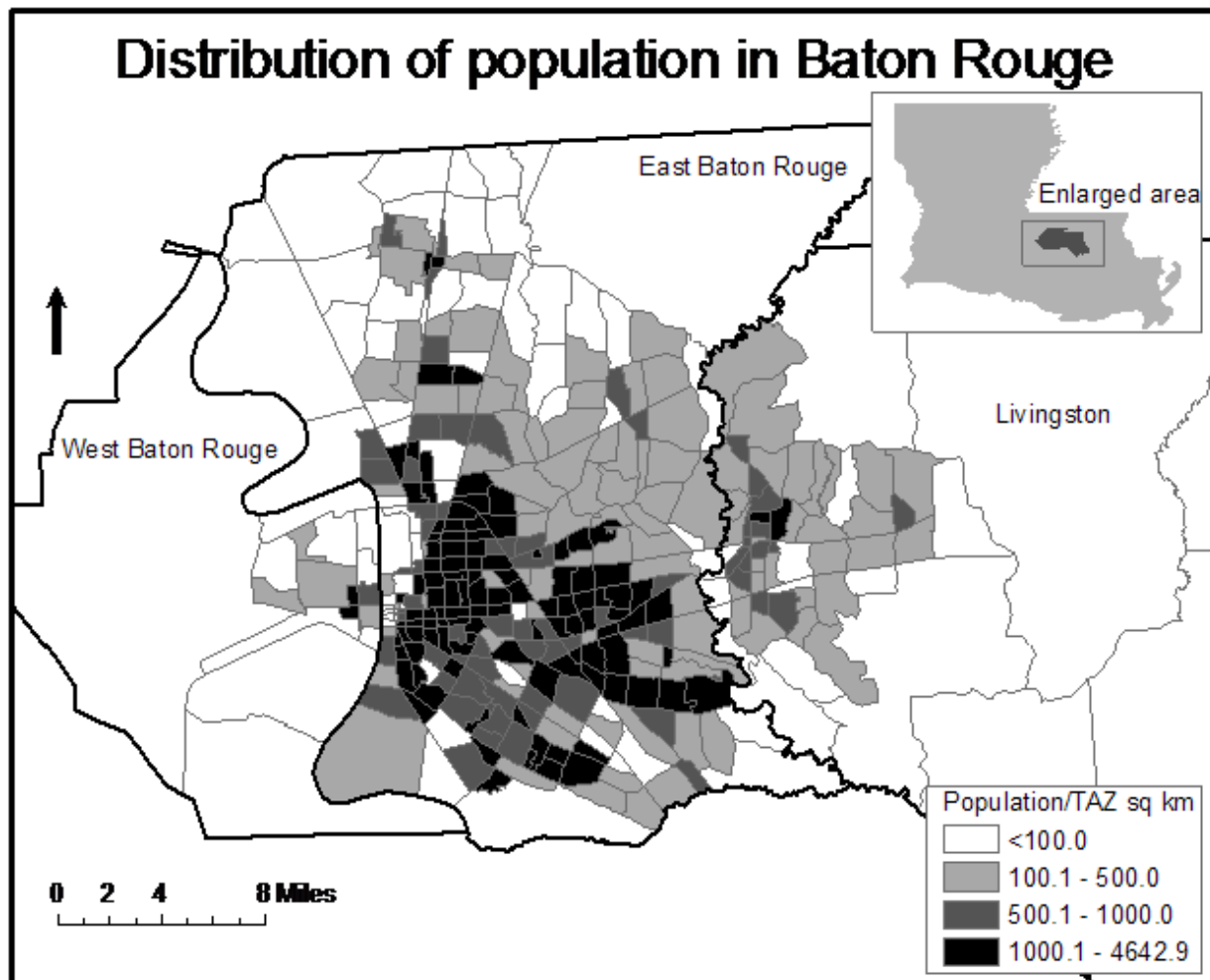


**Figure 13: Distribution of Population in Baton Rouge in 2000**

There are 443,375 residents in 2000, with 63% whites, 33% African-Americans, and 4% others in the study area (U.S. Census, 2000). Figure 13 illustrates population distribution across the study area. The area has an average population density of 700.8 people per square kilometer (or 1,815 people per square mile). Figure 14 below shows the distribution of resident workers across the study area. The more densely populated areas are located within the largest cities of Baton Rouge, Zachary, and Baker. Figure 15 illustrates the employment (jobs) distribution across the study area. Census 2000 Transportation Planning Package (CTPP) Parts 1 and 2 have been used to retrieve population and employment data at the TAZ-level, respectively.

The study area has 74% of the employment of the Baton Rouge Metropolitan Area. The highest employment density areas are mostly in the central city (Baton Rouge). The overall job to resident worker ratio (JWR) in the study area is 1.05, consistent with other metropolitan areas. In other words, there are 5% more jobs than resident workers in the area. Males comprise 52% of all resident workers, and slightly outnumber female workers.

The detailed individual travel data were extracted from the 1997 Baton Rouge Personal Transportation Survey (BRPTS) database that was collected by the Research Triangle Institute. The dataset has three files: household file, travel day file, and person file. Each contains several variables of some interest to our study (see Table 12). In addition to demographic and socioeconomic variables, the household file has geographic coordinates of household, and the person file has geographic coordinates of workplace and stops of other trip purposes. The location information enables us to geocode each trip's origin, destination and various stops along the way, and also identify land use where each household resides and associated neighborhood attributes (e.g., job-housing balance ratio).
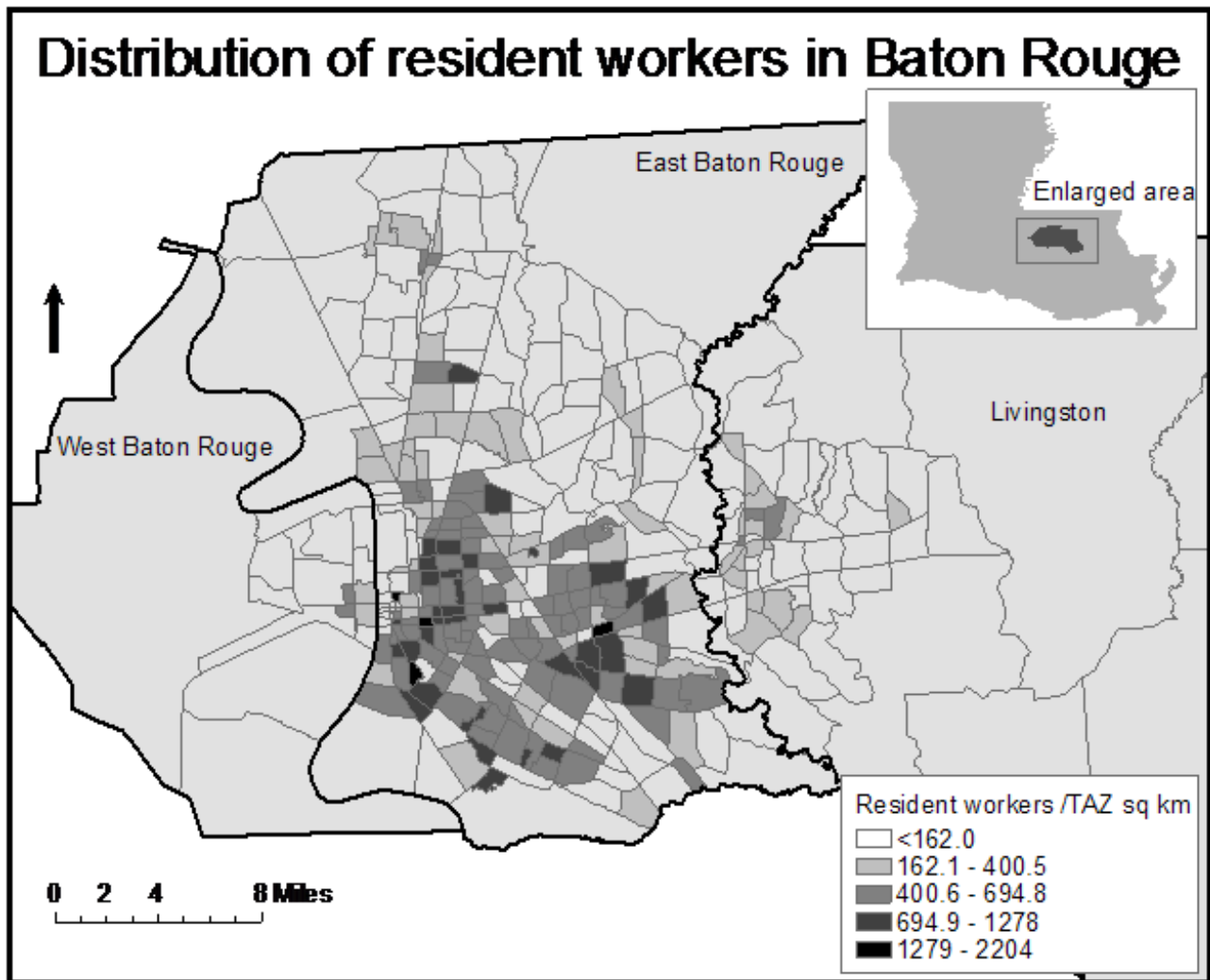


