International Journal of Geographical Information Science
Vol. 27, No. 10, September 2013, 1 -9

A geographic analysis of residential land use around Washington D.C. Metro stations

C. Hill*

Department of Geography and GeoInformation Science, George Mason University, Fairfax, VA, USA

(Received February 22, 2011; final version received May 16, 2011)

The geographic analysis of land use around transit rail services in large metropolitan areas has been a subject of interest and conflict since the first commuter rail system known as the Metropolitan Railway was constructed in 1863 in London, England. From the beginning of transit rail services, there have been numerous questions as to how the locations of rail stations have and will affect land use and the resulting effect on residential populations. This article presents an analysis of the Washington D.C. Metro stations in relation to their effect on surrounding residential land use. From a detailed study of land use data around the Washington D.C. Metro Stations, there will be an analysis to illustrate any relevant comparisons of land use from a predetermined surrounding distance and the effect of that usage on the surrounding residential population. These patterns or inconsistencies will be analyzed and tested to determine if there is a common effect and influence of Metro stations on residential land use throughout the District of Columbia. With any further or unanswered questions from this analysis the promise for future research can be decided relating to many topics in the field of geographic information systems.

Keywords: metro, transit, residential, land use, Washington D.C.

1. Introduction

When determining residential land use for analysis in a specific area, the use of geographic information systems (GIS) is valuable in establishing a connection between data and geographic location. GIS allows for the ability to process, calculate, and study

*Corresponding author. Email: chillf@gmu.edu

ISSN 1365-5555 print/ISSN 1362-5555 online

DOI: 10.1080/13658810802645555
http://www.informaworld.com

information about a location so that conclusions can be reached and in proposing recommendations. The topics relating to rapid transit and land use can be quite controversial subjects because of the potential positive and negative reactions which can lead to potential clashes among the private sector and the public (Moon 1990). Other factors need to be taken in account such as many of today's major cities are experiencing rapid population growth and people rely on the expansion of public transportation to handle this population growth. (Bowes and Ihanfeldt 2001).

In the framework of rail transportation and its effect on land use, the primary source is from a study which is over twenty years old comparing the evolution of San Francisco and Washington D.C. Metros utilizing decades of aerial photography, sample counts, and percentage based counts (Moon 1990). More recent literature considers in detail the population growth of urban areas along with their growing suburbs, and the need for smart land use, growth of public transportation, and external factors that lead to safe communities (Bowes and Ihanfeldt 2001, Peterson and Stokes 1985, Van Wee 2002).

Due the concern of the continued growth of population in the Washington, D.C. metropolitan area, there is need for present day localized information and analysis in order to evaluate and make recommendations regarding land use. In addition, all parties must recognize the need for accessible public transportation with a constantly growing population. In the research throughout this study, the method of studying land use will employ the use of comparing distances to usage of area. This information will assist in producing statistics and data output that will afford a look into the study areas of each Metro station and how their land uses compare. From a residential standpoint, there are numerous factors to consider such as; is it accessible, affordable, safe, time saving, environmentally friendly and convenient to satisfy everyday needs? GIS land use data from the Washington D.C. government should be sufficiently robust for analysis and extrapolation procedures and methodologies to discover and document which Metro stations within the District are residentially influenced by density percentage and type. Section 2 reviews the past literature relating to the studies of land use and transportation. This will then be followed by an explanation of the involved steps in which the data was statistically analyzed. Addition and future research opportunities are discussed in Section 6.

2. Literature Review

Literature from the 1990s is the most current material that contains research and analysis of Metro stations and their surrounding land use. The data was obtained by using aerial photography and surveying the land use by hand to determine the results. These results are of the suburban area stations located within Virginia and Maryland and do not include the stations within the District of Columbia. The lack of data on the District of Columbia is unfortunate and reduces the overall value of the material as well as the ability to compare and contrast change between urban and suburban areas from the 20 years ago to present day.

