University Transportation Research Center - Region 2

# Final Report

## Towards Socially and Economically Sustainable Urban Developments: Impacts of Toll Pricing on Residential Developments

Performing Organization: University at Buffalo/SUNY

December 2013

Sponsor:
University Transportation Research Center - Region 2

## University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

**Research**

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

**Education and Workforce Development**

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

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# TOWARDS SOCIALLY AND ECONOMICALLY SUSTAINABLE DEVELOPMENTS: IMPACTS OF TOLL PRICING ON RESIDENTIAL DEVELOPMENTS


## ABSTRACT

The goal of this research is to investigate the effects of road pricing on residential land use choices and to help select pricing policies that foster socially and economically sustainable residential development in urbanized residential areas. Under this goal, a residential land use choice model in logit form with shared aggregated data was developed. The model was designed to assess the impacts of various toll pricing policies and the resulting accessibility on a residential land use choice pattern. We selected the Great Buffalo-Niagara metropolitan area for a case study. The multinomial logit model was built at the census tract level, with four residential land use types—single-family houses, multiple-family houses, apartments and others—as main choice alternatives. With the estimated model, the following hypothetical toll pricing scenarios were tested are: (I) uniform increase of tolls for the entire region, (II) distance-based tolls for the entire region, and (III) uniform tolls for entering the downtown area only. We found that toll pricing strategies affect accessibility of zones, shaping a trend and pattern of the residential land use. More specifically, increased toll charges would urge people to choose multi-family house and apartments, encouraging a sustainable high density residential land use pattern.


**Keywords:** residential land use, toll pricing, accessibility, sustainable urban residential development, multinomial logit model

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# CONTENTS

# INTRODUCTION

Road pricing has gained more and more research attention due to its effectiveness in managing traffic congestion and financing transportation infrastructure during recent years. Most research efforts focus on the functionality of road pricing in managing traffic congestion and raising revenue. In contrast, little is known about the impact of such pricing policies on urban development over time. The lack of knowledge in this field has raised numerous concerns about social equity, economic sustainability, and political acceptability among road pricing among motorists, researchers, and policy makers. In this context, there is an urgent need to develop a modeling tool that investigates not only how road pricing affects the short-term mobility and reliability of transportation systems, but also how it would influence the long-term sustainability and equity of urban development.

To meet the need, this study investigates the impact of toll pricing on a residential land use choice in urban areas. We selected the Greater Buffalo-Niagara metropolitan area as the study case. Various data sources were compiled for the analytical purpose, including the parcel-level tax map, the American Community Survey (ACS) data, the American Housing Survey data, the employment information from OnTheMap.com, and the transportation cost of the buffalo region. The fused information was then used to generate the potential factors such as housing price, housing size, population age group, population income, and employment that influence the land use choice decision of residents. As a main factor tested, toll charges that are combined with the number of employees were used as the determinant to calculate the accessibility to an area.

Using the data collected, a series of multinomial logit models were developed. We related the decision of residential land use choice to the aforementioned factors at the census-tract level. Four residential land use types - such as single-family houses, multiple-family houses, apartments and others - are main choice alternatives. With various criteria, the best choice model was selected; this was then used to test several hypothetical toll pricing scenarios where we tried to identify the plausible pricing policies to promote sustainable residential development in the study area. Our scenarios include: the uniform increase of tolls for the entire region, the distance-based tolls for the entire region, and the uniform tolls for entering the downtown Buffalo only.

The main contribution of this study includes: (I) addressing the long-term impact of toll pricing policies on land use patterns in urban areas which has not actively been investigated; (II) connecting deep insights of toll pricing policies to sustainable residential land use in urban areas through the test of various toll pricing scenarios; and (III) laying the foundation for a more appropriate approach to evaluating toll pricing policies, i.e., the integrated land use and travel demand forecasting method that has the capacity of examining both the short-term and the long-run effects of toll pricing on urban residential development.

The report is organized as below. The ‘Review and Methodology’ section briefly summarizes and discusses the previous studies, introducing the description of discrete choice modeling. The ‘Case Study and Data Sources’ section introduces the background of our case study, data sources and data collection procedure. The ‘Data Processing’ section discusses data cleaning and fusing processes. The ‘Logit Model’ section describes the model estimation process and the best estimated model. Finally, ‘Toll Pricing Scenario’ discusses scenarios and analytical results. The report ends with conclusions that summarize the findings of this study.

# LITERATURE REVIEW

The concept of road pricing has been gaining support in the United States, Europe, and the Asia, with the recent London congestion pricing scheme as one of the largest and most visible applications. Its use in the United States can be tracked to December 27, 1995 when State Route 91 Express Lanes opened in Orange County, California (Orange County Transportation Authority, 2003). Since then, road pricing encompasses a variety of market-based approaches to respond to various congestion problems. The major applied variants of road pricing in the United States include: (I) High Occupancy Toll (HOT) lanes charged with variable tolls, and (II) variable tolls on existing toll roads or facilities (Federal Highway Administration, 2007).

With the wide application of road pricing, a series of evaluation studies were conducted to assess the feasibility and success of these pricing schemes. Most of them cover one or more of the following aspects: (I) impact on traffic distribution patterns (Santos et al., 2002; Beamon et al., 1999; Win et al., 2007; Litman, 2006; Keong, 2002); (II) impact on land use (Eliasson et al., 2001; Safirova et al., 2006; Tillema et al., 2010); (III) public and political acceptability (Link et al., 2003; Harrington et al., 2001; National Economic Development Office, 1991); (IV) equity impact (Flowerdew, 1993; Giuliano, 1994; Litman, 1996; Ecola et al., 2009; Levinson, 2010); and (V) behavior impact (Yelds et al., 2000; Holguín-Veras et al., 2005a; Holguín-Veras et al., 2005b; Holguín-Veras et al., 2006).

Besides the impacts of road pricing on travel patterns, the road pricing also contributes to an economic slowdown and the increase of transportation cost (Madsen et al., 2001). Therefore, it may affect land use patterns, and thus influence relocations of households, work places and shops in long term. Eliasson and Mattsson (2001) proposed a model to investigate this problem and found that the impact on location would be small in comparison to the impact on travel patterns.

There have been prompted some interest recently in effects of road pricing on land use patterns and social welfare. Safirova et al. (2006a,b) studied long-term impact of cordon tolls on social welfare, economics and land use using spatially disaggregated general equilibrium models. Tillema et al. (2010) studied effects of road pricing on housing location decisions based on preference data collected from Dutch residents. Larsen et al. (2008) analyzed how transportation costs affect job search. Madsen et al. (2008) proposed a modeling approach for regional economic effects of road pricing. Ying (2007) proposed a road pricing method with an integrated location and transport model.

# METHODOLOGY

Given the disaggregate nature of the available data, discrete choice modeling techniques are used to capture residential land use type choices. These techniques are intended to quantify the relationship between a choice decision and potential affecting factors of it. They have experienced fast growth during the past decades, and have been applied to diverse fields such as econometric, psychology and engineering. Multinomial Logit is considered to be the most suitable model type to be adopted by the case study.

The modeling process is composed of model calibration and validation. The calibration step is to use the existing data to quantify the relationship between the perceived attractiveness, also called utility, of a choice alternative and the potential explanatory variables, as shown in Equation (1). In this equation, the utility $U_{in}$ of alternative *i* perceived by decision maker *n* is composed of a measurable utility term $V_{in}$ and a random component $\varepsilon_{in}$. The measurable term, called systematic utility, $V_{in}$, can be formulated as a linear combination of the observed attributes (*X*) as shown in Equation (2). The random term, called random disturbance, $\varepsilon_{in}$, represents uncertainty of choice making behavior and errors caused by data collection or modeling approximation. The key step of model calibration is to estimate the marginal effect of each affecting factor, denoted by $\beta$, in the systematic utility function.

$$U_{in} = V_{in} + \varepsilon_{in}, \forall\, i \tag{1}$$

$$V_{in} = \beta X, \forall\, i \tag{2}$$

# Case Study and Data Sources

The Greater Buffalo-Niagara metropolitan area (hereafter, the BN metro area) was selected as our case study. There are several reasons for using this area. The main reason is that the BN metro area is a typical example of medium metropolitan areas that shares similar land use and travel patterns as other medium-size metropolitan areas in the U.S. Similar as most of other U.S. cities, it is auto-oriented whereas having almost all other modes, such as rail and buses, available in the transportation system as well. In addition, this area, encompassing the Niagara River border crossings, represents a strategic international corridor of critical importance to trade and tourism flow between the United States and Canada. These features make this area a unique study case for sustainable and equitable development.

In the case study, we first collected economic, land use and travel related data from various sources such as the U.S. Census Bureau, the New York State Department of Transportation, and the Greater Buffalo-Niagara Regional Transportation Council (a local Metropolitan Planning Organization). These data sets were integrated to form a comprehensive database, and then were used to estimate and validate the proposed modeling framework. Impact of various road pricing strategies on local economy, land use and travel patterns were tested based on the model. The modeling and scenario analysis results were summarized to imply the relationship between road pricing policies and long-term economic and social development of the area.

## *Data Sources*

Various publicly available data sources have been used to build the case study. The reference years of the case study shall be determined before data cleaning and fusion. After exploring the available data sources, the reference years of the major data sets were found to be year 2010 and 2000. For the 2010 case, all data sources have consistent records of census tracts, which would give the data processing a jump start. For the case of 2000, the housing characteristic data set and employment data set do not have consistent records of census tracts (as well as the attributes associated with the census tracts). The issue with the case of 2000 makes the data processing close to impossible, since the subjects do not match across different data sources. In addition, selection of the census tracts that we will include is crucial. As a result, all following work was based on the 2010 case. Brief instructions with screen captures are given on the collecting procedures of the ACS and OnTheMap data sets in the appendix, data sources adopted in this study are summarized as below:

- Parcel level tax map. Parcel level information is available for both Niagara and Erie county in the GIS format and is maintained for property tax purposes;
- American Community Survey: household related attributes (including rent, mortgage information) and residential demographic attributes are available in the census tract level for both counties. They are in .CSV files;
- American Housing Survey (AHS): data sets from AHS are in SAS files;
- OnTheMap.com: the website provides interactive data searching based on the Longitudinal Employer-Household Dynamics (LEHD) program. It provides employment information on a yearly basis;
- Construction cost. There is a construction cost survey for Buffalo area conducted in year 2010 (http://www.realestateinvestmentcenter.com/locations/74563-new-york-buffalo). Construction costs per square feet were recorded for a variety of buildings and land use types.

### *Matching TAZ-Based Data with Census Tract based data*

Since the land use model will be constructed on census tracts basis, TAZ transformation issue must be considered in order to successfully integrate with the travel demand model that is built on TAZs.

Census tracts and census blocks are defined and maintained by the nation census, and the related boundary information is standardized by Topologically Integrated Geographic Encoding and Referencing (TIGER). TAZ information is traditionally defined by MPOs and only available for certain metropolitan areas. So there is no authority providing standardized TAZ and census tracts transformation information in general.

According to Census Transportation Planning Products Program site widely known as CTPP data, there is no available information on census tracts to TAZ transformation, but they have an ongoing program called 'Block equivalency for TAZ' for 2010 census blocks (TAZ MTPS). There is no available deliverable so far, and there is no such program for 2000 census since TAZs were not universally defined. When we integrate the proposed model with other transportation model or module, it is possible to use census block to TAZ to accomplish the transformation compare to census tracts to TAZ.