**Figure 14: Distribution of Resident Workers in Baton Rouge in 2000**
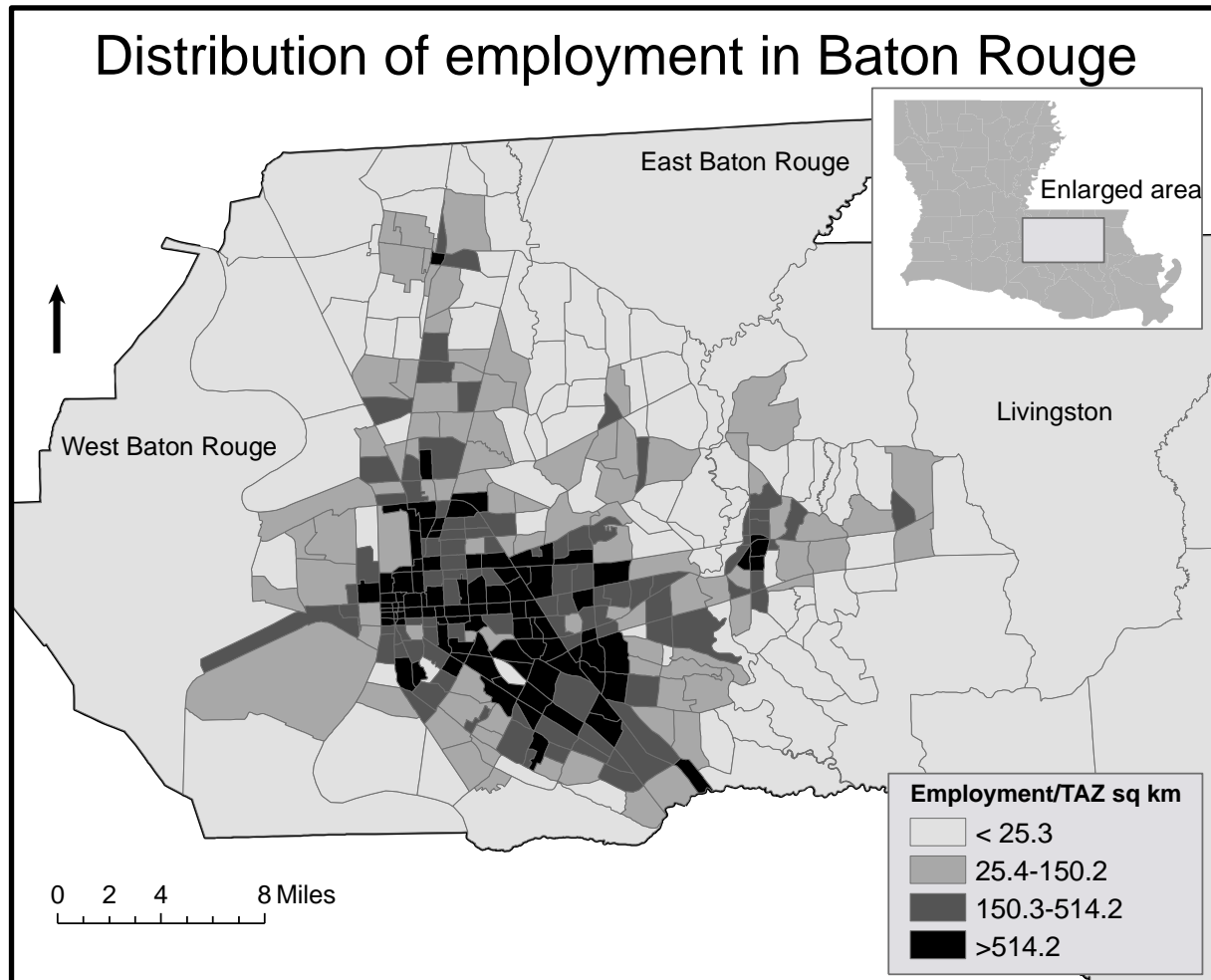
**Figure 15: Distribution of Employment in Baton Rouge in 2000**

The original data set contained 13,194 trips reported by all respondents. Our interest is limited to adults of age at least 16 years old. This results in 10,971 trips, made by 2,220 individuals in 1,286 households, in the dataset for the analysis. Table 13 presents some basic statistics from this dataset. Each respondent recorded all places visited during a 24-hour period, ordered from 4.00am to 3.59am. A travel day trip is defined as any time the respondent went from one address to another by any means of transportation. All trips in the database are organized into trip tours anchored by home, work, or some other place. The average number of daily trips is 4.94 per person and 8.53 per household, in line with the nationwide trip rates of 4.09 per person and 9.66 per household (Hu and Reuscher, 2004).

Among the 2,220 adults (>= 16 years old) included in this study, 1,513 were workers and 707 were non-workers. Among the 1,513 workers, 748 were males and 765 females; and among the 707 non-workers, 237 were males and 470 females. The 1,513 workers reported 7,605 trips with an average of 5.03 trips per person, and the 707 non-workers made 3,366 trips with an average of 4.76 trips per person.

**Table 12: Selected Variables in the 1997 Baton Rouge Personal Transportation Survey Data Files.**

| BR PTS 1997 HH File: | BR PTS 1997 Travel Day File: | Baton Rouge PTS 1997 Person File: |
|---|---|---|
| Household income category | Respondent is a worker | House ID |
| Number of adults in HH | Reason started day away from home | Person ID |
| Number of persons in HH age 0-4 | HH family income category | Person trips |
| Stories in apt. building | # of trip within chain | HH trips |
| Type of housing unit | Travel day on weekend | Highway congestion |
| Race | Travel day - day of week | Worry about traffic accident |
| Age | Where trip chain started | Poor walkways or sidewalks |
| Driver status | 1=persons 1st trip began at home | Rough pavement on neighborhood |
| Sex | # of vehicles in household (derived) | How often used public transportation |
| Worker status | # of HH members on the trip (derived) | Have full, part time job last wk or not |
| Travel day date (DD) | non-HH members on trip | One-way distance to work |
| Travel day date (MM) | # of non-HH members on trip | Minutes it took from home to work |
| Travel day date (YY) | Total # of persons on trip (derived) | Mode to Get to work |
| Travel day - day of week | Trip purpose for passenger | Main means of transportation to work |
| Other public transit available | Purpose of trip (1995 definition) | Latitude from geocoding - workplace |
| No. of workers in HH | Other HH members were also on trip? | Longitude from geocoding - workplace |
| Reported ZIP code for the HH | Was HH vehicle used on trip? | |
| Latitude from geocoding - HH | Number of drivers in HH | |
| Longitude from geocoding - HH | Distance (miles) | |
| Education of HH reference person | Mode of transportation code | |
| No. of phone numbers in HH | Travel time (min) | |

**Table 13: Basic Statistics of Selected Variables from 1997 Baton Rouge Personal Transportation Survey Data Files.**

| Age>=16 | N | Mean | Max | Mi | St.Dev. |
|---|---|---|---|---|---|
| Households | 1286 | | | | |
| Population | 2220 | | | | |
| Resident workers | 1513 | | | | |
| Resident non- | 707 | | | | |
| Household trips | 10971 | 14 | 52 | 0 | 8.5 |
| Age | 2220 | 42 | 90 | 16 | 15.1 |
| Annual mileage | 1990 | 1101. | 9999 | 0 | 2316.3 |
| Dist. to work | 1492 | 11.4 | 265 | 0 | 14.2 |
| Time to work | 1509 | 21.6 | 480 | 0 | 19 |
| Miles per trip | 2176 | 10 | 850 | 0 | 30 |
| Minutes per trip | 2205 | 17 | 660 | 1 | 26 |

## Defining Variables

### Land Use Types

Land use data were from two sources. A detailed zoning map for the East Baton Rouge Parish in the PDF format was downloaded from the Baton Rouge City Planning Commission web site (BRCPRC, 2009). To construct the land use data in GIS, we first saved the PDF file as a tag image file (a raster), then imported it into ArcGIS and georeferenced it. The georeferenced raster file was in a grid form, and which could be used later for a conversion into a shapefile by merging raster cells sharing the same land use types.

For West Baton Rouge Parish and Livingston Parish that are mostly rural, no land use maps or GIS data sets similar to that of East Baton Rouge Parish are available. The USGS 2001 data set from the Louisiana GIS Digital Map was used to identify land use categories for these two parishes. We first extracted the raster files representing land uses within parishes of West Baton Rouge and Livingston, and then converted them into shapefiles. Urban residential land use classes include developed low intensity, developed medium intensity and developed high-density. Outside urban areas, residential land types, agricultural (e.g., pasture/crops, cultivated crops, shrub/scrub, grassland) and sparsely populated forested areas were collapsed into a single category of agricultural/rural land uses.

A modified land use classification was employed in the study based on that developed by the BRCRPC for the East Baton Rouge parish reflecting the residential locations of the 1997 travel survey respondents. BRCPC (2009) developed the following land use classification for the zoning map: industrial, recreation, transportation communication utilities, vacant, office, commercial, public/semi-public, low density residential, medium density residential, high density residential, and agricultural. Since no travel survey respondents in the BRNPTS data set resided within the first four land use groups, these categories were not considered by the study.
The next three land use categories – office, commercial, and public/semi-public – were similar in terms of impact on travel behavior as all three are closely associated with employment location.
In addition, there were only a small number of survey respondents from each of the three land uses. They were combined into one group: commercial/office. Three residential categories differ by land use intensity and a prevalent housing structure type. Low density residential is different from the other residential types by lower population density; single-family detached houses are found across this land category. Medium density residential is characterized by smaller-lots subdivisions with higher population density, while high residential category is represented by areas with predominantly multi-family housing structures such as apartment complexes and condominiums (Homer et al., 2004).

Finally, the following categories are the consolidated land use types used in the analysis: commercial/office, agricultural, low density residential, medium density residential and high density residential.

Figure 16 shows residential locations of the BRPTS respondents superimposed on land use types. By overlaying the home locations of respondents and land uses, we are able to identify the corresponding land use of each respondent. Table 14 presents the distribution of the 1997 BRPTS survey respondents by parish of residence and type of land use. A majority of respondents (1118 out of 1286 households, or 86.9%) were in East Baton Rouge Parish. In the study area, 64.5% respondents resided in the low-density residential area, followed by agricultural (11.1%), medium-density residential (9.3%), commercial/office (8.7%) and lastly high-density residential (6.5%).