2.1 *Existing literature and methods for relating transit and land use*

Rapid transit and land use change are controversial subjects throughout both the urban and suburban areas (Moon 1990) with both factors having the ability to greatly impact and influence one another (Van Wee 2002). Today and historically many cities are dealing with problems that involve rapid population growth which causes traffic congestion, air pollution, and extensive development patterns (Black 1993, Bowes and Ihanfeldt 2001). Public transit is held to be a valuable alternative to automobile transportation since it can reduce the unwanted side effects of population growth (Bowes and Ihanfeldt 2001). Even more importantly, there is a positive correlation between rail transit with high percentages of ridership and increases in the demand and growth of nearby residential properties (Dewees 1976, Moon 1990, Van Wee 2002). As growth occurs in these areas of high growth and demand, land use of high residential density should show the positives outcomes of urban traffic congestion relief, reduced energy consumption, lower transportation costs, and improved transportation safety (Moon 1990, Lane 2010, Peterson and Stokes 1985). Conversely, increases of residential growth have the negative effects of higher crime density, residential crowding, high residential property values, and subjection to the environmental impacts of nearby transit (Bowes and Ihanfeldt 2001, Damm *et al.* 1980, Limtanakool *et al*. 2006).

To determine how land use values are found in relation to transportation the prior theory involved various functions forms involving hedonic price models (Damm *et al.* 1980). From this method, it was correlated to parcels with Metro rail stations resulting in the decline of housing prices in relation to the outgoing distance from a Metro rail station (Damm *et al.* 1980). This method demonstrated there is a consistent pattern which shows the closer the residential property is to a rail station the higher in value the property. In addition, the results from this method illustrated that some of the highest property values relating to land use were those of commercial and retail use (Damm *et al.* 1980).

A method for strategic planning of transportation called Washington-START, utilizes many factors of analysis including household optimization, measures of household income responses, sensitivity analysis, and run time analysis (Nelson *et al.* 2007). The data used in this method includes weekly benefit revenue comparisons of daily rail and bus ridership and includes optimal provision comparisons of the Washington D.C. transportation programs. The results from this method proved that Metro highest revenue totals are made within the center of the district city area and that both users and non-users of Metro rail in Washington D.C. could benefit from transit expansion and increased usage (Nelson *et al.* 2007).

3. Buffer percentage of area land use method

The buffer percentage of area land use method exploits the capturing of data within a set radius. The method employs the data captured from the set radius and prepares it for analysis. Percentage based figures can be concluded and incorporated to provide analysis of an area's surroundings. To be of use in finding the number and percentage of set based land use data for a set location, the figures must first be organized into categories. These categories for this research project include industrial, commercial, federal, residential,

transportation, and other. With these defined categories, a comparison to overall totals can construct percentage based figures which allow for users to see how the categorized data compares the land usage of a specific set area.

Once set areas have been analyzed and categorized, a further breakdown in data can occur to more fully understand how specific land use makes up an area around a set point (as shown below in Figures 1 and 2). To better understand how residential density relates to Washington D.C. metro stations, the categories of each land use must be compared in order to comprehend what type of land use most affects the area. The residential density can then be further refined into sub categories allowing for a comprehensive study in how residential land use plays into the set area of analysis.

