AGGREGATE RELATION BETWEEN RESIDENCE AND WORKPLACE
TRAVEL TIME IN LARGE URBAN AREAS

by

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ABSTRACT
AGGREGATE RELATION BETWEEN RESIDENCE AND WORKPLACE
LOCATIONS IN URBAN AREAS

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The formation of urban areas is a function of locations of residence and workplaces. Urban areas grow because more residents move in the area due to economic, life style, or other opportunities. This research presents a relationship between average commuting travel time and population and land area of metropolitan areas with more than 750,000 population in the United States. The hypothesis is that in spite of significant variation among large and small urban areas, the relative residence- employment locations follows a general and predictable pattern.

Forty Metropolitan Statistical Areas (MSA) are selected for the analysis. The commuting travel time is analyzed and related to population and land area to show the predictability of average home to work travel time among various MSAs. Public data sources from Federal Highway Administration and Census Bureau are presented, discussed and used. A regression estimation process is utilized and a non-linear model is produced. A validation process is applied to show the prediction accuracy of the model. Estimation and validation of the model show that average commute time can be estimated for a city within 4 minutes accuracy.
The implication of this research is that the size of the metropolitan areas has small but measureable effect on the relative location of residence and workplace. Depending on the size of the metropolitan area, for each increment of 100,000 population, the average travel time to work increases between 0.05 and 0.25 minutes.

The results of this research can be used in land use allocation models, transportation studies, and policy analysis. An example of the use of the developed model for policy discussion is provided. The proposed formula can estimate average commuter travel time based on population and land area of a city. Total population and area are usually available for current year and are provided in the demographic forecasting process for future years. The result of this study provides a connection between these aggregate urban characteristics and commuting travel time.
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CHAPTER 1
INTRODUCTION

This chapter explains the usefulness and applicability of this research. It defines the goal of this study, the relevance of the research to the larger context of urban form forecasting and transportation planning, and application of this work in practice and research.

1.1 Purpose

Understanding the dynamics of how the development in urban areas take place is a key to answer many practical questions for managing the development of a city. The formation of urban areas is a function of locations of residence and work places. Urban areas grow because more residents move in the area due to economic, life style, or other opportunities. The traditional theories of urban forms have created connection among different types of employments and residence, and to various success, have formulated the growth of the cities.

For properly serving the population in an urban area, knowledge about residents, employments and how these locations are connected to each other are essential. The information associated with home location helps the decision makers to plan and design the city for the amount of needs created by the people at neighborhoods and communities. The information about employments provides the city leaders about economic vitality and services of the city. These locations are connected through transportation infrastructure. These aspects of the urban system are interconnected and affect each other. This research explores how the complex system of natural and man-made components result in fairly simple and predictable travel time between residence and employment locations. The relative geographical locations of residence and employment is represented in urban form literature and commute travel studies. These fields are obviously interrelated.
The purpose of this research is to find aggregate relationships between residence and workplace in urban areas in the United States. The research finds a relationship between population and employment location for various urban forms based on aggregate information that is often available or can be easily obtained or forecasted. The relationship between residence and workplace is conceptualized in commute travel time. Commute travel time is related to the quality of transportation infrastructure and the development pattern of a city. Development pattern and transportation facilities are related to each other. The development follows the roads in search of economic return. Improvements to transportation facilities due to growth often happens, too, as the worsening congestion reports indicate (Schrank et. al 2012). The purpose is to analyze the overall relationship as it represents itself in form of average commute travel time, population, and land area.

1.2 Hypothesis

The hypothesis is that in spite of significant variation among large and small urban areas, the relative residence- employment locations follows a general and predictable rule that can be formulated in a non-linear regression formula. The hypothesis also asserts that the relationship between home and work location is a function of aggregate characteristics of the city such as population and total land area. The purpose of this research is to find this rule.

The relationship between work and residence locations can also be stated in terms of commuting trip length. The commute trip length can be defined in terms of distance, time, or a generalized cost (Nagurney and Dong 2000). Generalized cost is a measure for describing trips based on the sum of dollar value of travel time and the real cost of travel. Defining the relationship based on cost seems the most appropriate approach because it encompasses the other measures than time, but it poses a fundamental problem that the generalized cost variable cannot be measured in surveys. Even though out of pocket cost can be captured in surveys, the conversion to generalized cost can only be stated as a model estimated value (McFadden 1974). For this important reason, the hypothesis remains focused on travel time.
It is generally expected that in large metropolitan areas, people have more tolerance for longer distance and time between their work and residence locations. For example, residents of Los Angeles are expected to accept long distance travel and long delays in their home to work trips. In contrast, we expect to see much shorter work trip lengths for residents of St. Louis. Los Angeles population is around 16 Millions and St. Louis is home to about 2.5 Millions. The difference of congestion level, particularly in peak periods, is markedly different in these cities (Schrank, et. al. 2012). However, the average trip time to work reveals only 2 minutes difference, which is less than 10%. The difference in distance seems even counter intuitive as it shows the residence of Los Angeles live about 1.7 miles closer to their work locations than the residence of St. Louis. These differences are much less than what it seems to be the general perception (Downs 1992, Gillham 2002).

Inspired by unexpectedly low differences among residence-work distance and travel time in large metropolitan areas, the hypothesis of finding a mathematically descriptive formula for the commute travel time seems reasonable. This research is intended to provide a realistic insight about the formation of the cities.

In addition to average travel time between residence and workplace location, large cities probably follow similar frequency distribution of travel time between these points. As descriptive as average values are for policy decision making, they may not be directly utilized in forecasting process in urban land use models.

In continuation of this research, one can pursue a hypothesis that in addition of predictability of average time distance between residence and work location, the frequency distribution of this distance can also be described in a normalized frequency distribution form. The normalization of this distribution should be based on known or easily obtainable aggregate information of the urban area such as population and area.

Since this research presents a mathematical formula for home to work travel time based on aggregate information of the urban area, it can also quantifies the relative importance of the
changes of independent variables, such as population, in the formation of cities. It is expected that in most cases, particularly when land topology is not restrictive, the effects of aggregate characteristics are small.

1.3 Method

To conduct this research, data from various sources need to be extracted, cleaned up and converted into data sets that can be used in model estimation. The model estimation process uses regression analysis to recognize the descriptive variables, model structure, and estimate the coefficients. The performance of the estimated models is closely analyzed and selection of variables and structure are narrowed down to a single selected model. The final model prediction power is tested through a validation process. The validation step uses data that are not utilized in the estimation step. This ensures that the estimated model is unaware of the new data and properly measures the prediction power of the proposed model.

The data sources used in this thesis are all public data, which are freely available. Census Bureau data and Federal Highway Administration (FHWA) surveys provide sufficient data for this research. The detail of these and other related sources are discussed in Chapter 3. Understanding the data sources and data extraction are non-trivial activities in this work.

1.4 Implication in Understanding Urban Form

The hypothesis of the study has direct relation to understanding of the urban form in aggregate. If the travel time between residence and employment can be described in a fairly simple mathematical relationship regardless of local policies, planning restrictions, zoning rules, natural conditions, and other site and societal specific characters, then the urban form, as it shows itself in commute travel time, is a function of something more fundamental than local factors in the United States. Implementation of major national policies that affected urban form, such as interstate highway system and financing program for private homes, are examples of the non-local policies (Baum-Snow 2007, Margo 1992, Brueckner 2000 and 2001).
Baum-Snow research indicates that national highway program accounts for about one-third of the decline in central city population relative to population in the entire metropolitan area in the period from 1950 to 1990. Margo’s report associated half of the suburbanization occurred between 1950 and 1980 to increased income of households. The increased purchasing power was also accompanied by the federal government encouraging policy of home ownership. Various programs in the housing policy contributed to reducing the cost of homeownership.

The presence of non-local forces in urban formations may have created a level of consistency among the urban areas in development pattern. If the result of this study can adequately describe average commute travel time in different urban areas regardless of local policies, then it may indicate that the non-local factors have a dominant role in urban form development.

The power of predictability that this research offers is limited in the larger context of urban form but it is illuminating for planners to know the travel time between home and work. The travel time can be converted to distance for spatial checks.

The example of Los Angeles and St. Louis implies that if St. Louis grows as Los Angeles did and becomes 6 times more populated than what it was in 2010, the formation of the development happens in way that the impedance between residence and work locations in average will change only 10 percent. Therefore, the formation of the urban area has very low elasticity to the size of the urban area in terms of population. The results of this research either confirms or rejects this notion.

One of the major dis-benefits of urban sprawl is stated as increasing the commute time (Gillham, 2002). While there is no need for research to show that urban sprawl puts pressure of water, electricity, and energy infrastructure due to geographical distance, it is not clear if the sprawl urban form puts pressure on residents for their commute to work. This research provides an answer to this question.
1.5 Research Contribution

This research offers a simple formula for estimating the average travel time between home and work locations in large metropolitan areas of the United States based on basic information of population and land area. If the result of the research successfully achieves formulating such a relationship, it implies the urban form, in the context of home to work accessibility, is predictable based on merely aggregate characteristics of an urban area. Even though the results of this research does not provide geographical location of developments, it still establishes the relationship between these locations in aggregate level.

Identifying the average commute travel time provides a control check for the result of any estimation of land use and urban form through any forecasting process. Chapter 2 describes the relevant land use model structures that use the home to work accessibility measure. The result of this research makes it possible to check the output of the land use model against average travel time between work and residence through an external source. This test creates a measure for validation of the results.

In transportation planning process, knowing an average commute trip length in an area is important for both policy and technical decisions. Commuting in America reports, which describe trip characteristics based on average commute trip times, are used by congress for national policy making (Pisarski 2006). In transportation planning process, average commute trip time is used for estimation of work trip pattern in a region. To estimate the average home to work trip time, significant amount of resources is spent for household or business establishment travel surveys. This research offers another source based on independent aggregate variables which are readily available from U.S. Census Bureau.

1.6 Thesis Structure

Chapter 2 contains the literature review of the topic. The review tries to open up the subject of residence-work location relationship in the context of urban formation. The chapter continues by explaining the land use forecasting processes and their use of home-work relation.
Chapter 2 also addresses the studies that are done in transportation planning field for average commute trip travel time.

Chapter 3 covers the methodological process that the research uses. It describes the data sources available for the study. The chapter continues by describing the mathematical forms used in the analysis. The non-linear regression formula that are the results of this research are then presented with validation and calibration data comparisons.

Chapter 4 concludes the research and analyzes the validity of the proposed hypothesis. It also provides discussion on the implications of the results. References and an appendix follow the rest of the report. The appendix provides survey instruments used in Census Bureau data collections for the convenience of the readers.
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Urban planning is literally defined as “planning of city’s development” or “the planning of the physical and social development of a city through the design of its layout and the provision of services and facilities (Encyclopedia Encarta®, “World English Dictionary”). Encyclopedia of Britanica (Encyclopedia Britanica) defines urban planning as “design and regulation of the uses of space that focus on the physical form, economic functions, and social impacts of the urban environment and on the location of different activities within it.” These literal definitions do not provide any objective for the planning process. A more meaningful and useful definition is provided in (The Free Dictionary) as “programs pursued as a means of improving the urban environment and achieving certain social and economic objectives.” In all of these definitions, the formation of urban landscape is at the core of the planning process. To develop an efficient and fair structure for an urban area, in which residents live and grow safely and prosperously, a proper understanding of future development is necessary (Taylor 2007).

The planning process is a future oriented practice. Knowledge about future relates to understanding of the past and recognition of stable patterns to produce insights about the future. Experience around the world has shown that economic success will lead to fast growth in urban areas. Without proper foresight, the economically successful urban areas become magnets for migrant population whose demand for housing will surpass affordable existing housing stock. As a result, uncontrolled growth would take place and urban formation becomes captive of compulsive market forces without any corrective rules. The planning process tries to intervene and inform the society of the consequences of the future growth and develop proper rules and policies that guide the growth in a direction that is socially acceptable and environmentally
sustainable (Taylor 2007). The appropriateness of the planning process is determined by the power of the foresight provided in the decision making process. Forecasting the future urban formation provides the insight and empowers the policy makers to define relevant policies that can serve the society in both short and long run.

The growth in the United States urbanized areas has created larger cities. Figure 2.1 shows the percentage of urbanized population in the United States since 1790. The urban population share has been steadily increasing for more than 200 years. It seems that it is stabilizing just below 80%. Even though there are more people in urbanized areas every year, the rate of growth of urbanization has been decreasing from 30% per decade in 1870 to around 2% in 1990. In terms of absolute numbers, 38 million urban residents in 1870 has grown to 249 million in 1990 (U.S. Census 2000, “Urban and Rural Population”). The size of the cities in the country has drastically changed and new urban areas has been created. Along with urban size, the home to work travel time has also changed (Pisarski 2006).

Figure 2.1 U.S. Urban and rural Population percentages from 1790 to 1990 (U.S. Census 2000, “Urban and Rural Population”)
How these cities have become larger in terms of relative location of residential and work places and how the commute time has been affected have been studied by Gordon, Kumar, and Richardson (Gordon, Kumar, and Richardson 1989). They empirically showed that employment decentralization might reduce commute time. They used a combination of data from satellite imagery, census, and land use data for 82 U.S. metropolitan areas to find a relationship between average commute travel time by travel mode and measures of urban form. The measures for urban form included urban land area, proportion of workers in industrial and commercial employment, and land use density. They concluded that larger cities have longer commutes, industrial employment proportion in a city decreases commute time, employment proportion in the central city has positive correlation with commute travel time, and combined residential and employment decentralization decreases travel time to work.

Commute time has been also looked at from social justice standpoint in literature. Dubin has shown that men, non-Blacks, higher income households, and home owners have shorter travel time to work. Even though the commute distance may increase but the commute time may remain the same or decrease as a result of suburbanization (Dubin 1991). In few disaggregate studies, Levin formulates the residential location choice based on commute time, housing supply, and demographic factors (Levine 1990). He explains that low income workers commute time increases as a result of decentralization of the employment because low income workers has less mobility to move closer to new employment location.

A study conducted on U.S. commuting pattern by Crane and Chatman (Crane and Chatman 2004) concluded that urban sprawl has caused decentralization of both population and employment in a way that commute travel time increased only slightly. Their analyses showed in all urbanized areas as a whole, the average commute trip length in miles has only slightly increased from 10.7 miles in 1985 to 11.3 miles in 1997. This 5.5% increase may imply a hidden stability in the home-work location formation. However, Crane and Chatman study is based on American Housing Survey for all urbanized areas, as opposed to considering each urbanized
area as a single point of observation. Therefore, the results could be too aggregated to be used for any individual city.

Recent studies in health and economic science have also turn their attention to commute travel time. Frey and Stutzer (Stutzer and Frey 2008) have found that stress level in humans is related to their commute travel time. They concluded that there is a psychological cost to humans due to commute. This theory implies that the commute time tend to normalize across different areas based on human tolerance.

While the previous studies have examined commute time for various specific purposes, the attempts for connecting the average commute time to urban form are rare and base on old data. Other than the studies mentioned, the two analytical fields of urban land use modeling and transportation planning try to formally find a connection between home, work, and transportation networks. This study examines the commute travel time in individual large metropolitan areas and develops simple regression formula to predict the average commute trip time. If there is a behavioral stability in the urban formation, the developed model would show proper validation. The methodology, data, and validation results are addressed in Chapter 3.

The classical theories of land use suggest an equilibrium between housing cost and travel time. If all the participants in a perfect housing and labor market optimize, all the workers are fairly compensated for their travel time and cost from home, either by higher wages or by lower housing cost, Individual utility is then equalized over all possible locations within space. These concepts have been established in classical urban location theory (Alonso 1964, Mills 1972, Moses 1962, Muth 1969, and Huriot and Thisse 2000).

While Mono-centric city model provides valuable insights about the growth of the American cities, it is too simplistic to describe the new economic development patterns in urban formation. The decentralization of employments in the cities have weakened the descriptive power of the Mono-centric model. More contemporary attempts in modeling the urban formation has been emerged.
2.2. Land Use Models

The term "Land Use Model" here is referred to as a set of theories and processes that try to model the spatial allocation of the residential and non-residential land used in an urban area. A major deficiency for the Mono-centric model is that employment centers are no longer centralized in central business districts (CBD). Therefore, the value of land does not necessarily diminished as the distance to CBD increases. The presence of fairly ubiquitous highway and thoroughfare system provided accessibility to many areas other than downtowns. Therefore, the decision makers face more vibrant choices in locating both their businesses and residences.

This research focuses on a single aggregate aspect of residence-work travel time relation which needs to be satisfied regardless of the forecasting or modeling process that is employed to describe the growth or evolution of an urban area. This section describes how four sets of models address the issue of commuting time in their process either explicitly or implicitly. The four selected sets of models are geographical suitability models, gravity based models, input-output models, and micro-simulation agent based models. All land use models have to address the relationship between residence and workplace and therefore are relevant to this research. Understanding of the approaches that have been used in various models provides the stage for the subject of this study, which looks at the average of home to work travel time in different regions.

2.2.1. Geographical Suitability Models

This set of models and processes are built based on allocation of total stock of households and employments in a region. These can be quite simple geographical allocation based on previous trends in different households or employment sectors or could be complicated to maintain relationship among employment types and their corresponding households.

An example of geographical models is suitability models that are based on estimation of relative indexes for geographically defined areas. The indices represent local characteristics of the potential land for development. In these models, a geographic information systems (GIS)
software is used to define the resolution of the model and calculate various components that make the land unit suitable for certain type of employment or residential development. Other than the geographical resolution of the land, the number of household and employment groups define the structure of the model. The allocation process is sequential and then iterative by employment and households (Kockelman et al. 2008).

The suitability models can address the relative allocation of households and employment explicitly because the geographical positioning of households is sequentially done after the first set of employments are located. Therefore, the home-work travel time relationship can be maintained in the process.

2.2.2. Gravity models

Gravity models have a rich history in land use modeling. One of the first formal application of gravity concept in land use modeling was presented by Lowry in 1964 (Lowry 1964). Lowry model concept was based on distribution of the basic employment, which is provided to the model as an input. The gravity model is then used to distribute the workers related to the basic industry. Then, the service industry needed for the distributed population is estimated. In the subsequent step, the workers for the service industry are geographically allocated and the need for service is re-evaluated. If the service needs has not changed, the allocation is done. Otherwise, an iterative process between the service employment and workers is applied until they converge.

One of the commercial application of Lowry model was in Putman METROPILUS model (Putman 1983). This model is an enhanced version of the original Lowry model with components for allocation of employment (EMPAL), allocation of households (DRAM), and land consumption model (LANCON). The variables that are used in models are calibrated simultaneously based on two observed years. Even though transportation accessibility is introduced in the model but it is not possible to explicitly maintain a specific transportation measure between a group of households and employments because the calibration process estimates all the variables at the same time (NCTCOG 2013).
2.2.3. Input-Output Models

Input-output model are econometric models that represent the economy as a multi-dimensional matrix in which each component in a row or column interacts with the other components. Therefore, any change in one triggers an iterative process among all components until the whole matrix stabilizes. Each cell represents the amount of economic activity between the components (Kockelman et al. 2008).

A spatial form of input-output model is created in PECAS. PECAS incorporates the input-output concept with geographical dimension. The spatial components create flows in the model. Transportation accessibility is used as a cost in the model to relate the economic components in each area. The value of land is modified through the process. Transportation cost data can be used to control the relation between household and employment location. However, the locations are affected by many other factors in the input output model (Hunt and Abraham 2009).

