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Relationships between Land Use, Transportation, Household Expenditures, and Municipal Spending in Small Urban Areas

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ABSTRACT

This study developed a number of models to estimate the relationships between land use, transit ridership, household expenditures, and municipal spending, with a focus on small urban areas. First, a regression model was developed that estimated transit ridership in small urban areas as a function of service quantity, service characteristics, the unemployment rate, demographic characteristics, and population density. A second model, using American Community Survey data at the Census block group level, estimated the relationships between density and use of transit for commuting, as well as the impacts of living or working in the metro area's principal city on commuting behavior. Data from the U.S. Consumer Expenditure Survey were used to model relationships between dwelling type and age with household transportation expenditures. Lastly, a model was developed to estimate the impacts of land use and other factors on per capita municipal spending. The model was used to estimate spending for eight categories of expenditures that could be influenced by land use development.

Density was shown to be positively associated with transit ridership. The use of transit for commuting was found to increase with block group density, total metro population, if the area is within the principal city, and if a large percentage of workers commute to the principal city. Household transportation expenditures were found to be greater for those living in single-family detached structures and lowest for those living in high rises. Among households living in single-family detached structures, those in older homes were found to spend less on transportation. Density was also found to be negatively associated with per capita municipal expenditures for a number of cost categories.

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1. INTRODUCTION

Important relationships exist between land use, transportation, and household and municipal expenditures. Low-density, auto-oriented developments tend to promote auto dependency, as it is more difficult to make trips in these developments by walking, biking, or transit. Low-density, single-use developments result in longer distances between destinations, which leads to increased automobile use, increased vehicle miles traveled (VMT), and a reduction in trips made by alternative modes. While this has environmental implications – increased per capita VMT, pollutants, and greenhouse gas emissions – it also has economic implications. Households in low density, single-use, auto-oriented developments located far from city centers will likely need to spend more on transportation. They drive longer distances, take more trips by automobile, and do not have other reliable options. Therefore, they may own more vehicles than someone in a transit- or pedestrian-oriented neighborhood, and they may incur significantly greater transportation costs. The issue extends beyond households to municipalities as a whole. Lower density, auto-oriented developments require more infrastructure per capita than do more compact developments. This can result in an increase in per capita infrastructure and maintenance costs for cities. The per capita costs of providing some services, such as fire and police protection, street maintenance, solid waste collection, and sewer and water, could also increase when the population is more spread out.

Relationships between land use and transportation have been well studied. Some studies have also examined the relationship with household and municipal expenditures, though perhaps not as extensively. This study focuses on the relationships in smaller urban areas. Greater research and attention tends to be given to the larger urban areas, but small cities across the country are facing issues related to sprawl and auto-oriented development, and they need to be aware of how those development patterns impact transportation behavior as well as household and municipal expenditures.

In this study, a number of models were developed to estimate the relationships between land use, transportation behavior, and household and municipal expenditures, with a focus on small urban areas. The results are useful to planners in smaller communities evaluating the costs and benefits of different land use strategies or livability principles.

Section two provides a review of the literature. Previous studies that have examined the impacts of land use on transit ridership or transportation behavior, household transportation spending, and municipal expenditures are described and summarized. A series of models were then developed. These models and the data used are described in section three and results are presented in section four. Section five examines the use of smart growth strategies in smaller communities in the Upper Midwest, and conclusions are discussed in section six.

2. LITERATURE REVIEW

2.1 Impacts of Land Use on Transit Ridership

Land use characteristics include regional accessibility, density, land use mix, centeredness, roadway design, active transportation conditions, parking supply and management, and site design (Litman and Steele 2018). Ewing and Cervero (2010), in describing the built environment, refer to the Ds: density, diversity, design (street network characteristics), destination accessibility, and distance to transit. These factors can have an impact on whether someone owns a vehicle, how often or how far they drive, and if they make trips by walking, bicycling, ridesharing, or transit. A large body of literature has examined the impacts of land use and the built environment on travel behavior. Among these are a literature review by Litman and Steele (2018) and a meta-analysis by Ewing and Cervero (2010) that examined the built-environment-travel literature as of 2009.

Density is a commonly studied measure of land use. It can include the density of population, housing, employment, or some other activity. While density itself can have an impact on travel behavior, density is usually related to other land use characteristics, and the combined impact is much greater. Areas with greater density tend to have more land use mix, better accessibility, better transit services, shorter blocks, and better options for walking or biking. Litman and Steele (2018) concluded that a 10% increase in density typically reduced vehicle miles traveled (VMT) 0.5-1% as an isolated factor and 1-4% including associated factors.

Research has shown that transit demand increases with increases in population, housing, employment, or commercial density (Johnson 2003, Taylor et al. 2009, Chakraborty and Mishra 2013, Hu et al. 2016, Pasha et al. 2016). Both residential density and job or activity density are important. Dense areas will have more riders because there are more people and activities within walking distance of a transit stop. Furthermore, differences in density could imply other important differences. It may be more difficult to own and park automobiles in dense areas, and people in dense areas have less need to drive and may be less likely to own an automobile, because they can walk or bike to more places. While Chakraborty and Mishra (2013) found density to be important, they found that the effects differed between urban, suburban, and rural areas. In their study, household density was not a significant determinant of ridership in suburban areas, and employment density was not significant in rural areas.