## Data Processing

### *Processing the Parcel Level Data*

Since most of the available data was based on census tract level, the parcel level data has to be processed in order to be compatible with other data. There are four main attributes included in the parcel-level data of Erie County and Niagara County: property type code (single family, multiple family, agricultural etc.), lot size (measured in acre), assessed land value, and assessed total value. The following process has been done for the parcel level data for both counties: 1) join the parcel level data layer to the census tracts boundary layer; 2) generate basic statistics (such as summation, mean value, maximum and minimum), for each attribute for the census tracts layer; and 3) create reference, i.e., providing census tract ID,) for each entry in the parcel level data layer.

### *Categorizing Residential Land Use Type*

Before the data merging, it is necessary to define the filter (categorization on property type). There is an attribute 'CLASS' in the parcel level data, which is a 3 digits code indicating the detailed property type. There are 9 major categories and each one could include more than 10 property subcategories.

TABLE 1 CLASS CODE AND NAME

| Class Code | Class Name |
|---|---|
| 100 | Agricultural |
| 200 | Residential |
| 300 | Vacant Land |
| 400 | Commercial |
| 500 | Recreation & Entertainment |
| 600 | Community Services |
| 700 | Industrial |
| 800 | Public Services |
| 900 | Wild, Forested, Conservation Lands & Public Parks |

Please note that apartments are considered as 'Living Accommodations' in '400 Commercial'. See details on 200 and 400:

210 - One Family Year-Round Residence
220 - Two Family Year-Round Residence
230 - Three Family Year-Round Residence
240 - Rural Residence with Acreage
250 - Estate
260 - Seasonal Residences
270 - Mobile Home
280 - Residential - Multi-Purpose / Multi-Structure

410 - Living Accommodations
    411 - Apartments
    414 - Hotel

415 - Motel
416- Mobile Home Parks
417 - Camps, Cottages, Bungalows
418 - Inns, Lodges, Boarding and Rooming Houses, Tourist Homes, Fraternity and Sorority Houses
420 - Dining Establishments
430 - Motor Vehicle Services
440 - Storage, Warehouse and Distribution Facilities
450 - Retail Services
460 - Banks and Office Buildings
470 - Miscellaneous Services
480 - Multiple Use or Multipurpose

Following approach was adopted to group the above categories into:
A Residential: 200 Residential, 400 Commercial(partial);
A1 Single family residence: 210
A2 Multiple family residence: 220, 230
A3 Apartments:411
A4 Other residential: 240, 250, 260, 270, 280
B Commercial： 400 Commercial(partial);
C Industrial: 700 Industrial;
D Service: 500 Recreation & Entertainment, 600 Community Services and 800 Public Services;
E Others: 100 Agricultural, 300 Vacant Land and 900 Wild, Forested, Conservation Lands & Public Parks.
(See 'NYS_Property Type Classification Codes' for more information)

## *ESTIMATING PARCEL IMPROVEMENT SIZE*

Improvement size is the general measurement of the living space of the residential parcel. It is important attribute that provides a crucial characteristic of the residential parcel, but it was not available from the parcel level tax map data. In order to provide this important attribute, a method was adopted to derive the improvement size based on the lot size.

Scatterplots and regression models were generated to convert the average parcel lot size (LOTSIZE) to parcel improvement size (IMPSIZE). Lot size refers to the area of the land in the unit of square foot, while improvement size refers to the area of the living space in the unit of square foot. Linear regression models were built to find the quantitative connection between LOTSIZE (as an input variable $x$) and IMPSIZE (as an output variable $y$). Table 2 summarizes all the regression models tried, and Natural logarithm Transform 1 was found to be the most suitable model.

TABLE 2 REGRESSION MODEL FOR IMPROVEMENT SIZE

| R-Sq(adj) | SFD | SFA | MF | OTHR | *y* | *x* | Form |
|---|---|---|---|---|---|---|---|
| Linear | 1.30% | 19.60% | 11.00% | 3.00% | RATE | LOTSIZE | LINEAR |
| Exponential | 44.71% | 84.88% | 25.83% | ***95.99%*** | RATE | LOTSIZE | EXP |
| Piecewise Linear | 13.80% | 48.20% | 34.00% | 3.80% | RATE | LOTSIZE | LINEAR |
| Natural logarithm Transform 1 | ***80.70%*** | ***90.80%*** | ***62.80%*** | 75.90% | Ln(RATE) | Ln(LOTSIZE) | LINEAR |
| Natural logarithm Transform 2 | 1.50% | 6.60% | 2.80% | 1.40% | Ln(IMPSIZE) | LOTSIZE | LINEAR |
| Natural logarithm Transform 3 | 2.60% | 12.20% | 5.30% | 2.80% | IMPSIZE | Ln(LOTSIZE) | LINEAR |
| Natural logarithm Transform 4 | 4.70% | 9.10% | 10.60% | 1.60% | Ln(IMPSIZE) | Ln(LOTSIZE) | LINEAR |
| Natural logarithm Transform 5 | 2.40% | 13.60% | 10.80% | 2.60% | IMPSIZE | LOTSIZE+ Ln(LOTSIZE) | LINEAR |
| Natural logarithm Transform 6 | 4.60% | 8.90% | 10.50% | 1.50% | Ln(IMPSIZE) | LOTSIZE+ Ln(LOTSIZE) | LINEAR |

The best regression models selected from the above trials are:

Single-family house: Ln(IMPSIZE) = [6.58 - 0.900*Ln(LOTSIZE)] *Ln(LOTSIZE) (3)

Multiple-family house: Ln(IMPSIZE) = [6.70 - 0.906*Ln(LOTSIZE)]* *Ln(LOTSIZE) (4)

Apartment: Ln(IMPSIZE) = [5.94 - 0.789*Ln(LOTSIZE)] *Ln(LOTSIZE) (5)

Other residential: Ln(IMPSIZE) = [6.96 - 0.928*Ln(LOTSIZE)] *Ln(LOTSIZE) (6)

## *ESTIMATING HOUSE PRICE AND COST*

The total assessment value of each parcel obtained from the parcel level tax map data is considered to be an accurate and reliable measure of housing price. The assessment value generally is defined as estimated market value and usually determined based on recent sale price. To be noted, the assessment value could refer to the market value of the land, the improvement on the land (such as houses, buildings, etc.), and the combined total. In the study, the combined total value is used as the assessment value of a parcel.

Another common challenge is to estimate the construction cost of the house. Usually, the construction cost varies case by case, and it is very hard to obtain an accurate estimation. In addition, such information is often difficult to acquire. During the search, the most relevant and reliable source was found to be the construction cost survey conducted for the Buffalo area in 2010. The survey listed an average construction cost per squared feet by a variety of property types, which is the source of construction costs we used in this study. Regarding the residential construction cost in Buffalo area, information available in the survey is summarized in Table 3.

TABLE 3 CONSTRUCTION COST

| Property Type | Description | Cost per Sq. ft. |
|---|---|---|
| Residence (average quality tract home) | Average quality, two-story, frame, hardboard siding, appliances, laundry rooms, pool, 34 units, 30,000 square feet. | $89 |
| Residence (above average quality tract home) | One-story, hardboard siding, composition shingles, 1½ baths, two-car garage, 1,600 SF. Basement, landscaping, fencing, and deck not included. | $105 |
| Residence (luxurious quality tract home) | Two-story, wood siding, composition shingles, 2½ baths, balcony, two-car garage, 2,400 square feet. Basement, landscaping, fencing, and deck not included. | $165 |
| Small Apartment | Split level, wood siding/brick trim, shake singles, 3½ baths, balconies, three-car garage, 3,200 square feet. Basement, landscaping, fencing, and deck not included. | $97 |

## *DEFINING AND ESTIMATING ACCESSIBILITY*

Accessibility is an important measure that indicates the ability to access a land and effectiveness of transportation systems. It also can be used as an indicator of the effectiveness and sustainability of urban development. Generally, accessibility is defined as the degree of availability of certain product or service to as many users as possible. In the context of this study, accessibility is defined based on the opportunity and cost associated with travel activities. We used the number of employees or job available in an area as the indicator of activity opportunities that derive travels between locations. We used travel cost between census tracts as the cost measure in order to obtain realistic travel cost for the case study, a traffic assignment model was run by using TransCAD for the study area. The traffic assignment provided travel time for each census tract pair.  Only motorized trips were considered in traffic assignment since they are the dominant travels made in the study area. The accessibility of each destination zone was calculated by the following accessibility function:

$$A_i^n = \sum_j E_j^n \exp\left(-\beta\, C_{ij}\right) \qquad (7)$$

where:

$E_j^n$ is the attraction of census tract *j*;

$C_{ij}$ is the travel cost between census tract *i* and *j*; and

$\beta$ is a parameter controlling the scale and it was chosen as 0.45 after a series of sensitivity tests.

# MULTINOMIAL LOGIT MODELS FOR RESIDENTIAL LAND USE CHOICE

## *RESIDENTIAL LAND USE CHOICE SITUATION*

A residential land use choice situation was modeled to estimate the share of each residential land use type in the study area. Four residential land use types, including single-family house (SFH), multiple-family house (MFH), apartment complex (APT), and other residential properties (OTH) were considered as alternatives available to each census tract. Here, SFH refers to one family dwelling units constructed for year-round occupancy; MFH refers to two or more family dwelling units constructed for year-round occupancy; APT refers to commercially managed living accommodations; and OTH refers to all other types of residential properties, including seasonal residences, mobile home, and multi-purpose residential properties.

## *ATTRIBUTES SCREENING AND CORRELATION CHECK*

Over 100 attributes are included in modeling data set. The attributes fall into three categories: (I) alternative specific attribute such as house assessment value and improvement size; (II) accessibility; and (III) Zonal demographic and employment attribute: population density, population age group, medium household income, etc.  Table 4 shows the key attributes and their definitions.

TABLE 4 KEY ATTRIBUTES AND DEFINITIONS

| Attribute | Definition |
|---|---|
| TOTVA | Average total house assessment value of each land use type |
| IMPSQFT | Average improvement size of each residential land use type |
| ZAACC | Zone accessibility |
| ACSVAA | Average car ownership of each zone(number of cars owned by each household) |
| ZAPOPDS | Population density of zone (10,000 person/square mile) |
| OHAGE1R | Population age group of 29 or younger |
| OHAGE2R | Population age group of 30 to 54 |
| OHINCM1R | Population income group  of jobs with earnings $1250/month or less |
| OHINCM3R | Population income group  of jobs with earnings $3333/month or more |
| CTCOST | Average parcel construction cost |
| OMTOTAL | Total zone employment number |
| ZAAREA | Zone area size (square mile) |
| ZAPOP | Total zone population |
| ZAEMPDS | Employment density of zone (10,000 person/square mile) |

Given the size of the data set, attributes screening appeared to be necessary as it helps set priorities for attribute selection in the model estimation process. Priorities were given to accessibility and socio-demographic attributes followed by others.

In addition, correlation check was performed before the modeling process as a part of the attributes screening. We consider two attributes to be highly correlated if the correlation coefficient of the attribute pair is greater than 0.7 (absolute value). Those highly correlated attribute pairs include: construction cost and improvement size, zonal total employment and zonal employment density, and zonal household density and zonal population density. Highly correlated attributes would be excluded in any model to avoid the multicollinearity issue.