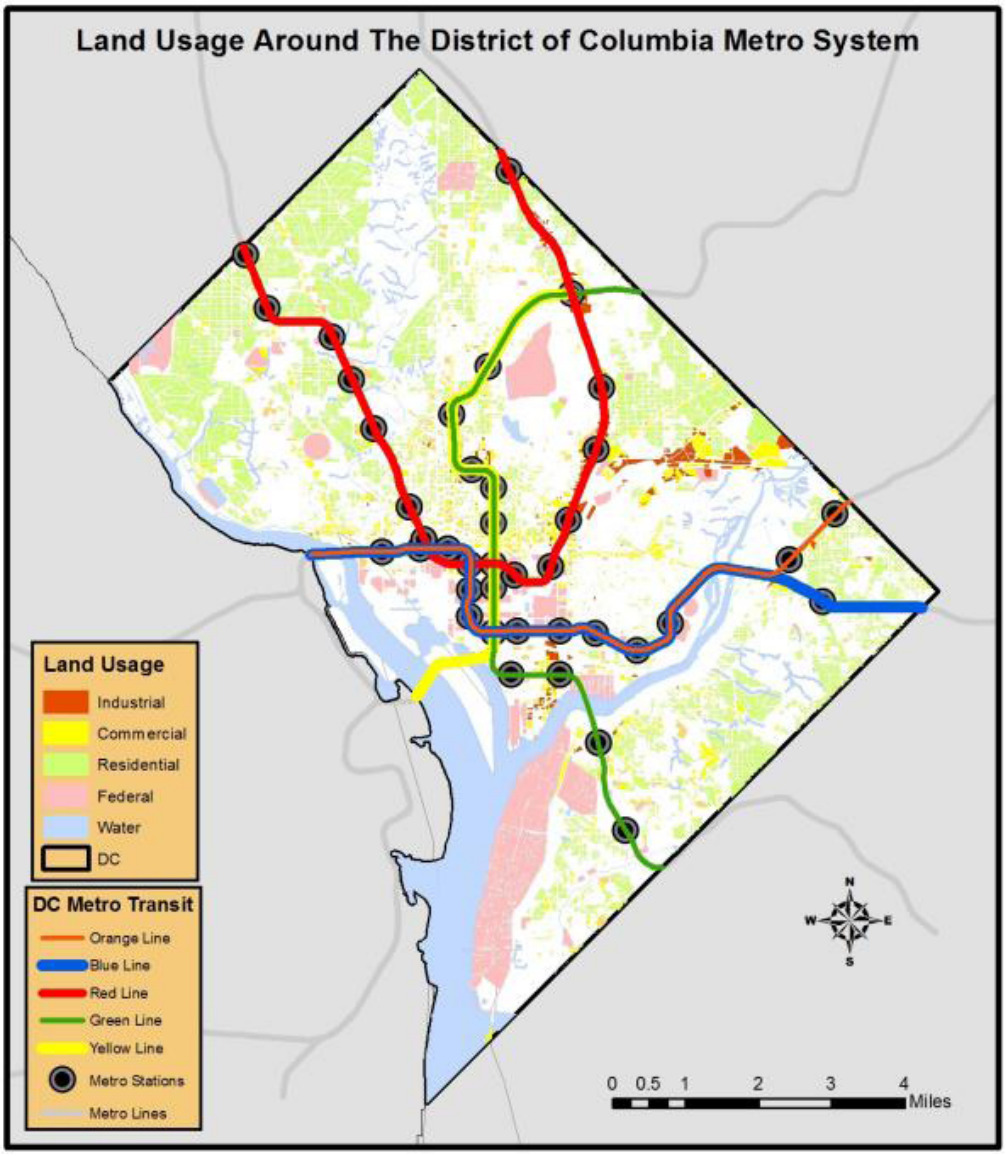

Figure 1. Washington D.C. land use and Metro transit map.