Diversity, or land use mix, refers to the number of different types of land uses in a given area. A mix of land uses reduces travel distances and allows for more trips to be made by walking. Ewing and Cervero (2010) found that a good jobs-housing balance was associated with increased walking. Litman and Steele (2018) concluded that mixed-use areas typically have 5-15% less vehicle travel, and Johnson (2003) found that an increase in mixed-use development within an eighth mile of a transit corridor positively impacts transit ridership.

Density and land use mix have been the primary variables used in transportation research to characterize land use. However, as Hess et al. (2001) argued, simple measures of density and land-use mix do not capture actual development patterns very well. Measuring the density of a large geographic area, such as a city, traffic analysis zone (TAZ), or census tract, results in high density areas being averaged with low density areas, obscuring actual land use patterns that could be impacting transportation behavior. Measures of land mix should consider land use types and if those types are complementary, as different types of land use mixes will impact travel behavior differently (Hess et al. 2001).

Other measures of land use, such as accessibility and design, may be just as important. Regional accessibility is the location of development relative to the regional urban center. In other words, it is the distance to downtown or the central business district (CBD). Living closer to the CBD would likely mean shorter travel distances and less driving. Litman and Steele (2018) found that residents living closer to the regional urban center typically drive 10-40% less than those living at the urban fringe. Ewing and Cervero (2010) noted that in some studies, regional accessibility is simply measured as the distance to the CBD, and other studies measure destination accessibility as the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations. They found that VMT is most strongly related to measures of accessibility to destinations. A decrease in accessibility or an increase in distance from downtown was found to have a positive relationship with VMT. Ewing and Cervero (2010) estimated an elasticity of VMT with respect to job accessibility by auto of -0.20. Destination accessibility was also found to be strongly, and positively, related to pedestrian or nonmotorized travel. Chow et al. (2006) showed that better regional accessibility to employment leads to a larger percentage of workers using transit.

Related to accessibility is centeredness. As Litman and Steele (2018) described, centeredness, or centricity, refers to the portion of jobs, commercial activity, entertainment, and other major activities concentrated in CBDs or multi-modal centers. Litman and Steele concluded that typically 30-60% of commuters to major commercial centers use transit or alternative modes, compared with 5-15% at dispersed locations.

Also important is the roadway design, or the characteristics of the street network. A grid network design provides a higher level of connectivity compared to suburban networks with curving streets and cul de sacs. A greater level of connectivity reduces average travel distances and makes it easier to travel by walking and biking. By making it easier to walk or bike, it is easier to access transit stops. Grid networks effectively shorten access distances and improve accessibility of bus stops. Design is often measured by intersection density or block size. Ewing and Cervero (2010) found that the likelihood of using transit was mostly strongly related to transit access, or the distance to a transit stop, and next in importance were road network variables. They found high intersection density and greater street connectivity was associated with increased transit use.

Other characteristics of roadway design include street width, design speed, sidewalk conditions, the streetscape, etc. These factors all influence the walkability of an area. Narrower, slower streets, with wide, continuous sidewalks, bicycle facilities and streetscaping produce a more pedestrian-friendly environment that encourages travel by alternative modes. Transit is more likely to succeed in walkable areas where users can easily access transit stops and their final destination by walking.

Previous research has shown that land use characteristics impact transit ridership (Chakraborty and Mishra 2013, Peterson 2011, Johnson 2003). Chakraborty and Mishra (2013) found that land use type, transit accessibility, and density, along with income, are significant predictors of transit ridership. They found that transit ridership increased in areas with greater household or employment density and decreased in areas with more miles of freeways and greater levels of auto ownership. Peterson (2011) studied the transit system in Fargo-Moorhead (ND-MN), and found ridership to be greater in areas of greater residential density and walkability, which was measured based on land-use mix, intersection density, and residential density. Johnson (2003) concluded that transit ridership could be increased through increased residential density in areas near transit corridors, mixed-use development within an eighth mile of transit corridors, and a greater proportion of retail development located within a quarter mile of transit.

2.2 Impacts of Land Use on Household Expenditures

The impacts of land use on travel behavior has implications for household expenditures. Lower density, auto-oriented developments are likely to have greater automobile use because few trips can be made by other modes, which can result in increased transportation costs.

To demonstrate the impact that land use and neighborhood characteristics have on household transportation costs, the Center for Neighborhood Technology (CNT) developed the Housing and Transportation (H+T) Affordability Index, which estimates the cost of both housing and transportation at the neighborhood level (Haas et al. 2013)(Center for Neighborhood Technology 2017). It estimates total transportation costs for a typical household within a neighborhood based on estimates for auto ownership, auto usage, and public transit usage, which are derived from regression models that estimate the impacts of neighborhood and household characteristics on these transportation variables. Once auto ownership, auto usage, and transit usage were estimated in a neighborhood, prices were assigned to each to estimate average household expenditures.

Neighborhood characteristics included in CNT's models were gross household density, regional household intensity (which is a gravity measure of all households in the region), fraction of rental housing units, fraction of single family detached housing, employment access index, employment mix index, block density, transit connectivity index, average available transit trips per week, transit access shed, and total number of jobs available within the transit access shed. CNT's model is described by Haas et al. (2013). They concluded that neighborhood characteristics are more important than household characteristics in explaining variations in household transportation costs.