In regression analysis presented in the next section, land use type is coded by multiple dummy variables. Four dummy-coded variables are sufficient to represent the five land use types. Given the largest number of respondents reside in low-density residential areas, we code low-density residential as the reference category (e.g., $x_1=x_2=x_3=x_4=0$), and the other four (comparison category) such as:

Agricultural: $x_1=1$, $x_2=x_3=x_4=0$
Commercial/office: $x_1=0$, $x_2=1$, $x_3=x_4=0$
Medium-density residential: $x_1=x_2=0$, $x_3=1$, $x_4=0$
High-density residential: $x_1=x_2=x_3=0$, $x_4=1$

In other words, the coefficient (and corresponding statistical significance) of $x_1$ indicates the impact of agricultural land use on the dependent variable (i.e., propensity of trip chaining) with comparison to the low-density residential; the coefficient of $x_2$ indicates the impact of commercial/office land use on the dependent variable with comparison to the low-density residential, and so on. This explains why only the four comparison categories are listed in the tables showing regression results.

**Table 14: Household in Parishes of East Baton Rouge, West Baton Rouge, and Livingston by Land Use Type.**

| Land use | EBRP | WBRP | Livingston | Total |
|---|---|---|---|---|
| agricultural | 100 | 7 | 36 | 143 |
| commercial/office | 112 | 0 | 0 | 112 |
| medium density residential | 113 | 3 | 3 | 119 |
| low density residential | 710 | 28 | 91 | 829 |
| high density residential | 83 | 0 | 0 | 83 |
| Total | 1118 | 38 | 130 | 1286 |

**Job-Housing Balance Ratio**

An employment (job) location is the destination for a worker's commuting trip. It also represents activity opportunities for the non-worker, particularly if the place is engaged in retail and various services. It is also observed that job accessibility and mixed land uses affect trip chaining, as indicated in the literature reviewed.
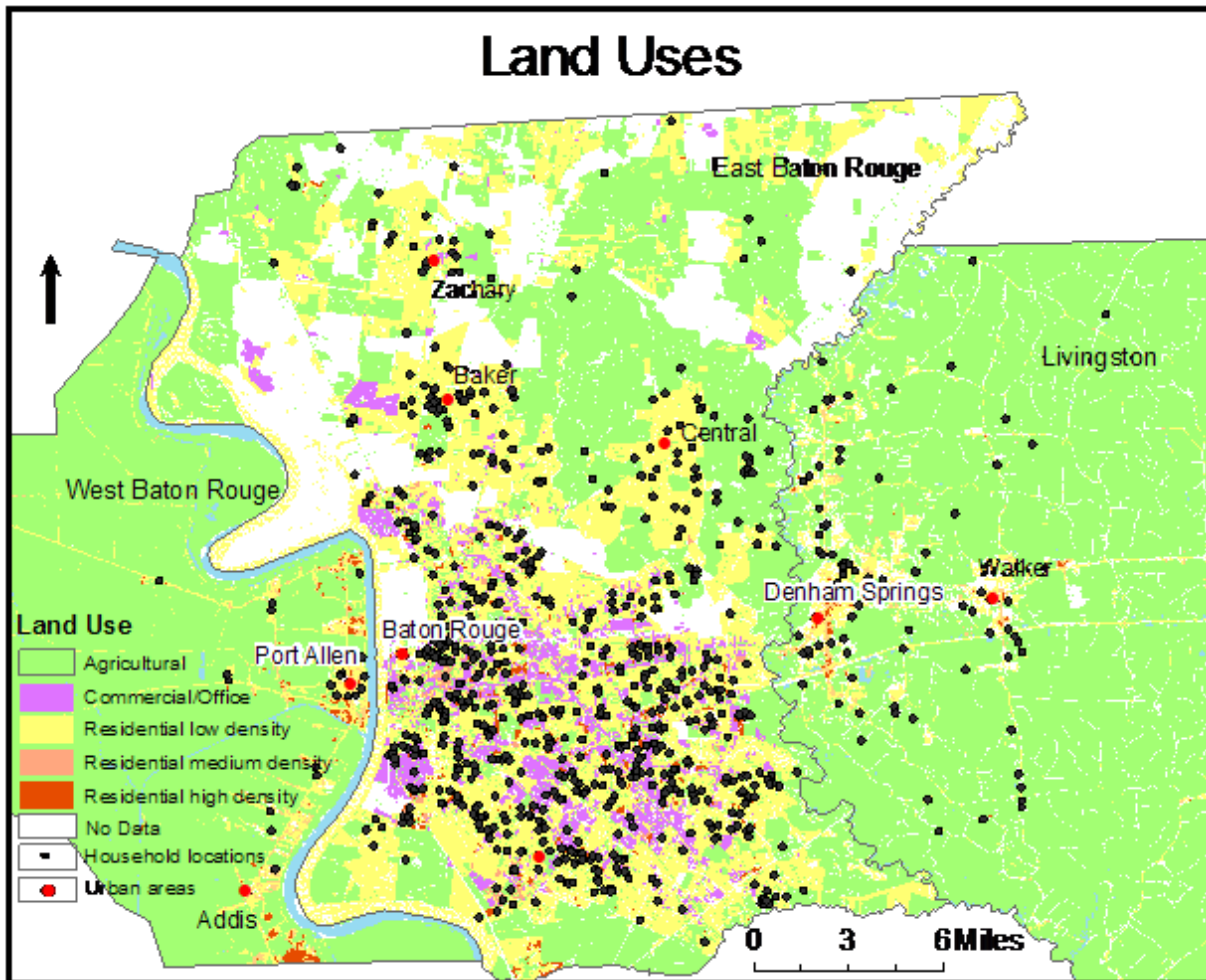
**Figure 16: Land Uses within Study Area and Home Locations of the Survey Respondents**

We use the index of *job-housing balance ratio* to capture the job accessibility and also the degree of mixed land uses. In practice, job-housing balance ratio is measured as the number of jobs per resident worker or job-worker ratio (JWR) in a geographic area (Cervero, 1989, 1996; Wang, 2000). This measure refers to the inequality between the number of jobs and number of resident workers within a geographical area (Wang, 2000). A ratio higher than 1 indicates that jobs outnumber resident workers and thus an area is relatively rich in job opportunities. A ratio smaller than 1 implies an area relatively poor in jobs. The traditional measure of JWR is computed within a geopolitical unit or a predefined arbitrary boundary (Peng, 1997). However, trips usually take place across geopolitical boundaries or analysis units. This study adopts the approach by Wang (2000) that defines the JWR ratio within a travel time range from a residential location, termed "catchment area".

The 2000 Census Transportation Planning Package (CTPP) parts 1 and 2 at the Traffic Analysis Zone (TAZ) were used to obtain data of resident workers and employment, respectively. First, travel times between the centroids of the TAZ within the study area were estimated based on the real-world road network taking into account the road type and varying travel speeds in different

urban settings (Luo and Wang, 2003). Second, the 2-step floating catchment area method was used to compute an accessibility within a range of travel times (Luo and Wang, 2003; Wang, 2006). The travel time of 25 minutes was chosen as a spatial cutoff value as on average a commuter spends between 20 to 22 minutes to get from a residence to a place of work (US Department of Transportation, 2001). By using CTPP 2000 parts 1 and 2 data accessibility can be computed for each of the TAZ. Figure 17 illustrates the spatial distribution of this job accessibility measure with the residential locations superimposed within the study area. Accessibility computed within 25 minutes of travel for each TAZ is fluctuating between values of 0.1 and 1.35, with the higher value indicating a better spatial access to jobs and opportunities both for the workers and non-workers. Accessibility is higher in the central areas due to greater jobs availability and is lower outside the urbanized area (Figure 17).
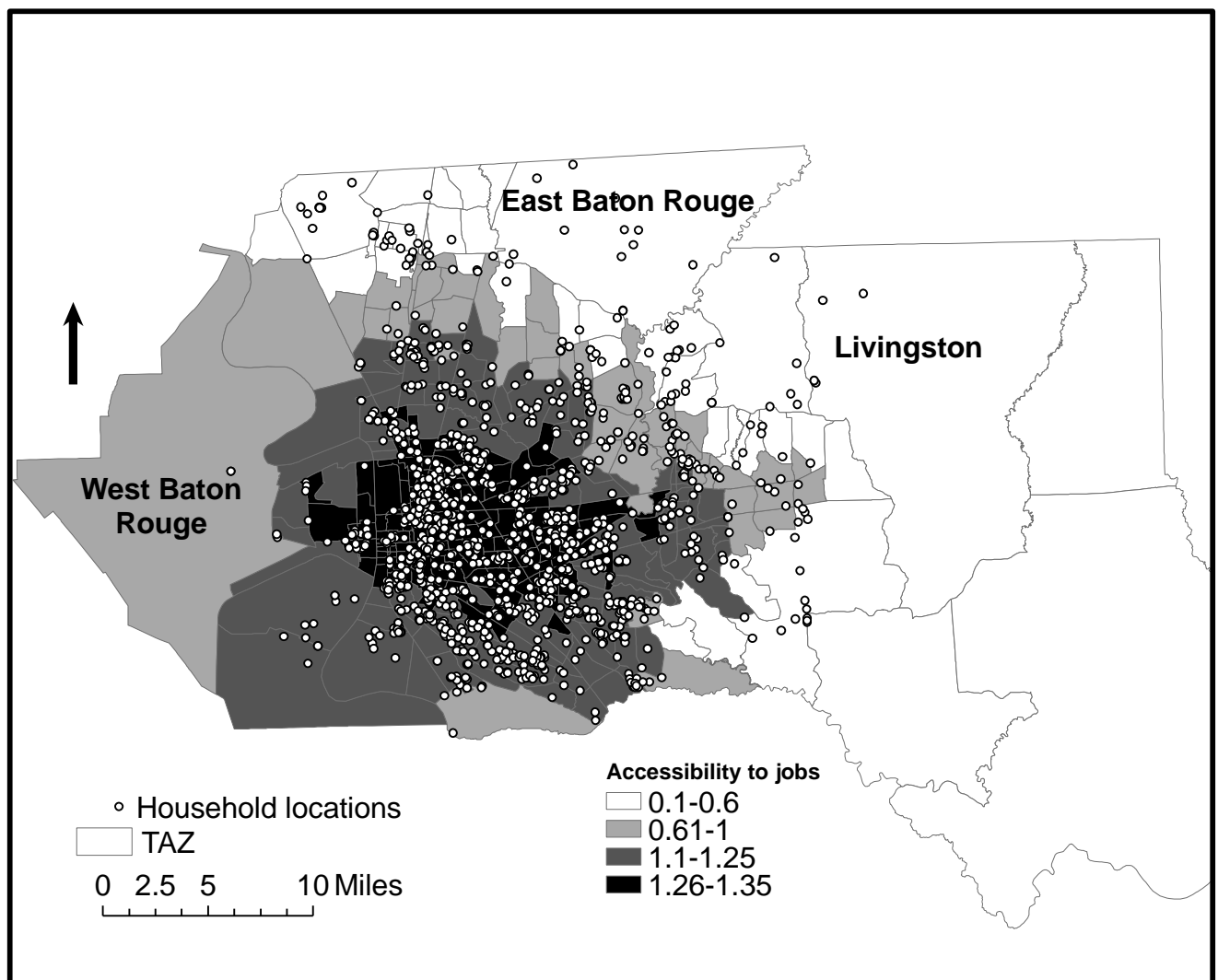