2.2.4. Micro-simulation Agent Based Models

The allocation of employment or household can be done in a micro-simulation framework in which the decision-makers are individually simulated. Each decision making agent is then faced with several choices. The decision making process is simulated through a several discrete choice models. Once all agents in the simulated environment made their decisions, the allocation of lands to different land uses is determined (UrbanSim Manual 2011). The agent-based approach is used in UrbanSim model platform. The agents are households, persons, businesses and jobs. The agents are kept in a list and are updated as the model progresses in time and process. The challenge with the agent-based micro-simulation models are the complexity, accuracy, and the size of the data. It would be very difficult to collect enough data to model a sequence of decisions for each agent. The advantage is that each decision can be modeled explicitly.

The effect of the transportation on residence and work location is explicitly addressed in UrbanSim for each agent or agent group. The overall formation of residence-work locations is simply the summation of each individual agent decision.
The generous degree of freedom in micro-simulation models warrants a need for overall check. Mirco-simulation models show some sort of response to any change that have an input for. This advantage of being able to analyze many policies needs assurance for maintaining a big picture in correct form, which is the essence of this research.

Several other land use models are in practice today but a significant majority of them stem from one of the examples provided. All of these models at least indirectly include a form of assumption for the relation between work and home. Therefore, the final results of them can be checked against the results of this research.

The relation between work and residence is also extensively used in transportation planning field. In addition to urban planners, the transportation planners are interested to know the commute time and the facilities or infrastructure that an urban area need for access to work from home. The next section explores the work that has been done in this regard in the field of transportation planning.

2.3. Transportation Models

Study of the relative location of home and work is one of the major subjects in transportation planning as the planners in this field have to design the transportation system in respond to the existing or future demand for trips. The most important type of the trip in transportation planning is the work trips. This is because not only access to work is a major public policy issue, but also work trips are significantly constrained within specific time frames, known as peak periods or rush hours. Obviously, the spatial aspect of home and work affects the use of the transportation networks. Hence, the transportation studies are as interested in home-work travel time as the urban planners.

For many years, the transportation planning and urban planning fields pursued different methods in answering the same questions. This is still mostly true as the science of land use and transportation planning has not provided an integrated and practical method for these fields (NCTCOG 2013). Even the United States federal government has at least two separate
departments responsible for policy making for housing and transportation as department of housing and urban development and department of transportation. The results of this research can certainly be related to transportation planning as much as it relates to urban studies.

Similar to the field of urban planning, the transportation planning field also uses mathematical modeling to organize and describe the movement of the people in the urban area. The models in the transportation planning fields use the demographic and land use data, which are usually obtained from the urban planners. Since the issue of home and work locations should be addressed in the urban planning side of data, in theory, the transportation planners could take it as an input and use it in their studies, but this is not the case in practice. As a result, the transportation planners take a fresh and different look at the home-work location relation in form of work trip distribution (NCTCOG 2013).

Trip distribution models associate the produced trips at the one of the trips to the attracted trips at the other end of the trips. The total number of trips is already calculated through use of land use and demographic data and trip rates. The trip distribution step identifies which trips goes to which destination.

Two types of trip distribution models that are widely used in the industry are gravity models and destination choice models. Both of these models were also used in the land use models for geographical location of residential and work place land uses.

Gravity models estimate the trip interchanges between two zones based on production, attraction, and the friction factor between the two zones. Friction factors represent the response to travel cost or time between a pair of zones. As the travel cost or time between two zones increases the trip interchange between them decreases.

Destination choice models distribute the produced trips from one zones to the most possible destinations based on characteristics of the destination and the trip cost and time between the pair.
When a transportation planning model performs trips distribution for trips between home and work locations, it practically identifies the geographical relation between residence and work, just as the land use models did. Therefore, the urban form and land use is clearly included in this process. For example, a high density mixed use urban form produces short trip length for home to work trips.

Both of these models explicitly address the relative locations of home and work. Unlike some land use models, such as METROPILUS, in which this relation can be implicit in the complex process of the models, transportation models require explicit and clear data for the travel time or distances. Therefore, it is possible to investigate the transportation data and study the urban form.

National Cooperative Highway Research Program (NCHRP) report 716 provides specific values for average home to work travel time for urbanized areas in the U.S. (Cambridge Systematics, Inc. et. al. 2012). The report summarizes the average trip length for home to work for all urban areas as 25 minutes. The variation is from 21 to 32 minutes from areas with less than 500,000 population to the areas with more than 1,000,000 residents.

Average home to work travel time is important in almost all transportation studies. This single measure provides a brief but meaningful image of the transportation and interaction of land uses in the area. However, collection of such a data is often costly. The data collection process includes some method of personal trip data collection, which is intrusive and hard to collect. For this reason, there has been few efforts in earlier transportation and land use studies to estimate the average home to work travel time. NCHRP 365 (Martin and McGuckin 1998) states that the average trip length for home to work trips is between 15 to 20 minutes for smaller communities and up to as much as 25 to 30 minutes for large metropolitan areas. These values are very similar to the studies that are done in a decade and half later in NCHRP 716 report. This seems to confirm the hypothesis of this research as the population of all of the urbanized area in the country has
increased significantly in this period but the average relative distance between home and work has not changed.

The NCHRP 365 report suggest an simple equation for the average home to work trip time in minutes:

\[
\text{Average } HBW \text{ Trip Length (minutes)} = 5.0 + 0.10 \times \sqrt{\text{Land Area}}
\]

This research could not find any validation of this formula in literature. The report also asserts that the commute travel time correlated more to area of a region than to the population. This research investigates this statement.

2.4. Summary

This chapter presented an overview of the studies related to home-work travel time both in the context of land use and transportation planning. The chapter described the urban formation and the complex forces behind it to provide a challenge that forecasting and modeling process face for depicting the urban form and transportation. Most prominent approaches for urban form modeling were briefly explained to show the relation of the topic of this study to the standard practice. Finally, an overview of the work in transportation planning with regards to commute time was presented to show the previous work and the relevance of this research to transportation studies.

The next chapter explains the data and the methodology that is applied in this research for derivation of a regression model to estimate the home to work travel time based on aggregate data of a region.
CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter covers the data sources and methods used in this study. The data sources for this research are publicly accessible through Census Bureau decennial survey, American Community Surveys (ACS), Census Transportation Planning Program (CTPP) of American Association of State Highway and Transportation Officials (AASHTO), and Federal Highway Administration (FHWA) National Households Travel Survey (NHTS) program. This chapter introduces these data sources and related definitions used throughout the research.

The methodology used in this research for relating the average home to work travel time to population and land area is non-linear regression estimation model. The results of the estimation process is presented in a separate section. This includes the calibration measures and performance of the model compared against the dataset used for estimation. This research uses 40 Metropolitan Statistical Areas (MSA) data form NHTS for derivation of the model.

The performance of the model is also compared to ACS data, which is independent of NHTS. Validation of the developed formula provides a measure for predictability of the model.

The observed data used for this study is obtained from three sources of decennial census, ACS, and NHTS. For model estimation purposes, census 2010 provides population and land area while NHTS 2009 is the sources of average commute times. The average commute times for validation are extracted form ACS 5-year 2007-2011. The ACS samples are distributed in the 5 year period and the average commute time coincides with the estimation data. The validation population and land area values are from census 2010 data.
3.2 Census Data

Article I, Section 2 of the U.S. Constitution, adopted in 1787 requires population count every 10 years across in the whole nation. The first census conducted in 1790 and reported 3.9 million inhabitants in the U.S. The early census only included population count but during the long history of census many questions were added to the survey form and many other surveys were added to Census Bureau activities, such as economic census and agricultural census.

Census data are the most important part of virtually any local and regional data collections in the nation. This is because the only control totals that are systematically collected in the nation is done through Census Bureau. The control totals provide a statistical method for expanding much smaller sample surveys to be useful for analysis. Commuter trips surveys are among the smaller sample surveys that benefit from census data.

Census Bureau has collected decennial census since 1790 but the contents of the surveys have changed during the years. During the last two census of 2000 and 2010 a fundamental change in design of the survey occurred that affected the travel data section of census. In census 2000, two survey forms were used for data collection. The short form, which everyone received included the minimum data for age, race, household and home data. Approximately 16% of people received the long form that included about 100 questions. The long form included data for journey to work questions. American Community Survey (ACS) was introduced in 2005 to census and replace the need for the long form from decennial census. Following sections provide a brief overview of the decennial census 2000 and ACS.

3.2.1. Decennial Census

Decennial census of 2010 asked for only 10 questions about the name, phone number, home ownership, type of home, number of household members, relationships, age, ethnicity and race of each person. It was designed to be simpler than its predecessors. Figure 3.1 shows the census 2010 form. The complete form is provided in appendix A. Census 2010 form did not
include any information about work and travel to work, which was a deviation from the past two decennial censuses.
In census 2000 long form, there is a set of questions about travel to work including time of departure, mode of transportation, and travel time. Almost 16% of households provided with this form, which created a basis for journey to work data. This data later was converted to census transportation planning package through efforts of departments of transportation of all states. A portion of census 2000 long form is shown in Figure 3.2 and the complete form is included in the appendix A.

![Figure 3.2 Part of Census 2000 long form related to travel to work](image)

3.2.2. American Community Survey

Starting in 2005, Census Bureau introduced a new type of survey to replace census long form. The form is a multi-page survey instrument to collect information about variety of subjects from mortgage, plumbing, and utility cost to income and work information. Part of the survey is related to work and travel to work information, which asks similar questions about travel to work as census long form did. Figure 3.3 is a snapshot of ACS 2012 form related to home to work trips. The questionnaire includes questions of the place of work, time of departure, travel time to work, and mode of travel.
Unlike decennial surveys, ACS is done constantly with the rate of 2.5 million households per year. To make the results statically acceptable for reporting, Census Bureau has created data sets for different geographical units and different time spans. ACS data is released annually for counties with more than 60,000 resident population. For counties more than 20,000 population, ACS samples are accumulated and for three years and corresponding reports become available in three year periods, such as 2006, 2007, and 2008, known as 3-year product. For smaller geographies with less than 20,000 resident population, the same process is done with 5 years of samples. Access to data is provided through Census Bureau web site of American Fact Finder. In this research, the validation data for the travel time analysis to work is provided from this source.

There are several definitions for census geographies but the one that are related to this research is Metropolitan Statistical Area (MSA). MSAs are defined by the U.S. Office of Management and Budget (OMB), and used by the U.S. Census Bureau and other federal government agencies for statistical purposes. The definition of MSA is based on the concept of a core urbanized area and its neighboring geographies, which could be partly rural and partly urban, that have significant interaction with the core area. For MSAs, the core area should have at least 50,000 population and interaction with neighboring areas is defined significant when more than 25% of commute trips interchanges happen with the core area. This research focuses on 40 larger MSAs that were included in NHTS data collection.
3.3 Census Transportation Planning Product Data

American Association of State Highway and Transportation Officials (AASHTO) is an organization that is created and funded by state Department of Transportation to manage activities that are common among DOTs. In the context of transportation planning, AASHTO is empowered by the states to manage creation of customized reports for transportation planning from Census Bureau data. From census 2000 long form and ACS data, characteristics of commute trips such as travel time, time of departure, and mode of transportation can be extracted and become publicly available.
Census Transportation Planning Program or CTPP is a program in AASHTO that facilitates creation of combination of commute travel data with household and employment characteristics of the person. These data sets add significant value to ASC summaries available from Census Bureau sources directly. This research has benefited from CTPP data in preparation of early stages of data for the analysis.

3.3.1. Accuracy Concerns

CTPP and ACS data are created from very small set of samples, which is about 2.5% per year. For small area studies, these sample rates may not be adequate for meaningful analysis because the margin of error becomes too large. Consideration of accuracy of estimates should be part of the analysis (U.S. Census Bureau 2008). The accuracy of data increases when either the geography of the area of analysis becomes larger than 60,000 or the time period of analysis covers more than one year. Both ACS and CTPP now report margin of error (MOE) alongside the extracted measures. MOE provides a sense of precision of a sample estimate. Standard Error (SE) can be calculated based on MOE and the confidence interval associated with the MOE. ACS provided MOEs are for confidence level of 90 percent. Therefore, SE can be calculated as $SE = \frac{MOE}{1.645}$. Coefficient of Variation (CV) indicates the amount of sampling error embedded in the ACS estimates. A small CV, indicates high accuracy of the estimate. ACS 5-year data always provide lower CVs than their 1-year counterparts. CV can be calculated as $CV = \frac{SE}{\text{Estimate}}$. Census Bureau Compass reports provide guidelines for inclusion of uncertainty in data analysis (U.S. Census Bureau 2008).

Table 3.1 provides an example of the ACS extracted data for population by home tenure for 20 largest MSAs from Table B25008 ACS 2011 1-Year dataset. For demonstration purposes the margin of error for population is shown in the table. As it is expected, the MOEs are reasonably small when the area is large. Yet, it should not be expected that the estimated values are real numbers as the accuracy not only relates to number of samples but also to the method of data collection.
Table 3.1 Twenty largest MSAs population based on ACS 2011 1-year estimate

<table>
<thead>
<tr>
<th>Rank</th>
<th>MSA</th>
<th>Population</th>
<th>MOE</th>
<th>Owner</th>
<th>Renter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New York-New Jersey-Long Isl, NY-NJ-PA</td>
<td>18,637,352</td>
<td>+/-9,594</td>
<td>10,114,460</td>
<td>8,522,892</td>
</tr>
<tr>
<td>2</td>
<td>Los Angeles-Long Beach-Santa Ana, CA</td>
<td>12,730,041</td>
<td>+/-6,315</td>
<td>6,516,106</td>
<td>6,213,935</td>
</tr>
<tr>
<td>3</td>
<td>Chicago-Joliet-Naperville, IL-IN-WI</td>
<td>9,348,796</td>
<td>+/-4,883</td>
<td>6,391,858</td>
<td>2,956,938</td>
</tr>
<tr>
<td>4</td>
<td>Dallas-Fort Worth-Arlington, TX</td>
<td>6,448,240</td>
<td>+/-5,285</td>
<td>4,144,595</td>
<td>2,303,645</td>
</tr>
<tr>
<td>5</td>
<td>Houston-Sugar Land-Baytown, TX</td>
<td>6,014,265</td>
<td>+/-5,396</td>
<td>3,861,688</td>
<td>2,152,577</td>
</tr>
<tr>
<td>6</td>
<td>Philadelphia-Camden-Wilmington, PA-NJ-DE-MD</td>
<td>5,827,917</td>
<td>+/-5,217</td>
<td>3,711,684</td>
<td>1,889,362</td>
</tr>
<tr>
<td>7</td>
<td>Washington-Arlington-Alexandria, DC-VA-MD-WV</td>
<td>5,601,046</td>
<td>+/-4,683</td>
<td>3,711,684</td>
<td>1,889,362</td>
</tr>
<tr>
<td>8</td>
<td>Miami-Fort Lauderdale-Pompano Beach, FL</td>
<td>5,592,615</td>
<td>+/-5,537</td>
<td>3,540,684</td>
<td>2,051,931</td>
</tr>
<tr>
<td>9</td>
<td>Atlanta-Sandy Springs-Marietta, GA</td>
<td>5,280,521</td>
<td>+/-5,991</td>
<td>3,447,326</td>
<td>1,833,195</td>
</tr>
<tr>
<td>10</td>
<td>Boston-Cambridge-Quincy, MA-NH</td>
<td>4,431,935</td>
<td>+/-3,992</td>
<td>2,942,071</td>
<td>1,489,864</td>
</tr>
<tr>
<td>11</td>
<td>San Francisco-Oakland-Fremont, CA</td>
<td>4,310,551</td>
<td>+/-4,224</td>
<td>2,453,305</td>
<td>1,857,246</td>
</tr>
<tr>
<td>12</td>
<td>Detroit-Warren-Livonia, MI</td>
<td>4,239,838</td>
<td>+/-3,499</td>
<td>2,696,024</td>
<td>1,527,887</td>
</tr>
<tr>
<td>13</td>
<td>Riverside-San Bernardino-Ontario, CA</td>
<td>4,223,911</td>
<td>+/-6,016</td>
<td>2,605,991</td>
<td>1,581,986</td>
</tr>
<tr>
<td>14</td>
<td>Phoenix-Mesa-Glendale, AZ</td>
<td>4,187,887</td>
<td>+/-4,724</td>
<td>2,174,487</td>
<td>1,259,334</td>
</tr>
<tr>
<td>15</td>
<td>Seattle-Tacoma-Bellevue, WA</td>
<td>3,433,821</td>
<td>+/-4,135</td>
<td>2,174,487</td>
<td>1,259,334</td>
</tr>
<tr>
<td>17</td>
<td>San Diego-Carlsbad-San Marcos, CA</td>
<td>3,049,086</td>
<td>+/-6,444</td>
<td>1,638,507</td>
<td>1,410,579</td>
</tr>
<tr>
<td>18</td>
<td>Tampa-St. Petersburg-Clearwater, FL</td>
<td>2,776,401</td>
<td>+/-4,614</td>
<td>1,854,219</td>
<td>922,182</td>
</tr>
<tr>
<td>19</td>
<td>St. Louis, MO-IL</td>
<td>2,758,024</td>
<td>+/-5,238</td>
<td>2,016,975</td>
<td>741,049</td>
</tr>
<tr>
<td>20</td>
<td>Baltimore-Towson, MD</td>
<td>2,662,001</td>
<td>+/-3,827</td>
<td>1,851,736</td>
<td>810,265</td>
</tr>
</tbody>
</table>

For the analysis performed in this study, the accuracy of data is sufficiently satisfied because the size of the MSAs that are considered for the analysis are larger than 750,000 population, which includes enough samples in both ACS and NHTS datasets. However, when the same estimated data from different sources are compared, there would be differences caused by method of data collection, type of question, expansion method, and other survey specific situations that are not covered in the number of samples. Validation section shows an example of the discrepancy between the two data sources.

3.4 National Household Travel Survey Travel Data

National Household Travel Survey program was created by Federal Highway Administration of U.S. Department of Transportation to conduct travel pattern survey of
households across the nation. The resulting data product is designed to assist planners, researchers and policy makers who need comprehensive travel data pattern in the U.S. The latest NHTS was conducted in 2009 and historic data form 1969 to 2001 are also available (National Household Travel Survey, NHTS Home).

NHTS 2009 data set includes household data, vehicle ownership, driver information, data about one-day trip making activities, data on telecommuting, and internet usage. Data related to cost of travel, paths, and exact work location is not provided. Privacy concern limits the accuracy of the location data.

NHTS was a random sample survey with additional households for certain locations in the nation. To conduct the analysis of this research, the data was extracted from nationally available data from online analysis tool (National Household Travel Survey, NHTS Analysis Tool). Since data records were already associated with MSAs, a complete data set for all MSAs could be extracted and summarized for this analysis.

Unlike ACS and decennial surveys, NHTS conducted through only phone interview. Therefore, there are no survey instruments.