In another study of household expenditures, Deka (2015) analyzed U.S. Consumer Expenditure (CE) Survey data and modeled the relationships between transportation expenditures and dwelling type, building age, number of household automobiles, public transit use, and metropolitan area size. Deka found that both housing and transportation expenditures were higher for those living in single-family detached homes, and older dwellings were found to have a negative association with both housing and transportation spending. Older dwellings are more likely to be located in urban rather than suburban developments, where walking and transit are more viable options. The study also found a negative association between transit use and transportation expenditure, suggesting that promotion of transit in poorly served areas could reduce household transportation costs.

2.3 Impacts of Land Use on Municipal Spending

Land use patterns can impact not just individual travel behavior and household expenditures but also municipal expenditures. Theoretically, cities that are less dense may need to spend more per person to build and maintain infrastructure and provide certain services. Sprawling cities have more miles of streets and water and sewer pipes per person to maintain, and services such as trash collection and fire and police protection have more miles to cover per person. Lynch and Zimmerman (2015) argued that large portions of the city budget, such as street construction and maintenance, water and sewer infrastructure, fire protection and police services, solid waste removal, and school transportation, are affected by the geographic pattern of development. The costs of many of these services depend, to some extent, on the distance traveled. For some services, such as fire and police, denser development could potentially reduce the number of facilities, vehicles, and personnel required.

More compact developments can lead to cost savings through economies of scale and economies of geographic scope (Muro and Puentes 2004). Economies of scale are exhibited when the marginal cost of providing services to each additional person decreases as more residents cluster within a smaller geographic area. Economies of geographic scope are found when the marginal cost decreases as each person locates more closely to existing major public facilities.

While land use patterns and public expenditures are theoretically related, a review of early empirical research by Carruthers and Úlfarsson (2003) concluded that the relationship between urban form and public service spending was ambiguous and controversial. Muro and Puentes (2004), on the other hand, reviewed the literature and concluded that more compact developments can lead to cost savings for road building, water and sewer, and annual operations and service delivery. A number of additional studies have been conducted since these earlier literature reviews.

Carruthers and Úlfarsson (2003) conducted an empirical analysis of the relationship between alternative development patterns and spending, using data for a cross-section of 283 metropolitan counties for 1982-1992. They studied 12 measures of public spending: total direct spending, capital facilities, roadways, other transportation, sewerage, trash collection, housing and community development, police protection, fire protection, parks, education, and libraries. They found that the per capita cost of many services decreases with density, after controlling for property value. Specifically, they found that per capita costs for capital facilities, roadways, police protection, education, and total public spending declined with increases in density.

The authors of that study followed up with an analysis of per capita spending by all continental U.S. counties in 2002 (Carruthers and Úlfarsson 2008). In this study they found that density is negatively associated with total direct spending and spending for education, parks and recreation, police protection, and roadways. For other costs, the effect of density was marginally significant or insignificant, and it was positively associated with spending for housing and community development. They also found that the percentage of county land that was developed had a positive effect on most types of spending. They concluded that, on balance, high-density, compact development costs less to support. With regard to the magnitude of the effect, Carruthers and Úlfarsson (2008) estimated that, in 2002, if development everywhere was 25% more dense, public services would cost $3.63 billion less annually, and the average county would save $1.18 million, with the largest effect being for spending on roadways.

While the research by Carruthers and Úlfarsson (2003, 2008) was based on county level data across the United States, other studies have analyzed the effects of land use and urban form on spending in specific municipalities or counties. For example, the city of Halifax, Canada, (Halifax Regional Municipality 2005) studied how different settlement patterns affect the cost of services delivered by the city. They studied eight different types of development patterns and, similar to other research, found that cost decreases with density for many services, especially for roads but also for libraries, parks and recreation, police, fire, water, transit, and sewer. Specifically for roads, they estimated that the cost per household is $1,053 for low density rural development (2.5 acres per dwelling unit), $280 for low density suburban (8,100 sq ft per dwelling unit), $124 for mid density urban (2,400 sq ft per dwelling unit), and $26 for high density urban (760 sq ft per dwelling unit). Total per household costs ranged from $5,240 for low density rural to $1,416 for high density urban. They also noted that operations and maintenance make up 60% to 90% of the overall service costs.

Other municipalities and counties conducted similar studies with similar results. Fulton et al. (2013) compiled and analyzed 17 case studies conducted by municipalities as well as at regional, state, or national levels. They classified development patterns into two different categories and examined the costs associated with each. Developments were classified as either smart growth or conventional suburban. They defined smart growth as being characterized by more efficient use of land, greater land use mix, and better connections between streets and neighborhoods. Conventional suburban was then defined by less efficient use of land, separated land uses, and development designed primarily for driving. Their main findings were that smart growth development costs about one-third less for upfront infrastructure and saves an average of 10% on ongoing delivery of services, specifically for police, ambulance, and fire. Hortas-Rico and Solé-Ollé (2010) conducted an empirical analysis of 2,500 Spanish municipalities and also found that low-density development patterns lead to greater costs for providing local public services.