**Figure 17: Spatial Distribution of the Job Accessibility with the Home Locations Superimposed.**

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**Travel Time and Distance for Trips**

Each trip was assigned to a chain with the origin (the starting point of a trip) and destination (the ending point of a trip) in terms of home, work, or other location identified. We identified trip chains including at least two stops, that is, including three or more separate trips in a single chain. There were 1,150 such true chains generated by 4426 trips, with the average value of 3.85 trips per each chain. All trips within a chain are sequentially numbered. Given that each household and its members had their unique numbers, it was possible to assign to each trip chain the household- and personal-level attributes. Distance in miles and travel time in minutes of the recorded trip is also recorded, therefore, it was possible to compute the travel time and distance, in minutes and miles, respectively, for each of the chain as a sum of the times and distances of the individual trip segments. Number of trips per each chain was also generated. Work respondents also provided information on one-way distance to work in miles, and minutes it took to get from home to work.

# Analysis and Discussion

**Descriptive Analysis**

To get some basic picture of trip chain behavior, Table 15 is compiled to show the breakdowns between chained and non-chained trips, and by work status and by gender. Non-workers were more likely (about 50%) to participate in trip chaining than workers (36%). Both working men and women had lower percentages (33% and 39% respectively) in chained trips than their non-work counterparts (42% and 54% respectively). Between men and women, women had a higher propensity to chain trip: working women chained 7% more trips than working men, and non-working women chained 12% more trips than non-working men.

Table 16 illustrates a distribution of households, persons, trips, and chains per different land use type. It is evident that land uses vary by the trip chaining rate, with the high density residential areas having the highest rate of 0.57 chains per person.

**Table 15: Trip Chaining by Work Status and Gender.**

| # trips part of chain (%) | Worker | | | Non-worker | | |
|---|---|---|---|---|---|---|
| | Male | Female | Total | Male | Female | Total |
| Yes | 1218 (32.9%) | 1529 (39.2%) | 2747 (36.12%) | 456 (41.6%) | 1223 (53.9%) | 1679 (49.9%) |
| No | 2484 (67.1%) | 2374 (60.8%) | 4858 (63.88%) | 639 (58.4%) | 1048 (46.1%) | 1687 (50.1%) |
| Total | 3702 | 3903 | 7605 | 1095 | 2271 | 3366 |

**Table 16: Households, Persons, Trips, and Chain by Land Use Type.**

| Land use | Households | Persons | Trips | trips/pers | Chains | chains/pers |
|---|---|---|---|---|---|---|
| agricultural | 143 | 334 | 1575 | 4.72 | 170 | 0.51 |
| commercial/office | 112 | 192 | 918 | 4.78 | 104 | 0.54 |
| medium density residential | 119 | 219 | 1042 | 4.76 | 118 | 0.54 |
| low density residential | 829 | 1360 | 6874 | 5.05 | 693 | 0.51 |
| high density residential | 83 | 115 | 562 | 4.89 | 65 | 0.57 |
| Total | 1286 | 2220 | 10971 | 4.94 | 1150 | 0.52 |

Figure 18 demonstrates trips which either were chained or were not chained originating from different land use types by employment status and gender. The non-workers appear to make more chained trips than do the workers (Figure 18). It can be further gleaned that female unemployed trip-makers make either an equal number or more chained trips than the unchained trips originating from every land use type, but more so from the agricultural areas (Figure 18). On the other hand, both employed male and female trip-makers make more unchained trips than chained trips (Figure 18).
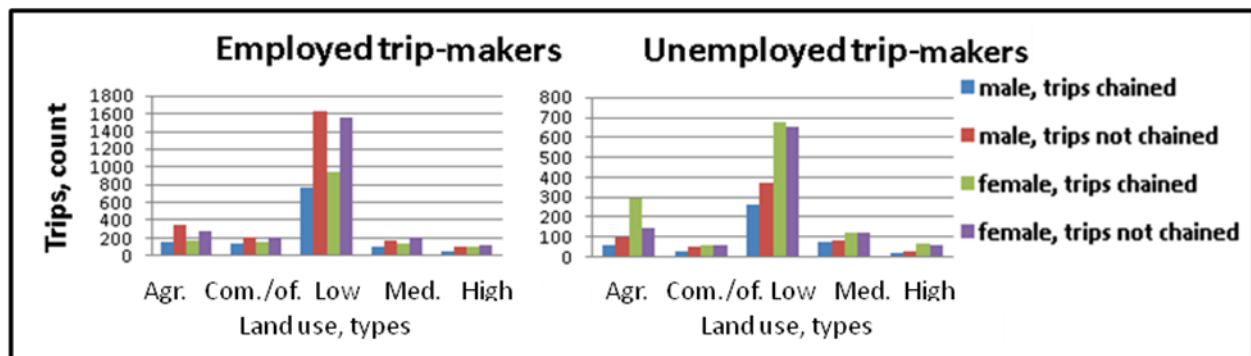


**Figure 18: Trips Chained by Land Use Type, Gender, and Employment Status.**

Figure 19 created from the data within the study area of Baton Rouge, Louisiana, supports this finding and demonstrates this typical travel behavior frequently revealed by the female worker: after leaving her house in the morning she accompanies her two children and makes two stops to drop them off at Central Middle and Central High School (trips 1 and 2) before proceeding to a work place (trip 3), thus, forming a trip chain consisting of three separate trips (Figure 19). Figure 20 demonstrates how two non-working women design their trips across the space. Despite living close to the Baton Rouge CBD, they travel away from the CBD area, with the person 1 forming one chain (trips 4 and 5), and person 2 formed two chains (trips 1, 2, and 3, and trips 6, 7, and 8, respectively).