Correlations: IMPSQFT, UNIT, TOTVA, CTCOST, OMTOTAL, ZAAREA, ZAPOP, ...

| | IMPSQFT | UNIT | TOTVA | CTCOST | OMTOTAL | ZAAREA | ZAPOP | ZAPOPDS |
|---|---|---|---|---|---|---|---|---|
| UNIT | -0.323 | | | | | | | |
| | 0.000 | | | | | | | |
| TOTVA | 0.591 | -0.110 | | | | | | |
| | 0.000 | 0.000 | | | | | | |
| CTCOST | *0.768 | 0.102 | 0.518 | | | | | |
| | 0.000 | 0.001 | 0.000 | | | | | |
| OMTOTAL | 0.072 | -0.038 | 0.000 | 0.053 | | | | |
| | 0.016 | 0.211 | 0.990 | 0.079 | | | | |
| ZAAREA | 0.012 | 0.016 | -0.042 | 0.020 | -0.041 | | | |
| | 0.692 | 0.603 | 0.161 | 0.497 | 0.177 | | | |
| ZAPOP | -0.002 | -0.032 | -0.030 | -0.015 | 0.055 | 0.182 | | |
| | 0.959 | 0.291 | 0.326 | 0.614 | 0.070 | 0.000 | | |
| ZAPOPDS | -0.068 | 0.026 | 0.047 | -0.061 | -0.200 | -0.438 | -0.123 | |
| | 0.025 | 0.395 | 0.117 | 0.041 | 0.000 | 0.000 | 0.000 | |
| ZAEMPDS | 0.075 | -0.026 | 0.085 | 0.069 | *0.769 | -0.163 | -0.175 | 0.140 |
| | 0.013 | 0.395 | 0.005 | 0.022 | 0.000 | 0.000 | 0.000 | 0.000 |
| ZAHHDDS | -0.068 | 0.032 | 0.008 | -0.060 | -0.202 | -0.413 | -0.136 | *0.966 |
| | 0.024 | 0.281 | 0.785 | 0.046 | 0.000 | 0.000 | 0.000 | 0.000 |
| ZAACC6 | -0.180 | -0.108 | 0.075 | -0.166 | -0.057 | -0.178 | -0.011 | 0.283 |
| | 0.000 | 0.000 | 0.012 | 0.000 | 0.060 | 0.000 | 0.718 | 0.000 |

| | ZAEMPDS | ZAHHDDS |
|---|---|---|
| ZAHHDDS | 0.127 | |
| | 0.000 | |
| ZAACC6 | 0.050 | 0.236 |
| | 0.098 | 0.000 |

Cell Contents: Pearson correlation
P-Value

FIGURE 1 CORRELATION MATRIX

## *MODEL ESTIMATION AND DISCUSSIONS*

Multinomial logit models, as discussed in the methodology section, were built to capture the market share of each residential land use type in a census tract. The final best model from calibration is presented in following table. As a general fitness measurement, the adjusted R-squared value is 0.19, which is generally considered as an acceptable value for a good multinomial logit model.

TABLE 5 RESIDENTIAL LAND USE CHOICE MODEL

| Variables | Coefficient | t-value |
|---|---|---|
| **Constant** | | |
| **2)MULTIPLE FAMILY HOUSE** | -4.0813 | -14.59 |
| **3)APARTMENT** | -8.4092 | -11.64 |
| **4)OTHERS** | -8.7030 | -15.54 |
| ***Alternative Specific Attributes*** | | |
| **TOTVA: Average total house assessment value of each land use type(100,000 dollars)** | | |
| **1)SINGLE FAMILY HOUSE** | -0.3609 | -17.40 |
| **2)MULTIPLE FAMILY HOUSE** | -0.2217 | -6.53 |
| **3)APARTMENT** | -0.0112 | -3.60 |
| **4)OTHERS** | -0.2150 | -8.78 |
| **IMPSQFT: Average improvement size of each residential land use type(1,000 square feet)** | | |
| **1)SINGLE FAMILY HOUSE** | -3.547 | -47.45 |
| **2)MULTIPLE FAMILY HOUSE** | -2.467 | -33.13 |
| **3)APARTMENT** | -0.302 | -9.54 |
| **4)OTHERS** | 1.547 | 22.65 |
| ***Accessibility Related Attributes*** | | |
| **ZAACC(ZAACC6L): Transformed zone accessibility** | | |
| **2)MULTIPLE FAMILY HOUSE** | 0.1877 | 21.82 |
| **3)APARTMENT** | 0.0474 | 2.31 |
| **4)OTHERS** | -0.3648 | -29.70 |
| **ACSVAA: Average car ownership of each zone(number of cars owned by each household)** | | |
| **2)MULTIPLE FAMILY HOUSE** | -1.2795 | -35.59 |
| **3)APARTMENT** | -2.7419 | -28.93 |
| **4)OTHERS** | -0.8306 | -10.07 |
| ***Zonal Demographic Attributes*** | | |
| **ZAPOPDS: Population density of zone (10,000 person/square mile)** | | |
| **2)MULTIPLE FAMILY HOUSE** | 0.5268 | 30.19 |
| **3)APARTMENT** | -0.1025 | -2.15 |
| **4)OTHERS** | 0.6451 | 11.44 |
| **OHAGE1R: Population age group of 29 or younger** | | |
| **2)MULTIPLE FAMILY HOUSE** | 10.0242 | 38.65 |
| **3)APARTMENT** | 19.0864 | 27.53 |
| **4)OTHERS** | 4.0637 | 6.10 |
| **OHAGE2R: Population age group of 30 to 54** | | |
| **2)MULTIPLE FAMILY HOUSE** | 2.5125 | 8.78 |
| **3)APARTMENT** | -0.8959 | -1.14 |
| **4)OTHERS** | -2.4727 | -3.89 |
| **OHINCM1R: Population income group of jobs with earnings $1250/month or less** | | |
| **2)MULTIPLE FAMILY HOUSE** | -4.9937 | -19.84 |
| **3)APARTMENT** | -8.8885 | -12.96 |
| **4)OTHERS** | 5.5259 | 9.24 |
| **OHINCM3R: Population income group of jobs with earnings $3333/month or more** | | |
| **2)MULTIPLE FAMILY HOUSE** | -6.3195 | -39.68 |
| **3)APARTMENT** | -0.1679 | -0.42 |
| **4)OTHERS** | -6.5056 | -19.46 |
| ***Summary Statistics*** | | |
| **Number of Observations = 289** | **Adjusted R-square = 0.19** | |

The identified affecting attributes (except constant) were grouped into three categories:

- *Alternative specific attributes*: This set of attributes capture the variations among choice alternatives and usually considered to be the crucial component of the model. Total assessment value (TOTVA) showed negative impacts on all choice alternatives, indicating that property with higher price would result a lower utility and less likely to be chosen. It is rational behavior as assessment value indicates the market value (as well as sale price) of the property, and buyer will always prefer a lower price tag given choices with similar condition. Single-family house is the most price-sensitive residential housing type since it showed the greatest absolute value among all alternatives. On the other hand, apartment appeared to be the least price-sensitive one. Similarly, improving size or living space (IMPSQFT) was also identified as a negatively affecting attribute for all alternatives except for OTH. Single-family house appeared to be the most sensitive one to improvement size while apartment was the least sensitive one. The reasoning behind the pattern is that rent would be the major affecting factor than the property assessment value and improvement size in this case of alternative while it is one the contrary for the case of single-family house;
- *Accessibility related attributes*: Zone accessibility (ZAACC6L) was found to have significant positive impact on multiple-family house, some positive impact on apartment and negative impact on others. For all attributes other than alternative specific attributes, single-family house was set up as the reference group. When analysis the calibrated parameters, the corresponding calibrated parameters for the reference group were assumed to be zero. Not surprisingly, single-family house was less sensitive to accessibility when compare with multiple-family house and apartment due to the culture of pursuing suburban life and thus single-family houses are usually in reclusive location with better privacy. One reason of the insensitive of apartment to accessibility came from the nature of this type of living accommodation: a considerable percentage of apartments were student housing (which would be close to campus) and senior home, which do not weight commuting cost (as well as accessibility) as a major factor. Another identified accessibility related attribute is average household car ownership (ACSVAA). Apartment alternative was one most negatively impacted by ACSVAA, and then followed by multiple-family house, other and single-family house. In another word, if a zone is mainly consisted of apartment or multiple-family houses, it attracts household with lower car ownership than a zone dominated by single-family house does. This observation agreed with the fact that single-family house residents usually rely on driving passenger car while higher density residential area (apartment and multiple-family house) sometime better served by public transportation and less dependent on driving. Both accessibility and car ownership are considered as important transportation sustainability indicators of the land use pattern, travel behavior of population;
- *Zonal demographic attributes*: Population age group and income group attributes were identified to be important affecting factors in the model. Population age group of 29 or younger (OHAGE1R) were found to have the most significant positive impacts on the alternatives of apartment and multiple-family houses since they would be more suitable for the need and financial situation of "starters" households, while most growing family would choose single-family houses as their first choice. Population age group of 30 to 54 showed negative impact on the apartment alternative, which again verified the reality that prime age population are the major consumer of single-family house rather than apartment. There are three population income groups, the low income group (OHINCM1R) had positive impact on others, which indicating other residential housing type (including mobile home) was more affordable and attractive to low income group household. On the other hand, the high-income group (OHINCM3R) showed negative parameters for all alternatives except single-family house, which reflects the fact that wealthy middle class can afford and choose single-family house as their primary choice.

# TOLL PRICING SCENARIOS

The residential land use choice model was used as the evaluation tool to assess the impact of toll pricing strategies on residential land use choices. We argued that toll charges, as a part of overall travel cost, would affect accessibility to land and thus influence the market shares of residential land use types in an area.