While much of the research has been focused on metropolitan areas, similar results have been found in mostly rural or non-metropolitan areas of Montana and Wyoming (Lieske et al. 2012, Sonoran Institute et al. 2009, RPI Consulting LLC and Sonoran Institute 2007, RPI Consulting 2012). In urban areas, developments with one-acre lots on the edge of the city would be considered sprawl, but in rural Natrona County, Wyoming, the issue is large 35-50 acre ranchettes or developments with 6-10 acre lots far from any city or the nearest highway. In this setting, encouraging developments with one-acre lots adjacent to a city was found to significantly reduce the budget gap for the county (RPI Consulting 2012).

Most of the research has been focused on costs, but development patterns can also impact revenue potential. Some research has shown that denser development patterns produce an increase in property tax revenue per acre (Mckeeman 2012, Fulton et al. 2013). Fulton et al. (2013) found that smart growth generates ten times more tax revenue per acre than conventional suburban development.

Not all research, however, has shown the financial benefits of increased density and smart growth development patterns. Kotchen and Schulte (2009) conducted a meta-analysis of 125 cost-of-community-service studies conducted through 2007 that compared the ratio of expenditures to revenue. For residential areas, they estimated a negative relationship between density and this ratio, as expected, but they did not find it to be statistically significant. Further, they found a positive relationship for commercial/industrial, and agricultural/open space areas.

On balance, the research tends to show that increased density and smart growth development patterns reduce public service expenditures for local governments. A number of studies have shown a reduction in total costs. With regard to specific services, different studies provide different results. While it may be expected that many costs would decrease with density, most studies tend to show some cost reductions to be significant and others not significant or non-existent. Many studies find costs decrease with density for roadways, police, and fire protection, while other show similar results for parks and recreation, libraries, or education. Fewer studies have shown reductions in costs for water, sewer, or sold waste, though it may be expected. Some costs are also shown to increase with density, such as housing and community development.

3. METHODS AND DATA

3.1 Impacts of Land Use on Transit Ridership

Internal and external conditions can both impact transit ridership. Internal factors are those within the control of the transit agency, such as service quality and quantity and fare levels. External factors are beyond the control of the agency, such as demographics, economics conditions, and land use characteristics. This study developed two models of transit use in small urban areas that include land use, specifically density, as an explanatory variable. The first uses data from the National Transit Database (NTD), and the second examines data from the American Community Survey (ACS) on commuting to work.

3.1.1 Model of Transit Ridership for Small Urban Transit Systems

A regression model was developed that estimates transit ridership using a cross section of data for small urban areas. Ridership was modeled as a function of service characteristics, service area demographics, economic conditions, land use, and characteristics of competing modes of transportation.

Service characteristics are defined by the quantity and quality of service provided and fare levels. The *Transit Capacity and Quality of Service Manual* identified three measures of availability and three measures of comfort and convenience as indicators of fixed-route transit quality of service (Kittelson & Associates Inc. et al. 2013). While important, the comfort and convenience factors are not included in this analysis due to these data not being available in a national database. Further, it is expected that the availability measures would have a greater impact on ridership. The availability measures are frequency, service span, and access. Frequency and service span are included in the model. Frequency is measured as the average network frequency, and service span is measured as the average number of hours per day that fixed-route service is available. The quantity of service provided is measured in terms of vehicle revenue hours. It is expected that increases in each of these would positively impact ridership, and fare levels are expected to negatively affect ridership.

Certain demographic groups may be more likely to use transit. In particular, lower-income individuals or those without access to an automobile may be more transit-dependent. Some small urban areas have a high percentage of university students who may be more likely to use transit.

Economic conditions, in particular employment rates, have been shown to impact transit use. As unemployment rates increase, there are fewer people commuting to work, which may negatively impact transit use.

Characteristics of competing modes could also have an effect on transit use. This includes gasoline costs, parking costs and availability, congestion, etc. Because of a lack of data for each municipality, these factors were not included in the study. Further, because the study uses cross-section data rather than time series data, differences in gasoline prices may not be as great, and because the study focuses on smaller urban areas, parking costs and congestion may not be as important.

Population density for the service area is used as a characteristic of land use. While other land use variables are also important, and population density may not be the most important, it is the simplest variable to measure at a city-wide level for a nationwide sample of cities. As noted earlier, density is also highly associated with other land use measures that encourage transit use, providing a measure of overall compactness. Service area and population data were obtained from the NTD, which may be more appropriate than Census data because transit services do not necessarily follow municipal boundaries.

An alternative land use measure is the city-wide Walk Score index. Walk Score developed a walkability index, the Walk Score index, that measures how walkable an area is on a 0-100 scale. The score awards points for the number of amenities within walking distance of an address, and using a decay function, fewer points are awarded for more distant amenities. The index accounts for population density as well as road metrics such as block length and intersection density, which impact pedestrian friendliness. The index may be useful for predicting transit use since it accounts for important land use characteristics that may influence ridership, including residential and activity density and walkable access to amenities.

Walk Score created an overall ranking for every city by first calculating the Walk Score for approximately every block, which is technically a grid of latitude and longitude points spaced about 500 feet apart. These points are then weighted by population density to estimate the city-wide Walk Score. Weighting by population density results in a score that better reflects where people live, and cities are not penalized for open spaces such as parks or bodies of water. An alternative model was estimated that used city-wide Walk Score as a predictor of transit ridership in place of population density.