**Logistic Regression Models**

Travelers are assumed to make travel decisions to maximize the travel utility (i.e., satisfaction) within temporal and spatial constraints, as well as by those imposed by other factors such as income, household role, life cycle stage, etc. (McFadden, 1974; Reilly and Landis, 2002). Such a behavior can be modeled by logistic regression quantitatively. In this study, we use several
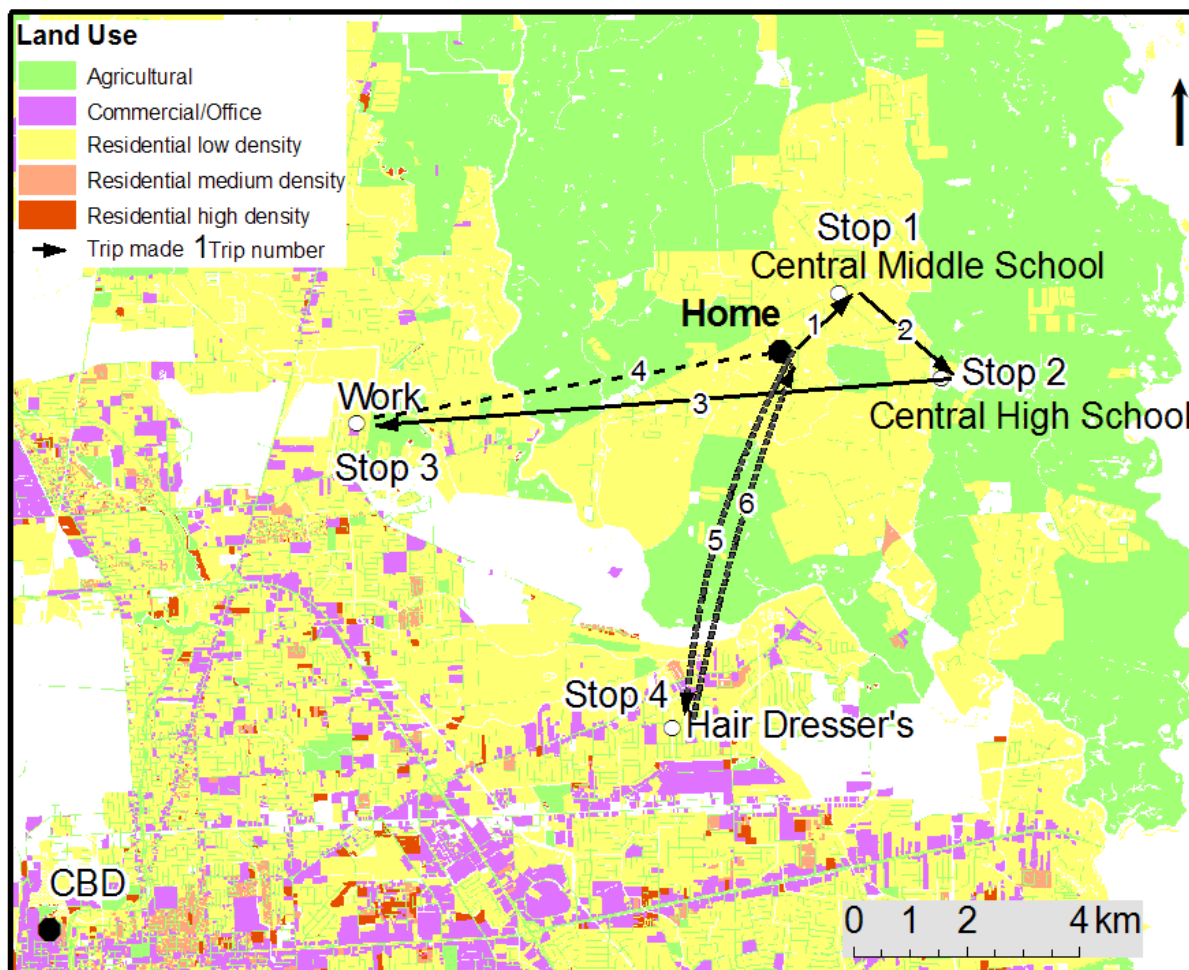
**Figure 19: Space Visualization of Trip Chaining by a Female Worker.**
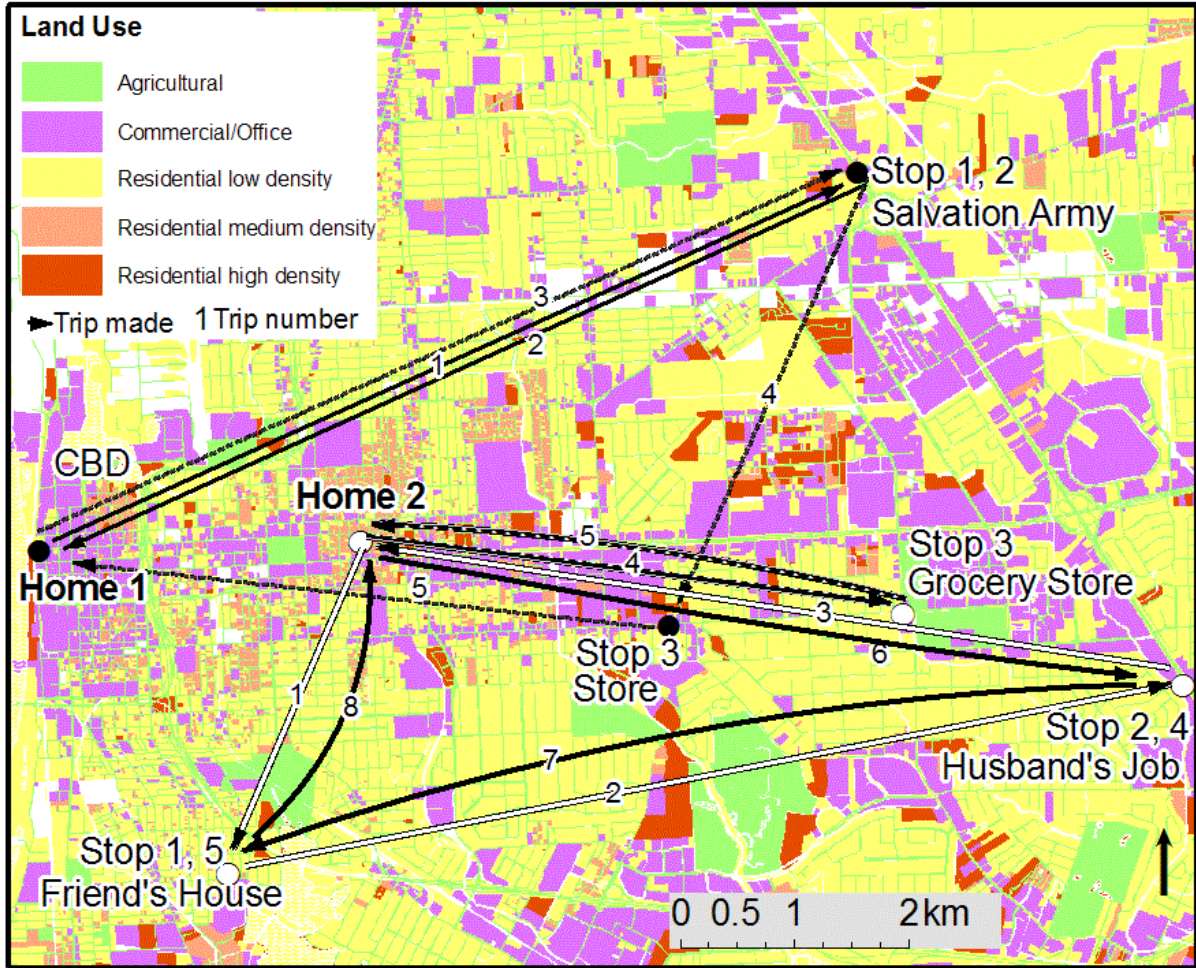
**Figure 20: Space Visualization of Trip Chaining by Female Non-workers.**

logistic models to examine the impacts of various factors (i.e., land use and individual attributes) on whether workers and non-workers decide to chain trips.

A simple (standard) logistic regression model is written as:

$$logit\left[\pi(x)\right] = \log\left(\frac{\pi(x)}{1-\pi(x)}\right) = \alpha + \beta\,\mathbf{X},$$

where $\mathbf{X}$ is a vector of independent variables, and coefficients $\alpha$ and $\beta$ are to be estimated by the model. The ratio of the probability of an individual making a chained trip $\pi(x)$ versus the probability of a non-chained trip $1-\pi(x)$ is of critical interest to researchers, and is often called "odds ratio". The logarithmic value of the odds ratio forms the dependent variable, termed "logit".

In our study, there are four sets of independent variables:

(1) attributes of individual traveler such as work status (=1 for workers and 0 for non-workers) and gender (=1 for females and 0 for males)
(2) trip cost, and travel time to work (for workers only) of individual traveler
(3) five land use categories as coded previously by four dummy variables $x_1$, $x_2$, $x_3$ and $x_4$
(4) job accessibility.

The above variables are grouped into two types: variables from (1), (2), and (3) are measured for *individual trip makers*, while variable (4) is measured at the *neighborhood (TAZ) level*. One may include more variables from both the individual and neighborhood levels. We limit the selection of variables to the aforementioned eight (nine for workers only) variables as our interest focuses on the impacts of work status, gender, trip cost, land use and job access.

The simple logistic regression model is sufficient if the model only includes either variables of individuals or variables at the neighborhood level. However, because of the hierarchical structure of the data (e.g. individual trip-makers cluster within TAZs, those within the same TAZ are more similar than those across different TAZs), a more advanced model, namely "*multilevel logistic regression model*", is needed if both individual and neighborhood variables are used (Li et al, 2006). A model that ignores such structure may overestimate the significance of the predicting variables. Multilevel modeling accounts for the hierarchical data structure.

SAS for Windows version 9.1 (SAS Institute, Cary, NC, U.S.A.) has been used to carry out the regression analyses. PROC LOGISTIC is used for the standard logistic regression, and PROC GLIMMIX is used to implement the multilevel logistic regression (Schabenberger, 2005). Both techniques were used to run the models, however, to strengthen the reliability of the results.

First, to determine an impact of employment status on decision whether or not to chain trips, these 2 groups (workers and non-workers) were compared in terms of their propensity to combine several trips. For that purpose, a logistic regression was conducted. The variable "worker" was coded as 0 for a worker, and 1 for a non-worker, so that work individuals were the reference group. The variable "gender" was coded likewise, as 0 for a male, and 1 for a female, with the former being the reference category. Model 1 models the probability of a trip to be a part of a chain with just two predictors, being a non-worker and a female traveler.
For model 2, we used logistic regression model to define the probability of an employed or non-employed individual of choosing whether or not to chain trips (to combine at least two activities into a single trip) as a function of work status, gender, and land use factors such as a type of land use. Model 3 consists of the previous variables, as well as a trip cost (represented by trip travel time reported by the respondents in minutes), and accessibility to jobs and therefore to opportunities (proxied by jobs to housing ratio computed within 25 minutes of travel of respondent's home TAZ).

Next, trips were categorized into two groups: those made by workers and non-workers, respectively. Therefore, the following logit models were run separately for workers and non-workers to see the impact of the predictors on these categories of interest. These specific models included the same variables as for the previous case, except that the model examining the workers' propensity to choose whether or not to chain a trip, included also the time to work in minutes as reported by the respondents. The rationale for the inclusion was that employed

individuals are subject to stricter temporal and spatial constraints than the non-workers are, and therefore, a distance to work might be important for the trip chaining decision. To control for the gender effect, the "workers" and the "non-workers" models were run separately for male and female employed and non-employed travelers, respectively.

## Discussion

The results of the estimation from the standard logistic and GLIMMIX models are shown in the Table 17 below. The first column shows the results of the logit model with just two predictors, non-worker and a female traveler. The effect of an employment status on a likelihood of a trip to be chained controlling for a gender is estimated first (Model 1). The odds ratio, which is a point estimate, indicates that a trip by an unemployed person is 1.66 times (or 66%) more likely to be chained to other trips, than a trip made by an employed person. Table 17 also reports the effect of a gender. A female traveler is 1.44 times (or 44%) is more likely to chain trips than a male traveler. The GLIMMIX model results are similar to results obtained by the logit model. The models are highly significant, and indicate that both categories, non-employed and female travelers, tend to chain trips more compared to the male and employed travelers.

Table 17 reports results of models 2 and 3 containing employment status, gender, as well as land use measures as predictors. The land use measures included land use by type (agricultural, office/commercial, medium developed residential, high developed residential, low developed residential; the last one was a reference category); spatial access to jobs (and, therefore, opportunities) represented by a ratio of jobs to resident workers within 25 minutes of travel; the cost of a trip proxied by time it takes to complete a trip reported by the respondents in minutes. As expected, land use measures are significant in explaining the choice of a person whether or not to make a chain trip.

As Table 16 showed, land uses vary by the trip chaining rate, with the high density residential areas having the highest rate. We wanted to test the hypothesis that land uses might affect differently workers' and non-workers' choice of trip chaining. Therefore, the models investigated the impact of land uses separately for workers and non-workers controlling for a gender effect.