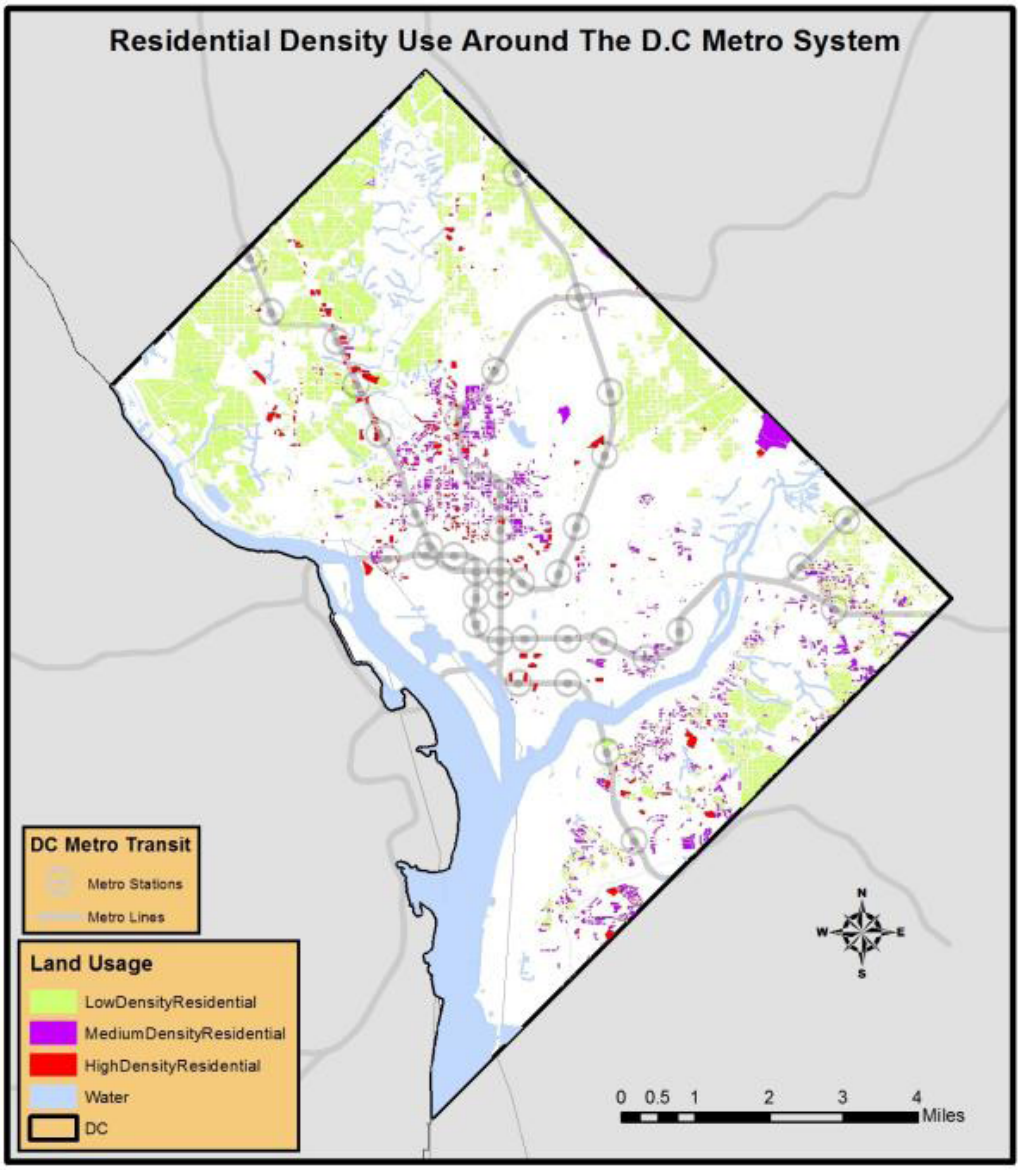

Figure 2. Washington D.C. residential density land use.

4. Data and Study area

The study area for this research project consists of eight selected Washington D.C. Metro stations from each of the eight wards. Each Metro station is analyzed with a one mile buffer zone containing the surrounding land use data. From the data descriptions of the surrounding area, the land use data is sorted into the categories of; transportation, commercial, federal, industrial, high density residential, medium density residential, low-medium density residential, low density residential, and other. This data was obtained through The District of Columbia Geographic Information Systems website which is regulated by the government. Once sorted into categories, percentage based values are

calculated for each one station's category areas by dividing the station focus area by the total station area.