The dependent variable is annual, system-wide transit ridership for the transit agency. Independent variables include service quantity, measured as vehicle revenue hours, three service characteristics – frequency, span of service, and fare levels – the unemployment rate, the percentage of the service area population that is college aged, the percentage of the service area population without access to a vehicle, and the population density of the service area, or Walk Score. The model is specific to fixed-route bus ridership.

As Taylor et al. (2009) noted, transit service supply and consumption affect each other, and most studies of transit ridership had failed to account for this simultaneity. In other words, while increases in transit service supply, measured as vehicle revenue hours, leads to increased ridership, increased ridership also leads to increases in service supply. Determining cause and effect, therefore, is difficult, and not accounting for the simultaneity of supply and consumption can lead to biased and inconsistent results. The simultaneity bias can be accounted for by estimating a system of equations. To do so, this study estimated equations for transit ridership and supply simultaneously using three-stage least squares estimation (3SLS), where ridership and supply, measured as vehicle revenue hours, are assumed to be endogenous. Vehicle revenue hours were estimated as a function of ridership and service area population. The two equations were estimated as follows:

$$\ln R_i = \alpha_0 + \alpha_1 \ln VRH_i + \alpha_2 \ln FQ_i + \alpha_3 \ln S_i + \alpha_4 \ln FARE_i + \alpha_5 U_i + \alpha_6 CPOP_i + \alpha_7 NV_i + \alpha_8 \ln DEN_i + \varepsilon_i \qquad (1)$$

$$\ln VRH_i = \beta_0 + \beta_1 \ln R_i + \alpha_2 \ln POP_i + e_i \qquad (2)$$

where $\ln R_i$ = log of annual unlinked fixed-route passenger trips for transit system i
$\ln VRH_i$ = log of vehicle revenue hours for transit system i
$\ln FQ_i$ = log of average system frequency for transit system i
$\ln S_i$ = log of average number of hours per day that service is available for transit system i
$\ln FARE_i$ = log of average fare paid by passengers for transit system i

U_i = unemployment rate in the city served by transit system i
$CPOP_i$ = percentage of population in the city served by transit system i that is college students
NV_i = percentage of population in the city served by transit system i that does not have a vehicle
$lnDEN_i$ = log of population density in the city served by transit system i
$lnPOP_i$ = log of service area population for transit system i

The analysis was limited to small urban systems, which were defined as those with a service area population greater than 50,000 and less than 200,000. Agencies were excluded if they were located within a larger metropolitan area with a population more than 500,000, and only full reporters to the NTD were included, which includes urban systems operating more than 30 vehicles. None of the resulting agencies provide rail or bus rapid transit, so the analysis focused on fixed-route bus service.

Fixed-route bus ridership data for 2016 for each of these agencies were obtained from the NTD. Service span data were also obtained from the NTD. This was measured as the average number of hours per day that service was provided, including weekends. To estimate frequency, vehicle revenue miles from the NTD was divided by total hours that service was available during the year to determine vehicle revenue miles per service hour, and this number was divided by the network route miles to calculate trips per hour. Directional route miles for mixed traffic right-of-way were obtained from the NTD for 2014. These data were not available for 2016, but it is assumed that changes in route miles would have been minor. Fare levels were estimated from the NTD by calculating fare revenues per unlinked trip.

City-level unemployment rates for 2016 were obtained from the Bureau of Labor Statistics. Demographic data were obtained from the American Community Survey (ACS) 2012-2016 five-year estimates. Population density was measured based on service area and population data reported to the NTD.

Complete data were available for 110 transit agencies in the United States. Transit systems operated by universities were excluded. Table 3.1 provides descriptive statistics. Transit agency ridership ranged from 107 thousand to 12.6 million trips per year, with an average of 1.7 million trips.

Table 3.1 Descriptive Statistics for Variables in Transit Ridership Model

Variable	Mean	Standard Deviation	Minimum	Maximum
Unlinked passenger trips	1,711,212	1,893,528	106,983	12,612,900
Service area population	115,124	42,877	52,576	199,668
Population density (per square mile)	2,251	1,083	10	5,405
Vehicle revenue hours	76,392	51,810	10,679	306,537
Frequency (vehicles per hour)	1.3	0.8	0.2	5.7
Span (hours per day)	14.0	2.2	8.7	18.8
Fare	$0.74	$0.32	$0.00	$1.81
Unemployment rate	5.0%	1.7%	2.1%	11.8%
College population (% of total population)	14.4%	12.3%	4.6%	65.4%
Population with no vehicle (% of total)	4.0%	2.2%	1.5%	16.9%
Walk Score (1-100 index)	40.0	9.1	21.0	66.0

3.1.2 Model of Transit Use for Commuting to Work

A second model was estimated using data from the American Community Survey (ACS). The ACS commute-to-work data provides information on modes used for commuting to work. The data can be analyzed at different geographic levels. This study analyzed the data at the Census block group level. This provides finer geographic detail than the city-level analysis.

The number of individuals within a Census block group commuting by transit can be estimated as a function of geographic and demographic data. Population density is expected to be positively associated with transit use. Further, if the block group is within the metro area's principal city, transit use may be greater because the area likely has better accessibility to major activity centers and transit service quality may be better. Those living outside the principal city may be more likely to commute by transit if they work within the principal city. The ACS provides information about whether the block group is within the principal city and the number of workers with each block group who work in the principal city. Similar to the previous model, demographic data analyzed included percentage of households without access to a vehicle and percentage of population consisting of college students. Population of the metro area was also included as an explanatory variable because larger metro areas may have better transit service and conditions such as congestion and higher parking costs that could contribute to greater use of transit.