Table 18 below reports results separately for workers and non-workers. Because workers are subject to stricter temporal and spatial constraints than the non-workers are, time to work (in minutes) reported by respondents was included into a model. Within the workers category, time to work is significantly related to trip chaining, with the longer time contributing the positive decision to chain trips. This finding was in agreement with the results of Wallace et al (2000) and McGuckin et al (2005): the greater the distance between home and work, the more likely is the trip chaining. However, in this study this is only significant for the women workers. Another factor which is important for trip chaining for female workers only is the trip cost represented in take to complete a trip. As expected, there is negative relationship between a propensity of an individual to decide to chain trips or not and a trip cost: a greater trip cost makes a trip less likely to be part of a chain. The possible explanation of this factor not affecting male workers is that generally women produce more trips, but at the same time being more heavily involved into family-related matters, they are under stricter temporal constraints than are the male workers.

Interesting to note that job accessibility impacts men and women differently, with the former group taking advantage of the close home proximity to opportunities to chain trips, while the latter group does not do so.

Importance of the employment availability at work end, specifically retail and service industries, for a trip chaining was noted by earlier research (Adler and Ben-Akiva, 1979; Bhat, 1997). Our study indicates that an access to jobs, and therefore opportunities for an employed female trip maker from her home location, decreases the chance of a trip to become a part of a chain. This implies that working women add trips that are rather closer to their work location that home. The greater spatial and temporal importance of work locations compared to home locations in terms of trip chaining is explained by the employment availability to satisfy specific purposes such as shopping, escorting a passenger, or eating out (Hanson, 1980; Damm, 1980).

Some studies noted association between density and trip chaining with the increase in the former resulting in the decrease in the number of trips chained. Accordingly, our results from the both standard logistic and GLIMMIX models show that more densely occupied land uses contribute to more trip chaining for female workers. The point estimate indicates that if an employed woman resides on a medium or high developed residential area, the chances of her trip to be a part of a chain are about 44 and 92% higher, respectively, than if a female trip maker lives on a different land use type.

Non-workers appear to be affected by land uses in terms of their propensity to chain trips differently than do the workers. Agricultural/rural, normally located outside urban areas, are conducive for the trips to be chained if the traveler is a non-working female. The chances that a trip originating from this land type is chained are at least 2.3 times higher compared to other land types. Similarly, an earlier study by Misra and Bhat (2000) found that non-workers living outside urban areas are more likely to trip chain as compared to those non-workers whose homes are located in urban areas. However, non-working women living on denser areas still commute. Figure 20 demonstrates how two non-working women design their trips across the space. Despite living close to the Baton Rouge CBD, they travel away from the CBD area, with the person 1 forming one chain (trips 4 and 5), and person 2 formed two chains (trips 1, 2, and 3, and trips 6, 7, and 8, respectively).

Another land use factor that seems to be conducive for a decision to consolidate trips into a chain for a female non-worker is a spatial access to opportunities within 25 minutes of travel which significantly increases the likelihood of a trip to be added to other trips. The odds ratio indicates that living within travel proximity to jobs/or opportunities increases the probability for trips to be chained by more than 50%.

Surprisingly, male travelers seem to be less affected by land uses than do the female travelers. This finding refers both to working and non-working males. The only significant land use factors contributing to chaining trips is a spatial accessibility to opportunities for both employment groups, however, in GLIMMIX models this land use measure is not significant.

Combining several away-from-home activities into one single trip, or trip chaining, might alleviate travel-related problems. There is evidence of a change in travel patterns at least of the

working trip-makers with increasingly more travelers including non-work trips to their daily work commutes (Bianco and Lawson, 1996, Lee et al, 2002). As a result, some legs of such trips might lengthen. For example, working female employees have been found to spend more time commuting due to traveling longer distances as work trips were combined with other domestic and child-care-related trips (Rosenbloom and Burns, 1994).

Overall, employed and not employed travelers seem to be affected by the land use from different perspectives. For the former category, space and time are important, so that shorter trip duration and denser land at the place of residence, i.e., shorter distances between destinations contribute to chain formations. As for the non-employed persons, they are less restricted by time and space, therefore, contrary to finding for the workers, trip costs expressed by the trip travel time does not impact their decision of chaining trips in either men or women. However, spatial accessibility to opportunities within 25 minutes of travel is important for the non-worker to combine several trips. Similarly, less dense residential areas contribute to chain formation for non-workers. If a female non-worker resides on agricultural/rural area, then her chances to chain trips also increase by 2.3 times. Other land use types such as office /commercial, and all residential areas do not seem to affect the trip chaining behavior everything else holding constant.

## Conclusion

There is empirical evidence that 40% of all trips are part of trip chains, that is travel that involves multiple stops; with the percentage of such trips increasing (O'Kelly, 1981; Ghaly, 1990). Workers and non-workers alike chain their trips, one of the reasons to that might be an increasing time pressure (Dellaert et al., 1998). Women tend to trip chain more than do men, therefore, our analysis also controlled for the gender of a traveler. The purpose of this study was to examine the land use impacts on travel behavior in the context of the trip chaining within Baton Rouge region. Specifically, we wanted to examine whether urban land use influences such travel behavior of the employed and non-employed persons differently. For that, our analysis was restricted to only people who are at least 16 years old. The premise of the study was that land use is a useful measure in explaining trip chaining in working and non-working trip makers.

Among the unique approaches that the study employs is the choice to use different types of land uses instead of population and employment densities, the method frequently used in the past. We grouped these types as agricultural/rural, commercial/office, low density residential, medium density residential, and high density residential categories. We also applied a multilevel modeling approach to account for the hierarchical data structure (individual trip-makers are nested within different TAZs). As was expected, land use types of the trip origin appear to impact the trip chaining patterns. However, this influence is different for workers and non-workers. For example, medium and high developed residential areas of a female worker increase her chances to chain trips, whereas these land types are not conducive to chain trips for a not employed traveler. In contrast, an agricultural land of residence positively impacts the latter's propensity to chain trips, but not the former's.

Within both groups, female trip makers consistently chain more trips than do male travelers. This finding was in agreement with previous studies on gender differences in trip making and trip chaining behavior (McGuckin and Murakami, 1999; NHTS, 2004). The obligation to retain the

**Table 17: Results of the Logistic (LogReg) and Multilevel Logistic (GLIMMIX) Models.**

| Model | 1 | | | | 2 | | | | 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LogReg | | GLIMMIX | | LogReg | | GLIMMIX | | LogReg | | GLIMMIX | |
| Category | coef | OR | coef. | t-value | coef | OR | coef. | t-value | coef | OR | coef. | t-value |
| intercept | -1.63*** | 0.19 | -1.87*** | -17.9 | -1.67*** | 0.19 | -1.93*** | -18.04 | -1.65*** | 0.19 | -2.1*** | -7.85 |
| Worker Status | 0.51*** | 1.66 | 0.56*** | 11.8 | 0.5*** | 1.64 | 0.54*** | 11.23 | 0.5*** | 1.64 | 0.54*** | 11.07 |
| Gender | 0.36*** | 1.44 | 0.42*** | 9.8 | 0.36*** | 1.44 | 0.42*** | 9.77 | 0.37*** | 1.44 | 0.43*** | 9.78 |
| Ag./rural | | | | | 0.18** | 1.2 | 0.29*** | 3.45 | 0.19** | 1.21 | 0.31*** | 3.56 |
| Comm. /office | | | | | 0.1 | 1.1 | 0.09 | 1.01 | 0.1 | 1.11 | 0.1 | 1.18 |
| Med. Resid. | | | | | 0.08 | 1.08 | 0.14 | 1.53 | 0.08 | 1.1 | 0.15 | 1.6 |
| High Resid. | | | | | 0.17 | 1.19 | 0.27* | 2.4 | 0.17 | 1.2 | 0.27* | 2.42 |
| Trip cost | | | | | | | | | -0.002* | 0.99 | -0.002* | -2.9 |
| Job access | | | | | | | | | 0.01 | 1.01 | 0.17 | 0.77 |

Note: OR=odds ratio, coef.=coefficient, *-level of significance =0.05, **-level of significance =0.01,
***-level of significance =0.001

**Table 18: Results of the Logistic (LogReg) and Multilevel Logistic (GLIMMIX) Models for Workers and Non-workers, by Gender.**

| Work Status | Workers, male | | | | Non-workers, male | | | |
|---|---|---|---|---|---|---|---|---|
| Category | LogReg | | GLIMMIX | | LogReg | | GLIMMIX | |
| | Coef. | OR | Coef. | t | Coef. | OR | Coef. | t |
| intercept | -1.35*** | | -1.2** | -2.74 | -1.13*** | | -1.51*** | -2.7 |
| Ag./rural | 0.14 | 1.16 | -0.13 | -0.77 | 0.08 | 1.09 | 0.92*** | 3.96 |
| Comm. /office | 0.14 | 1.15 | 0.3 | 1.67 | -0.22 | 0.8 | -0.76* | -2.37 |
| Med. Resid. | 0.27 | 1.29 | -0.03 | -0.12 | 0.21 | 1.24 | 0.22 | 0.84 |
| High Resid. | 0.22 | 1.25 | 0.48 | 1.89 | 0.07 | 1.07 | 0.74* | 2.51 |
| Trip cost | -0.002 | 0.99 | -0.002* | -1.99 | 0.006 | 1.006 | -0.002 | -0.92 |
| Job access | 0.35* | 1.38 | 0.23 | 0.6 | 0.55* | 1.74 | 0.79 | 1.64 |
| TIMEWK | 0.002 | 1.002 | 0.002 | 1.23 | na | na | na | na |
| **Work Status** | **Workers, female** | | | | **Non-workers, female** | | | |
| Category | LogReg | | GLIMMIX | | LogReg | | GLIMMIX | |
| | Coef. | OR | Coef. | t | Coef. | OR | Coef. | t |
| intercept | 0.23 | | 0.19 | 0.44 | -0.46* | | -1.56*** | -3.81 |
| Ag./rural | -0.2 | 0.8 | -0.11 | -0.56 | 0.83*** | 2.3 | 1.39*** | 7.51 |
| Comm. /office | 0.23 | 1.25 | 0.29 | 1.85 | -0.05 | 0.95 | -0.12 | -0.58 |
| Med. Resid. | 0.36** | 1.44 | 0.42* | 2.24 | -0.07 | 0.94 | 0.21 | 1.19 |
| High Resid. | 0.66 | 1.92 | 0.95*** | 4.44 | 0.011 | 0.99 | 0.27 | 1.21 |
| Trip cost | -0.005* | 0.99 | -0.005* | -2.11 | -0.002 | 0.99 | 0.002 | 1.11 |
| Job access | -0.79*** | 0.45 | -0.9* | -2.52 | 0.44* | 1.56 | 1.02** | 2.94 |
| TIMEWK | 0.008** | 1.007 | 0.003 | 0.88 | na | na | na | na |

Note: coef.=coefficient, *-level of significance =0.05, **-level of significance =0.01, ***-level of significance =0.001

principal responsibility to attend to family-related activities by women explains this gender-related travel difference (Hanson and Hanson, 1980). Among all female drivers, single women with children tend to chain such household-sustaining trips to the work commutes while averaging about 5 trips per day (McGuckin and Murakami, 1999).