Although at the time of this study there were 40 Metro stations in operation within Washington D.C. area, this project observed the detail of eight Metro stations as described above, chosen because each station's location within one of the eight wards. From this selection, the stations included are Anacostia of Ward 8; Columbia Heights of Ward 4; Dupont Circle of Ward 1; Georgia Avenue of Ward 4; Minnesota Avenue of Ward 7; Rhode Island Avenue of Ward 5; Tenleytown of Ward 5; and Union Station of Ward 6 (Figure 3). All of these Metro stations serve at least one or more Metro lines. Note that a few of the Metro stations do have some brief over laps in buffer areas of other stations. The percentages of land use area for each of the eight Metro stations are within their one mile buffer areas, the summary of these statistical percentages are detailed in Table 1. In specific, note the high percentages of transportation land use which is the leading percentage in six out of eight Metro stations. These values account for many transportation factors which include roads, parking, alleys, and right of ways.

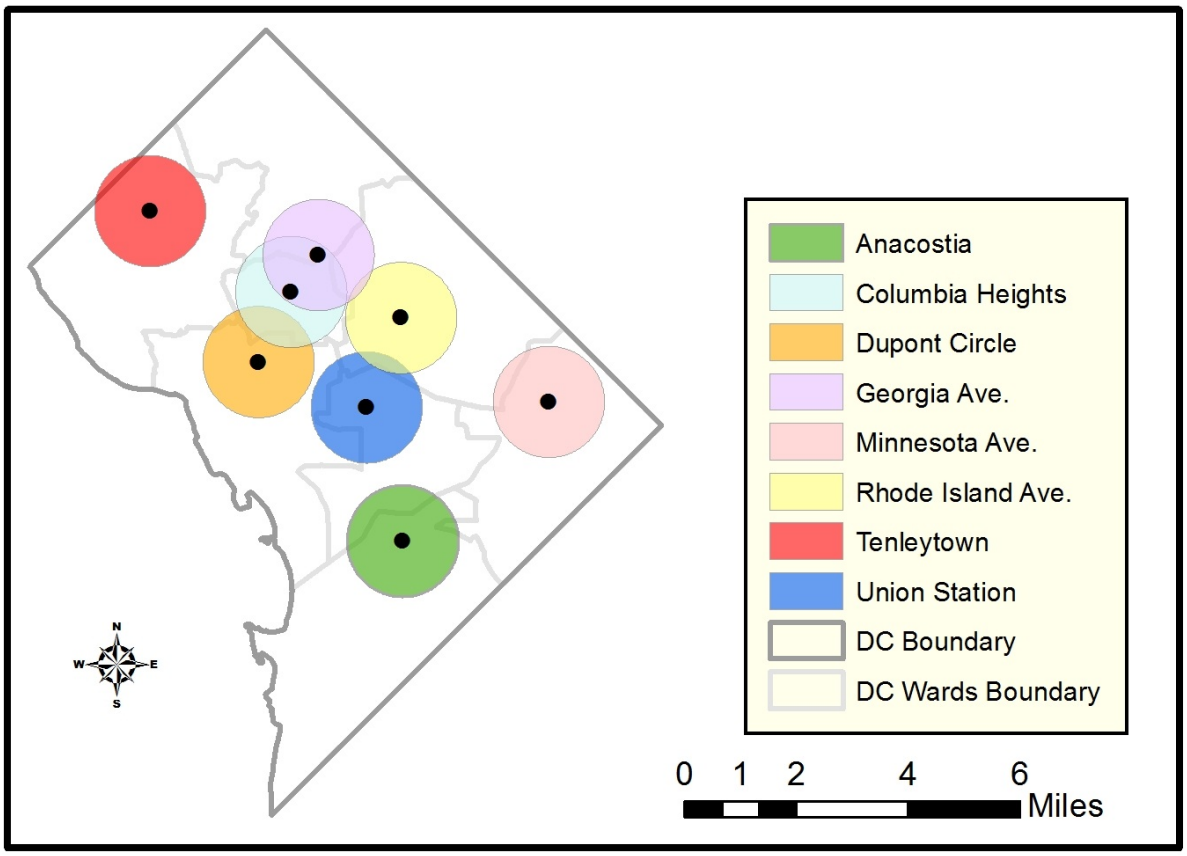

Figure 3. Washington D.C. eight Metro stations study areas with a one mile buffer.