## *SCENARIO DEFINITION AND CONFIGURATION*

A total of nine scenarios were defined for the study case, including 1 base case and 8 toll pricing scenarios. The assumed monetary value of the toll was transformed into an additional travel time as in the generalized travel cost. Three groups of scenarios are: (I) Scenarios 1, 2, 3, and 4: toll as a uniform cost increase for every zone; (II) Scenarios 1, 5, 6 and 7: density-based (congestion) toll; and (III) Scenarios 1, 8 and 9: zone-based (downtown) toll. The definition and configuration of each scenario is summarized in the following table:

TABLE 6 SCENARIO DEFINITIONS

| Scenario ID | Definition |
|---|---|
| Scenario 1 | base case with no toll |
| Scenario 2 | $1 toll for any traveler entering the study area, which is equivalent of 4 minute extra travel time |
| Scenario 3 | $2.5 toll for any traveler entering the study area, which is equivalent of 10 minute extra travel time |
| Scenario 4 | $2.5 toll for any traveler entering the study area, which is equivalent of 20 minute extra travel time |
| Scenario 5 | $1 toll for destination zones with employment and population ration(EMP/POP) >0.5, which is equivalent of 4 minute extra travel time |
| Scenario 6 | $2.5 toll for destination zones with EMP/POP ratio>1, which is equivalent of 10 minute extra travel time |
| Scenario 7 | $2.5 toll for destination zones with EMP/POP ratio>1, which is equivalent of 10 minute extra travel time; and $1 toll for destination zones with 0.5<EMP/POP ratio <1, which is equivalent of 4 minute extra travel time |
| Scenario 8 | $1 toll for any traveler entering the study area , defined as census tracts 71.02 (007102), 165 (016500), which is equivalent of 4 minute extra travel time |
| Scenario 9 | $2.5 toll for any traveler entering the study area , defined as census tracts 71.02 (007102), 165 (016500), which is equivalent of 10 minute extra travel time |

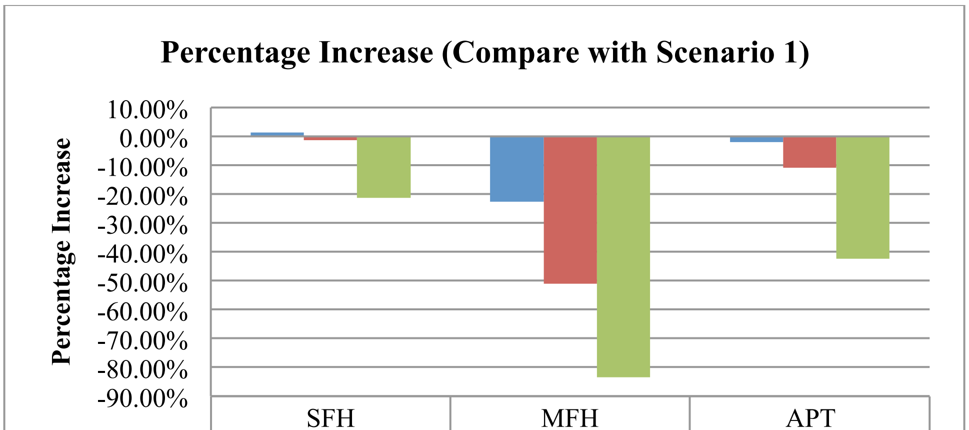
Value of time was chosen as $15/hour and used to convert toll cost to travel time (minutes). The conversion was done by taking the average of the average monthly income of workers live in each zone and divided by 40 hours per week and 4 weeks per month. To be noted, the cost increase is per capita based on the zone population, which is different from the opportunity (defined as the number of employment of other zones) in the zone accessibility.

## *PREDICTIONS FROM RESIDENTIAL LAND USE CHOICE MODEL*

With the calibrated multinomial logit model for the residential land use type choice, the predictions can be performed with updated input data. With respective to the toll pricing scenarios, the zone accessibility was adjusted according to the scenario definitions. By running the model with the updated inputs, the scenario predictions were obtained and analyses were conducted based on the predictions.

### *SCENARIO GROUP I: UNIFORM TOLL*

By imposing uniform tolls, single-family house, multiple-family house and apartment all showed a decrease on their shares. Multiple-family house was the most sensitive one and had the most severe drop among the three. On the other hand, when the uniform tolls increased, the predicted number of units of others appeared to have an unrealistic exponential increase due to the limitation of the logit model. There is an assumption that the total number of observations does not change and every decision maker (census tract) has to pick an alternative as the decision.

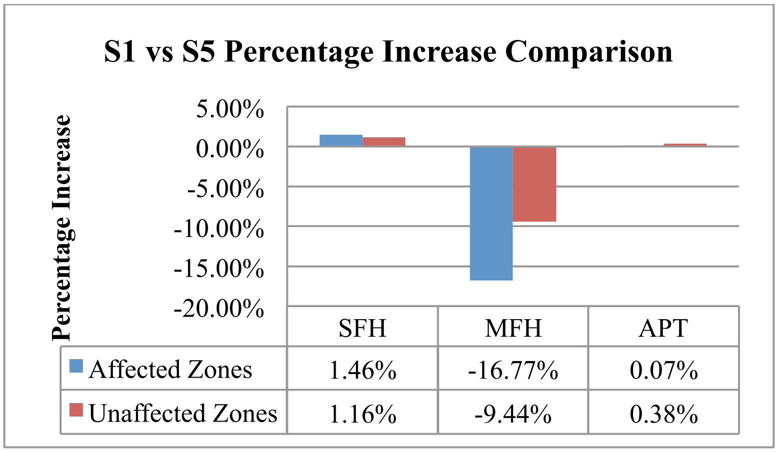


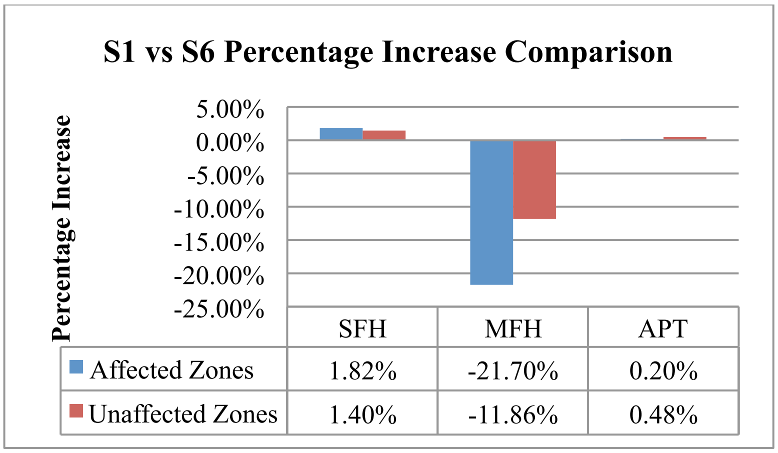

| | SFH | MFH | APT |
|---|---|---|---|
| Scenario 2 | 1.26% | -22.66% | -2.04% |
| Scenario 3 | -1.38% | -51.10% | -10.95% |
| Scenario 4 | -21.24% | -83.46% | -42.29% |

FIGURE 2 UNIFORM TOLL PRICING SCENARIOS COMPARISON

### *SCENARIO GROUP II: DENSITY-BASED TOLL*

Density-based toll pricing scenarios revealed a consistent pattern across the three scenarios (Scenarios 5, 6 and 7). Affected zones always had a more severe change than unaffected zones with the exception of apartment. When density-based tolls were imposed, single-family houses showed a minor increase of share due to the dropped accessibility, while multiple-family houses always showed a contrary reaction. The predictions on apartment were quite different, the affected zones always showed a relatively milder change. It implicates that apartment land use type may benefit from the density-based tolls.



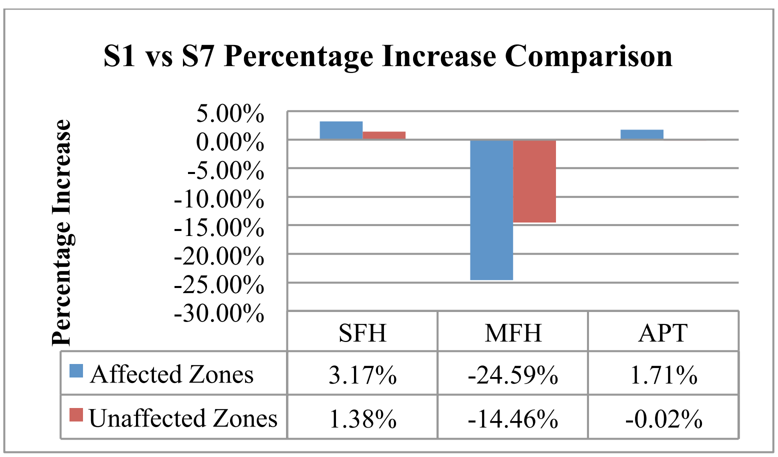




FIGURE 3 DENSITY-BASED TOLL PRICING SCENARIOS COMPARISON

### *Scenario Group III: Zone-based Toll (Entering or Exiting Downtown)*

Zone-based toll was designed to reduce or limit trips entering or exiting congested downtown area. The idea behind this scenario set is to avoid single-center urban planning and encourage mixed land use with smart growth strategy. By imposing this zone-based toll, the residential land use type shift to single-family house, apartment and others. It also appears to be a trend of high density and mix-use development.

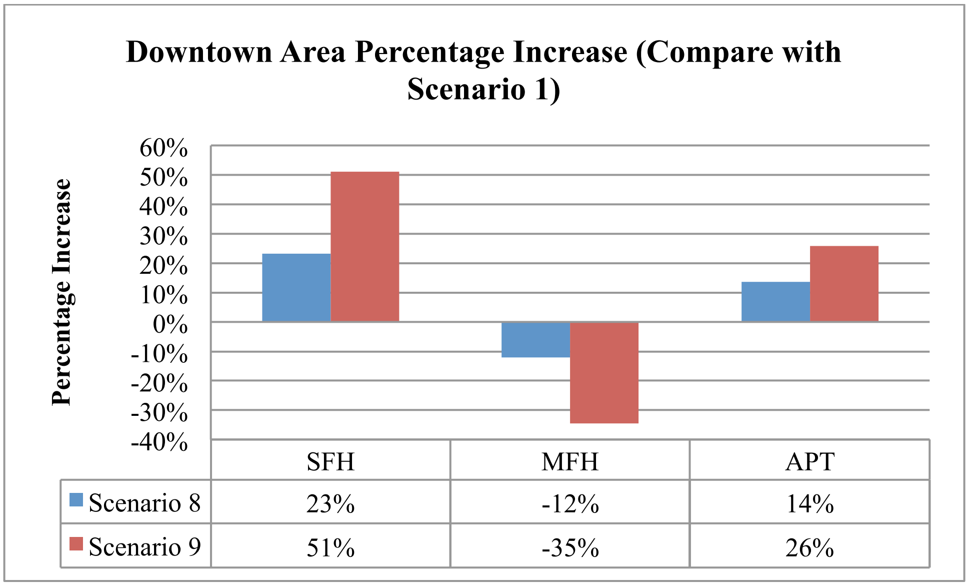



FIGURE 4 ZONE-BASED TOLL PRICING SCENARIOS COMPARISON

# CONCLUSIONS

In this study, a multinomial logit model approach was applied for the purpose to evaluate the impacts of different toll pricing strategies on residential land use choices. This study selected the BN metro area as its study case. Various data sources were fused to support the analysis. The best logit model was estimated based on a consolidated information-rich data set with the special consideration of residential land use types available to a census tract.

Three groups of attributes were found to have significant impact on the residential land use choices. They are included in the estimated multinomial logit model: (1) alternative specific attribute such as house assessment value and improvement size; (2) accessibility; and (3) Zonal demographic attribute. As the core attributes in the study, accessibility was found to have positive impact on the choice of higher density residential land use. Demographic attributes such as population age group and income group also provided unique implications on the residential land use: higher income results in preference in lower density residential land use, while younger population prefer higher density residential land use.

Three groups of toll pricing scenarios, such as the uniform toll, the density-based toll and the zone-based toll, were evaluated for their impacts on residential land use choice. As found, when imposing tolls, the alternative of single-family house was usually positively affected, while the alternative of multiple-family house was always negatively affected. Uniform toll price appeared to be the most effective strategy, but not necessarily the most rational one. The density-based toll pricing and zone-based toll pricing offered more sensible approaches to achieve the goal of land use and transportation sustainability.