Generally, short trips are more desirable than long ones in terms of saving time. The economic theory assumes that holding other conditions equal, travelers act to minimize their travel distance and seek to visit places closer to their homes. These theoretical expectations are supported by empirical findings: travelers choose a trip with the less trip cost among alternative trip chain configurations (Brooks et al., 2008). However, the utility maximization theory is questioned when there is discrepancy between the theoretical predictions and real-world observations implying that individual travelers might not always seek to minimize their travel and other factors such as psychological factors might be of importance in economic behavior (Kahneman and Tversky, 1979; Schoemaker, 1982). Brooks et al (2008) debate that the behavior of a traveler might be different when factors such as a product expense are included into a decision process. As an example, they offer to consider a trip to an expensive, but a remotely located restaurant which might be weighted differently than the common time saving expectations suggest. Dellaert et al. (1998) similarly found that certain types of trips such as shopping trips involving a purchase of expensive items might be less sensitive regarding time saving.

Our results imply that the maximum utility assumption holds true, both for the employed and unemployed travelers, but is reflected in travel patterns of these groups of interest differently. Workers group is sensitive about reducing trip cost in terms of the trip travel time: the longer time it takes to make a trip, the less likely is this trip be added to other away-from home activities by an employed woman. This kind of behavior is explained by the stronger time/space constraints for the working travelers. In contrast, within our study area, non-working women do not seem affected by the trip cost. Instead, non-workers try to reduce total travel by combining activities into chains closer to their homes: the more jobs, and therefore opportunities are there within 25 minutes of travel, the greater are the chances for chaining trips. This finding provides an empirical support to an earlier claim that working women experience a greater time pressure than either working men or non-working women (Hanson and Hanson, 1980). At the same time, due to being less spatially restricted, working men generally travel distinctly longer distances overall, as well as longer distances per trip, as reflected in the revealed trip costs insensitivity in working men's trip chaining patterns.

Workers are more likely to chain trips as the distance to their work locations increases. An earlier study by Kondo and Kitamura, (1987) found that larger distances between the home and work location make chances for a chain greater. Similar finding was obtained by Ingene and Ghosh (1990). They modeled the consumers' trip chaining decision using different arrays of store outlets. According to their model, consumers are more likely to chain trips with an increase in the distance between the consumer's home and the closest outlet. Our results conform to these earlier findings: on average, a longer distance to work places, in terms of time in minutes, is more alluring to initiate a trip chain, than otherwise.

Discrete choice theory approach was adopted to yield some insights concerning a trip maker's propensity to chain trips (Adler and Ben-Akiva, 1979). Among the limitations of the study is that Baton Rouge Personal Transportation data used for analysis are relatively not new, as surveys of

this kind are conducted every 10 years at the national level, but much less frequently for the areas such as chosen for the study. In addition, some individual-level attributes which might potentially contribute to a trip-chaining such as single-person households or female-headed households with children (who generally tend to make more trips) (McGuckin and Murakami, 1999; Hanson, 2004), or race and age of a trip-maker, as well as neighborhood-level variables such as average income, have not been used. Therefore, as any model balancing costs such as complexity versus simplicity, among others (Shoemaker, 1982), results of the study should be interpreted with caution. There is an obvious need for studies to prospectively evaluate the land use effects on travel behavior of trip makers. Inclusion of different geographical locations from different parts of the world might allow for a better understanding of how the land use can impact trip chaining patterns.

# Conclusion

This chapter summarizes the results and conclusions of the previous sections. Chapters II through IV are related to each other as each examines the relationship between land uses and travel behavior, however, from different perspectives. Among the travel behavior measures used in this research, there are: commuting duration (that is, time in minutes required to get from a place of residence to a commuter's workplace), commuting distance (that is, distance in miles from a home location to a commuter's workplace), and trip chaining (that is, combining several away-from-home activities into a single trip). Results and conclusions along with the objectives of the chapters comprising this dissertation are given after the summary on data and study area used for this research.

To investigate such a relationship, the data used in this research came from the following sources. The first data source is the Baton Rouge Personal Transportation Survey (BRPTS) carried out in 1997 in the Baton Rouge area, Louisiana, consisting of a household file (1396 households), a person file (3069 persons), and a trip file (13194 trips). To achieve specific research purposes, Chapters 1 and 2 used data on 1,104 working commuters who provided coordinates of their home and work locations, while Chapter 3 used data on 2,220 adult trip-makers, both workers and non-workers, (who were at least 16 years old) from the BRPTS dataset. The second source is the US Census Transportation Planning Package (CTPP) for the years 1990 and 2000, parts 1 and 2 at the Traffic Analysis Zone (TAZ). The CTPP contains a wide range of population data at the place of both residence and work, as well as commuting times, transportation mode, vehicle usage, among others, aggregated to different spatial units with the smallest being Traffic Analysis Zones (TAZ).

Sharing the same data source, three chapters focused on the same study area. It covers completely the Baton Rouge urbanized area, as well as urban clusters within Livingston and West Baton Rouge parishes, and is referred to as Baton Rouge region elsewhere in the study. The Baton Rouge region is a part of Baton Rouge MSA, Louisiana. It lies along the eastern banks of the Mississippi River and is located within the Capital Region Planning Commission district, which is its designated MPO. It encompasses a diverse range of land use types across urban, suburban, and rural settings.

Three major objectives for this study were:

1. Examine the land use impact on commuting times and distances using multi-level modeling approach;
2. Examine the effect of monocentric (single employment center) and polycentric urban structure (multiple employment centers) on commuting within study area;
3. Investigate how land use impacts the trip chaining propensity among Baton Rouge employed and non-employed trip-makers.

# Objective 1

For the first objective, Chapter II used a multi-level modeling approach to examine the role of the geographical location and the effect of population composition in accounting for a place-to-place differentiation in commuting. This approach was chosen for the following reasons. Using neighborhood characteristics which are typically at the aggregate level might result in ecological fallacy (Robinson, 1950), while regression analysis of individual-level travel data, suggested as a way to overcome the shortcomings of aggregate data (Boarnet and Sarmiento, 1998), faces missing the context in which such individual behavior takes place, leading to atomistic fallacy (Alker, 1969), therefore, the variability between different places is not accounted for (Jones and Duncan, 1996). A multi-level modeling approach accounts for the variability between subjects at the lower level; in addition, it considers the geographical variability between places at the higher level. That way both the contextual, i.e., spatial features at the neighborhood level, and compositional, i.e., aspatial information representing socio-economic and demographical characteristics of the individuals, is investigated in the models simultaneously. By specifying individual commuters nested within TAZ areas, the multi-level models isolate the relationship of each level to individual commuting (Weber and Kwan, 2003; McLafferty and Wang, 2008).

Land uses were represented by five land use types such as agricultural, commercial/office, residential low density, medium density and high density, with the low density residential category being a reference. Another land use measure used in the study was jobs to workers ratio (JWR). Essentially, JWR standardizes the job distribution in a particular area on the basis of the distribution of workers residing in this area, thus, expressing the relationship between employment and workers (Forstall and Green, 1997; Wang, 2007). It also serves to reflect the availability of commercial land uses within a person's travel catchment area. Proximity to a high-performing school was used as the final land use measure, as some studies on commuting noted the importance of neighborhood characteristics including good-quality schools, among others, (Fan et al, in press) that might affect the residential locations, and therefore, impact the journey to work travel.

At the neighborhood (TAZ) level, the following aspatial variables were chosen: the percent of the minority population, percent of population below poverty level, and percent of workers commuting to work in SOV. Other socio-economic and demographic variables at the individual level came from the 1997 Baton Rouge Personal Transportation Survey (BRPTS) and included the following: education attainment (less than high school, some college, and a degree), household income, household size, race (White, Black, Asian), life cycle (1 or 2 adults with no children, 1 or 2 adults children less than 16 y.o., 1 or 2 adults children of 16-18 y.o., retired), number of workers per household, driving status (usually drives-yes, and usually drives-no), employment status (dummy 1 - worker, dummy 2 - non-worker), age, gender (dummy 1- male, dummy 2 - female), and work type (full, part).

The models examined the degree of association between several aspects of land use and travel behaviors, considered alone and controlling for socio-economic factors. To estimate the impact of the individual-level and contextual attributes on commuting, the independent variables were entered into the models in blocks.

The first model included only the types of land uses to determine whether land use types, proximity to jobs and a high-performing school, affect commuting. The land use types consist of the categories such as agricultural, commercial/office, low density residential, medium density residential, and high density residential, with the low residential being the reference category. Jobs to workers ratio (JWR) computed within 25 minutes travel catchment area was used to reflect both land use mix and job availability around the residential areas. Members of the households located within 2 miles of distance to a high-performing school were hypothesized to have to commute longer than those outside such school catchment areas.