Table 1. Land use area statistics for eight Metro stations.

Metro Station	Transportation	Commercial	Federal	Industrial	Residential	Other
Anacostia	26.34%	11.32%	2.10%	1.20%	54.68%	4.36%
Columbia Heights	44.95%	14.81%	0.05%	0.70%	37.16%	2.33%
Dupont Circle	38.07%	16.03%	0.45%	0.47%	36.18%	8.80%
Georgia Ave	47.86%	8.70%	0.07%	0.22%	32.02%	11.13%
Minnesota Ave	35.60%	5.42%	0.06%	0.38%	48.15%	10.39%
Rhode Island Ave	48.44%	8.23%	0.31%	3.25%	30.19%	9.58%
Tenley Town	51.72%	4.02%	0.33%	0.03%	35.48%	8.43%
Union Station	42.30%	16.77%	1.45%	1.60%	23.78%	14.10%

All data computed for the area within a one mile buffer of the Metro stations.

With residential density being the key for this study, data was focused on the four categories of high density residential, medium density residential, low-medium density residential and low density residential as seen in below Table 2. This data within the table breaks down the total percentage basis for the total residential density categories.

A few quality issues exist within the data. First, the land use has not been updated for the Washington D.C. area since 2006. In the timespan between relating to the current day, there has probably been a gain or loss within all the categories of the study areas.

Table 2. Residential land use statistics for eight Metro stations.

Metro Station	High Density Residential	Medium Density Residential	Low-Medium Density Residential	Low Density Residential	Total
Anacostia	0.80%	5.76%	15.67%	32.45%	54.68%
Columbia Heights	2.72%	9.66%	21.44%	3.34%	37.16%
Dupont Circle	2.90%	8.43%	13.61%	11.24%	36.18%
Georgia Ave	1.01%	5.05%	20.58%	5.38%	32.02%
Minnisota Ave	0.09%	4.41%	14.89%	28.77%	48.15%
Rhode Island Ave	0.28%	3.08%	16.60%	10.24%	30.19%
Tenley Town	0.69%	1.01%	7.58%	26.20%	35.48%
Union Station	0.88%	3.03%	18.27%	1.60%	23.78%

All data computed for the area within a one mile buffer of the Metro stations.

5. Results

The objectives of this study are to present the study of land use with a one mile buffer of eight different Washington D.C. area Metro stations in order to closely observe their residential density.

5.1 Comparison of results

The results are summarized in Tables 1 and 2. From the buffer percentage method show that the two most dominate categories of land usage were transportation and residential density. However, areas with high transportation land use percentages dominated Metro station buffer zones. In six out of eight of the Metro station buffer areas, transportation led as the principal land use. Of the two Metro station areas that were not dominated by transportation, they were led by residential density. These two areas are also noticed as nearing more of the Washington D.C. borders rather than being near the center of the district.

Throughout the buffer areas for the Metro station stops the residential percentages are between 23.78% to 54.68%. When divided into the four residential density subcategories there were low percentages of high density and medium density compared to the high dominating in most cases low-medium density and low density areas. The higher totals for high density residential areas were more prevalent in the center of the Washington D.C. area while stations far away from the center of the district rose in low density residential.