This study uses the data from NHTS 2009 of 40 MSAs for home to work average travel time as observed data. The values for land area and population are extracted from Census Bureau American Fact Finder web site for year 2009. The data is summarized Table 3.2.
Table 3.2 Average home to work travel time from NHTS 2009

<table>
<thead>
<tr>
<th>No.</th>
<th>MSA</th>
<th>Home-Work Time (min)</th>
<th>Land Area (mile²)</th>
<th>Population 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Atlanta-Sandy Springs-Marietta, GA</td>
<td>30.5</td>
<td>8,436</td>
<td>5,268,860</td>
</tr>
<tr>
<td>2</td>
<td>Austin-Round Rock-San Marcos, TX</td>
<td>23.6</td>
<td>4,269</td>
<td>1,716,289</td>
</tr>
<tr>
<td>3</td>
<td>Boston-Cambridge-Quincy, MA-NH</td>
<td>30.5</td>
<td>3,528</td>
<td>4,552,402</td>
</tr>
<tr>
<td>4</td>
<td>Charlotte-Gastonia-Rock Hill, NC-SC</td>
<td>24.9</td>
<td>3,121</td>
<td>1,758,038</td>
</tr>
<tr>
<td>5</td>
<td>Chicago-Joliet-Naperville, IL-IN-WI</td>
<td>33.1</td>
<td>7,281</td>
<td>9,461,105</td>
</tr>
<tr>
<td>6</td>
<td>Cincinnati-Middletown, OH-KY-IN</td>
<td>22.8</td>
<td>4,443</td>
<td>2,130,151</td>
</tr>
<tr>
<td>7</td>
<td>Cleveland-Elyria-Mentor, OH</td>
<td>24.8</td>
<td>2,021</td>
<td>2,077,240</td>
</tr>
<tr>
<td>8</td>
<td>Columbus, OH</td>
<td>24.4</td>
<td>4,014</td>
<td>1,836,536</td>
</tr>
<tr>
<td>9</td>
<td>Dallas-Fort Worth-Arlington, TX</td>
<td>27.8</td>
<td>9,032</td>
<td>6,371,773</td>
</tr>
<tr>
<td>10</td>
<td>Grand Rapids-Wyoming, MI</td>
<td>22.5</td>
<td>2,817</td>
<td>774,160</td>
</tr>
<tr>
<td>11</td>
<td>Greensboro-High Point, NC</td>
<td>21.7</td>
<td>2,017</td>
<td>723,801</td>
</tr>
<tr>
<td>12</td>
<td>Houston-Sugar Land-Baytown, TX</td>
<td>30.4</td>
<td>8,931</td>
<td>5,946,800</td>
</tr>
<tr>
<td>13</td>
<td>Indianapolis-Carmel, IN</td>
<td>23.2</td>
<td>3,900</td>
<td>1,756,241</td>
</tr>
<tr>
<td>14</td>
<td>Jacksonville, FL</td>
<td>26.0</td>
<td>3,239</td>
<td>1,345,596</td>
</tr>
<tr>
<td>15</td>
<td>Las Vegas-Paradise, NV</td>
<td>22.1</td>
<td>7,984</td>
<td>1,951,269</td>
</tr>
<tr>
<td>16</td>
<td>Los Angeles-Long Beach-Santa Ana, CA</td>
<td>30.6</td>
<td>4,905</td>
<td>12,828,837</td>
</tr>
<tr>
<td>17</td>
<td>Louisville-Jefferson County, KY-IN</td>
<td>23.1</td>
<td>4,159</td>
<td>1,283,566</td>
</tr>
<tr>
<td>18</td>
<td>Memphis, TN-MS-AR</td>
<td>22.9</td>
<td>4,631</td>
<td>1,316,100</td>
</tr>
<tr>
<td>19</td>
<td>Miami-Fort Lauderdale-Pompano Beach, FL</td>
<td>30.8</td>
<td>5,137</td>
<td>5,564,635</td>
</tr>
<tr>
<td>20</td>
<td>Milwaukee-Waukesha-West Allis, WI</td>
<td>21.6</td>
<td>1,472</td>
<td>1,555,908</td>
</tr>
<tr>
<td>21</td>
<td>Nashville-Davidson--Murfreesboro--Franklin, TN</td>
<td>24.8</td>
<td>5,755</td>
<td>1,589,934</td>
</tr>
<tr>
<td>22</td>
<td>New York-Northern New Jersey-Long Island, NY-NJ-PA</td>
<td>36.1</td>
<td>6,765</td>
<td>18,897,109</td>
</tr>
<tr>
<td>23</td>
<td>Oklahoma City, OK</td>
<td>19.8</td>
<td>5,576</td>
<td>1,252,987</td>
</tr>
<tr>
<td>24</td>
<td>Philadelphia-Camden-Wilmington, PA-NJ-DE-MD</td>
<td>28.2</td>
<td>4,656</td>
<td>5,965,343</td>
</tr>
<tr>
<td>25</td>
<td>Phoenix-Mesa-Glendale, AZ</td>
<td>25.9</td>
<td>14,736</td>
<td>4,192,887</td>
</tr>
<tr>
<td>26</td>
<td>Pittsburgh, PA</td>
<td>27.7</td>
<td>5,343</td>
<td>2,356,285</td>
</tr>
<tr>
<td>27</td>
<td>Portland-Vancouver-Hillsboro, OR-WA</td>
<td>24.3</td>
<td>6,762</td>
<td>2,226,009</td>
</tr>
<tr>
<td>28</td>
<td>Providence-New Bedford-Fall River, RI-MA</td>
<td>26.7</td>
<td>1,605</td>
<td>1,600,852</td>
</tr>
<tr>
<td>29</td>
<td>Raleigh-Cary, NC</td>
<td>24.9</td>
<td>2,143</td>
<td>1,130,490</td>
</tr>
<tr>
<td>30</td>
<td>Rochester, MN</td>
<td>20.6</td>
<td>2,962</td>
<td>1,054,323</td>
</tr>
<tr>
<td>31</td>
<td>Sacramento--Arden-Arcade--Roseville, CA</td>
<td>25.8</td>
<td>5,154</td>
<td>2,149,127</td>
</tr>
<tr>
<td>32</td>
<td>Salt Lake City, UT</td>
<td>24.4</td>
<td>9,667</td>
<td>1,124,197</td>
</tr>
<tr>
<td>33</td>
<td>San Antonio-New Braunfels, TX</td>
<td>25.4</td>
<td>7,398</td>
<td>2,142,508</td>
</tr>
<tr>
<td>34</td>
<td>San Diego-Carlsbad-San Marcos, CA</td>
<td>25.8</td>
<td>4,256</td>
<td>3,095,313</td>
</tr>
<tr>
<td>35</td>
<td>San Francisco-Oakland-Fremont, CA</td>
<td>28.4</td>
<td>2,499</td>
<td>4,335,391</td>
</tr>
<tr>
<td>36</td>
<td>Seattle-Tacoma-Bellevue, WA</td>
<td>28.2</td>
<td>5,941</td>
<td>3,439,809</td>
</tr>
<tr>
<td>37</td>
<td>St. Louis, MO-IL</td>
<td>27.9</td>
<td>8,724</td>
<td>2,812,896</td>
</tr>
<tr>
<td>38</td>
<td>Tampa-St. Petersburg-Clearwater, FL</td>
<td>24.7</td>
<td>2,543</td>
<td>2,783,243</td>
</tr>
<tr>
<td>39</td>
<td>Virginia Beach-Norfolk-New port New.s, VA-NC</td>
<td>25.7</td>
<td>2,660</td>
<td>1,671,683</td>
</tr>
<tr>
<td>40</td>
<td>Washington-Arlington-Alexandria, DC-VA-MD-WV</td>
<td>38.0</td>
<td>5,664</td>
<td>5,582,170</td>
</tr>
</tbody>
</table>

Average 26.3 5,154 3,490,546.58
3.5 Modeling and Evaluation Methods

The premise of this research is to find a relationship between home and work travel time in urban areas. The strategy for finding this relationship is to start with simple linear regression model and only increase the complexity of the model if needed. The next level of complexity would be non-linear regression analysis. This section describes these methods.

The expectation is that even without a complex model, the effects of aggregate area characteristics are somewhat moderate on home to work travel time. The aggregate characteristics that are considered for a region should be easily available form public sources, such as census web site. This research considers only population and area of an urban area to fit this criteria. A direct result of these measures is density that may come into formulation. Other more subtle aggregate characteristics such as distribution of income, employment types, and age distribution may be useful but are not easily predictable.

3.5.1. Model Estimation Approach

Multiple linear and non-linear regression analyses are used to find the relationship between home to work average travel time, population and land area. In both model forms, the sum of the square of error is minimized to estimate the parameters (Ostle, et al., 1996).

The independent variables that can be considered for the model are limited to population and land area of the MSAs. A derived variable of density, which is the ratio of population to the land area is also considered in the process of estimation. As mentioned in the previous chapters, the essence of this research is to estimate the commute time based on overall characteristics of a city. Therefore, the number of variables are very limited.

The model estimation approach tries to find the best form of these variables in a linear model. This is done through step-wise analysis of each variable. After each model run, the model is analyzed and its adequacy for estimation is evaluated. Each model result contributes to the possible combination of relevant variables and linear and non-linearity of the model. This method is useful in this particular case because there are only three variables that may end up in the
model. If the number of variables were higher, a rigorous examination of different combinations may have been needed.

To examine the linear relationship among the three main variables, Pearson correlation coefficients are shown in Table 3.3. Area and population do not show much of a correlation. It is possible that one or both of these variables correlate well with the commute time. The model tests will determine that. Density and area do not seem to be linearly related to each other, and as it expected, increase of the area decreases the density. The fairly high correlation between density and population indicate that their presence in one model may not help to produce a much better result than the presence of only one of them. However, this is only a speculation and should be tested in the model estimation process.

Table 3.3 Linear correlation among independent variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Area</th>
<th>Population</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>-</td>
<td>0.29616</td>
<td>-0.1792</td>
</tr>
<tr>
<td>Population</td>
<td>-</td>
<td>-</td>
<td>0.8343</td>
</tr>
<tr>
<td>Density</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Correlation analysis does not necessarily determine the appropriate variables in the model, but it can help to exclude the unlikely variables before the analysis particularly for the models with many variables. The estimation process in this study, examines several combinations of the variables and gradually builds the expectation of the final model.

To examine the performance of the models, three performance measures are used. The first measure for performance evaluation of a model is R-square. It measures the proportion of the sum of the squared deviations in the dependent estimated variable from the observed values to the squared deviations of the dependent variable observed values from its own mean value. R-squared is provides an overall sense of model performance. The closer the value is closer to one, the more capable the model is in estimating the observations. R-square is a good indicator of a proper model when it is high but it does not provide any guidance about improvements to the model. This is because the individual actual estimation errors are not explicitly shown in this aggregate measure. Use of Adjusted R-square is usually better than R-squared because it
provides a more fair comparison among models with different degree of freedoms, but in the case of models with one to three variables, Adjusted R-square does not provide more guidance than the R-square since the number of variables are already limited to less than three.

The two other measures that are looked at are 45-degree observed versus estimation graph and individual residual or error points. These graphs provide information about the individual points, which may be used in grouping them for creation of new variables. In this study, the size of the cities may play a role in the model as Cambridge Systematics publication has indicated (Cambridge Systematics Inc. et al. 2012).

3.6 Model Estimation

The estimation process starts with the simplest model and ends with the model that satisfies measures of effectiveness. This section provides details of estimation of eight models, in which the last one represents the suggested model for the report.

The estimation process results in a non-linear model that can estimate the travel time from home to work for a MSA based on population and density. This model results in R-square of 84% with individual errors less than 3 minutes.

The summary of the estimated models is provided in Table 3.4. The first three scenarios test the single variable linear models. These three models provide a base for comparison and inclusion of other variables for the linear models. Scenario 4 vindicates the conclusion from the correlation test. Scenarios 5 and 6 are equivalent and together with 7 provide an important indication for inclusion of size dummy variable in the model. The first 7 scenarios show that linear model for all cities cannot produce acceptable model and non-linear model need to be tested. They also informed the estimation process that population and density are the likely variables for the non-linear tests. Scenario 8 shows the result of the successful non-linear model. The rest of this section provides detail examinations of these models.
Table 3.4 Summary of the estimated models

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cities</th>
<th>Constants</th>
<th>Variables</th>
<th>Type</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All</td>
<td>0000</td>
<td>x-</td>
<td>LR</td>
<td>0.430</td>
</tr>
<tr>
<td>2</td>
<td>All</td>
<td>0000</td>
<td>-x</td>
<td>LR</td>
<td>0.045</td>
</tr>
<tr>
<td>3</td>
<td>All</td>
<td>0000</td>
<td>-x</td>
<td>LR</td>
<td>0.299</td>
</tr>
<tr>
<td>4</td>
<td>All</td>
<td>0000</td>
<td>x-x</td>
<td>LR</td>
<td>0.430</td>
</tr>
<tr>
<td>5</td>
<td>All</td>
<td>1000</td>
<td>x-</td>
<td>LR</td>
<td>0.488</td>
</tr>
<tr>
<td>6</td>
<td>All</td>
<td>0100</td>
<td>x-</td>
<td>LR</td>
<td>0.488</td>
</tr>
<tr>
<td>7</td>
<td>All</td>
<td>1001</td>
<td>x-</td>
<td>LR</td>
<td>0.505</td>
</tr>
<tr>
<td>8</td>
<td>Pop &gt;= 4</td>
<td>1000</td>
<td>x-x</td>
<td>NLR</td>
<td>0.837</td>
</tr>
<tr>
<td></td>
<td>Pop &lt; 4</td>
<td>0101</td>
<td>x-</td>
<td>NLR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1011</td>
<td>x-x</td>
<td>NLR</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
1. Population in millions
2. Area in thousand square miles
3. Density in million people in thousand square miles
4. LR = Linear Regression, NLR = Non-Linear Regression

The first and simplest model tries to estimate the average home to work travel time in a region based on only linear relation with population in million. The estimation results and performance of the model is shown in Table 3.5. Figure 3.4 depicts the performance of the model estimated values versus the observed average trip times. The performance of the model would be considered perfect if every point falls on the 45-degree line in the graph. Figure 3.5 shows the magnitude of differences between the model and the observed values. Figure 3.6 contains the percentage of the estimation error.
Table 3.5 Model SC1 estimation results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Average Trip Length (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>40</td>
</tr>
<tr>
<td>R-square</td>
<td>0.430</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>23.549</td>
<td>36.688</td>
</tr>
<tr>
<td>PopulationMillion</td>
<td>0.819</td>
<td>5.886</td>
</tr>
</tbody>
</table>

Figure 3.4 SC1 Model versus actual average home to work trip travel time

Correlation value of 0.655 shows there is a relation between the population and average home to work travel time but the R-squared of 0.430 is at best moderate. The performance of SC1 model is not satisfactory as the scatter gram does not show even
distribution around the 45-degree line. There are also several of large differences that shows the weakness in descriptive power of the model.

Figure 3.5 SC1 model average home to work trip travel time differences

Figure 3.6 SC1 model average home to work trip travel time differences
Model SC2 is similar to SC1 but instead of population it uses the land area of the region.

The estimation results and performance information are provided in Table 3.6. and Figures 3.7 to 3.9.

Table 3.6 Model SC2 estimation results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Trip Length (min)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Observations</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-square</td>
<td>0.045</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>24.612</td>
<td>19.768</td>
</tr>
<tr>
<td>Area Thousand</td>
<td>0.325</td>
<td>1.475</td>
</tr>
</tbody>
</table>

Figure 3.7 SC2 Model versus actual average home to work trip travel time
Correlation value of 0.213 shows there is insignificant relation between the area and average home to work travel time. The R-squared of 0.045 is very weak and unacceptable. The unsatisfactory performance of SC2 model is also clear from the scatter gram and the difference charts.

Figure 3.8 SC2 model average home to work trip travel time differences
Model SC3 uses density as the independent variable. The estimation results and performance information are provided in Table 3.7 and Figures 3.10 to 3.12.

Table 3.7 Model SC3 estimation results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Trip Length (min)</td>
<td>(Constant)</td>
<td>23.393</td>
</tr>
<tr>
<td></td>
<td>DensityMillionThousand</td>
<td>3.999</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>R-square</td>
<td>0.299</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3.10 SC3 Model versus actual average home to work trip travel time

Correlation value of 0.547 shows there is a relation between the density of area and average home to work travel time but the relationship is too weak for density to be the single predictor of commute trip time. The R-squared of 0.299 is also weak for this model. The performance of SC3 model is certainly better than SC2 but still the scatter gram and the discrepancy charts show unsatisfactory calibration results.
Figure 3.11 SC3 model average home to work trip travel time differences

Figure 3.12 SC3 model average home to work trip travel time differences
SC4 model test the model based on population and density combined. SC1 and SC3 showed modest relevance of these two variables. The estimation results and performance information are provided in Table 3.8 and Figures 3.13 to 3.15.

Table 3.8 Model SC4 estimation result

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Average Trip Length (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>40</td>
</tr>
<tr>
<td>R-square</td>
<td>0.430</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>23.550</td>
<td>28.740</td>
</tr>
<tr>
<td>DensityMillionThousand</td>
<td>-0.007</td>
<td>-0.004</td>
</tr>
<tr>
<td>PopulationMillion</td>
<td>0.820</td>
<td>3.123</td>
</tr>
</tbody>
</table>
Correlation value improved to 0.655, which shows the combination of population and density is effective in predicting the average travel time to work. The R-squared of 0.43 is in the middle range of rendering proper performance. The performance of SC4 based on the scatter gram and the discrepancy charts has improved but there are still differences of -10 min and up to 30% errors in the model.
The existence of large errors for large metropolitan areas suggests that these cities may need a separate constants in the regression equation. The next three models test adding various
constants for different size groups. SC5 tests the effect of adding a constant for cities with more than 4 million population. The estimation results and performance information are provided in Table 3.9 and Figures 3.16 to 3.18.

Table 3.9 Model SC5 estimation result

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Average Trip Length (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>40</td>
</tr>
<tr>
<td>R-square</td>
<td>0.488</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>23.735</td>
<td>38.272</td>
</tr>
<tr>
<td>PopulationMillion</td>
<td>0.435</td>
<td>2.533</td>
</tr>
<tr>
<td>LargeCity4Mil</td>
<td>3.238</td>
<td>2.270</td>
</tr>
</tbody>
</table>

Figure 3.16 SC5 Model versus actual average home to work trip travel time
Correlation value of SC5 model suggest modest improvement from SC1 model to 0.699. The R-squared of 0.488 is also modest. The performance of SC5 based on the scatter gram and the discrepancy charts has improved. The points are closer to the 45-degree line, but the model is not proper for forecasting. The range of differences has decreased when compared to model SC1 but they are still too large.

Figure 3.17 SC5 model average home to work trip travel time differences
Continuing the validity of inclusion of size specific constants in the model, SC6 includes two constants for small and large cities. Since these dummy variables are related to each other, the model cannot estimate coefficients for both of them. Therefore, it eliminates one of them and the results become equivalent to SC5.

Model SC7 tests dividing the cities with less than 4 million population into two groups at the break point of 2 million population. The estimation results and performance information are provided in Table 3.10 and Figures 3.19 to 3.21.
Table 3.10 Model SC7 estimation result

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Trip Length (min)</td>
<td>(Constant)</td>
<td>23.319</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>R-square</td>
<td>0.505</td>
<td></td>
</tr>
<tr>
<td>Independent Variables</td>
<td>PopulationMillion</td>
<td>0.443</td>
</tr>
<tr>
<td></td>
<td>LargeCity4Mil</td>
<td>4.025</td>
</tr>
<tr>
<td></td>
<td>SmallCity2to4Mil</td>
<td>1.276</td>
</tr>
</tbody>
</table>

Correlation value improved to 0.710, which shows providing constants for smaller cities is effective in predicting the average travel time to work. The R-squared of 0.505 is the largest these models have achieved so far, which is probably a moderate performance. The improvement
of SC7 performance based on the scatter gram and the discrepancy charts shows both improvement and deterioration. The percentage chart shows slight improvement as compared to SC5 but the range of errors in the discrepancy chart has increased to 6 minutes. In any case, SC7 is performance is unacceptable.