The model includes Census block groups in all U.S. cities with a population of 50,000 to 200,000. This results in 45,119 observations. Slightly more than half of these block groups reported having no transit commuters. Many of these may have poor or no service. Because a large number of observations reported no transit use, two models were estimated. The first is a binary logit model that predicts the probability that the number of transit users in the block group is greater than zero. For those block groups that have at least one transit user, the second model estimates the number of transit users within the block group. Because the dependent variable in the second model is represented by count data that exhibits overdispersion, it is modeled using a negative binomial model. The equations were estimated as follows:

$$BTC_i = \gamma_0 + \gamma_1 lnW_i + \gamma_2 HNV_i + \gamma_3 CPOP_i + \gamma_4 PC_i + \gamma_5 WPC_i + \gamma_6 lnDEN_i + \gamma_7 lnMPOP_i + \varepsilon_i \quad (3)$$

$$TC_i = \lambda_0 + \lambda_1 lnW_i + \lambda_2 HNV_i + \lambda_3 CPOP_i + \lambda_4 PC_i + \lambda_5 WPC_i + \lambda_6 lnDEN_i + \lambda_7 lnMPOP_i + e_i \quad (4)$$

where BTC_i = binary variable equal to 1 if block group i has any transit commuters, 0 otherwise
TC_i = number of transit commuters in block group i
lnW_i = log of number of workers in block group i
HNV_i = percentage of households in block group i with no vehicle
$CPOP_i$ = percentage of population in block group i that consists of college students
PC_i = percentage of population in block group i that lives in the metro area's principal city
WPC_i = percentage of population in block group i that lives outside but works in the principal city
$lnDEN_i$ = log of the population density for block group i
$lnMPOP_i$ = log of the metro area population where block i is located

This model used 2012-2016 ACS 5-year data from 45,211 Census block groups from U.S. cities with populations of 50,000 to 200,000. Table 3.2 provides a summary of the data used in the model and shows the differences between Census block groups that had at least one transit commuter and those without. The average population of a Census block group is 1,605, and the average population density is 6,185 per square mile. The average population density in block groups with transit commuters (7,897 per square mile) is shown to be higher than that for block groups without any transit commuter (4,231 per square mile). Median population densities are 5,516 for those with transit commuters, 3,295 for those without, and 4,352 overall. Block groups with transit commuters are also shown to have a significantly higher percentage of households without access to a vehicle (11% vs. 6%, on average), and, on average, are from larger metro areas.

Table 3.2 Descriptive Statistics for Transit Commuter Model

	All Census Block Groups (n=45,211)		Block Groups with No Transit Commuters (n=21,122)		Block Groups with Transit Commuters (n=24,089)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Population	1,605	1,087	1,517	1,062	1,682	1,102
Population density (per square mile)	6,185	6,997	4,231	4,150	7,897	8,397
Population of city	102,193	41,734	102,584	42,469	101,849	41,077
Population of metro area	3,695,942	4,580,495	2,614,353	3,572,264	4,644,313	5,124,838
Workers	746	530	693	515	793	539
Transit commuters	27	58	0	0	52	71
Live in principal city (%)	55%	48%	56%	48%	53%	49%
Live and work in principal city (%)	37%	35%	39%	36%	35%	35%
Live outside but work in principal city (%)	17%	22%	17%	22%	17%	22%
Households with no vehicle (%)	9%	11%	6%	9%	11%	12%
College population (%)	9%	11%	8%	8%	10%	12%

Although the data is limited to cities with a population of 50,000 to 200,000, many of these cities are suburbs in large metropolitan areas. To determine if the results would be any different if only smaller metro areas were studied, the models were re-run including only Census block groups located in metro areas with total metro population of less than 500,000. This results in 12,974 Census block groups, of which 4,988 had at least on transit commuter. Statistics are shown in Table 3.3.

Table 3.3 Descriptive Statistics for Transit Commuter Model: Small Metro Areas

	All Census Block Groups (n=12,974)		Block Groups with No Transit Commuters (n=7,986)		Block Groups with Transit Commuters (n=4,988)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Population	1,462	1,023	1,423	918	1,525	1,168
Population density (per square mile)	4,060	4,283	3,390	3,328	5,133	5,303
Population of city	102,540	40,332	101,932	41,908	103,515	37,654
Population of metro area	270,687	118,597	263,888	120,030	281,572	115,446
Workers	662	487	644	450	691	540
Transit commuters	12	27	0	0	31	36
Live in principal city (%)	84%	34%	80%	37%	88%	29%
Live and work in principal city (%)	61%	29%	59%	31%	63%	27%
Live outside but work in principal city (%)	8%	19%	10%	20%	5%	15%
Households with no vehicle (%)	9%	11%	7%	9%	12%	13%
College population (%)	10%	15%	8%	11%	13%	19%

3.2 Impacts on Household Expenditures

Data from CNT's Housing and Transportation (H+T) Affordability Index were analyzed to show the relationship between land use and household expenditures in small urban areas of the Upper Great Plains and Midwest. The 2017 update of the H+T Index includes all Census block groups in the United States, and the data can be obtained from the H+T website.