It has been shown in this article that a percentage based analysis can demonstrate what type of land use is around a Washington D.C. Metro station. From these percentages, only two stations were dominated by residential density while the other six were dominated by transportation. This reveals that transportation land use is a fundamentally important aspect of Washington D.C. and that the station areas are more focused on transportation orientation rather than residential density. However, if residential is not the leader of the land use percentages it still dominates with percentage of land use ranging from at least 23% to the highest total of 55%. When analyzed by subcategories, residential density from the middle of Washington D.C. to its borders tends to decrease in terms of high density residential and rise in terms of low density residential.

6. Conclusions

It has been demonstrated in this article that the buffer percentage method can well address the issues of residential land use in the Washington D.C area by determining the exact percentages of land use types by utilizing a set buffer study area. This method of analysis allows for the greatest factors of area land use within a set area affecting the surrounding population more accurately assist in providing future land use development.

This study helps to reconfirm that transportation is of high importance to the area population of Washington D.C. since the highest totals of land use for every metro station examined showed high percentages of residential and transportation land use. These high percentages show that residential land use around Washington D.C. metro stations

coincide with the importance of area transportation. Area transportation is significant to Washington D.C. as it is a dynamic metropolitan area with a rapidly growing and changing populous. The area transportation system is not keeping pace to properly respond to the population growth. The consequences of not properly factoring and addressing rapid area population growth are congested roadways, increased pollution, public transportation overflow and land use changes to meet the needs of the population. Failure to respond in a timely manner using a controlled method to the population growth issues will present harsh realities and reduce options. Well researched, defined and practical options to the land use issues will result in smarter and safer decisions and offer a brighter future for the area population of Washington D.C.

7. Future research

As mentioned earlier in this article, the current data is from the 1990s. Great strides in technology offers flexibility and quick tabulations of data. Analytical and mapping software capabilities should be incorporated into future research from the start. Efforts should continue with in depth analysis of residential density around Washington D.C.'s Metro stations. A correlation of area population to the figures of residential density would provide a conclusion of the effect on the selected eight Metro station areas. A further analysis of residential property values within the one mile buffer areas of the selected stations could also provide for greater insight towards explaining and understanding the effect of residential density.

The buffer percentage analysis method could be used to study and compare more Washington D.C. area Metro stations and then expanding this method to other metro stations from different cities. The overall importance is to study the pattern and percentage analysis to determine whether and the impact of Metro/rail stations effect nearby residential density.

Acknowledgments

Thank you to all of the authors and anonymous critiques who provided me with constructive feedback on this article. If there are any remaining errors or omissions they are the sole accountability of the authors.

References

Black, W.R., 1993. Transport route location, *Journal of Transport Geography*, 1, 86-94.

Bowes, D.R. and Ihlanfeldt, K.R., 2001. Identifying the impacts of rail transit stations on residential property values, *Journal of Urban Economics*, 50, 1-25.

Damm, D., Lerman S.R., Lerner-Lam, E. and Young, J., 1980. Response of Urban Real Estate Value in Anticipation of the Washington Metro. *Journal of Transportation Economics and Policy*, 14, 315-336.

Dewees, D., 1976. Subway effects of property values, *The Journal of Urban Economics*, 3, 357-369.

Lane, B.W, 2010. The relationship between recent gasoline price fluctuations and transit ridership in major US cities. *Journal of Transport Geography*, 18, 214-225.

Limtanakool, N., Dijst, M., Schwanen, T., 2006. The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium- and longer-distance trips, *Journal of Transport Geography*, 14, 327–341.

Moon, H., 1990. Land use around suburban transit stations. *Transportation*, 17, 67-88.

Nelson, P., Baglino, A., Harrington, W., Safirova, E. and Lipman, A., 2007. Transit in Washington, DC: Current benefits and optimal level of provision, *Journal of Urban Economic*, 62, 231-251.

Peterson, R.L., Stokes, R.W., 1985. Land use and innovative funding impacts in a permanent busway/park-and-ride transit system, *Texas Transportation Institute at UMTA*, 1-151.

Van Wee, B., 2002. Land use and transport: Research and policy challenges. *The Journal of Transport Geography*, 10, 259-271.