Figure 3.20 SC7 model average home to work trip travel time differences
The last 7 models showed that size specific constants have direct effect on the performance of the model but they were unable to produce well performing models. The analysis of model SC3 showed that density is a potential variable for a descriptive model of average travel time to work. However, the linear models showed inability to produce appropriate prediction power. This observation led the model development process to examine the non-linear relationship among the variables. Tests on non-linear constructs with the benefits of linear model knowledge of potential variables resulted in model SC8. The separation of cities at 4 million population proved to be effective except for Washington D.C, which presented a specific challenge for modeling. Hence, the model includes a constant for Washington D.C. The final results of the non-linear tests is shown in model SC8. The estimation results and performance information are provided in Table 3.11 and Figures 3.22 to 3.24.
Table 3.11 Model SC8 estimation result

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Average Trip Length (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>40</td>
</tr>
<tr>
<td>R-square</td>
<td>0.837</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Estimated Coefficient</th>
<th>t stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>if population &lt; 4 Million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>20.500</td>
<td>22.3793</td>
</tr>
<tr>
<td>PopulationMillion</td>
<td>2.000</td>
<td>4.179157</td>
</tr>
<tr>
<td>if population &gt;= 4 Million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PopulationMillion^1.2</td>
<td>0.200</td>
<td>3.170071</td>
</tr>
<tr>
<td>Density^0.03</td>
<td>28.000</td>
<td>30.26754</td>
</tr>
</tbody>
</table>

Figure 3.22 SC8 Model versus actual average home to work trip travel time
Correlation value of 0.914 between observed trip times and estimated ones is very high.

The resulting R-squared of 0.837 is in the acceptable range of creating proper performance.

The performance of SC8 based on the scatter gram and the discrepancy charts has drastically improved from linear models and the range of differences has decreased to less than 3 minutes and 15%.

Figure 3.23 SC8 model average home to work trip travel time differences
The distribution of error size is shown in Table 3.11. More than 75% of the observation points have less than 2 minutes error. With the average home to work time of 26.2 minutes, this is merely 7.6% error. Table 3.12 summarizes NHTS 2009 observed, SC8 model estimated, and the difference for average home to work travel times by MSA. The overall averages are virtually the same and equal to 26.2 minutes. The largest model estimated error is -3.25 minutes for Oklahoma City. The average of absolute estimation error is 1.3 minutes.

The distribution of error size is shown in Table 3.11. More than 75% of the observation points have less than 2 minutes error. With the average home to work time of 26.2 minutes, this is merely 7.6% error. Table 3.12 summarizes NHTS 2009 observed, SC8 model estimated, and the difference for average home to work travel times by MSA. The overall averages are virtually the same and equal to 26.2 minutes. The largest model estimated error is -3.25 minutes for Oklahoma City. The average of absolute estimation error is 1.3 minutes.

Table 3.12 Frequency distribution of error for model SC8

<table>
<thead>
<tr>
<th>Absolute Error</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1 min</td>
<td>16</td>
<td>40%</td>
</tr>
<tr>
<td>1 to 2 min</td>
<td>14</td>
<td>35%</td>
</tr>
<tr>
<td>2 to 3 min</td>
<td>9</td>
<td>23%</td>
</tr>
<tr>
<td>3 to 4 min</td>
<td>1</td>
<td>3%</td>
</tr>
<tr>
<td>total</td>
<td>40</td>
<td>100%</td>
</tr>
</tbody>
</table>
Having reached to an acceptable performance level for SC8 model, the next step is to validate the model with independent data.

Table 3.13 NHTS 2009 observed, and SC8 model estimated average Home to Work travel times in minutes by MSA

<table>
<thead>
<tr>
<th>No.</th>
<th>MSA</th>
<th>Observed-NHTS</th>
<th>Model -SC8</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Atlanta, GA</td>
<td>29.24</td>
<td>30.52</td>
<td>1.28</td>
</tr>
<tr>
<td>2</td>
<td>Austin-San Marcos, TX</td>
<td>23.93</td>
<td>23.59</td>
<td>-0.35</td>
</tr>
<tr>
<td>3</td>
<td>Boston--Worcester--Lawrence, MA--NH--ME--CT</td>
<td>29.61</td>
<td>30.45</td>
<td>0.84</td>
</tr>
<tr>
<td>4</td>
<td>Charlotte--Gastonia--Rock Hill, NC--SC</td>
<td>24.02</td>
<td>24.88</td>
<td>0.87</td>
</tr>
<tr>
<td>5</td>
<td>Chicago--Gary--Kenosha, IL--IN--WI</td>
<td>31.23</td>
<td>33.10</td>
<td>1.87</td>
</tr>
<tr>
<td>6</td>
<td>Cincinnati--Hamilton, OH--KY--IN</td>
<td>24.76</td>
<td>22.78</td>
<td>-1.98</td>
</tr>
<tr>
<td>7</td>
<td>Cleveland--Akron, OH</td>
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</tr>
<tr>
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<td>Columbus, OH</td>
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</tr>
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<td>Dallas--Fort Worth, TX</td>
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<td>27.81</td>
<td>-1.89</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>13</td>
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</tr>
<tr>
<td>14</td>
<td>Jacksonville, FL</td>
<td>23.19</td>
<td>26.01</td>
<td>2.82</td>
</tr>
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<td>-2.26</td>
</tr>
<tr>
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<td>22.86</td>
<td>-0.27</td>
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<tr>
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<td>Miami--Fort Lauderdale, FL</td>
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<td>30.81</td>
<td>1.02</td>
</tr>
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<td>-2.04</td>
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<tr>
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<td>24.78</td>
<td>1.10</td>
</tr>
<tr>
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<td>New York--Northern New Jersey--Long Island, NY--NJ--CT--PA</td>
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<td>1.11</td>
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<td>23</td>
<td>Norfolk--Virginia Beach--New port New s, VA--NC</td>
<td>23.84</td>
<td>25.70</td>
<td>1.86</td>
</tr>
<tr>
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<td>19.76</td>
<td>-3.25</td>
</tr>
<tr>
<td>25</td>
<td>Philadelphia--Wilmington--Atlantic City, PA--NJ--DE--MD</td>
<td>30.07</td>
<td>28.25</td>
<td>-1.82</td>
</tr>
<tr>
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<td>Phoenix--Mesa, AZ</td>
<td>28.24</td>
<td>25.93</td>
<td>-2.32</td>
</tr>
<tr>
<td>27</td>
<td>Pittsburgh, PA</td>
<td>25.21</td>
<td>27.74</td>
<td>2.52</td>
</tr>
<tr>
<td>28</td>
<td>Portland-- Salem, OR--WA</td>
<td>24.95</td>
<td>24.32</td>
<td>-0.63</td>
</tr>
<tr>
<td>29</td>
<td>Providence--Fall River--Warwick, RI--MA</td>
<td>23.70</td>
<td>26.69</td>
<td>2.99</td>
</tr>
<tr>
<td>30</td>
<td>Raleigh--Durham--Chapel Hill, NC</td>
<td>22.76</td>
<td>24.94</td>
<td>2.18</td>
</tr>
<tr>
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<td>Rochester, NY</td>
<td>22.61</td>
<td>20.57</td>
<td>-2.03</td>
</tr>
<tr>
<td>32</td>
<td>Sacramento--Yolo, CA</td>
<td>24.80</td>
<td>25.80</td>
<td>1.00</td>
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<tr>
<td>33</td>
<td>Salt Lake City--Ogden, UT</td>
<td>22.75</td>
<td>24.43</td>
<td>1.69</td>
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<tr>
<td>34</td>
<td>San Antonio, TX</td>
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<td>25.40</td>
<td>0.61</td>
</tr>
<tr>
<td>35</td>
<td>San Diego, CA</td>
<td>26.69</td>
<td>25.77</td>
<td>-0.92</td>
</tr>
<tr>
<td>36</td>
<td>San Francisco--Oakland--San Jose, CA</td>
<td>29.79</td>
<td>28.43</td>
<td>-1.36</td>
</tr>
<tr>
<td>37</td>
<td>Seattle--Tacoma--Bremerton, WA</td>
<td>27.38</td>
<td>28.17</td>
<td>0.79</td>
</tr>
<tr>
<td>38</td>
<td>St. Louis, MO--IL</td>
<td>26.13</td>
<td>27.87</td>
<td>1.75</td>
</tr>
<tr>
<td>39</td>
<td>Tampa--St. Petersburg--Clearwater, FL</td>
<td>26.07</td>
<td>24.71</td>
<td>-1.36</td>
</tr>
<tr>
<td>40</td>
<td>Washington--Baltimore, DC--MD--VA--WV</td>
<td>38.01</td>
<td>38.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td><strong>26.21</strong></td>
<td><strong>26.26</strong></td>
<td><strong>0.05</strong></td>
</tr>
</tbody>
</table>

52
3.7 Model Validation

To perform a validation on a model, new observation data needs to be constructed. The new observation data can be extracted from ACS/CTPP data sets and compared to the model estimated values. Validation test shows the real predictability of the model because the new observed data is not used in the model estimation process. Since the validation data is from a different source than NHTS 2009, there may be differences stemming from the data collection method, design, and other factors. Figure 3.25 shows the differences between two observed data sources of NHTS and ACS. As the graph shows, the discrepancy between the two datasets is almost entirely within 4 minutes with ACS showing almost consistently higher values than NHTS.

![Figure 3.25 Comparison of observed average home to work travel time from NHTS and ACS](image)

Table 3.14 summarizes the comparison between the two observed data sources. The two data sources report fairly similar values for the average home to work travel time. All NHTS
values fall within a 4-minute band of ACS travel times. The R-square of 0.76 indicates an imperfect relationship between the two sources.

Table 3.14 Comparison of average home to work travel time based on NHTS and ACS

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Observations</td>
<td>40</td>
</tr>
<tr>
<td>Average_ACS (min)</td>
<td>27.47</td>
</tr>
<tr>
<td>Average_NHTS (min)</td>
<td>26.23</td>
</tr>
<tr>
<td>R-Square</td>
<td>0.76</td>
</tr>
<tr>
<td>Correlation</td>
<td>0.87</td>
</tr>
</tbody>
</table>

To conduct the validation for the model, average home to work travel times, population, and land area were assembled together from Census Bureau website. 58 MSAs with more than 750,000 population were selected for the validation test. Figure 3.26 shows the validation comparison result on a graph. Table 3.15 summarizes the comparison measures between ACS home to work average travel times and SC8 model estimated values. Correlation value of 0.76 suggests that SC8 model estimated values are fairly well correlated to the ACS extracted data, considering that the two observed sources have a correlation of 0.87. Model estimated travel times of 11 out of 58 points fall out of 4 minute band from ACS values. According to this test, more than 80% of times, SC8 model estimates an average travel time to work for an MSA with less than 4 minutes error. Table 3.16 includes a complete table of the validation points.
Figure 3.26 Comparison of observed average home to work travel time from SC8 model and ACS

Table 3.15 Comparison of average home to work travel time based on SC8 model and ACS

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Observations</td>
<td>58</td>
</tr>
<tr>
<td>Average H-W from ACS (min)</td>
<td>27.11</td>
</tr>
<tr>
<td>Average H-W from CS8 Model (min)</td>
<td>24.81</td>
</tr>
<tr>
<td>R-square</td>
<td>0.58</td>
</tr>
<tr>
<td>Correlation</td>
<td>0.76</td>
</tr>
</tbody>
</table>
Table 3.16 Observed and estimated commute time for validation MSAs

<table>
<thead>
<tr>
<th>No.</th>
<th>MSA</th>
<th>Pop2010</th>
<th>Area (Mile²)</th>
<th>ACS0711(min)</th>
<th>SC8(min)</th>
<th>Error(min)</th>
<th>Error%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Albany-Schenectady-Troy, NY Metro Area</td>
<td>870,716</td>
<td>2844</td>
<td>24.13</td>
<td>22.24</td>
<td>-1.89</td>
<td>-8%</td>
</tr>
<tr>
<td>2</td>
<td>Albuquerque, NM Metro Area</td>
<td>887,077</td>
<td>9391</td>
<td>25.54</td>
<td>22.27</td>
<td>-3.27</td>
<td>-13%</td>
</tr>
<tr>
<td>3</td>
<td>Allentown-Bethlehem-Easton, PA-NJ Metro Area</td>
<td>821,173</td>
<td>1470</td>
<td>28.83</td>
<td>22.14</td>
<td>-6.68</td>
<td>-23%</td>
</tr>
<tr>
<td>4</td>
<td>Atlanta-Sandy Springs-Marietta, GA Metro Area</td>
<td>5,268,860</td>
<td>8436</td>
<td>32.72</td>
<td>29.08</td>
<td>-3.64</td>
<td>-11%</td>
</tr>
<tr>
<td>5</td>
<td>Austin-Round Rock-San Marcos, TX Metro Area</td>
<td>1,716,289</td>
<td>4269</td>
<td>27.33</td>
<td>23.93</td>
<td>-3.40</td>
<td>-12%</td>
</tr>
<tr>
<td>6</td>
<td>Bakersfield-Delano, CA Metro Area</td>
<td>839,631</td>
<td>8227</td>
<td>24.86</td>
<td>22.18</td>
<td>-2.68</td>
<td>-11%</td>
</tr>
<tr>
<td>7</td>
<td>Baltimore-Towson, MD Metro Area</td>
<td>2,710,489</td>
<td>2632</td>
<td>31.90</td>
<td>25.92</td>
<td>-5.98</td>
<td>-21%</td>
</tr>
<tr>
<td>8</td>
<td>Baton Rouge, LA Metro Area</td>
<td>802,484</td>
<td>4074</td>
<td>28.03</td>
<td>22.10</td>
<td>-5.92</td>
<td>-21%</td>
</tr>
<tr>
<td>9</td>
<td>Birmingham-Hoover, AL Metro Area</td>
<td>1,128,047</td>
<td>5341</td>
<td>28.11</td>
<td>22.76</td>
<td>-5.36</td>
<td>-19%</td>
</tr>
<tr>
<td>10</td>
<td>Boston-Cambridge-Quincy, MA-NH Metro Area</td>
<td>4,552,402</td>
<td>3528</td>
<td>31.17</td>
<td>29.45</td>
<td>-1.72</td>
<td>-6%</td>
</tr>
<tr>
<td>11</td>
<td>Bridgeport-Stamford-Norwalk, CT Metro Area</td>
<td>916,829</td>
<td>632</td>
<td>29.99</td>
<td>22.33</td>
<td>-7.65</td>
<td>-26%</td>
</tr>
<tr>
<td>12</td>
<td>Buffalo-Niagara Falls, NY Metro Area</td>
<td>1,135,509</td>
<td>1583</td>
<td>22.79</td>
<td>22.77</td>
<td>-0.02</td>
<td>0%</td>
</tr>
<tr>
<td>13</td>
<td>Charlotte-Gastonia-Rock Hill, NC-SC Metro Area</td>
<td>1,758,038</td>
<td>3121</td>
<td>26.98</td>
<td>24.02</td>
<td>-2.96</td>
<td>-11%</td>
</tr>
<tr>
<td>14</td>
<td>Chicago-Joliet-Naperville, IL-IN-WI Metro Area</td>
<td>9,461,105</td>
<td>7281</td>
<td>33.39</td>
<td>31.19</td>
<td>-2.20</td>
<td>-7%</td>
</tr>
<tr>
<td>15</td>
<td>Cincinnati-Middletown, OH-KY-IN Metro Area</td>
<td>2,130,151</td>
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<td>25.94</td>
<td>24.76</td>
<td>-1.18</td>
<td>-5%</td>
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<tr>
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<td>26.12</td>
<td>24.65</td>
<td>-1.47</td>
<td>-6%</td>
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<td>Columbia, SC Metro Area</td>
<td>767,598</td>
<td>3746</td>
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<td>22.04</td>
<td>-3.22</td>
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<td>Columbus, OH Metro Area</td>
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<td>24.74</td>
<td>24.17</td>
<td>-0.56</td>
<td>-2%</td>
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<td>Dallas-Fort Worth-Arlington, TX Metro Area</td>
<td>6,371,773</td>
<td>9032</td>
<td>28.84</td>
<td>29.55</td>
<td>0.72</td>
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<td>1726</td>
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<td>22.18</td>
<td>-0.65</td>
<td>-3%</td>
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<tr>
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<td>Denver-Aurora-Broomfield, CO Metro Area</td>
<td>2,543,482</td>
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<td>25.59</td>
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<td>29.22</td>
<td>1.01</td>
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<td>774,160</td>
<td>2817</td>
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<td>608</td>
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<td>29.36</td>
<td>-1.08</td>
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<td>1,756,241</td>
<td>3900</td>
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<td>24.01</td>
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<td>-8%</td>
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<td>1,345,596</td>
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<td>-15%</td>
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<tr>
<td></td>
<td>Metropolitan Division</td>
<td>Population</td>
<td>Total Sales</td>
<td>Sales per Capita</td>
<td>Percent Change</td>
<td>Percent Change</td>
<td>Percent Change</td>
</tr>
<tr>
<td>---</td>
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<td>24.40</td>
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<td>-7%</td>
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<td>Los Angeles-Long Beach-Santa Ana, CA Metro Area</td>
<td>12,828,837</td>
<td>4905</td>
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<td>33.09</td>
<td>2.29</td>
<td>7%</td>
</tr>
<tr>
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<td>Louisville/Jefferson County, KY-IN Metro Area</td>
<td>1,283,566</td>
<td>4159</td>
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<td>23.07</td>
<td>-2.21</td>
<td>-9%</td>
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<td>McAllen-Edinburg-Mission, TX Metro Area</td>
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<td>1589</td>
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<td>22.05</td>
<td>-0.58</td>
<td>-3%</td>
</tr>
<tr>
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<td>4631</td>
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<td>23.13</td>
<td>-2.60</td>
<td>-10%</td>
</tr>
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<td>5,564,635</td>
<td>5137</td>
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<td>-0.07</td>
<td>0%</td>
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<td>1472</td>
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<td>23.61</td>
<td>-0.70</td>
<td>-3%</td>
</tr>
<tr>
<td>39</td>
<td>Minneapolis-St. Paul-Bloomington, MN-WI Metro Area</td>
<td>3,279,833</td>
<td>6098</td>
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<td>27.06</td>
<td>0.54</td>
<td>2%</td>
</tr>
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<td>Nashville-Davidson--Murfreesboro--Franklin, TN Metro Area</td>
<td>1,589,934</td>
<td>5755</td>
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<td>23.68</td>
<td>-4.28</td>
<td>-15%</td>
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<td>862,477</td>
<td>612</td>
<td>25.87</td>
<td>22.22</td>
<td>-3.64</td>
<td>-14%</td>
</tr>
<tr>
<td>42</td>
<td>New Orleans-Metairie-Kenner, LA Metro Area</td>
<td>1,167,764</td>
<td>2995</td>
<td>27.30</td>
<td>22.84</td>
<td>-4.46</td>
<td>-16%</td>
</tr>
<tr>
<td>43</td>
<td>New York-Northern New Jersey-Long Island, NY-NJ-PA Metro Area</td>
<td>18,897,109</td>
<td>6765</td>
<td>37.17</td>
<td>35.68</td>
<td>-1.49</td>
<td>-4%</td>
</tr>
<tr>
<td>44</td>
<td>Oklahoma City, OK Metro Area</td>
<td>1,252,987</td>
<td>5576</td>
<td>23.36</td>
<td>23.01</td>
<td>-0.35</td>
<td>-2%</td>
</tr>
<tr>
<td>45</td>
<td>Omaha-Council Bluffs, NE-IA Metro Area</td>
<td>865,350</td>
<td>4401</td>
<td>21.60</td>
<td>22.23</td>
<td>0.63</td>
<td>3%</td>
</tr>
<tr>
<td>46</td>
<td>Orlando-Kissimmee-Sanford, FL Metro Area</td>
<td>2,134,411</td>
<td>3519</td>
<td>28.71</td>
<td>24.77</td>
<td>-3.94</td>
<td>-14%</td>
</tr>
<tr>
<td>47</td>
<td>Oxnard-Thousand Oaks-Ventura, CA Metro Area</td>
<td>823,318</td>
<td>1865</td>
<td>27.18</td>
<td>22.15</td>
<td>-5.03</td>
<td>-19%</td>
</tr>
<tr>
<td>48</td>
<td>Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area</td>
<td>5,965,343</td>
<td>4656</td>
<td>30.40</td>
<td>29.91</td>
<td>-0.49</td>
<td>-2%</td>
</tr>
<tr>
<td>49</td>
<td>Phoenix-Mesa-Scottsdale, AZ Metro Area</td>
<td>4,192,887</td>
<td>14736</td>
<td>28.21</td>
<td>28.08</td>
<td>-0.13</td>
<td>0%</td>
</tr>
<tr>
<td>50</td>
<td>Pittsburgh, PA Metro Area</td>
<td>2,356,285</td>
<td>5343</td>
<td>27.52</td>
<td>25.21</td>
<td>-2.31</td>
<td>-8%</td>
</tr>
<tr>
<td>51</td>
<td>Portland-Vancouver-Hillsboro, OR-WA Metro Area</td>
<td>2,256,009</td>
<td>6762</td>
<td>26.89</td>
<td>24.95</td>
<td>-1.93</td>
<td>-7%</td>
</tr>
<tr>
<td>52</td>
<td>Providence-New Bedford-Fall River, RI-MA Metro Area</td>
<td>1,600,852</td>
<td>1605</td>
<td>26.10</td>
<td>23.70</td>
<td>-2.40</td>
<td>-9%</td>
</tr>
<tr>
<td>53</td>
<td>Raleigh-Cary, NC Metro Area</td>
<td>1,130,490</td>
<td>2143</td>
<td>26.54</td>
<td>22.76</td>
<td>-3.78</td>
<td>-14%</td>
</tr>
<tr>
<td>54</td>
<td>Richmond, VA Metro Area</td>
<td>1,258,251</td>
<td>5752</td>
<td>26.32</td>
<td>23.02</td>
<td>-3.30</td>
<td>-13%</td>
</tr>
<tr>
<td>55</td>
<td>Riverside-San Bernardino-Ontario, CA Metro Area</td>
<td>4,224,851</td>
<td>27583</td>
<td>32.43</td>
<td>27.59</td>
<td>-4.84</td>
<td>-15%</td>
</tr>
<tr>
<td>56</td>
<td>Rochester, NY Metro Area</td>
<td>1,054,323</td>
<td>2962</td>
<td>22.57</td>
<td>22.61</td>
<td>0.04</td>
<td>0%</td>
</tr>
<tr>
<td>57</td>
<td>Sacramento--Arden-Arcade--Roseville, CA Metro Area</td>
<td>2,149,127</td>
<td>5154</td>
<td>27.41</td>
<td>24.80</td>
<td>-2.61</td>
<td>-10%</td>
</tr>
<tr>
<td>58</td>
<td>St. Louis, MO-IL Metro Area</td>
<td>2,812,896</td>
<td>8724</td>
<td>26.85</td>
<td>26.13</td>
<td>-0.72</td>
<td>-3%</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>2,665,648</td>
<td>4984</td>
<td>27.11</td>
<td>24.81</td>
<td>-2.31</td>
<td>-9%</td>
</tr>
</tbody>
</table>