To examine the relationships between land use variables and transportation use and costs for small cities in the Upper Great Plains and Midwest, city-wide data were obtained from the H+T Index for cities with populations of 40,000 to 250,000 from an eight-state region (Montana, Wyoming, North Dakota, South Dakota, Nebraska, Minnesota, Iowa, and Wisconsin). This includes 57 total cities. Correlations were calculated between two measures of land use – resident density and gross household density – and estimates for transportation use and costs and greenhouse gas (GHG) emissions for the 57 cities, using H+T Index data.

The H+T Index data provide estimates of transportation costs based on estimated transportation use determined through regression modeling. Household transportation costs can be more directly estimated based on survey data from the Consumer Expenditure (CE) Surveys conducted by the U.S. Department of Labor's Bureau of Labor Statistics (BLS). The CE interview survey collects data on total household transportation expenditures. Transportation expenditures are defined as "total outlays for transportation last quarter including down payment, principal and finance charges paid on loans, gasoline and motor oil, maintenance and repairs, insurance, public and other transportation, and vehicle rental licenses and other charges."

Unfortunately, the CE data do not include any neighborhood or community land use information, and responses cannot be mapped to specific communities. The data, however, can still provide some insight on how development types affect household expenditures on transportation. The survey collects information about the type of building in which the respondent resides. Respondents are classified as living in one of the following building types:

1) Single-family detached structure
2) Row or townhouse
3) Duplex
4) 3-plex or 4-plex
5) Garden (multi-unit structure having 2-4 floors)
6) High-rise (multi-unit structure having 4 or more floors)
7) Other type of apartment (such as basement or attic apartment)
8) Mobile home or trailer
9) College dormitory
10) Other

Although neighborhood or community land use data are not available, it could be reasonably assumed that those living in single-family homes live in lower density areas, while those in garden and high-rise apartments live in higher density areas. These data were analyzed to determine if those living in single-family homes pay more in transportation costs than those living in apartments.

The CE data do include information about the population of the primary sampling unit as well as whether the respondent lives in an urban area. These data were analyzed to determine if those living in urban areas pay more or less for transportation and if transportation costs differ by population size.

Other variables are also likely to impact household transportation spending and need to be accounted for. In particular, larger households, and those with greater income are likely to spend more on transportation, and older adults travel less and, therefore, probably spend less. Men also tend to drive more and may spend more on transportation. The CE data includes after-tax household income, family size, and age and sex of the respondent.

A regression model was developed using CE public-use microdata (PUMD) for 2017. Total household expenditures on transportation were estimated as a function of building type, population, whether the respondent lives in a metro area, after-tax household income, family size, respondent age, and respondent sex, as follows:

$$\ln TE_i = \rho_0 + \rho_1 SF_i + \rho_2 TOWN_i + \rho_3 GARDEN_i + \rho_4 MOBILE_i + \rho_5 POP_i + \rho_6 URBAN_i + \rho_7 \ln INC_i + \rho_8 FSIZE_i + \rho_9 AGE1_i + \rho_{10} AGE2_i + \rho_{11} AGE3_i + \rho_{12} MALE_i + \varepsilon_i \quad (5)$$

where $\ln TE_i$ = log of household transportation expenditures for the previous quarter for individual i

SF_i = dummy variable equal to 1 if individual i lives in detached single-family housing structure, 0 otherwise

$TOWN_i$ = dummy variable equal to 1 if individual i lives in townhome, rowhouse, duplex, 3-plex, or 4-plex, 0 otherwise

$GARDEN_i$ = dummy variable equal to 1 if individual i lives in garden apartment building, 0 otherwise

$MOBILE_i$ = dummy variable equal to 1 if individual i lives in mobile home or trailer, 0 otherwise

POP_i = population of population sampling unit where individual i lives

$URBAN_i$ = dummy variable equal to 1 if individual i lives in urban area, 0 otherwise
$lnINC_i$ = log of total family income for individual i after estimated taxes in the past 12 months
$FSIZE_i$ = number of family members in household for individual i
$AGE1_i$ = dummy variable equal to 1 if individual i younger than 25, 0 otherwise
$AGE2_i$ = dummy variable equal to 1 if individual i aged 65 to 74, 0 otherwise
$AGE3_i$ = dummy variable equal to 1 if individual i aged 75 or older, 0 otherwise
$MALE_i$ = dummy variable equal to 1 if individual i is male, 0 if female

Building types were categorized into five groups: 1) single-family homes, 2) townhomes, which was expanded to include row and townhomes, duplexes, 3-plexes, and 4-plexes, 3) garden apartments, 4) high-rise apartments, and 5) mobile homes. Respondents living in other types of buildings, such as basement or attic apartments, college dorms, and others were excluded from the analysis. Four dummy variables were included in the model to represent building type, with high-rise apartments used as the reference. It is hypothesized that those living in single-family homes spend more on transportation and those in higher density apartments spend less.

It is also hypothesized that those living in urban areas and in higher population areas spend less on transportation because they have more transportation options available. Population was measured on a 1-5 scale, where 1=less than 125 thousand, 2=125-329.9 thousand, 3=0.33-1.19 million, 4=1.20-4 million, and 5=more than 4 million.