Accessibility was proven to have profound impacts on the residential land use choice, and it is also one of the most important affecting factors in land use planning as well as toll pricing policy design. Toll pricing was also verified as a promising approach to better shape the urban land use in long term. Based on the findings, future work will be aiming at developing non-residential land use type choice model and bridging the land use choice model module with travel demand module, and construct the integrated land use and travel demand model. Also, it needs to add whether there is a spatial aggregation error when combining different geographical levels to an upper level. We will measure in a following study.

# REFERENCE

Beamon, B.M. and Griffin, P. M., 1999. A Simulation-Based Methodology for Analyzing Congestion and Emissions on a Transportation Network. Simulation Vol. 72 (2), pp. 105-114.

Ecola, L., T. Light, 2009. "Equity and Congestion Pricing: A Review of the Evidence", Technical Report, RAND Corporation.

Eliasson, J., L.-G. Mattsson, 2001. "Transport and Location Effects of Road Pricing: A Simulation Approach", Journal of Transport Economics and Policy, 35(3), pp. 417-456.

Federal Highway Administration (FHWA), 2007. Value Pricing Pilot Program. http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/projtypes/pricingtollfacil.htm.

Flowerdew, A., 1993. Urban Traffic Congestion in Europe: Road Pricing and Public Transport Demand. Research Report. the Economics Intelligence Unit, London.

Giuliano, G., 1994. Equity and Fairness Considerations of Congestion Pricing. Curbing Gridlock, Vol. 2, Transportation Research Board.

Harrington, W., Krupnick, A. J., and Alberini, A., 2001. Overcoming Public Aversion to Congestion Pricing. Transportation research. Part A, Policy and practice. 35, no. 2, pp. 87–105.

Holguín-Veras, J., K. Ozbay and A. De Cerreño, 2005a. Evaluation Study of New Jersey Turnpike Authority's Time of Day Pricing Initiative. Final Report submitted to the Federal Highway Administration and the New Jersey Department of Transportation (accessible at http://knowledge.fhwa.dot.gov/cops/hcx.nsf/All+Documents/BA2414CE1EAC182685256DC500674090/$FILE/NJTA%20proposal%20-FINAL-%205-22-01.pdf).

Holguín-Veras, J., K. Ozbay and A. De Cerreño, 2005b. Evaluation Study of Port Authority of New York and New Jersey's Time of Day Pricing Initiative. Final Report submitted to the Federal Highway Administration and the New Jersey Department of Transportation (accessible at http://www.rpi.edu/~holguj2/PA/PANYNJ%20Final%20Report.pdf).

Holguín-Veras, J., Q. Wang, N. Xu, K. Ozbay, M. Cetin and J. Polimeni, 2006. The Impacts of Time of Day Pricing on the Behavior of Freight Carriers in a Congested Urban Area: Implications to Road Pricing. Transportation Research Part A: Policy and Practice, 40, pp. 744-766.

Keong, C. K., 2002. Road Pricing Singapore's Experience. The Third Seminar of the IMPRINT-EUROPE Thematic Network: Implementing Reform on Transport Pricing.

Larsen M. M., N. Pilegaard, J. van Ommeren, 2008. "Transportation Costs in a Multiregional Equilibrium Job Search Model", In: Road Pricing, the Economy and the Environment (Eds. C. Jensen-Butler, B. Sloth, M. M. Larsen, B. Madsen, O. A. Nielsen), Springer-Verlag Berlin Heidelberg.

Levinson, D., 2010. "Equity Effects of Road Pricing: A Review", Transport Reviews, 30(1), pp. 33-57.

Link, H. and Polak, J., 2003. Acceptability of Transport Pricing Measures among Public and Professionals in Europe. Transportation research record. No. 1839, pp. 34-44.

Litman, T., 1996. Using Road Pricing Revenue: Economic Efficiency and Equity Considerations. Transportation Research Record 1558.

Litman, T.A., 2006. London Congestion Pricing: Implications for Other Cities. Victoria Transport Policy Institute. http://www.vtpi.org/london.pdf.

Madsen, B., and Jensen-Butler, C., 2001. Modelling the Local Economic Impacts of Road Pricing, SØM Publication No. 46, Society, Economics & Environment Research Centre, Institute of Local Government Studies. Denmark. http://www.akf.dk/som/pdf/som46.pdf.

Madsen, B., C. Jensen-Butler, J. Kronbak, S. Leleur, 2008. "A Systems Approach to Modelling the Regional Economic Effects of Road Pricing", In: Road Pricing, the Economy and the Environment (Eds. C. Jensen-Butler, B. Sloth, M. M. Larsen, B. Madsen, O. A. Nielsen), Springer-Verlag Berlin Heidelberg.

National Economic Development Office, 1991. A Road User Charge: Londoner's Views, Report on Survey Findings. Harris/NEDO, London.

Orange County Transportation Authority (OCTA), 2003. 91 Express Lanes Toll Policy. http://www.91expresslanes.com/generalinfo/tollpolicy.asp

Safirova, E. S. Houde, C. Coleman, W. Harrington, D. A. Lipman, 2006a. "Long-Term Consequences of Congestion Pricing: A Small Cordon in the Hand is Worth Two in the Bush", Technical Report, Resources for the Future, RFF DP 06-42, Washington, D.C.

Safirova, E., S. Houde, D. A. Lipman, W. Harrington, A. Baglino, 2006b. "Congestion Pricing: Long-Term Economic and Land-Use Effects", Technical Report, Resources for the Future, RFF DP 06-37, Washington, D.C.

Santos, G and Rojey, L., 2002. Distributional Impacts of Road Pricing: the Truth Behind the Myth. 82nd TRB Annual Meeting 03-3211, Washington, DC.

Tillema, T., B. van Wee, D. Ettema, 2010. "Road Pricing and Relocation Decisions of Dutch Households", Urban Studies, 47(14), pp. 3013-3033.

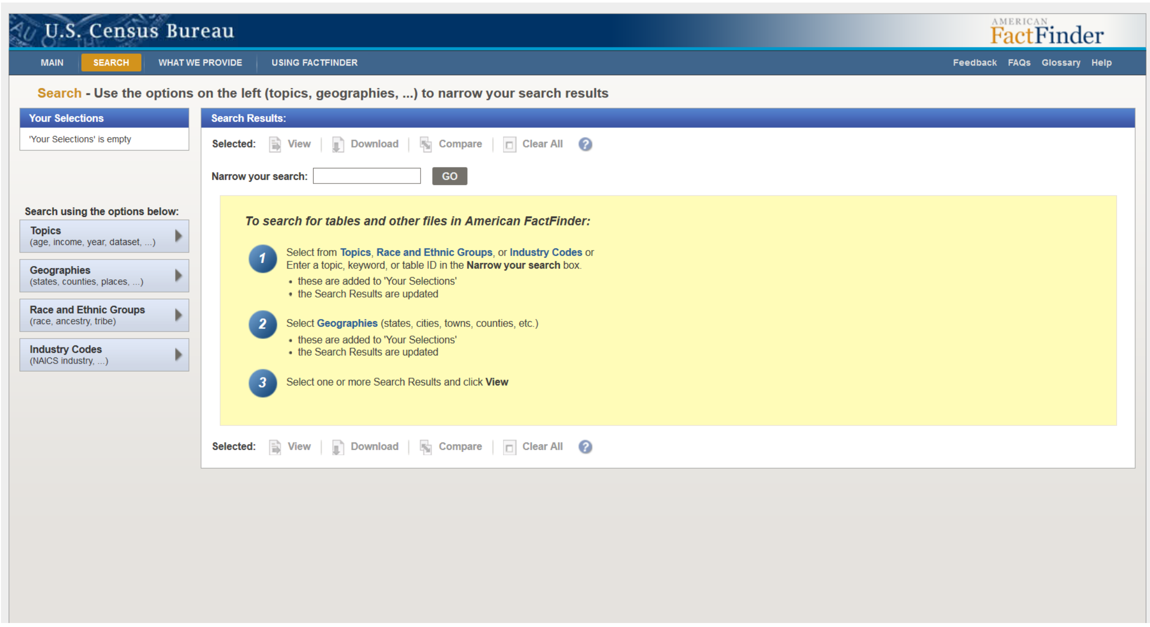
Win, Z. N., Kubota, H., and Sakamoto, K., 2007. Study on the Effectiveness of Congestion Pricing Schemes by Using Traffic Simulation Method. The 11th World Conference on Transportation Research, Berkeley.

Yelds, A. and Burris, M., 2000. Variable Toll Pricing Program, Lee County, Florida, Revealed Preference Telephone Survey Findings. 2000 Transportation Research Board Annual Meeting.

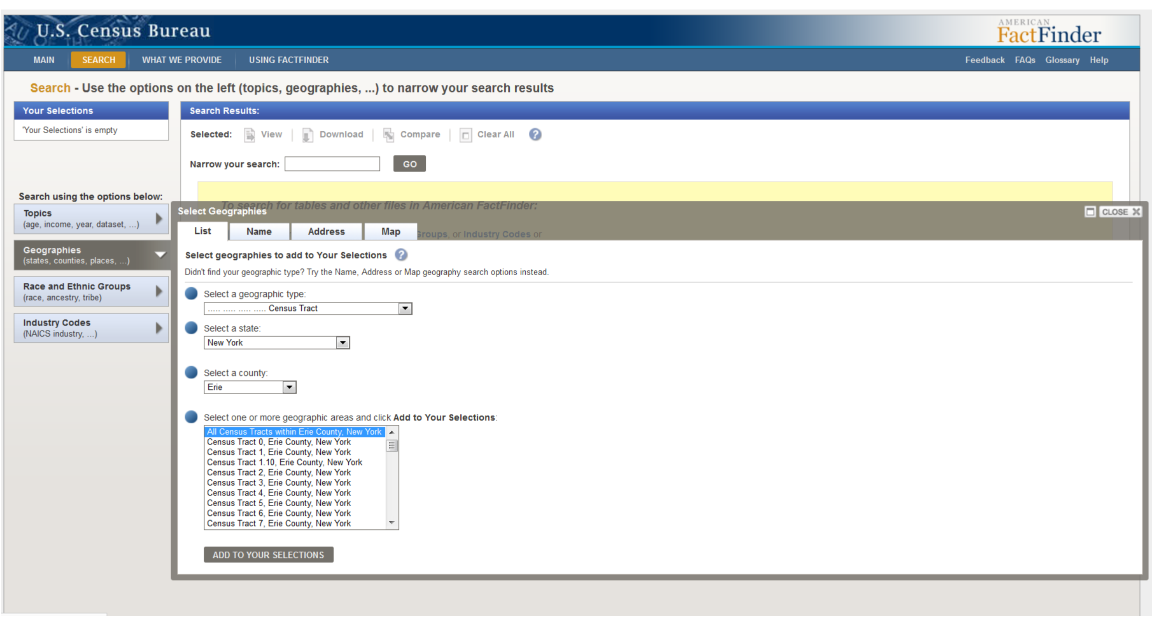
Ying, J.Q., 2007. "Optimal Pricing Design Methods in Integrated Location/Transport Models", Proceedings of the 86th Transportation Research Board Annual Meeting, Washington, D.C.