Table 3.16 Continued
CHAPTER 4

CONCLUSION

4.1 Research Findings

The premise of this study was based on finding a simple relationship between home to work average travel time and aggregate characteristics of a large region. Large region is defined as metropolitan areas with more than 750,000 population and aggregate characteristics are population and land area of the region.

The study found the following formula, relating the commute time to population and area of a region:

If population < 4,000,000 then

\[ \text{Commute time} = 20.5 + 2.0 \times \left( \frac{\text{population}}{1,000,000} \right) \]

If population \( \geq \) 4,000,000 then

\[ \text{Commute time} = 0.2 \times \left( \frac{\text{population}}{1,000,000} \right)^{1.2} + 28 \times \left( \frac{\text{population}}{1000 \times \text{land area}} \right)^{0.03} \]

In this formula, the commute time is in minute and land area is in sq. miles.

The performance of this relationship based on the estimation stage reported 0.9 correlation between estimated and observed values and no more than 3 minutes discrepancy for each individual city. The validation process based on independent data source showed correlation of 0.76 between observed and estimated commute times, even though the two sources of observed data had their own differences. The estimation observed data was from NHTS and the validation data was obtained from ACS.

The estimation performance and validation results suggest accepting the hypothesis of this research that the average home to work travel time can be approximated with aggregate
characteristics of the region, which are population and land area. The relationship is quiet simple and for a large majority of metropolitan areas, which are less than 4,000,000 population, is linear. For very large metropolitan areas, the relationship becomes non-linear and includes both population and density.

4.2 Discussions

The study showed that the average commute travel time in metropolitan areas increases as population grows but the rate of increase is between 0.25 to 0.5 minutes for each increment of 500,000 increase in population assuming the land area of metropolitan city stays the same.

The land area is negatively correlated to commute time for very large metropolitan cities, which have more than 4 million population. As the land area increases, assuming the population stays the same, the commute time deceases.

Figures 4.1 and 4.2 show the effect of increase in population keeping the land area at 3000 sq. mile for very large metropolitan areas. For metropolitan cities with population between 750,000 and 4 million, the relationship of commute time and population is linear. For each 100,000 population increase, the commute time increases 0.2 minutes. For very large metropolitan areas, the relationship of population and commute time is exponential but it appears that it can be approximated with linear relation, as the curve in the Figure 4.2 seems very close to linear. For every 500,000 population increase, the commute travel time increases about 0.25 minutes but it ranges from 0.23 to 0.26 minutes.

Figure 4.3 shows the effect of increase in land area, keeping the population the same as 5,000,000, as an example of a very large metropolitan cities. The effect of land area increase is negative but rather small. For a metropolitan area with the population of 5,000,000, if the area increases from 5000 to 6000 sq. miles, the commute time decreases 0.15 minutes.

The relative significance of the first and second term of formula for very large metropolitan cities can be investigated through values estimated from the validation data.
Figure 4.1 Population and commute time relation for metropolitans with population between 750,000 and 4,000,000

Figure 4.2 Population and commute time relation for very large metropolitans with more than 4,000,000 population
The average commute travel time for the 12 very large cities in the validation data is 30.2 minutes. For these cities, the average value calculated from the first term of the equation is 2.2 minutes, which is 7% of the value. This ratio means the average commute time in a region can be 7% explained through population and 93% through density on average. Figure 4.4 depicts the average commute time based on its population and density components for very large metropolitan areas. The significance of the population component is clearly higher is the three largest metropolitan areas of New York, Los Angeles, and Chicago with the average of 14%. Table 4.1 contains the values of the population and density components for 12 metropolitan areas with more than 4,000,000 population.
Figure 4.4 Population and density component values of the estimated average commute time for metropolitan areas with more than 4,000,000 population

Table 4.1 Values of population and density terms of the commute time formula for metropolitan areas with more than 4,000,000 population

<table>
<thead>
<tr>
<th>MSA</th>
<th>HW Est. (min)</th>
<th>Pop Component</th>
<th>Density Comp</th>
<th>Pop Component</th>
<th>Density Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York-Northern New Jersey-Long Island, NY-NJ-PA Metro Area</td>
<td>35.7</td>
<td>6.8</td>
<td>28.9</td>
<td>19%</td>
<td>81%</td>
</tr>
<tr>
<td>Los Angeles-Long Beach-Santa Ana, CA Metro Area</td>
<td>33.1</td>
<td>4.3</td>
<td>28.8</td>
<td>13%</td>
<td>87%</td>
</tr>
<tr>
<td>Chicago-Joliet-Naperville, IL-IN-WI Metro Area</td>
<td>31.2</td>
<td>3.0</td>
<td>28.2</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area</td>
<td>29.9</td>
<td>1.7</td>
<td>28.1</td>
<td>6%</td>
<td>94%</td>
</tr>
<tr>
<td>Miami-Fort Lauderdale-Pompano Beach, FL Metro Area</td>
<td>29.6</td>
<td>1.6</td>
<td>28.1</td>
<td>5%</td>
<td>95%</td>
</tr>
<tr>
<td>Dallas-Fort Worth-Arlington, TX Metro Area</td>
<td>29.6</td>
<td>1.8</td>
<td>27.8</td>
<td>6%</td>
<td>94%</td>
</tr>
<tr>
<td>Boston-Cambridge-Quincy, MA-NH Metro Area</td>
<td>29.4</td>
<td>1.2</td>
<td>28.2</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Houston-Sugar Land-Baytown, TX Metro Area</td>
<td>29.4</td>
<td>1.7</td>
<td>27.7</td>
<td>6%</td>
<td>94%</td>
</tr>
<tr>
<td>Detroit-Warren-Ulvonia, MI Metro Area</td>
<td>29.2</td>
<td>1.2</td>
<td>28.1</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Atlanta-Sandy Springs-Marietta, GA Metro Area</td>
<td>29.1</td>
<td>1.5</td>
<td>27.6</td>
<td>5%</td>
<td>95%</td>
</tr>
<tr>
<td>Phoenix-Mesa-Glendale, AZ Metro Area</td>
<td>28.1</td>
<td>1.1</td>
<td>27.0</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Riverside-San Bernardino-Ontario, CA Metro Area</td>
<td>27.8</td>
<td>1.1</td>
<td>26.7</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Average</td>
<td>30.2</td>
<td>2.2</td>
<td>27.9</td>
<td>7%</td>
<td>93%</td>
</tr>
</tbody>
</table>
4.3 Application Example

This section shows a hypothetical application of the developed model to analyze a planning policy goal in a very large metropolitan area with more than 4,000,000 population.

The metropolitan statistical area of Phoenix, Arizona has a very low population density of 0.44 person per Acre, according to Census 2010. To decrease the traffic and congestion on roadway system, it seems reasonable to increase the population density in the area as a growth policy. It is not clear how this goal can be achieved but the Phoenix MSA is so large that even without any specific new policy, there are plenty of available land to almost double the population. According to 2010 census, the population of the MSA is 4.1 million. If the population of the area increases to 8.4 million within the same land area, the density will increase to 0.89 person per Acre. In this density, the population is still fairly dispersed and the urban form is similar to Atlanta, Georgia in 2010. Using the developed formula, the average commute trip in the Phoenix area with more than double density and population, would increase to 30 minutes from 28 minutes. Table 4.2 contains various density and average commute travel times for the Phoenix area.

Table 4.2 Commute travel times for various population density scenarios for Phoenix area

<table>
<thead>
<tr>
<th>Density (pop/acre)</th>
<th>Area (Acre)</th>
<th>Population</th>
<th>Commute Time(min)</th>
<th>% Change in Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.44</td>
<td>9,431,282</td>
<td>4,192,887</td>
<td>28.1</td>
<td>0%</td>
</tr>
<tr>
<td>0.49</td>
<td>9,431,282</td>
<td>4,664,451</td>
<td>28.3</td>
<td>11%</td>
</tr>
<tr>
<td>0.54</td>
<td>9,431,282</td>
<td>5,136,015</td>
<td>28.6</td>
<td>22%</td>
</tr>
<tr>
<td>0.59</td>
<td>9,431,282</td>
<td>5,607,579</td>
<td>28.8</td>
<td>34%</td>
</tr>
<tr>
<td>0.64</td>
<td>9,431,282</td>
<td>6,079,143</td>
<td>29.0</td>
<td>45%</td>
</tr>
<tr>
<td>0.69</td>
<td>9,431,282</td>
<td>6,550,708</td>
<td>29.2</td>
<td>56%</td>
</tr>
<tr>
<td>0.74</td>
<td>9,431,282</td>
<td>7,022,272</td>
<td>29.5</td>
<td>67%</td>
</tr>
<tr>
<td>0.79</td>
<td>9,431,282</td>
<td>7,493,836</td>
<td>29.7</td>
<td>79%</td>
</tr>
<tr>
<td>0.84</td>
<td>9,431,282</td>
<td>7,965,400</td>
<td>29.9</td>
<td>90%</td>
</tr>
<tr>
<td>0.89</td>
<td>9,431,282</td>
<td>8,436,964</td>
<td>30.1</td>
<td>101%</td>
</tr>
</tbody>
</table>
This result may seem unexpected since increasing population density has not decreased the commute time. There is some validity in this expectation because increasing density usually is accompanied with other development policies that have connection to transportation such as increasing the public transportation, encouraging mixed use developments, or introducing toll roads. Yet, the experience of the implemented policies in other cities has not directly shown that change in density can drastically change the commute travel time. To illustrate this point, Table 4.3 contains the information of Dallas Fort Worth and Phoenix side-by-side. In this table, Dallas Fort Worth is used as an example of the implemented past policies of growth in the Midwest of the United States because it has similar lack of land area restriction for development. Other larger than Phoenix metropolitan areas with similar geographical characteristics, such as Atlanta, GA, would offer the same conclusion.

<table>
<thead>
<tr>
<th>MSA</th>
<th>Phoenix, AZ MSA</th>
<th>Dallas Fort Worth, TX MSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population 2010</td>
<td>4,192,887</td>
<td>6,371,773</td>
</tr>
<tr>
<td>Area 2010 (sq. mile)</td>
<td>14,736</td>
<td>9,032</td>
</tr>
<tr>
<td>Area 2010 (Acre)</td>
<td>9,431,282</td>
<td>5,780,531</td>
</tr>
<tr>
<td>Density (pop/Acre)</td>
<td>0.44</td>
<td>1.10</td>
</tr>
<tr>
<td>Obs. HW Travel Time_ACS (min)</td>
<td>28.2</td>
<td>28.8</td>
</tr>
<tr>
<td>Est. HW Travel Time (min)</td>
<td>28.1</td>
<td>29.6</td>
</tr>
</tbody>
</table>

If the future of Phoenix can be similar to Dallas Fort Worth, the average home to work travel time would be around 29 minutes base on ACS data. As table 4.2 shows, the model also estimated 29 minutes for 6.5 million population of Phoenix. This implies that the model estimation is relevant if similar land use and growth policies that led to the growth of Dallas Fort Worth are implemented in Phoenix area.

The proposed model is based on previous experiences and is not aware of new innovation that can happen in future. Therefore, it is possible to be wrong, but it is still very
useful because informs the policy makers of the effects of experienced policies based on observed data. Basically, one can conclude that if the goal is to bring down the average commute travel time through aggressive policy of doubling the population density in Phoenix, the goal will not materialize through following the growth strategies that were applied in Dallas Fort Worth. These strategies are probably very similar to what Phoenix policy makers has applied.

### 4.4 Future Research

The product of this research is able to provide an estimate for average commute travel time for large metropolitan areas based on very basic knowledge of a city, which are population and land area. Population and land area are available from Census Bureau web site for all MSAs in the U.S. For forecasting purposes, population and land area are high level numbers for regions that can be provided through various forecast methods. This research provided a simple and intuitive method for converting those data in to commute travel time. There are several paths for continuation of this research.

The average value of commute time can become much more useful if it accompanied by the frequency distribution of commute time values. An estimate of commute time distribution is available from ACS and CTPP data. At the early stages of this search, development of a generic frequency distribution for commute time was also considered but was not included in this work due to time limitation. The early investigation of the distribution of commute time for various travel times in minutes for 10 cities showed the potential for development of a normalized frequency distribution based on population or average commute time. It is conceivable to develop a generic distribution form or function for commute travel time. Such an effort, increases the applicability of this research in land use models as it can be directly applied for geographical allocation of residents and employments.

The average commute time can also be estimated for different population groups. Even though average commute value for all population group is very useful in describing the urban
form, it is not useful in describing what various groups of population experience in their commute. Many planning studies have much more focused scope than the whole population, such as commute time by gender, race, ethnicity, income, or education. This data is also available from public sources.

This researched limited its focus on large metropolitan areas. The data for cities with population less than 750,000 is also available from ACS. Similar methodology can be used to develop a simple model.

A more fundamental research can be done to improve the data sources of this research for calculation of the land area for an MSA. The definition on MSA is fairly complicated. Some values for population and area seem to be due to political boundaries rather than the urban form. For example, the area of Phoenix MSA is reported to be almost 50 percent larger than Dallas Fort Worth MSA. This is probably due to larger county sizes in Arizona than Texas. While this may not be a huge problem but it can certainly affect the model structure and estimation of coefficients. Use of better data can make the model more relevant and more accurate. The proposed model still performs sufficiently accurate, though.
APPENDIX A

CENSUS SURVEY FORMS
Start Here / Please use a black or blue pen.

1. How many people were living or staying in this house, apartment, or mobile home on April 1, 2000?

<table>
<thead>
<tr>
<th>Number of people</th>
<th>INCLUDE in this number</th>
<th>DO NOT INCLUDE in this number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>special children, roommates, or housemates</td>
<td>college students living away all semester</td>
</tr>
<tr>
<td></td>
<td>residing here on April 1, 2000 who have no other permanent place to stay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>people living here most of the time while working, even if they have another place to live</td>
<td></td>
</tr>
</tbody>
</table>

2. Is this house, apartment, or mobile home —

<table>
<thead>
<tr>
<th>Mark</th>
<th>ONE box</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned by you or someone in this household with a mortgage or loan</td>
<td></td>
</tr>
<tr>
<td>Owned by you or someone in this household and clear without a mortgage or loan</td>
<td></td>
</tr>
<tr>
<td>Rented for cash rent</td>
<td></td>
</tr>
<tr>
<td>Occupied without payment of cash rent</td>
<td></td>
</tr>
</tbody>
</table>

3. Please answer the following questions for each person living in this house, apartment, or mobile home. Start with the name of one of the people living here who were 15 years of age or older. If there is no such person, start with any adult living or staying here. We will refer to this person as Person 1.

<table>
<thead>
<tr>
<th>What is this person's name? Print name below.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last Name</td>
</tr>
</tbody>
</table>

4. What is Person 1's telephone number? We may call this person if we don't understand an answer.

| Area Code | Number |

5. What is Person 1's sex? Male | Female |

6. What is Person 1's age and what is Person 1's date of birth?

<table>
<thead>
<tr>
<th>Age on April 1, 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month</td>
</tr>
</tbody>
</table>

Note: Please answer BOTH Questions 7 and 8.

7. Is Person 1 Spanish/Hispanic/Latino? Mark the "No" box and list one of the people living here who were 15 years of age or older. If no one is Spanish/Hispanic/Latino, list one of the people living here who were 15 years of age or older who is not Spanish/Hispanic/Latino. If no one is either Spanish/Hispanic/Latino or not Spanish/Hispanic/Latino, list one of the people living here who were 15 years of age or older who is another group.

<table>
<thead>
<tr>
<th>Yes, Spanish/Hispanic/Latino</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, Mexican, Mexican Amer., Cuban</td>
</tr>
<tr>
<td>Yes, other Spanish/Hispanic/Latino — Part group</td>
</tr>
</tbody>
</table>

8. What is Person 1's race? Mark one or more races to indicate the race the person considers themselves to be.

| White |
| Black, African Am., or Negro |
| American Indian, Native Hawaiian, Aleut, or Eskimo |
| Asian Indian, Japanese, Korean, Vietnamese, Chinese, or Philippine |
| Other Asian — Print race |
| Other White — Print race |
| Some other race — Print race |

Note: If more people live here, continue with Person 2.
Person 2

1. What is Person 2's name? Print name below.
   Last Name
   First Name

2. How is this person related to Person 1? Mark □ ONE box.
   □ Husband/wife
   □ Natural-born son/daughter
   □ Adopted son/daughter
   □ Stepmother/stepfather
   □ Brother/sister
   □ Father/mother
   □ Grandchild
   □ Parent-in-law
   □ Son-in-law/daughter-in-law
   □ Other relative — Print exact relationship.