To determine whether differences in population composition at the neighborhood (TAZ) level account for the variations in individual commuting, demographic and socio-economic variables, such as the percentages of the minority population, population below poverty, and that of the transportation mode by single-occupancy vehicles (SOV), were added into the third model. The final model examines the effect of individual-level attributes, therefore the following variables were added into the fourth model: age, gender, race, education, income, driving status, number of workers, work status, and life cycle stage. All models were estimated using SAS statistical software.

The findings show that different land uses produce significantly different commuting times. For example, the shortest commuting is associated with the medium density residential area, from where a commuter travels on average 3.42 minutes less (but not distance) compared to the base category, low density residential area. However, spatial job proximity appears more important compared to land use types. Living within at least 25 minutes of jobs is beneficial to commuters as they experience shorter commutes, by as much as almost 11 minutes, and 8 miles, respectively. Living within a high-performing school catchment area seems also contributing to a reduction in travel time and distance.

Surprisingly, the socio-economic attributes such as the percentages of the minority population, and percent of the transportation mode by single-occupancy vehicles (SOV) have not shown an association with commuting, while the percent of population below poverty has revealed such a connection. An increase in the population below poverty, all else being held constant, was statistically associated with a reduction in commuting. However, introduction of these variables did not reduce the importance of the land use, as medium density residential area, closeness to a high-performing school, and job proximity were significant. So, it can be concluded that socio-economic variables taken at the aggregate level alone cannot explain the difference in commuting.

Another conclusion can be reached when individual characteristics are added. Among such individual-level variables the most important in explaining commuting appear to be education level, life cycle, gender of employed person, work status, and number of workers in the household. Regarding education, those who have been schooled less, for example less than a high school diploma, travel by almost 6 minutes less than other education groups. It can be explained by this category being the least choosy and willing to fill any job gap within close proximity of their residence. Sharing the drive, or car-pooling, in contrast, appears to increase commuting time by almost 4 minutes. Regarding the life cycle, an important determinant in commuting, those adults without children seem to reduce their journey to work by 3.56 minutes.

Probably such individuals choose to live in apartment complexes rather than family-oriented neighborhoods, therefore enjoying shorter commuting duration. The work status also determines whether a person travels longer or not; thus, those who have part time jobs seem to find their employment close to their residence as their commuting is 2.35 minutes shorter than those who have a full-time employment. Gender of an employed individual is also important in explaining commuting; for example, female workers travel approximately 2 minutes shorter than do the male workers.

And finally, having additional workers in a household seems to decrease commuting by 1.1 minutes. Income appears to affect only commuting distance, larger income is associated with the longer commuting. It was a surprise to find no association between both income and commuting time, and commuting and racial membership, since some previous studies voiced a concern regarding racial inequality in terms of access to jobs and therefore impacting commuting.

Among the land use measures only the jobs to workers ratio (JWR) is still highly significant, therefore implying the importance of land use in explain difference in travel behavior. However, other land use measures represented by different types no longer are useful to explain the observed differences in commuting.

## Objective 2

The second objective was to investigate the relationship between the urban structure reflected by employment centers and travel behavior. Specifically, Chapter III focuses on examining the employment structure within the Baton Rouge region of Louisiana and its effect on the patterns of commuting times and distances in the study area. It seeks to answer the question of whether the polycentric system is more beneficial than the monocentric one to commuters in terms of saving travel time and distance by testing a "co-location theory".

It has been approached with two steps. First, employment centers have been identified. We used the notion of in-net commuting and the job to resident workers (JWR) ratio was used as the main criterion to define job concentrations in the study area. Because the data used in this study come from 1997, it has been decided to identify job concentrations for two periods, 1990 and 2000. Respectively, the changes from 1990 to 2000 have been also examined.

Second, using the 1997 BRPTS data, the commuting patterns from the perspectives of both the monocentric and polycentric urban structures were investigated. Those employed individuals who work within the Central Business District (CBD) area, the proxy for a monocentric job location, have been identified. The workers employed within the other job centers, a proxy to a polycentric structure, have been also found. Their commuting times and distances (as reported by the survey participants) have been compared. We found that even when people living close to the employment center choose to work in a different area, on general, those commuting to multi-centers spend less time and travel less distance compared to workers who choose to work within the CBD. Among the factors, other than living close to and choosing to work at the nearest employment center, there is congestion, associated with a monocentric job location.

# Objective 3

Chapter IV aims to examine the relationship between land use and trip chaining behavior. Specifically, land use measures are used to explain the likelihood of residents combining activities into a multi-stop trip chains in the Baton Rouge region. Additionally, we wanted to examine whether urban land use influences differently such travel behavior of the employed and non-employed persons, as well as by gender. For that, our analysis was restricted to only people who are at least 16 years old. The premise of the study was that land use is a useful measure in explaining trip chaining in working and non-working trip makers.

Regarding the gender impact within both groups, workers and non-workers, female trip makers consistently chain more trips than do male travelers, which is in agreement with previous studies on gender differences in trip chaining behavior largely due to family responsibilities (Hanson and Hanson, 1980; McGuckin and Murakami, 1999; NHTS, 2001).

Land use types of the trip origin appear to impact trip chaining patterns, but differently for workers and non-workers. But the greatest difference was found between employed and non-employed women, rather than men of either employment status. It was expected to find that less dense areas such as agricultural would be more conducive to trip chaining than other land use types. However, we found this to be true only for non-employed female trip-makers. In contrast, their employed counterparts do not seem to trip chain from this land type. Other land use types, medium and high developed residential areas, on the other hand do appear to increase chances of a female worker to chain trips, whereas these land types are not conducive to chain trips for a non-employed traveler.

Both groups have been found to save travel costs, but in different fashions. The workers' group reduces trip cost in terms of the trip travel time: the longer time it takes to make a trip, the less likely an employed woman will add this trip to other away-from home activities. This kind of behavior is explained by the stronger time and space constraints for working travelers. In contrast, within our study area, the trip cost does not seem to affect non-working women, and the latter seem to benefit by living close to job/opportunity locations: the more jobs, therefore opportunities within 25 minutes of travel, the greater the chances for chaining trips. This finding was in agreement with an earlier study on difference in urban activity patterns (Hanson and Hanson, 1980).

The distance to work is another significant determinant of trip chaining within the workers' group: as the distance to work locations increases the likelihood is greater to chain trips. This finding supports earlier results by Kondo and Kitamura (1987), and Ingene and Ghosh (1990).

Discrete choice theory approach was adopted to yield some insights concerning a trip maker's propensity to chain trips (Adler and Ben-Akiva, 1979).

Standard logistic and multi-level logistic regression models were run. Multi-level model accounts for the nested character of the data (e.g. individual trip-makers cluster within TAZs, those within the same TAZ are more similar than those across different TAZs). Results of both methods were compared.

## Significance of the Research

Studying these problems continues to be of interest to geographers, and further, is very important because every year we spend more and more time behind the wheel, not necessarily because of the urban sprawl and lengthening of trip distances. For example, since 1995, the average time needed to get to a place of work (commuting time) increased by 10%, while the average distance from a home location to a workplace (commuting distance) has remained relatively stable (NHTS, 2004). These daily minutes spent inside a private vehicle translate into hours and hours of time which otherwise could have been spent with family, doing work-related activities, and pursuing hobbies. Additionally, unmanaged travel contributes to other environmental problems, such as air pollution, among others. Given that most U.S. metropolitan areas are expected to have at least a 50% increase in population within the next 30 years, traffic mitigation is important. That is why I consider studying the connection between land use and travel behavior a potential way to find a solution to manage travel characterized by less stressful commutes and to provide more family time and a lower cost of living.

This will also help urban planners, policymakers, as well as researchers, and analysts to make well-informed decisions with regard to land use policies and predict their impact on public transportation. "Greater understanding of travel patterns allows communities to plan, invest in, and operate transportation systems that are better suited to the public's needs in areas such as travel demand forecasting, multimode travel, transportation safety, and facility accessibility and use by all segments of the population." (NHTS, 2004, p.5).

## Limitations of the Research

Among the limitations of this study, the retrospective design of the study and cross-classification nature of the data should be noted, as no cause and effect conclusion can be made, but associations only. There is an obvious need for studies to prospectively evaluate the land use effects on travel behavior of trip makers.

Second, the data are not new, as surveys of this kind, i.e., National Household Travel Survey, initiated by the U.S. Department of Transportation in 1969, are conducted about every 10 years at the national level, but such surveys are conducted much less frequently for the areas such as chosen for the study. There is a gap between 1997 travel data and some data obtained from the Census 2000.

To analyze the relationship between land use and travel behavior, the land use types that were used lacked consistent classification between East Baton Rouge, West Baton Rouge, and Livingston Parishes, which might have decreased the overall accuracy of the results.

We used the spatial data, which might be spatially autocorrelated. The multilevel model used in Chapter IV takes into consideration the hierarchical data structure, but not the possible correlation between observed data. No specific attempt has been done to include a term accounting for the spatial proximity of data into the model.

With all this said, as with any model balancing costs such as complexity versus simplicity, among others (Shoemaker, 1982), results of the study should be interpreted with caution.

## Suggestions for Future Work

We seek to develop models accounting for the effect of the spatial autocorrelation. We plan to do it by adding another independent variable, AUTOCOV, into the model of logistic regression. It can be done by computing this term for all the households and for different catchment areas.

The study attempted to understand the role of land use in travel behavior; however, it was accomplished within a relatively small territory. This means the results cannot be transferred to other areas, which might exhibit different relationships. Therefore, inclusion of different geographical locations from different parts of the world might allow for a better understanding of how land use can impact travel behavior patterns.

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## Vita.

Anzhelika Antipova was born in Tashkent, Uzbekistan, in 1970. She has always been interested in the subject of geography and has traveled a lot. Anzhelika received her undergraduate education and Honors Diploma in geography (specifically, economical and social geography) at Odessa State University, Odessa, Ukraine. After moving to the USA, she obtained her Master of Arts Degree in geography at Louisiana State University.