# APPENDIX A: COLLECTION OF AMERICAN COMMUNITY SURVEY (ACS) DATA SET

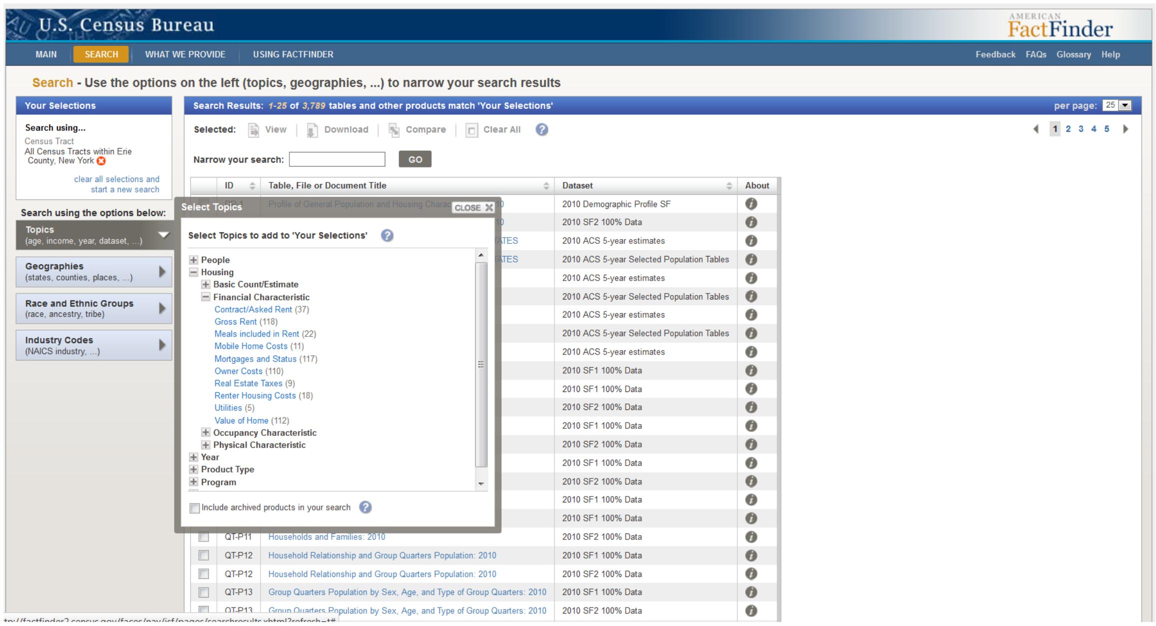
1. Go to FactFinder site of U.S. Census Bureau (http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t).



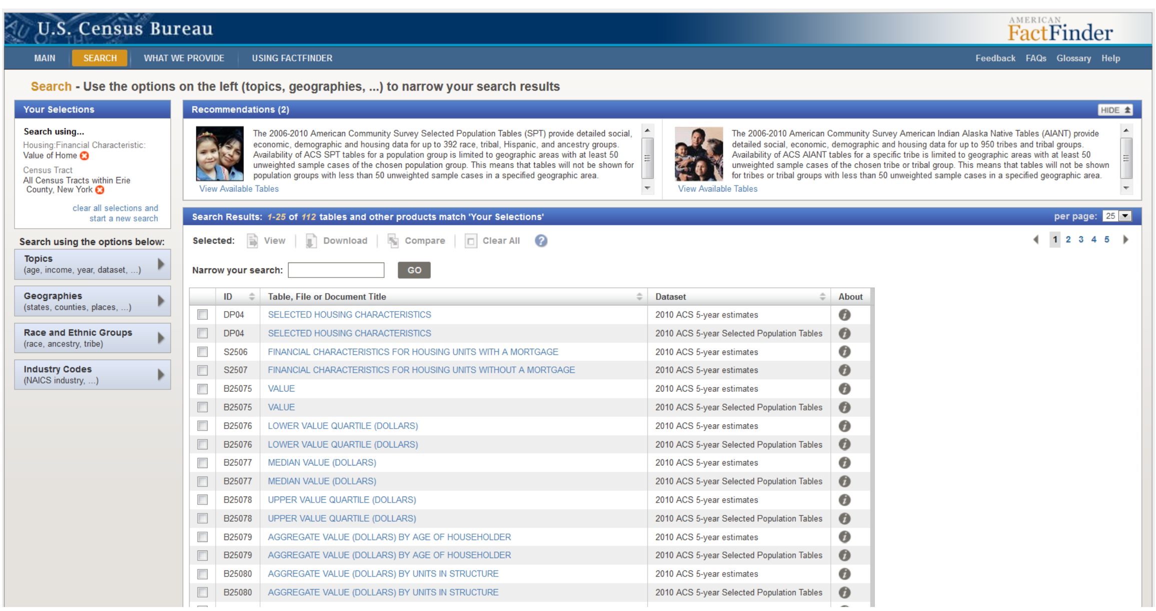

2. Start by defining 'Geographies' in the search options. Select 'Census Tract' as the geographic type and then select particular or all census tracts in certain desired state and county. All census tracts from Erie County, NY are selected in this demonstration.



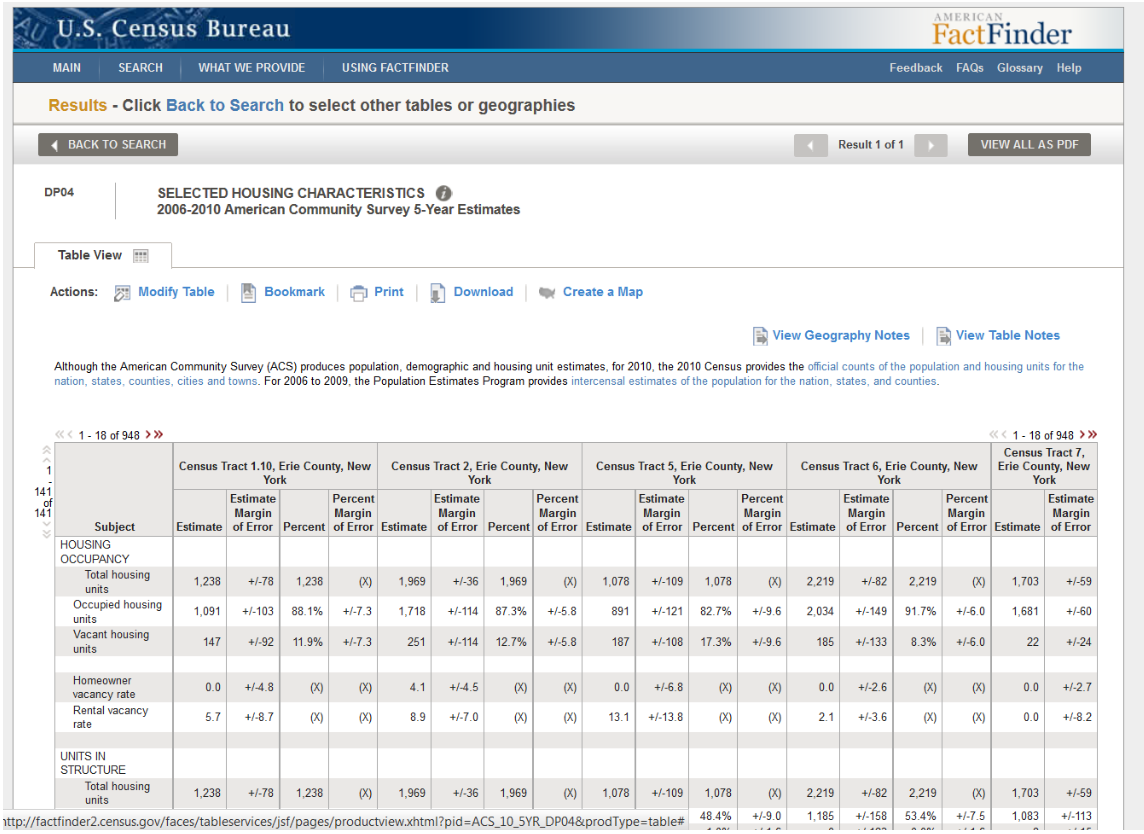
3. After adding the geographies selections, select desired topics. For the case study, housing related financial information will be focus. As shown in the following figure, rent, housing cost and value of home are identified under the 'Financial Characteristic' under 'Housing' topic.




4. After adding 'Value of home' to the selections, the search engine finds out the available data sets satisfying all selected criteria.

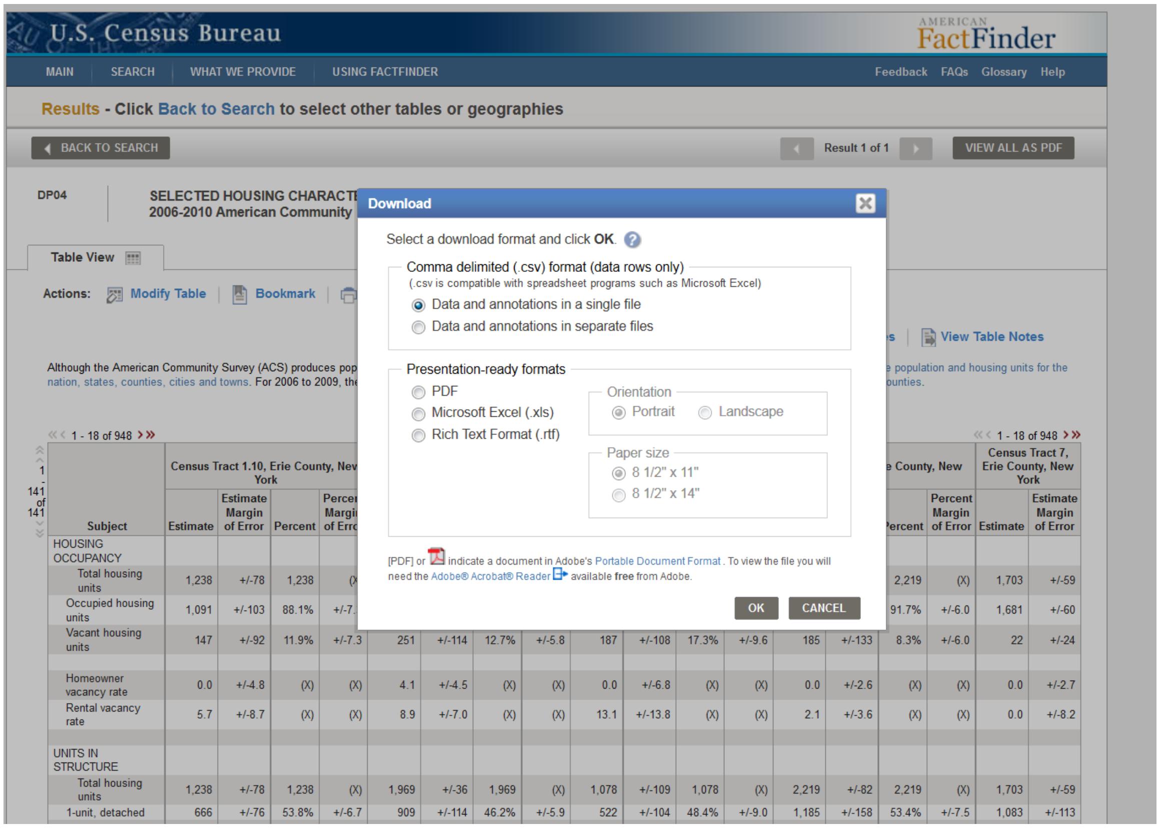


5. Select a data set from the search results and view the partial data set. The site also provides various viewing options as well as downloads options.