3. What is this person’s sex? Mark □ ONE box.
   □ Male
   □ Female

4. What is this person’s age and what is this person’s date of birth?
   Age on April 1, 2000

5. Is this person Spanish/Hispanic/Latino? Mark □ the “No” box if not Spanish/Hispanic/Latino.
   □ Yes, Mexican
   □ Yes, Cuban
   □ Yes, Puerto Rican
   □ Yes, Other Hispanic/Latino — Print group.

6. What is this person’s race? Mark □ one or more races to indicate what this person considers himself/herself to be.
   □ White
   □ Black, African Am., or Negro
   □ American Indian or Alaska Native — Print name of enrolled or principal tribe.
   □ Asian Indian
   □ Japanese
   □ Native Hawaiian
   □ Chinese
   □ Korean
   □ Guamanian or Chamorro
   □ Filipino
   □ Vietnamese
   □ Samoan
   □ Other Asian — Print race
   □ Other Pacific Islander — Print race
   □ Some other race — Print race
   □ Some other race — Print race

   □ If more people live here, continue with Person 3.

Person 3

1. What is Person 3’s name? Print name below.
   Last Name
   First Name

2. How is this person related to Person 1? Mark □ ONE box.
   □ Husband/wife
   □ Natural-born son/daughter
   □ Adopted son/daughter
   □ Stepmother/stepfather
   □ Brother/sister
   □ Father/mother
   □ Grandchild
   □ Parent-in-law
   □ Son-in-law/daughter-in-law
   □ Other relative — Print exact relationship.

3. What is this person’s sex? Mark □ ONE box.
   □ Male
   □ Female

4. What is this person’s age and what is this person’s date of birth?
   Age on April 1, 2000

5. Is this person Spanish/Hispanic/Latino? Mark □ the “No” box if not Spanish/Hispanic/Latino.
   □ Yes, Mexican
   □ Yes, Cuban
   □ Yes, Puerto Rican
   □ Yes, Other Hispanic/Latino — Print group.

6. What is this person’s race? Mark □ one or more races to indicate what this person considers himself/herself to be.
   □ White
   □ Black, African Am., or Negro
   □ American Indian or Alaska Native — Print name of enrolled or principal tribe.
   □ Asian Indian
   □ Japanese
   □ Native Hawaiian
   □ Chinese
   □ Korean
   □ Guamanian or Chamorro
   □ Filipino
   □ Vietnamese
   □ Samoan
   □ Other Asian — Print race
   □ Other Pacific Islander — Print race
   □ Some other race — Print race
   □ Some other race — Print race

   □ If more people live here, continue with Person 4.
<table>
<thead>
<tr>
<th>Person 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. What is Person 4's name?</strong> Print name below.</td>
</tr>
<tr>
<td>First Name</td>
</tr>
<tr>
<td><strong>2. How is this person related to Person 1?</strong> Mark ONE box.</td>
</tr>
<tr>
<td>Husband/wife</td>
</tr>
<tr>
<td>Natural-born son/daughter</td>
</tr>
<tr>
<td>Adopted son/daughter</td>
</tr>
<tr>
<td>Stepson/stepdaughter</td>
</tr>
<tr>
<td>Brother/sister</td>
</tr>
<tr>
<td>Father/mother</td>
</tr>
<tr>
<td>Grandchild</td>
</tr>
<tr>
<td>Parent-in-law</td>
</tr>
<tr>
<td>Son-in-law/daughter-in-law</td>
</tr>
<tr>
<td>Other relative — Print exact relationship.</td>
</tr>
<tr>
<td><strong>3. What is this person's sex?</strong> Mark ONE box.</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td><strong>4. What is this person's age and what is this person's date of birth?</strong></td>
</tr>
<tr>
<td>Age on April 1, 2000</td>
</tr>
<tr>
<td><strong>NOTE:</strong> Please answer BOTH Questions 5 and 6.</td>
</tr>
<tr>
<td><strong>5. Is this person Spanish/Hispanic/Latino?</strong> Mark <strong>No</strong> box if not Spanish/Hispanic/Latino.</td>
</tr>
<tr>
<td>Yes, Puerto Rican</td>
</tr>
<tr>
<td>Yes, Mexican, Mexican Am., Chicano</td>
</tr>
<tr>
<td><strong>6. What is this person's race?</strong> Mark <strong>one or more races</strong> to indicate what this person considers himself/herself to be.</td>
</tr>
<tr>
<td>White</td>
</tr>
<tr>
<td>American Indian or Alaska Native — Print name of enrolled or principal tribe.</td>
</tr>
<tr>
<td>Chinese</td>
</tr>
<tr>
<td>Filipino</td>
</tr>
<tr>
<td>Other Asian — Print race</td>
</tr>
<tr>
<td>Some other race — Print race</td>
</tr>
<tr>
<td><strong>If more people live here, continue with Person 5.</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Person 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. What is Person 5's name?</strong> Print name below.</td>
</tr>
<tr>
<td>First Name</td>
</tr>
<tr>
<td><strong>2. How is this person related to Person 1?</strong> Mark ONE box.</td>
</tr>
<tr>
<td>Husband/wife</td>
</tr>
<tr>
<td>Natural-born son/daughter</td>
</tr>
<tr>
<td>Adopted son/daughter</td>
</tr>
<tr>
<td>Stepson/stepdaughter</td>
</tr>
<tr>
<td>Brother/sister</td>
</tr>
<tr>
<td>Father/mother</td>
</tr>
<tr>
<td>Grandchild</td>
</tr>
<tr>
<td>Parent-in-law</td>
</tr>
<tr>
<td>Son-in-law/daughter-in-law</td>
</tr>
<tr>
<td>Other relative — Print exact relationship.</td>
</tr>
<tr>
<td><strong>3. What is this person's sex?</strong> Mark ONE box.</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td><strong>4. What is this person's age and what is this person's date of birth?</strong></td>
</tr>
<tr>
<td>Age on April 1, 2000</td>
</tr>
<tr>
<td><strong>NOTE:</strong> Please answer BOTH Questions 5 and 6.</td>
</tr>
<tr>
<td><strong>5. Is this person Spanish/Hispanic/Latino?</strong> Mark <strong>No</strong> box if not Spanish/Hispanic/Latino.</td>
</tr>
<tr>
<td>Yes, Puerto Rican</td>
</tr>
<tr>
<td>Yes, Mexican, Mexican Am., Chicano</td>
</tr>
<tr>
<td><strong>6. What is this person's race?</strong> Mark <strong>one or more races</strong> to indicate what this person considers himself/herself to be.</td>
</tr>
<tr>
<td>White</td>
</tr>
<tr>
<td>American Indian or Alaska Native — Print name of enrolled or principal tribe.</td>
</tr>
<tr>
<td>Chinese</td>
</tr>
<tr>
<td>Filipino</td>
</tr>
<tr>
<td>Other Asian — Print race</td>
</tr>
<tr>
<td>Some other race — Print race</td>
</tr>
<tr>
<td><strong>If more people live here, continue with Person 6.</strong></td>
</tr>
</tbody>
</table>
Persons 7 – 12

If you didn’t have room to list everyone who lives in this house or apartment, please list the others below. You may be contacted by the Census Bureau for the same information about these people.

Person 7 — Last Name
First Name
MI

Person 8 — Last Name
First Name
MI

Person 9 — Last Name
First Name
MI

Person 10 — Last Name
First Name
MI

Person 11 — Last Name
First Name
MI

Person 12 — Last Name
First Name
MI

The Census Bureau estimates that, for the average household, this form will take about 10 minutes to complete, including the time for reviewing the instructions and answers. Comments about the estimate should be directed to the Associate Director for Finance and Administration, Attn: Paperwork Reduction Project 090700856, Room 3160, Federal Building 3, Bureau of the Census, Washington, DC 20233.

Respondents are not required to respond to any information collection unless it displays a valid approval number from the Office of Management and Budget.

Thank you for completing your official U.S. Census 2000 form.

The “Informational Copy” shows the content of the United States Census 2000 “short” form questionnaire. Each household will receive either a short form (100 percent questions) or a long form (100 percent and sample questions). The short form questionnaire contains 6 population questions and 1 housing question. On average, about 5 in every 8 households will receive the short form. The content of the forms resulted from reviewing the 1990 census data, consulting with federal and non-federal data users, and conducting tests.

For additional information about Census 2000, visit our website at www.census.gov or write to the Director, Bureau of the Census, Washington, DC 20233.
If you need help completing this form, call 1-800-XXXX-XXXX between 8:00 a.m. and 9:00 p.m., 7 days a week. The telephone call is free.

TDD — Telephone display device for the hearing impaired. Call 1-800-XXXX-XXXX between 8:00 a.m. and 9:00 p.m., 7 days a week. The telephone call is free.

¿NECESITA AYUDA? Si necesita ayuda para completar esta cuestionario llame al 1-800-XXXX-XXXX entre las 8:00 a.m. y las 9:00 p.m., 7 días a la semana. La llamada telefónica es gratuita.
# List of Persons

Please be sure you answered question 1 on the front page before continuing.

Please print the names of all the people who you indicated in question 1 were living or staying here on April 1, 2000.

**Example** — Last Name  
**JOHNSON**  
First Name  
**ROBIN**  
MI

Start with the person, or one of the people living here who owns, is buying, or rents this house, apartment, or mobile home. If there is no such person, start with any adult living or staying here.

**Person 1** — Last Name  
First Name  
MI

**Person 2** — Last Name  
First Name  
MI

**Person 3** — Last Name  
First Name  
MI

**Person 4** — Last Name  
First Name  
MI

**Person 5** — Last Name  
First Name  
MI

**Person 6** — Last Name  
First Name  
MI

**Person 7** — Last Name  
First Name  
MI

**Person 8** — Last Name  
First Name  
MI

**Person 9** — Last Name  
First Name  
MI

**Person 10** — Last Name  
First Name  
MI

**Person 11** — Last Name  
First Name  
MI

**Person 12** — Last Name  
First Name  
MI

Next, answer questions about Person 1.

### FOR OFFICE USE ONLY

A. JIC1  
B. JIC2  
C. JIC3  
D. JIC4
Person 1

Your answers are important! Every person in the Census counts.

What is this person’s name? Print the name of Person 1 from page 2.

Last Name

First Name

What is this person’s telephone number? We may contact this person if we don’t understand an answer.

Area Code + Number

What is this person’s sex? Mark ONE box.

Male

Female

What is this person’s age and what is the person’s date of birth?

Age on April 1, 2000

Print numbers in boxes.

Month

Day

Year of birth

NOTE: Please answer BOTH Questions 5 and 6.

5. Is this person Spanish/Hispanic/Latino? Mark the “No” box if NOT Spanish/Hispanic/Latino.

No, not Spanish/Hispanic/Latino

Yes, Mexican, Mexican American, Chicano

Yes, Puerto Rican

Yes, Cuban

Yes, other Spanish/Hispanic/Latino — Print group.

6. What is this person’s race? Mark one or more races to indicate what this person considers himself/herself to be.

White

Black, African Am., or Negro

American Indian or Alaska Native — Print name of enrolled or principal tribe

Asian Indian

Chinese

Filipino

Japanese

Korean

Vietnamese

Other Asian — Print race

Some other race — Print race

Native Hawaiian

Guamanian or Chamorro

Samoan

Other Pacific Islander — Print race

What is this person’s marital status?

Married

Widowed

Divorced

Separated

Never married

8. At any time since February 1, 2000, has this person attended regular school or college?

Yes, public school, public college

Yes, private school, private college

Question is asked of all persons on the short (100 percent) and long (sample) forms.
Person 1 (continued)

8. What grade or level was this person attending?  
Mark one box:
☐ Nursery school
☐ Kindergarten
☐ Grade 1 to grade 4
☐ Grade 5 to grade 8
☐ Grade 9 to grade 12
☐ College undergraduate years (freshman to senior)
☐ Graduate or professional school (for example: medical, dental, or law school)

9. What is the highest degree or level of school this person has completed?  
Mark one box:
☐ No schooling completed
☐ Nursery school to 4th grade
☐ 5th grade or 6th grade
☐ 7th grade or 8th grade
☐ 9th grade
☐ 10th grade
☐ 11th grade
☐ 12th grade, NO DIPLOMA
☐ HIGH SCHOOL GRADUATE — high school diploma or the equivalent (for example: GED)
☐ Some college credit, but less than 1 year
☐ 1 or more years of college, no degree
☐ Associate degree (for example: AA, AAS)
☐ Bachelor’s degree (for example: BA, AB, BS)
☐ Master’s degree (for example: MA, MEd, MS, MBA)
☐ Professional degree (for example: MD, DDS, DVM, LLB, JD)
☐ Doctorate degree (for example: PhD, EdD)

10. What is this person’s ancestry or ethnic origin?  
(For example: Italian, Jamaican, African American, Cambodian, Cape Verdian, Norwegian, Dominican, French Canadian, Haitian, Korean, Lebanese, Polish, Nigerian, Mexican, Taiwanese, Ukrainian, and so on.)

11. Does this person speak a language other than English at home?  
☐ Yes  
☐ No → Skip to 12

12. What is this language?  
(For example: Korean, Italian, Spanish, Vietnamese)

13. How well does this person speak English?  
☐ Very well  
☐ Well  
☐ Not well  
☐ Not at all

14. Where was this person born?  
☐ In the United States — Print name of state
☐ Outside the United States — Print name of foreign country, or Puerto Rico, Guam, etc.

15. Is this person a CITIZEN of the United States?  
☐ Yes, born in the United States → Skip to 18a  
☐ Yes, born in Puerto Rico, Guam, the U.S. Virgin Islands, or Northern Mariana Islands
☐ Yes, born abroad of American parent or parents
☐ Yes, a U.S. citizen by naturalization
☐ No, not a citizen of the United States

16. When did this person come to live in the United States?  Print numbers in boxes.

17. Did this person live in this house or apartment 5 years ago (on April 1, 1995)?  
☐ Person is under 5 years old → Skip to 32  
☐ Yes, this house → Skip to 16  
☐ No, outside the United States — Print name of foreign country, or Puerto Rico, Guam, etc., below; then skip to 16.

☐ No, different house in the United States
Person 1 (continued)

b. Where did this person live 5 years ago?
Name of city, town, or post office

Did this person live inside the limits of the
city or town?
☐ Yes
☐ No, outside the city/town limits

Name of county

Name of state

ZIP Code

16

Does this person have any of the following
long-lasting conditions:

a. Blindness, deafness, or a severe
vision or hearing impairment? Yes No

b. A condition that substantially limits
one or more basic physical activities
such as walking, climbing stairs,
reaching, lifting, or carrying? Yes No

17

Because of a physical, mental, or emotional
condition lasting 6 months or more, does
this person have any difficulty in doing any
of the following activities:

a. Learning, remembering, or
concentrating? Yes No

b. Dressing, bathing, or getting around
inside the home? Yes No
c. (Answer if this person is 16 YEARS OLD
OR OVER.) Going outside the home
alone to shop or visit a doctor’s office? Yes No
d. (Answer if this person is 16 YEARS OLD
OR OVER.) Working at a job or business? Yes No

18

Was this person under 15 years of age on
April 1, 2000?
☐ Yes → Skip to 33
☐ No

19

a. Does this person have any of his/her own
grandchildren under the age of 18 living in this
house or apartment?
☐ Yes
☐ No → Skip to 20a

b. Is this grandparent currently responsible
for most of the basic needs of any grandchild(ren)
under the age of 18 who live(s) in this house
or apartment?
☐ Yes
☐ No → Skip to 20a

c. How long has this grandparent been responsible
for the(s) grandchild(ren)? If the grandparent is
financially responsible for more than one grandchild, answer
the question for the grandchild for whom the grandparent
has been responsible for the longest period of time.
☐ Less than 6 months
☐ 6 to 11 months
☐ 1 or 2 years
☐ 3 or 4 years
☐ 5 years or more

20a

Has this person ever served on active duty in
the U.S. Armed Forces, military Reserves, or
National Guard? Active duty does not include training
for the Reserves or National Guard, but DOES include
activation, for example, for the Persian Gulf War.

☐ Yes, now on active duty
☐ Yes, on active duty in past, but not now
☐ No, training for Reserves or National
Guard only → Skip to 21
☐ No, never served in the military → Skip to 21

b. When did this person serve on active duty
in the U.S. Armed Forces? Mark ☐ a box for
EACH period in which this person served.
☐ April 1995 or later
☐ August 1990 to March 1995 (including Persian Gulf War)
☐ September 1980 to July 1990
☐ May 1975 to August 1980
☐ Vietnam era (August 1964—April 1975)
☐ February 1955 to July 1964
☐ Korean conflict (June 1950—January 1955)
☐ World War II (September 1940—July 1947)
☐ Some other time

21

c. In total, how many years of active-duty military
service has this person had?
☐ Less than 2 years
☐ 2 years or more
Person 1 (continued)

23. LAST WEEK, did this person do ANY work for either pay or profit? Mark the "Yes" box even if the person worked only 1 hour, or helped without pay in a family business or farm for 15 hours or more, or was on active duty in the Armed Forces.

- Yes
- No → Skip to 25a

22. At what location did this person work LAST WEEK? If this person worked at more than one location, print where he or she worked most last week.

- Address (Number and street name)
- Name of city, town, or post office
- Is the work location inside the limits of that city or town?
- Yes
- No, outside the city/town limits
- Name of county
- Name of U.S. state or foreign country
- ZIP Code

23a. How did this person usually get to work LAST WEEK? If this person usually used more than one method of transportation during the trip, mark the box of the one used for most of the distance.

- Car, truck, or van
- Bus or trolley bus
- Streetcar or trolley car
- Subway or elevated rail
- Railroad
- Ferryboat
- Taxicab
- Motorcycle
- Bicycle
- Walked
- Worked at home → Skip to 27
- Other method

23b. If "Car, truck, or van" is marked in 23a, go to 23b. Otherwise, skip to 24a.

- Drove alone
- 2 people
- 3 people
- 4 people
- 5 or 6 people
- 7 or more people

24a. What time did this person usually leave home to go to work LAST WEEK?

- a.m.
- p.m.

24b. How many minutes did it usually take this person to get from home to work LAST WEEK?

Min.

25. Answer questions 25-26 for persons who did not work for pay or profit last week. Others skip to 27.

25a. LAST WEEK, was this person on layoff from a job?

- Yes → Skip to 25c
- No

25b. LAST WEEK, was this person TEMPORARILY absent from a job or business?

- Yes, on vacation, temporary illness, labor dispute, etc. → Skip to 26
- No → Skip to 25d

25c. Has this person been informed that he or she will be recalled to work within the next 6 months or been given a date to return to work?

- Yes → Skip to 25e
- No

25d. Has this person been looking for work during the last 4 weeks?

- Yes
- No → Skip to 26

25e. LAST WEEK, could this person have started a job if offered one, or returned to work if recalled?

- Yes, could have gone to work
- No, because of own temporary illness
- No, because of all other reasons (in school, etc.)

26. When did this person last work, even for a few days?

- 1995 to 2000
- 1994 or earlier, or never worked → Skip to 31
<table>
<thead>
<tr>
<th>Number</th>
<th>Question/Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td><strong>Industry or Employer</strong> — Describe clearly this person's chief job, activity, or business last week. If this person had more than one job, describe the one at which this person worked the most hours. If this person had no job or business last week, give the information for his/her last job or business since 1995.</td>
</tr>
<tr>
<td>28</td>
<td><strong>Occupation</strong> — What kind of work was this person doing? (For example: registered nurse, personnel manager, supervisor of order department, auto mechanic, accountant, etc.)</td>
</tr>
<tr>
<td>29</td>
<td><strong>Was this person</strong> — Mark ONE box.</td>
</tr>
<tr>
<td>30</td>
<td><strong>In 1999</strong>, did this person work at a job or business at any time?</td>
</tr>
<tr>
<td>31</td>
<td><strong>INCOME in 1999</strong> — Mark the &quot;Yes&quot; box for each income source received during 1999 and enter the total amount received during 1999 to a maximum of $999,999. If net income was a loss, enter the amount and mark the &quot;Loss&quot; box next to the dollar amount.</td>
</tr>
<tr>
<td>32</td>
<td><strong>a. Wages, salary, commissions, bonuses, or tips from all jobs</strong> — Report amount before deductions for taxes, bonds, dues, or other items.</td>
</tr>
<tr>
<td>33</td>
<td><strong>b. Self-employment income from own nonfarm businesses or farm businesses, including proprietorships and partnerships</strong> — Report NET income after business expenses.</td>
</tr>
</tbody>
</table>

---

**Person 1 (continued)**
Person 1 (continued)

HOUSING QUESTIONS

31. Interest, dividends, net rental income, royalty income, or income from estates and trusts — Report even small amounts credited to an account.
   - Yes
   - Annual amount — Dollars
     $ 123,456.78
   - No

32. What was this person’s total income in 1999? Add entries in questions 31a—31h; subtract any losses. If net income was a loss, enter the amount and mark ☐ the “Loss” box next to the dollar amount.
   - Annual amount — Dollars
     $ 123,456.78
   - None

33. Now, please answer questions 33—53 about your household.

34. Is this house, apartment, or mobile home —
   - Owned by you or someone in this household with a mortgage or loan?
   - Owned by you or someone in this household free and clear (without a mortgage or loan)?
   - Rented for cash rent?
   - Occupied without payment of cash rent?

35. Which best describes this building? Include all apartments, flats, etc., even if vacant.
   - A mobile home
   - A one-family home detached from any other house
   - A one-family house attached to one or more houses
   - A building with 1-2 apartments
   - A building with 3 or 4 apartments
   - A building with 5 to 9 apartments
   - A building with 10 to 19 apartments
   - A building with 20 to 49 apartments
   - A building with 50 or more apartments
   - Boat, RV, van, etc.

36. About when was this building first built?
   - 1999 or 2000
   - 1995 to 1998
   - 1990 to 1994
   - 1980 to 1989
   - 1970 to 1979
   - 1960 to 1969
   - 1950 to 1959
   - 1940 to 1949
   - 1939 or earlier

37. When did this person move into this house, apartment, or mobile home?
   - 1999 or 2000
   - 1995 to 1998
   - 1990 to 1994
   - 1980 to 1989
   - 1970 to 1979
   - 1969 or earlier

38. How many rooms do you have in this house, apartment, or mobile home? Do NOT count bathrooms, porches, balconies, foyers, halls, or half-rooms.
   - 1 room
   - 2 rooms
   - 3 rooms
   - 4 rooms
   - 5 rooms
   - 6 rooms
   - 7 rooms
   - 8 rooms
   - 9 or more rooms
### Person 1 (continued)

38. How many bedrooms do you have; that is, how many bedrooms would you list if this house, apartment, or mobile home were on the market for sale or rent?
   - [ ] No bedroom
   - [ ] 1 bedroom
   - [ ] 2 bedrooms
   - [ ] 3 bedrooms
   - [ ] 4 bedrooms
   - [ ] 5 or more bedrooms

39. Do you have COMPLETE plumbing facilities in this house, apartment, or mobile home; that is, 1) hot and cold piped water, 2) a flush toilet, and 3) a bathtub or shower?
   - [ ] Yes, have all three facilities
   - [ ] No

40. Do you have COMPLETE kitchen facilities in this house, apartment, or mobile home: that is, 1) a sink with piped water, 2) a range or stove, and 3) a refrigerator?
   - [ ] Yes, have all three facilities
   - [ ] No

41. Is there telephone service available in this house, apartment, or mobile home from which you can both make and receive calls?
   - [ ] Yes
   - [ ] No

42. Which FUEL is used MOST for heating this house, apartment, or mobile home?
   - [ ] Gas: from underground pipes serving the neighborhood
   - [ ] Gas: bottled, tank, or LP
   - [ ] Electricity
   - [ ] Fuel oil, kerosene, etc.
   - [ ] Coal or coke
   - [ ] Wood
   - [ ] Solar energy
   - [ ] Other fuel
   - [ ] No fuel used

43. How many automobiles, vans, and trucks of one-ton capacity or less are kept at home for use by members of your household?
   - [ ] None
   - [ ] 1
   - [ ] 2
   - [ ] 3
   - [ ] 4
   - [ ] 5
   - [ ] 6 or more

44. Answer ONLY if this is a ONE-FAMILY HOUSE OR MOBILE HOME — All others skip to 45.
   a. Is there a business (such as a store or barber shop) or a medical office on this property?
      - [ ] Yes
      - [ ] No
   b. How many acres is this house or mobile home on?
      - [ ] Less than 1 acre → Skip to 45
      - [ ] 1 to 9.9 acres
      - [ ] 10 or more acres
   c. In 1998, what were the actual sales of all agricultural products from this property?
      - [ ] None
      - [ ] $1 to $999
      - [ ] $1,000 to $4,999
      - [ ] $5,000 to $9,999
      - [ ] $10,000 or more

45. What are the annual costs of utilities and fuels for this house, apartment, or mobile home? If you have lived here less than 1 year, estimate the annual cost.
   a. Electricity
      - Annual cost — Dollars
      - [ ] $1,000
      - [ ] OR
      - [ ] Included in rent or in condominium fee
      - [ ] No charge or electricity not used
   b. Gas
      - Annual cost — Dollars
      - [ ] $1,000
      - [ ] OR
      - [ ] Included in rent or in condominium fee
      - [ ] No charge or gas not used
   c. Water and sewer
      - Annual cost — Dollars
      - [ ] $1,000
      - [ ] OR
      - [ ] Included in rent or in condominium fee
      - [ ] No charge
   d. Oil, coal, kerosene, wood, etc.
      - Annual cost — Dollars
      - [ ] $1,000
      - [ ] OR
      - [ ] Included in rent or in condominium fee
      - [ ] No charge or these fuels not used
For Person 2, repeat questions 3-32 of Person 1.
For Persons 3–6. repeat questions 1-32 of Person 2.

NOTE – The content for Question 2 varies between Person 1 and Persons 2–6.

Thank you for completing your official U.S. Census form. If there are more than six people at this address, the Census Bureau may contact you for the same information about these people.
United States Census 2010

This is the official form for all the people at this address. It is quick and easy, and your answers are protected by law.

Start here

The Census must count every person living in the United States on April 1, 2010. Before you answer Question 1, count the people living in this house, apartment, or mobile home using our guidelines:

- Count all people, including babies, who live and sleep here most of the time.

The Census Bureau also conducts counts in institutions and other places:
- Do not count anyone living away either at college or in the Armed Forces.
- Do not count anyone in a nursing home, jail, prison, detention facility, etc., on April 1, 2010.
- Leave these people off your form, even if they will return to live here after they leave college, the nursing home, the military, jail, etc. Otherwise, they may be counted twice.

The Census must also include people without a permanent place to stay:
- If someone who has no permanent place to stay is staying here on April 1, 2010, count that person. Otherwise, he or she may be missed.

How many people were living or staying in this house, apartment, or mobile home on April 1, 2010?

Number of people

5. Please provide information for each person living here. Start with a person living here who owns or rents this house, apartment, or mobile home. If the owner or renter lives somewhere else, start with any adult living here. This will be Person 1.

What is Person 1's name? Print name below:

Last Name

First Name

6. What is Person 1's sex? Mark ONE box.

- Male
- Female

7. What is Person 1's age and what is Person 1's date of birth?

Age on April 1, 2010

Month

Day

Year of birth

NOTE: Please answer BOTH Question 8 about Hispanic origin and Question 9 about race. For this census, Hispanic origins are not races.

8. Is Person 1 of Hispanic, Latino, or Spanish origin?

- No, not of Hispanic, Latino, or Spanish origin
- Yes, Mexican, Mexican American, Chicano
- Yes, Puerto Rican
- Yes, Cuban
- Yes, another Hispanic, Latino, or Spanish origin — Print origin, for example, Argentinian, Colombian, Dominican, Nicaraguan, Salvadoran, Spanish and others.

9. What is Person 1's race? Mark ONE or more boxes.

- White
- Black, African American, or Negro
- American Indian or Alaska Native — Persons of Samoan or principal tribe
- Asian Indian
- Chinese
- Filipino
- Hawaiian
- Hawaiian and Guamanian or Chamorro
- Japanese
- Korean
- Samoan
- Other Asian — Print race, for example, Filipino, Laotian, Thai, Korean, Cambodian, and so on
- Some other race — Print race

10. Does Person 1 sometimes live or stay somewhere else?

- No
- Yes — Mark ONE box at that apply.

- In college housing
- In the military
- At a seasonal or second residence
- In a nursing home
- For child custody
- In jail or prison
- For another reason

If more people were counted in Question 1, continue with Person 2.
1. **Print name of Person 2**
   - Last Name
   - First Name

2. **How is this person related to Person 1?** Mark ONE box.
   - Husband or wife
   - Biological son or daughter
   - Adopted son or daughter
   - Stepson or stepdaughter
   - Brother or sister
   - Grandchild

3. **What is this person's sex?** Mark ONE box.
   - Male
   - Female

4. **What is this person's age and what is this person's date of birth?**
   - Print numbers in boxes.
   - Age on April 1, 2010
   - Month
   - Day
   - Year of birth

   **NOTE:** Please answer BOTH Question 5 about Hispanic origin and Question 6 about race. For this census, Hispanic origins are not races.

5. **Is this person of Hispanic, Latino, or Spanish origin?**
   - No, not of Hispanic, Latino, or Spanish origin
   - Yes, Mexican, Mexican American, Chicano
   - Yes, Puerto Rican
   - Yes, Cuban
   - Yes, another Hispanic, Latino, or Spanish origin — Print race, for example, Argentinean, Colombian, Dominican, Mexican, Salvadoran, Spaniard, and so on.
   - Some other race — Print race.

6. **What is this person's race?** Mark ONE, or more boxes.
   - White
   - Black, African Am., or Negro
   - American Indian or Alaska Native — Print name of tribal or principal tribe.
   - Asian Indian
   - Japanese
   - Chinese
   - Korean
   - Filipino
   - Other Asian — Print race, for example, Hmong, Laotian, Thai, Pakistani, Cambodian, and so on.
   - Native Hawaiian
   - Guamanian or Chamorro
   - Samoan
   - Other Pacific Islander — Print race, for example, Fijian, Tongan, and so on.
   - Some other race — Print race.

7. **Does this person sometimes live or stay somewhere else?**
   - No
   - Yes — Mark X for all that apply.
   - In college housing
   - In the military
   - At a seasonal or second residence
   - For another reason

   **NOTE:** If more people were counted in Question 1 on the front page, continue with Person 3.
Print name of Person 4

1. Print name of Person 5

2. How is this person related to Person 7? Mark X ONE box.
   - Husband or wife
   - Parent-in-law
   - Biological son or daughter
   - Adopted son or daughter
   - Stepson or stepdaughter
   - Brother or sister
   - Father or mother
   - Grandchild
   - Other relative
   - Unmarried partner
   - Roommate or boarder
   - Roommate or boarder

3. What is this person’s sex? Mark X ONE box.
   - Male
   - Female

4. What is this person’s age and what is this person’s date of birth?
   Please report babies as age 0 when the child is less than 1 year old.
   Print numbers in boxes.
   Age on April 1, 2010
   Month
   Day
   Year of birth

NOTE: Please answer BOTH Question 5 about Hispanic origin and Question 6 about race. For this census, Hispanic origins are not races.

5. Is this person of Hispanic, Latino, or Spanish origin?
   - Yes, not of Hispanic, Latino, or Spanish origin
   - Yes, Mexican, Mexican Am., Chicano
   - Yes, Puerto Rican
   - Yes, Cuban
   - Yes, another Hispanic, Latino, or Spanish origin

6. What is this person’s race? Mark X one or more boxes.
   - White
   - Black, African Am., or Negro
   - American Indian or Alaska Native — Print code 1 or principal tribe.

   - Asian Indian
   - Japanese
   - Chinese
   - Filipino
   - Other Asian

   - Samoan
   - Other Pacific Islander — Print race, for example, Hawaiian, Samoan, or Tongan
   - Some other race — Print race.

7. Does this person sometimes live or stay somewhere else?
   - No
   - Yes — Mark X, all that apply.
   - In college housing
   - In the military
   - In jail or prison
   - At a seasonal or second residence
   - For another reason

If more people were counted in Question 1 on the front page, continue with Person 5.
1. Print name of Person 6

Last Name ___________________________

First Name ___________________________

[ ] Mr. [ ] Ms. [ ] Mrs. [ ] [ ] [ ]

2. How is this person related to Person 1? Mark [ ] ONE box.

[ ] Husband or wife
[ ] Parent in law
[ ] Biological son or daughter
[ ] Son-in-law or daughter-in-law
[ ] Adopted son or daughter
[ ] Other relative
[ ] Stepson or stepdaughter
[ ] Roomer or boarder
[ ] Brother or sister
[ ] Housemate or roommate
[ ] Father or mother
[ ] Unmarried partner
[ ] Grandchild
[ ] Other nonrelative

3. What is this person’s sex? Mark [ ] ONE box.

[ ] Male [ ] Female

4. What is this person’s age and what is this person’s date of birth? Please report babies as age 0 when the child is less than 1 year old. Print numbers in box.

Age on April 1, 2010
Month ___________ Day ___________ Year of birth ___________

NOTE: Please answer BOTH Question 5 about Hispanic origin and Question 6 about race. For this census, Hispanic origins are not races.

5. Is this person of Hispanic, Latino, or Spanish origin?

[ ] No, not of Hispanic, Latino, or Spanish origin
[ ] Yes, Mexican, Mexican American, Chicano
[ ] Yes, Puerto Rican
[ ] Yes, Cuban
[ ] Yes, another Hispanic, Latino, or Spanish origin — For example, Jesuitian, Caribou, Guatemalan, Mexican, Panamanian, Salvadorian, Spanish, and so on.

6. What is this person’s race? Mark [ ] ONE or more boxes.

[ ] White
[ ] Black, African American, or Negros
[ ] American Indian or Alaska Native — Print name of unlisted or special tribes
[ ] Asian Indian
[ ] Japanese
[ ] Chinese
[ ] Korean
[ ] Filipino
[ ] Vietnamese
[ ] Other Asian — Print race, for example, Chavas, Lao, Thai, Pakistani, Cambodian, and so on.
[ ] Some other race — Print race.

7. Does this person sometimes live or stay somewhere else? Mark [ ] all that apply.

[ ] No
[ ] Yes — Mark [ ] all that apply

[ ] In college housing
[ ] In the military
[ ] At a seasonal or second residence
[ ] For other reason

If more than six people were counted in Question 1 on the front page, turn the page and continue.
Use this section to complete information for the rest of the people you counted in Question 1 on the front page. We may call for additional information about them.

<table>
<thead>
<tr>
<th>Person</th>
<th>Last Name</th>
<th>First Name</th>
<th>Sex</th>
<th>Age on April 1, 2010</th>
<th>Date of Birth</th>
<th>Related to Person 1?</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes No</td>
</tr>
<tr>
<td>8</td>
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<td>Yes No</td>
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<td>9</td>
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<td>Yes No</td>
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<td>10</td>
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<td>Yes No</td>
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<tr>
<td>11</td>
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<td></td>
<td></td>
<td>Yes No</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes No</td>
</tr>
</tbody>
</table>

Thank you for completing your official 2010 Census form.
If your enclosed postage-paid envelope is missing, please mail your completed form to:

U.S. Census Bureau
National Processing Center
1501 East 10th Street
Jeffersonville, IN 47132

If you need help completing this form, call 1-866-777-0800 between 8:00 a.m. and 9:00 p.m., 7 days a week. The telephone call is free.

TDD — Telephone display device for the hearing impaired. Call 1-866-789-2010 between 8:00 a.m. and 9:00 p.m., 7 days a week. The telephone call is free.

¿NECESITA AYUDA? Si usted necesita ayuda para completar este cuestionario, llame al 1-866-728-2010 entre las 8:00 a.m. y 9:00 p.m., 7 días a la semana. Las llamadas telefónicas es gratis.

The U.S. Census Bureau estimates that, for the average household, this form will take about 10 minutes to complete, including the time for reviewing the instructions and answers. Send comments regarding this burden estimate or any other aspect of this burden to: Paperwork Reduction Project 0607-0019-C, U.S. Census Bureau, AMS02-00138, 4600 Silver Hill Road, Washington, DC 20233. You may e-mail comments to <Paperwork@cen.gov>, see “Paperwork Project 0607-0019-C” as the subject.

Respondents are not required to respond to any information collection unless it displays a valid approval number from the Office of Management and Budget.
THE American Community Survey

This booklet shows the content of the American Community Survey questionnaire.

Please complete this form and return it as soon as possible after receiving it in the mail.

This form asks for information about the people who are living or staying at the address on the mailing label and about the house, apartment, or mobile home located at the address on the mailing label.

If you need help or have questions about completing this form, please call 1-800-364-7271. The telephone call is free.

¿NECESITA AYUDA? Si usted habla español y necesita ayuda para completar su cuestionario, llame sin cargo al 1-877-833-5625. Usted tambièn puede pedir un cuestionario en español o completar su entrevista por teléfono con un entrevistador que habla español.

For more information about the American Community Survey, visit our web site at: http://www.census.gov/acs/www/

Start Here

Please print today’s date.
Month Day Year

Please print the name and telephone number of the person who is filling out this form. We may contact you if there is a question.

Last Name

First Name MI

Area Code + Number

How many people are living or staying at this address?

• INCLUDE everyone who is living or staying here for more than 2 months.
• INCLUDE yourself if you are living here for more than 2 months.
• INCLUDE anyone else staying here who does not have another place to stay, even if they are here for 2 months or less.
• DO NOT INCLUDE anyone who is living somewhere else for more than 2 months, such as a college student living away or someone in the Armed Forces on deployment.

Number of people

Fill out pages 2, 3, and 4 for everyone, including yourself, who is living or staying at this address for more than 2 months. Then complete the rest of the form.
### Person 1

(Person 1 is the person living or staying here in whose name this house or apartment is owned, being bought, or rented. If there is no such person, start with the name of any adult living or staying here.)

#### 1. What is Person 1's name?
- Last Name (Please print): [ ]
- First Name: [ ]
- MI: [ ]

#### 2. How is this person related to Person 1?
- [ ] Person 1

#### 3. What is Person 1's sex?
- [ ] Male
- [ ] Female

#### 4. What is Person 1's age and what is Person 1's date of birth?
- [ ] Age (in years): 
- [ ] Month: 
- [ ] Day: 
- [ ] Year of birth:

→ NOTE: Please answer BOTH Question 5 about Hispanic origin and Question 6 about race. For this survey, Hispanic origin is not race.

#### 5. Is Person 1 of Hispanic, Latino, or Spanish origin?
- [ ] No, not of Hispanic, Latino, or Spanish origin
- [ ] Yes, Mexican, Mexican American, Chicano
- [ ] Yes, Puerto Rican
- [ ] Yes, Cuban
- [ ] Yes, another Hispanic, Latino, or Spanish origin — Print origin, for example, Argentinean, Colombian, Dominican, Nicaraguan, Salvadoran, Spaniard, and so on.
- [ ] Other Hispanic, Latino, or Spanish origin — Print origin, for example, Argentinean, Colombian, Dominican, Nicaraguan, Salvadoran, Spaniard, and so on.