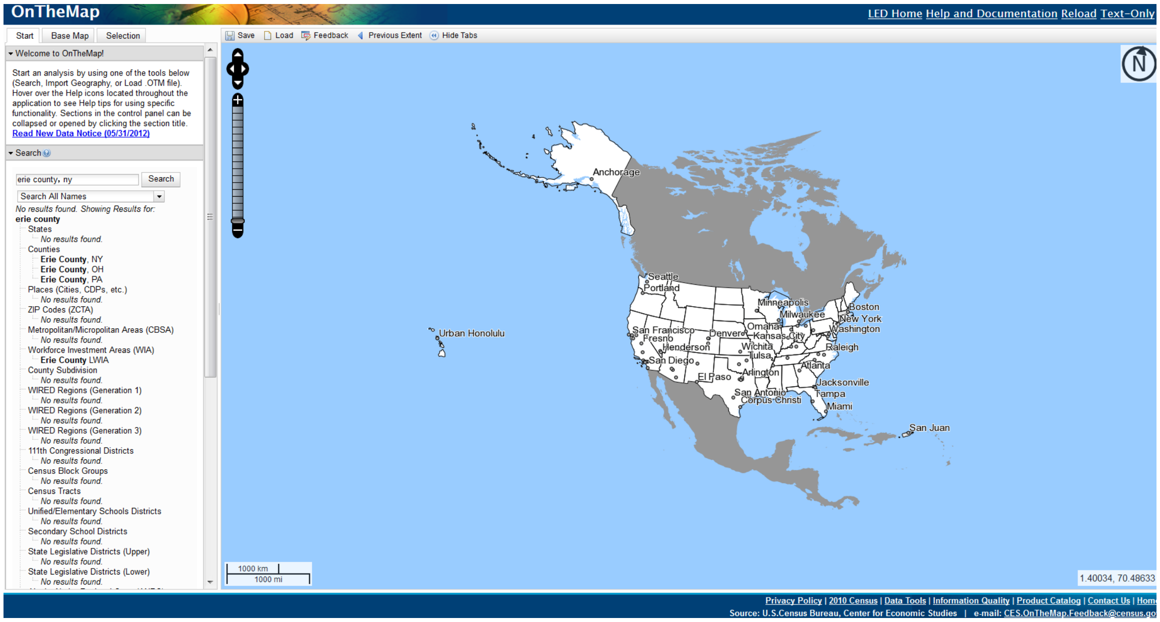

| | Census Tract 1.10, Erie County, New York | | | | Census Tract 2, Erie County, New York | | | | Census Tract 5, Erie County, New York | | | | Census Tract 6, Erie County, New York | | | | Census Tract 7, Erie County, New York | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subject | Estimate | Estimate Margin of Error | Percent | Percent Margin of Error | Estimate | Estimate Margin of Error | Percent | Percent Margin of Error | Estimate | Estimate Margin of Error | Percent | Percent Margin of Error | Estimate | Estimate Margin of Error | Percent | Percent Margin of Error | Estimate | Estimate Margin of Error |
| HOUSING OCCUPANCY | | | | | | | | | | | | | | | | | | |
| Total housing units | 1,238 | +/-78 | 1,238 | (X) | 1,969 | +/-36 | 1,969 | (X) | 1,078 | +/-109 | 1,078 | (X) | 2,219 | +/-82 | 2,219 | (X) | 1,703 | +/-59 |
| Occupied housing units | 1,091 | +/-103 | 88.1% | +/-7.3 | 1,718 | +/-114 | 87.3% | +/-5.8 | 891 | +/-121 | 82.7% | +/-9.6 | 2,034 | +/-149 | 91.7% | +/-6.0 | 1,681 | +/-60 |
| Vacant housing units | 147 | +/-92 | 11.9% | +/-7.3 | 251 | +/-114 | 12.7% | +/-5.8 | 187 | +/-108 | 17.3% | +/-9.6 | 185 | +/-133 | 8.3% | +/-6.0 | 22 | +/-24 |
| | | | | | | | | | | | | | | | | | | |
| Homeowner vacancy rate | 0.0 | +/-4.8 | (X) | (X) | 4.1 | +/-4.5 | (X) | (X) | 0.0 | +/-6.8 | (X) | (X) | 0.0 | +/-2.6 | (X) | (X) | 0.0 | +/-2.7 |
| Rental vacancy rate | 5.7 | +/-8.7 | (X) | (X) | 8.9 | +/-7.0 | (X) | (X) | 13.1 | +/-13.8 | (X) | (X) | 2.1 | +/-3.6 | (X) | (X) | 0.0 | +/-8.2 |
| | | | | | | | | | | | | | | | | | | |
| UNITS IN STRUCTURE | | | | | | | | | | | | | | | | | | |
| Total housing units | 1,238 | +/-78 | 1,238 | (X) | 1,969 | +/-36 | 1,969 | (X) | 1,078 | +/-109 | 1,078 | (X) | 2,219 | +/-82 | 2,219 | (X) | 1,703 | +/-59 |
| | | | | | | | | | | | 48.4% | +/-9.0 | 1,185 | +/-158 | 53.4% | +/-7.5 | 1,083 | +/-113 |

6. To download a data set, click download link when viewing the data set and choose desired format.

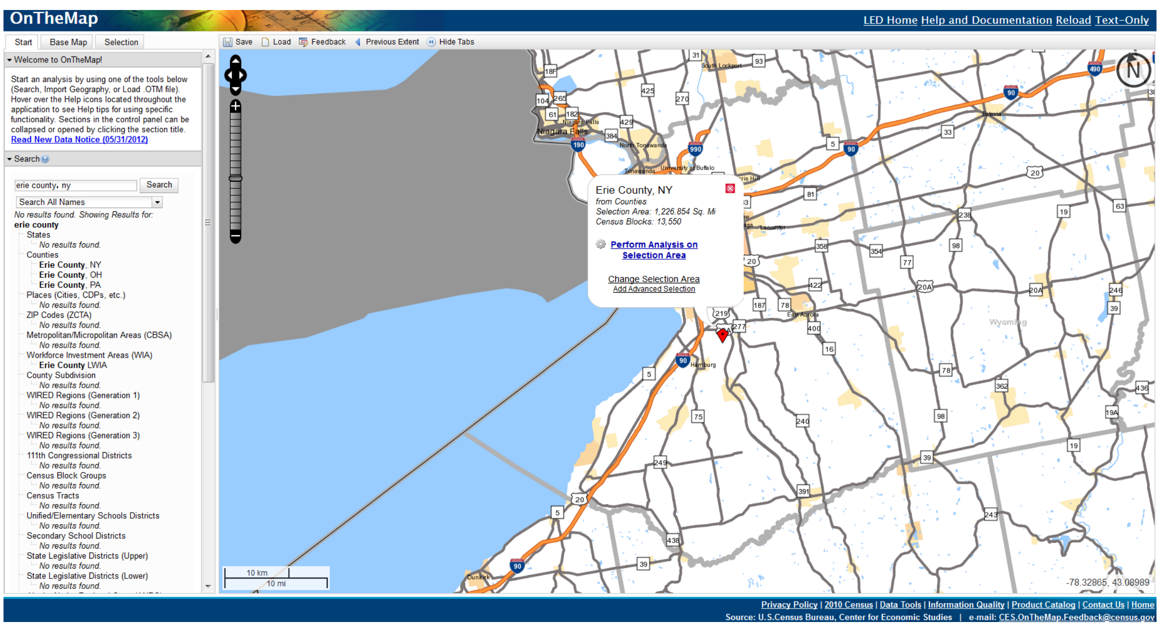

U.S. Census Bureau
AMERICAN FactFinder
MAIN
SEARCH
WHAT WE PROVIDE
USING FACTFINDER
Feedback
FAQs
Glossary
Help
Results - Click Back to Search to select other tables or geographies
BACK TO SEARCH
Result 1 of 1
VIEW ALL AS PDF
DP04
SELECTED HOUSING CHARACT
2006-2010 American Community
Table View
Actions:
Modify Table
Bookmark
View Table Notes
Download
Select a download format and click OK.
Comma delimited (.csv) format (data rows only)
(.csv is compatible with spreadsheet programs such as Microsoft Excel)
Data and annotations in a single file
Data and annotations in separate files
Presentation-ready formats
PDF
Microsoft Excel (.xls)
Rich Text Format (.rtf)
Orientation
Portrait
Landscape
Paper size
8 1/2" x 11"
8 1/2" x 14"
[PDF] or indicate a document in Adobe's Portable Document Format. To view the file you will need the Adobe® Acrobat® Reader available free from Adobe.
OK
CANCEL
1 - 18 of 948
Census Tract 1.10, Erie County, New York
Census Tract 7, Erie County, New York
Subject
Estimate
Estimate Margin of Error
Percent
Percent Margin of Error
HOUSING OCCUPANCY
Total housing units
Occupied housing units
Vacant housing units
Homeowner vacancy rate
Rental vacancy rate
UNITS IN STRUCTURE
1-unit, detached

# APPENDIX B: COLLECTION OF ONTHEMAP DATA SET

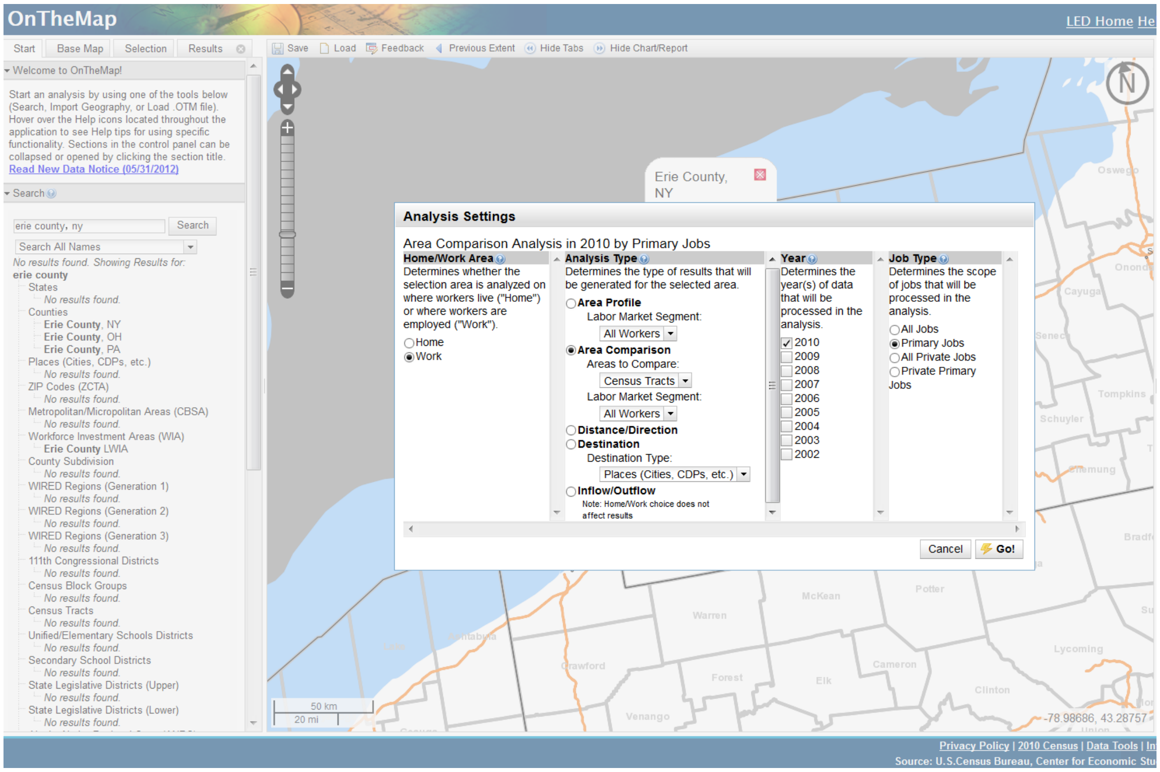
1. Go to OnTheMap website (http://onthemap.ces.census.gov/), and start by searching the desired geographic area. In the demonstration, 'Erie County, NY' is the key words and desired geographic area.