#### 6. What is Person 1's race?
- [ ] White
- [ ] Black, African Am., or Negro
- [ ] American Indian or Alaska Native — Print name of enrolled or principal tribe.
- [ ] Asian Indian
- [ ] Chinese
- [ ] Filipino
- [ ] Other Asian — Print race, for example, Austra, Latvian, Thai, Pakistani, Cambodian, and so on.
- [ ] Other Pacific Islander — Print race, for example, Fijian, Tongan, and so on.
- [ ] Some other race — Print race.

### Person 2

#### 1. What is Person 2's name?
- Last Name (Please print): [ ]
- First Name: [ ]
- MI: [ ]

#### 2. How is this person related to Person 1?
- [ ] Husband or wife
- [ ] Biological son or daughter
- [ ] Adopted son or daughter
- [ ] Stepson or stepdaughter
- [ ] Brother or sister
- [ ] Father or mother
- [ ] Grandchild
- [ ] Parent-in-law
- [ ] Son-in-law
- [ ] Daughter-in-law
- [ ] Other relative
- [ ] Renter or boarder
- [ ] Housemate or roommate
- [ ] Unmarried partner
- [ ] Foster child
- [ ] Other nonrelative

#### 3. What is Person 2's sex?
- [ ] Male
- [ ] Female

#### 4. What is Person 2's age and what is Person 2's date of birth?
- [ ] Age (in years): 
- [ ] Month: 
- [ ] Day: 
- [ ] Year of birth:

→ NOTE: Please answer BOTH Question 5 about Hispanic origin and Question 6 about race. For this survey, Hispanic origin is not race.

#### 5. Is Person 2 of Hispanic, Latino, or Spanish origin?
- [ ] No, not of Hispanic, Latino, or Spanish origin
- [ ] Yes, Mexican, Mexican American, Chicano
- [ ] Yes, Puerto Rican
- [ ] Yes, Cuban
- [ ] Yes, another Hispanic, Latino, or Spanish origin — Print origin, for example, Argentinean, Colombian, Dominican, Nicaraguan, Salvadoran, Spaniard, and so on.

#### 6. What is Person 2's race?
- [ ] White
- [ ] Black, African Am., or Negro
- [ ] American Indian or Alaska Native — Print name of enrolled or principal tribe.
- [ ] Asian Indian
- [ ] Chinese
- [ ] Filipino
- [ ] Other Asian — Print race, for example, Austra, Latvian, Thai, Pakistani, Cambodian, and so on.
- [ ] Other Pacific Islander — Print race, for example, Fijian, Tongan, and so on.
- [ ] Some other race — Print race.
Housing (continued)

1. LAST MONTH, what was the cost of electricity for this house, apartment, or mobile home?
   Last month's cost – Dollars
   □ Yes
   □ No

2. LAST MONTH, what was the cost of gas for this house, apartment, or mobile home?
   Last month's cost – Dollars
   □ Yes
   □ No

3. IN THE PAST 12 MONTHS, did anyone in this household receive Food Stamps or a Food Stamp benefit card? Include government benefits from the Supplemental Nutrition Assistance Program (SNAP).  Do NOT include WIC or the National School Lunch Program.
   □ Yes
   □ No

4. Is this house, apartment, or mobile home part of a condominium?
   □ Yes
   □ No

5. What is the monthly condominium fee? For renters, answer only if you pay the condominium fee in addition to your rent; otherwise, mark the "None" box.
   Monthly amount – Dollars
   □ Yes
   □ No

6. Is this house, apartment, or mobile home part of a condominium?
   □ Yes
   □ No

7. What are the annual real estate taxes on THIS property?
   Annual amount – Dollars
   □ Yes
   □ No

8. What is the annual payment for fire, hazard, and flood insurance on THIS property?
   Annual amount – Dollars
   □ Yes
   □ No

9. a. What is the monthly rent for this house, apartment, or mobile home?
   Monthly amount – Dollars
   □ Yes
   □ No

b. Does the monthly rent include any meals?
   □ Yes
   □ No
Housing (continued)

19. Do you or any member of this household have a mortgage, deed of trust, contract to purchase, or similar debt on this property?
   - Yes, mortgage, deed of trust, or similar debt
   - Yes, contract to purchase
   - No → SKIP to question 20

20. Monthly amount – Dollars

   OR
   - No regular payment required → SKIP to question 20

21. Does the regular monthly mortgage payment include payments for real estate taxes on this property?
   - Yes, taxes included in mortgage payment
   - No, taxes paid separately or not required

22. Does the regular monthly mortgage payment include payments for fire, hazard, or flood insurance on this property?
   - Yes, insurance included in mortgage payment
   - No, insurance paid separately or not insured

23. Monthly amount – Dollars

Answer questions about PERSON 1 on the next page if you listed at least one person on page 2. Otherwise, SKIP to page 26 for the mailing instructions.
<table>
<thead>
<tr>
<th>Person 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Please copy the name of Person 1 from page 2, then continue answering questions below.</strong></td>
</tr>
<tr>
<td><strong>Last Name:</strong> [ ]</td>
</tr>
<tr>
<td><strong>First Name:</strong> [ ]</td>
</tr>
<tr>
<td><strong>Middle Initial (MI):</strong> [ ]</td>
</tr>
<tr>
<td><strong>Where was this person born?</strong></td>
</tr>
<tr>
<td>[ ] In the United States - Print name of state.</td>
</tr>
<tr>
<td>[ ] Outside the United States - Print name of foreign country, or Puerto Rico, Guam, etc.</td>
</tr>
<tr>
<td><strong>Is this person a citizen of the United States?</strong></td>
</tr>
<tr>
<td>[ ] Yes, born in the United States - SKIP to question 10a</td>
</tr>
<tr>
<td>[ ] Yes, born in Puerto Rico, Guam, the U.S. Virgin Islands, or Northern Mariana Islands</td>
</tr>
<tr>
<td>[ ] Yes, born abroad of U.S. citizen parent or parents</td>
</tr>
<tr>
<td>[ ] Yes, U.S. citizen by naturalization - Print year of naturalization</td>
</tr>
<tr>
<td>[ ] No, not a U.S. citizen</td>
</tr>
</tbody>
</table>
| **When did this person come to live in the United States? Print numbers in boxes. Year:** [ ] [
| **a. At any time in the last 3 months, has this person attended school or college? Include only nursery or preschool, kindergarten, elementary school, home school, and school which leads to a high school diploma or a college degree.** |
| [ ] No, has not attended in the last 3 months - SKIP to question 11 |
| [ ] Yes, public school, public college |
| [ ] Yes, private school, private college, home school |
| **b. What grade or level was this person attending?** Mark (X) ONE box. |
| [ ] Nursery school, preschool |
| [ ] Kindergarten |
| [ ] Grade 1 through 12 - Specify grade 1 - 12 |
| [ ] College, undergraduate years (freshman to senior) |
| [ ] Graduate or professional school beyond a bachelor's degree (for example: MA or PhD program, or medical or law school) |
| [ ] No schooling completed |
| [ ] Nursery school |
| [ ] Kindergarten |
| [ ] Grade 1 through 11 - Specify grade 1 - 11 |
| [ ] 12th grade - NO DIPLOMA |
| [ ] Regular high school diploma |
| [ ] GED or alternative credential |
| [ ] College or some college |
| [ ] Some college credit, but less than 1 year of college credit |
| [ ] 1 or more years of college credit, no degree |
| [ ] Associate's degree (for example: AA, AS) |
| [ ] Bachelor's degree (for example: BA, BS) |
| [ ] Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA) |
| [ ] Professional degree beyond a bachelor's degree (for example: MD, DDS, DVM, LLB, JD) |
| [ ] Doctorate degree (for example: PhD, EdD) |
| **What is the highest degree or level of school this person has completed? Mark (X) ONE box.** |
| [ ] If currently enrolled, mark the previous grade or highest degree received. |
| [ ] NO SCHOOLING COMPLETED |
| [ ] Nursery school |
| [ ] Kindergarten |
| [ ] Grade 1 through 11 - Specify grade 1 - 11 |
| [ ] 12th grade - NO DIPLOMA |
| [ ] Regular high school diploma |
| [ ] GED or alternative credential |
| [ ] College or some college |
| [ ] Some college credit, but less than 1 year of college credit |
| [ ] 1 or more years of college credit, no degree |
| [ ] Associate's degree (for example: AA, AS) |
| [ ] Bachelor's degree (for example: BA, BS) |
| [ ] Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA) |
| [ ] Professional degree beyond a bachelor's degree (for example: MD, DDS, DVM, LLB, JD) |
| [ ] Doctorate degree (for example: PhD, EdD) |
| **What is this person's ancestry or ethnic origin?** |
| [ ] (For example: Italian, Jamaican, African Am, Cambridge, Dale Ventury, Norwegian, Dominican, Karen, Ukrainian, Asian, etc.) |
| **Does this person speak a language other than English at home?** |
| [ ] Yes |
| [ ] No - SKIP to question 15a |
| **What is this language?** |
| [ ] (For example: Korean, Italian, Spanish, Vietnamese) |
| **How well does this person speak English?** |
| [ ] Very well |
| [ ] Well |
| [ ] Not well |
| [ ] Not at all |
| **Did this person live in this house or apartment 1 year ago?** |
| [ ] Person is under 1 year old - SKIP to question 16 |
| [ ] Yes, this house - SKIP to question 16 |
| [ ] No, outside the United States and Puerto Rico - Print name of foreign country, or U.S. Virgin Islands, Guam, etc. Below; then skip to question 16 |
| [ ] No, different house in the United States or Puerto Rico |
| **Where did this person live 1 year ago?** |
| [ ] Address (Number and street name): [ ] |
| **Name of city, town, or post office:** [ ] |
| **Name of U.S. county or municipio in Puerto Rico:** [ ] |
| **Name of U.S. state or ZIP Code:** [ ] [ ] |
### Person 1 (continued)

**a. LAST WEEK, did this person work for pay at a job (or business)?**
- [ ] Yes → SKIP to question 36
- [ ] No → Did not work (or retired)

**b. LAST WEEK, did this person do ANY work for pay, even for as little as one hour?**
- [ ] Yes
- [ ] No → SKIP to question 35a

**At what location did this person work LAST WEEK?** If this person worked at more than one location, print where he or she worked most last week.

<table>
<thead>
<tr>
<th>a. Address (Number and street name)</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the exact address is not known, give a description of the location such as the building name or the nearest street or intersection.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b. Name of city, town, or post office</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c. Is the work location inside the limits of that city or town?</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] Yes</td>
</tr>
<tr>
<td>[ ] No, outside the city/town limits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>d. Name of county</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>e. Name of U.S. state or foreign country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>f. ZIP Code</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**How did this person usually get to work LAST WEEK?** If this person usually used more than one method of transportation during the trip, mark X(X) the box of the one used for most of the distance.

- [ ] Car, truck, or van
- [ ] Motorcycle
- [ ] Bus or trolley bus
- [ ] Bicycle
- [ ] Streetcar or trolley car
- [ ] Walked
- [ ] Subway or elevated
- [ ] Worked at home → SKIP to question 33a
- [ ] Railroad
- [ ] Ferryboat
- [ ] Taxi/cab
- [ ] Other method

**Answer question 32 if you marked “Car, truck, or van” in question 31. Otherwise, SKIP to question 33.**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] No, did not work</td>
<td></td>
</tr>
<tr>
<td>[ ] Yes, could have gone to work</td>
<td></td>
</tr>
<tr>
<td>[ ] No, because of own temporary illness</td>
<td></td>
</tr>
<tr>
<td>[ ] No, because of all other reasons (in school, etc.)</td>
<td></td>
</tr>
</tbody>
</table>

**During the LAST 4 WEEKS, has this person been ACTIVELY looking for work?**
- [ ] Yes
- [ ] No → SKIP to question 38

**During the LAST 4 WEEKS, did this person leave a job if offered one, or return to work if recalled?**
- [ ] Yes
- [ ] No → SKIP to question 39

**What time did this person usually leave home to go to work LAST WEEK?**
- [ ] Hour: [ ] Minute: [ ] a.m.
- [ ] p.m.

**How many minutes did it usually take this person to get from home to work LAST WEEK?**
- [ ] Minutes: [ ]

**Answer questions 35 - 38 if this person did NOT work last week. Otherwise, SKIP to question 39.**

**When did this person last work, even for a few days?**
- [ ] Within the past 12 months
- [ ] 1 to 5 years ago → SKIP to question 39
- [ ] Over 5 years ago or never worked → SKIP to question 39

**a. During the PAST 12 MONTHS (52 weeks), did this person work 50 or more weeks?**
- [ ] Yes → SKIP to question 40
- [ ] No

**b. How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?**
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**During the PAST 12 MONTHS, how many hours did this person usually work each WEEK?**
- [ ] Usual hours worked each week: [ ]

**c. Has this person been informed that he or she will be recalled to work within the next 6 months OR been given a date to return to work?**
- [ ] Yes → SKIP to question 37
- [ ] No

**d. LAST WEEK, was this person TEMPORARILY absent from a job or business?**
- [ ] Yes
- [ ] No → SKIP to question 37

**e. LAST WEEK, was this person on layoff from a job?**
- [ ] Yes → SKIP to question 35c
- [ ] No

**f. LAST WEEK, was this person actively looking for work?**
- [ ] Yes
- [ ] No → SKIP to question 38

**g. How many people, including this person, usually rode to work in the car, truck, or van?**
- [ ] Person(s): [ ]

**39** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**40** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**41** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]

**42** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**43** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**44** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]

**45** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**46** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**47** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]

**48** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**49** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**50** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]

**51** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**52** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**53** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]

**54** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**55** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**56** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]

**57** How many weeks did this person work 50 or more weeks?
- [ ] Yes → SKIP to question 40
- [ ] No

**58** How many weeks did this person work, even for a few hours, including paid vacation, paid sick leave, and military service?
- [ ] 50 to 52 weeks
- [ ] 48 to 49 weeks
- [ ] 40 to 47 weeks
- [ ] 27 to 29 weeks
- [ ] 14 to 26 weeks
- [ ] 13 weeks or less

**59** How many people, including this person, usually rode to work in the car, truck, or van?
- [ ] Person(s): [ ]
Person 1 (continued)

Answer questions 41–46 if this person worked in the past 5 years. Otherwise, SKIP to question 47.

41–46 CURRENT OR MOST RECENT JOB ACTIVITY. Describe clearly this person’s chief job activity or business last week. If this person held more than one job, describe the one at which this person worked the most hours. If this person had no job or business last week, give information for his/her last job or business.

Was this person:

☐ an employee of a PRIVATE FOR-PROFIT company or business, or of an individual, for wages, salary, or commissions?
☐ an employee of a PRIVATE NOT-FOR-PROFIT, tax-exempt, or charitable organization?
☐ a local GOVERNMENT employee (city, county, etc.)?
☐ a state GOVERNMENT employee?
☐ a Federal GOVERNMENT employee?
☐ SELF-EMPLOYED in a business, professional practice, or farm?
☐ SELF-EMPLOYED in an INCORPORATED business, professional practice, or farm?
☐ working WITHOUT PAY in family business or farm?

For whom did this person work?

If now on active duty in the Armed Forces, mark (X) this box and print the branch of the Armed Forces.

Name of company, business, or other employer:

What kind of business or industry was this?

☐ manufacturing?
☐ wholesale trade?
☐ retail trade?
☐ other (agriculture, construction, service, government, etc.):

Is this mainly:

☐ manufacturing?
☐ wholesale trade?
☐ retail trade?
☐ other (agriculture, construction, service, government, etc.):

What kind of work was this person doing?

(For example: registered nurse, personnel manager, supervisor of order department, secretary, accountant)

What were this person’s most important activities or duties?

(For example: patient care, directing billing policies, supervising order clerks, typing and filing, reconciling financial records)

INCOME IN THE PAST 12 MONTHS

Mark (X) the “Yes” box for each type of income this person received, and give your best estimate of the TOTAL AMOUNT during the PAST 12 MONTHS. (NOTE: “The past 12 months” is the period from today’s date one year ago up through today.)

Mark (X) the “No” box to show types of income NOT received.

If net income was a loss, mark the “Loss” box to the right of the dollar amount.

For income received jointly, report the appropriate share for each person— or, if box not possible, report the whole amount for all one person and mark the “No” box for the other person.

a. Wages, salary, commissions, bonuses, or tips from all jobs. Report amount before deductions for taxes, bonds, dues, or other items.

☐ Yes → TOTAL AMOUNT for past 12 months
☐ No → TOTAL AMOUNT for past 12 months

b. Self-employment income from own nonprofit businesses or farm businesses, including proprietorships and partnerships. Report net income after business expenses.

☐ Yes → TOTAL AMOUNT for past 12 months
☐ No → TOTAL AMOUNT for past 12 months

Loss

What was this person’s total income during the PAST 12 MONTHS? Add together the amounts in questions 41–46, mark (X) the “Loss” box if necessary, and enter the amount in the box titled TOTAL AMOUNT for past 12 months.

Loss

TOTAL AMOUNT for past 12 months

f. Any public assistance or welfare payments from the state or local welfare office.

☐ Yes → TOTAL AMOUNT for past 12 months
☐ No → TOTAL AMOUNT for past 12 months

g. Retirement, survivor, or disability pensions. Do NOT include Social Security.

☐ Yes → TOTAL AMOUNT for past 12 months
☐ No → TOTAL AMOUNT for past 12 months

h. Any other sources of income received regularly such as Veterans’ VA payments, unemployment compensation, child support or alimony. Do NOT include lump sum payments such as money from an inheritance or the sale of a home.

☐ Yes → TOTAL AMOUNT for past 12 months
☐ No → TOTAL AMOUNT for past 12 months

Continue with the questions for Person 2 on the next page. If no one is listed as person 2 on page 2, SKIP to page 28 for mailing instructions.
The balance of the questionnaire has questions for Person 2, Person 3, Person 4, and Person 5. The questions are the same as the questions for Person 1.
Mailing Instructions

Please make sure you have...

- listed all names and answered the questions on pages 2, 3, and 4
- answered all Housing questions
- answered all Person questions for each person.

Then...

- put the completed questionnaire into the postage-paid return envelope. If the envelope has been misplaced, please mail the questionnaire to:
  U.S. Census Bureau
  P.O. Box 5240
  Jeffersonville, IN 47199-5240
- make sure the barcode above your address shows in the window of the return envelope.

Thank you for participating in the American Community Survey.

The Census Bureau estimates that, for the average household, this form will take 38 minutes to complete, including the time for reviewing the instructions and answers. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to: Paperwork Project 0607-0010; U.S. Census Bureau, 4600 Silver Hill Road, AMSR - JK13, Washington, D.C. 20233. You may email comments to: Paperwork@cen.gov; use “Paperwork Project 0607-0010” as the subject. Please DO NOT RETURN your questionnaires to this address. Use the enclosed preaddressed envelope to return your completed questionnaires.

Respondents are not required to respond to any information collection unless it displays a valid approval number from the Office of Management and Budget. This 8-digit number appears in the bottom right on the front cover of this form.

Form ACS-1(INFO)(2012)-KFI (07-14-2011)
REFERENCES


Lowry, Ira S. (1964), A Model of Metropolis RAND Memorandum 4025-RC


Schrank, David; Eisele, Bill; and Lomax Tim (2012). TTI’s 2012 URBAN MOBILITY REPORT Powered by INRIX Traffic Data, Texas A&M Transportation Institute; The Texas A&M University System.


BIOGRAPHICAL INFORMATION

Azadeh Rahmani received her bachelor degree in Biology from the University of Texas at Arlington. She started her master program in the City and Regional Planning program in 2010. Her professional interests are in planning, economic development, and management. Volunteering for non-profit organizations to help the local community has been a significant portion of her life. She is married and has two daughters.