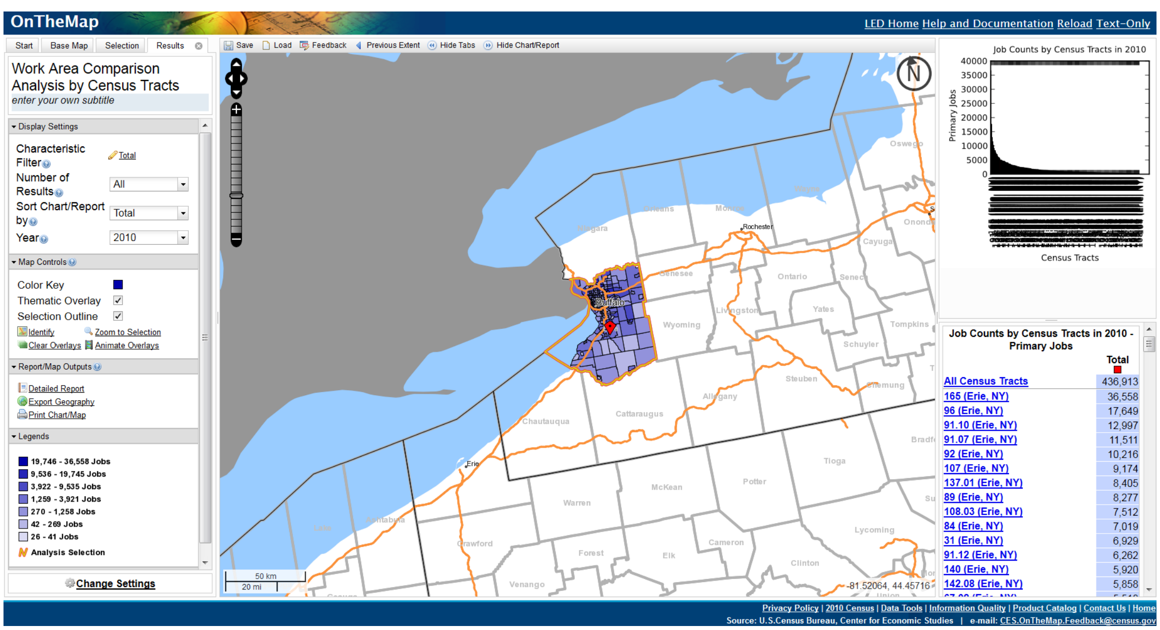

2. Select the desired search result by double clicking, then start further analysis by clicking 'Perform Analysis on Selection Area'



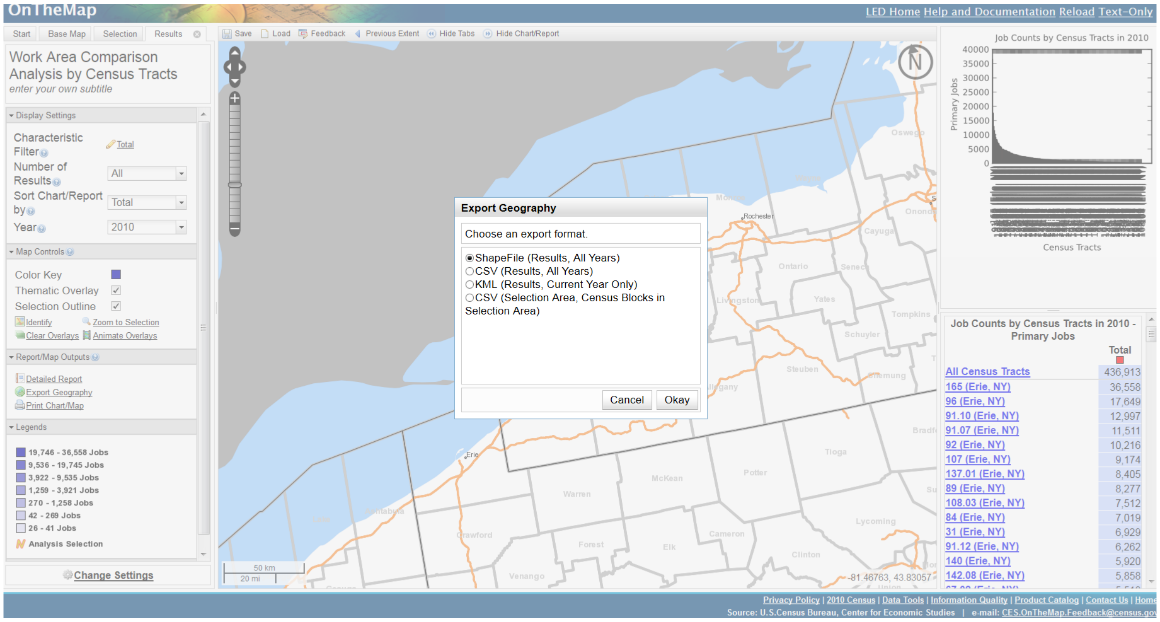

3. Define 'Home/Work Area' as 'Work', 'Year' as '2010', 'Job Type' as 'Primary Jobs' and 'Analysis type' as 'Census Tracts' under 'Area to Compare', and click 'Go!'.

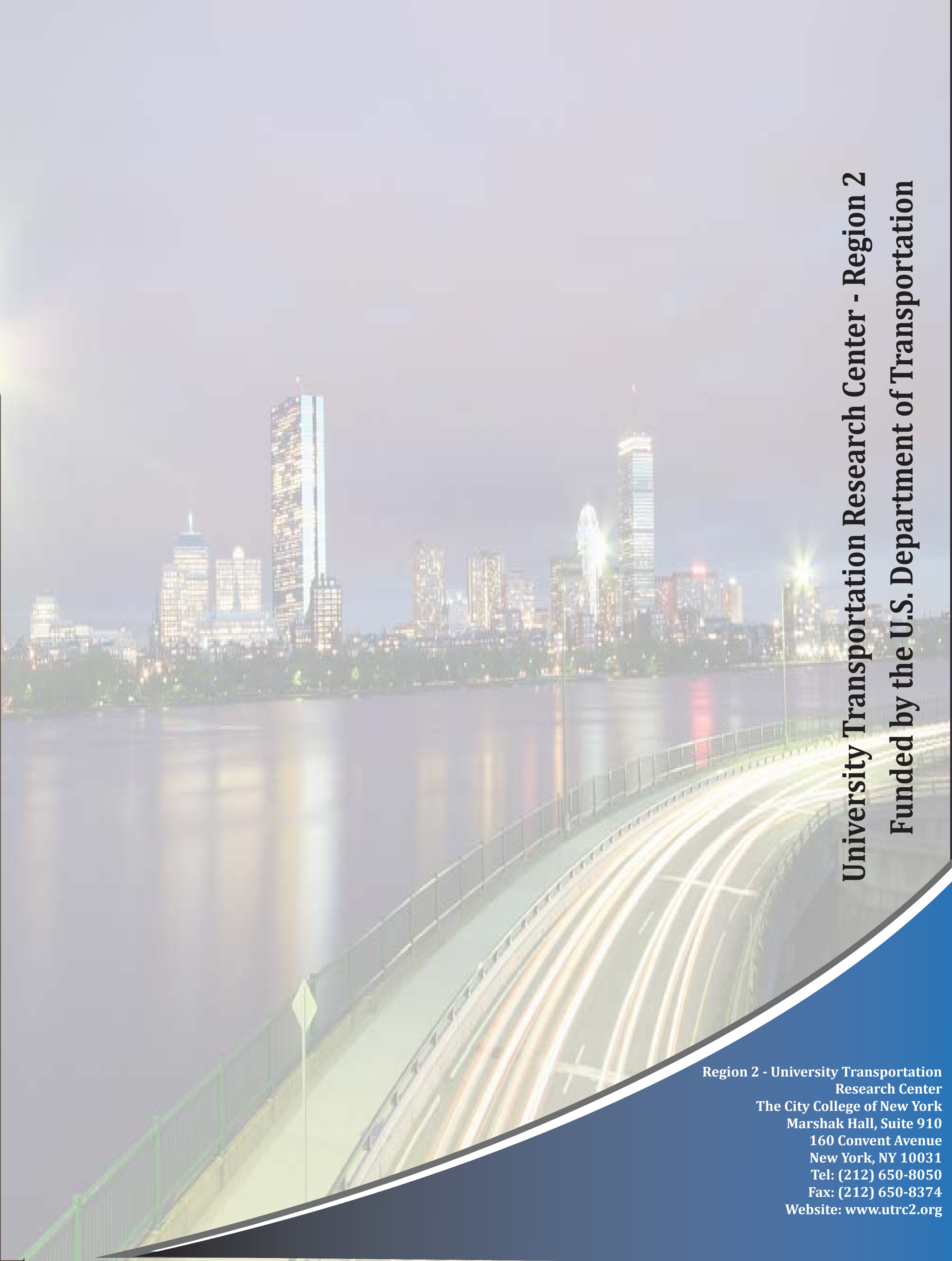



4. View the analysis results in the website interface. In order to download the analysis information for all census tracts, change the ‘Number of Results’ to ‘All’ under ‘Display Settings’.




5. Download the data set by clicking ‘Export Geography’ under ‘Report/Map Outputs’ tab. And export and download desired data sets. ShapeFile contains complete boundary information as well as employment related attributes, while the CSV file provides the most crucial attributes in the format of table.


OnTheMap
LED Home Help and Documentation Reload Text-Only
Work Area Comparison Analysis by Census Tracts
enter your own subtitle
Export Geography
Choose an export format.
ShapeFile (Results, All Years)
CSV (Results, All Years)
KML (Results, Current Year Only)
CSV (Selection Area, Census Blocks in Selection Area)
Cancel
Okay
Job Counts by Census Tracts in 2010
Job Counts by Census Tracts in 2010 - Primary Jobs
All Census Tracts 436,913
165 (Erie, NY) 36,558
96 (Erie, NY) 17,649
91.10 (Erie, NY) 12,997
91.07 (Erie, NY) 11,511
92 (Erie, NY) 10,216
107 (Erie, NY) 9,174
137.01 (Erie, NY) 8,405
89 (Erie, NY) 8,277
108.03 (Erie, NY) 7,512
84 (Erie, NY) 7,019
31 (Erie, NY) 6,929
91.12 (Erie, NY) 6,262
140 (Erie, NY) 5,920
142.08 (Erie, NY) 5,858
Change Settings



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