It is expected that those with greater after-tax income will spend more on transportation. Those with larger family sizes are also expected to spend more because they make more trips and have greater transportation needs. Age was categorized into four groups: under 25, 25-64, 65-74, and 75 or older. It is expected that the working-age group, 25-64, spends more on transportation because they generally make more trips, and it is hypothesized that the oldest respondents spend the least on transportation as they tend to drive the least. Men also tend to drive more, so it is expected that costs will be higher if the respondent is male.

For single-family detached structures, the CE data also includes the year in which the home was built. This provides some clues about the neighborhood in which the house is located. Older single-family homes tend to be in neighborhoods that are denser and more accessible by walking, biking, and transit, whereas newer neighborhoods tend to be more auto-dependent. Therefore, families in older neighborhoods may spend less on transportation costs. To test this hypothesis, the model was re-run including only single-family detached structures, with the addition of the age of the house as an independent variable. Because the relationship between house age and transportation expenditures may not be linear, age was measured with dummy variables representing different eras. One dummy variable was for houses built before 1945, representing the period before suburbanization when houses were built in traditional urban developments. A second dummy variable was for houses built from 1945 through 1969, representing the first wave of suburbanization. A third dummy variable was for houses built from 1970 through 1999, and the reference is houses built in 2000 or later. The model was estimated as follows:

$$lnTE_i = \mu_0 + \mu_1 PRE45_i + \mu_2 SUB1_i + \mu_3 SUB2_i + \mu_4 POP_i + \mu_5 URBAN_i + \mu_6 lnINC_i + \mu_7 FSIZE_i + \mu_8 AGE1_i + \mu_9 AGE2_i + \mu_{10} AGE3_i + \mu_{11} MALE_i + e_i \quad (6)$$

where $PRE45_i$ = dummy variable equal to 1 if individual i's home was built before 1945, 0 otherwise
$SUB1_i$ = dummy variable equal to 1 if individual i's home was built during first wave of suburbanization from 1945-1969, 0 otherwise
$SUB2_i$ = dummy variable equal to 1 if individual i's home was built during second wave of suburbanization from 1970-1999, 0 otherwise

The other variables were previously defined.

CE data were available for 24,231 observations to estimate the model in Equation 5. Table 3.4 shows the descriptive statistics for the variables in the model. The average household transportation expenditures for the previous quarter was $1,570, and the median was $900. A large majority of the respondents, 79%, live in single-family detached homes, 12% in townhomes, 1% in garden apartments, 5% in mobile homes, and 2% in high rises. Most respondents, 93%, live in an urban area. The average after-tax family income was $70,227, with the median being $55,297.

Table 3.4 Descriptive Statistics for Household Transportation Expenditures Model

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
Transportation expenses	1,570	900	2,834	1	90,237
Single-family home	0.79	1	0.40	0	1
Townhome	0.12	0	0.33	0	1
Garden apartment	0.01	0	0.11	0	1
Mobile home	0.05	0	0.22	0	1
High rise	0.02	0	0.14	0	1
Population	3.28	4	1.32	1	5
Urban	0.93	1	0.26	0	1
After-tax income	70,227	55,297	56,368	1	585,081
Family size	2.57	2	1.45	1	15
Age <25	0.03	0	0.17	0	1
Age 25-64	0.70	1	0.46	0	1
Age 65-74	0.17	0	0.37	0	1
Age 75+	0.10	0	0.31	0	1
Male	0.48	0	0.50	0	1

The model in Equation 6, which was limited to single-family houses, was run using data for 14,891 observations. The year that the houses were built ranged from the oldest in 1915 to the newest in 2017, the year of the survey. The median year was 1975. About 14% of houses were built before 1945, 25% from 1945 to 1969, 41% from 1970 to 1999, and 21% in the 2000s.

3.3 Impacts of Land Use on Municipal Spending

A model was also developed to estimate the impacts of land use and other factors on per capita municipal spending. The model was used to estimate spending for eight categories of expenditures that could be influenced by land use development. These included fire protection, streets and highways, libraries, parks and recreation, police, sewer, solid waste management, and water.

Municipal expenditures can be influenced by both demand and cost factors. If there is a greater demand for services, expenditures may increase. Likewise, if costs to provide the service increase, expenditures would also likely increase. Land use can be considered a cost factor, because as densities decrease, it may become more costly for cities to provide services, as measured per capita. Other cost factors include labor costs and other input costs. Demand may be influenced by income levels. Areas with higher income levels may demand and have the capacity to support increased spending on services and infrastructure. The age of a neighborhood could also impact demand for some services. Older neighborhoods may have greater needs for some services, such as fire protection and infrastructure maintenance and repair. Population growth could also impact per capita expenditures. Rapid growth could create a need for increased infrastructure investment. On the other hand, some studies have shown that growth reduces per capita cost as the added population helps share in the cost of services (Carruthers and Úlfarsson 2008). Total population may also have an impact on per capita expenditures, either positive or negative, if either economies or diseconomies of size exist.

Municipal expenditure data are available from the U.S. Census Bureau's Annual Survey of State and Local Government Finances. Expenditure data were obtained for five years, 2012-2016, for municipalities for the eight expenditure categories previously listed. For each spending category, the survey further categorized the expenditures as being for current operations, construction, and land and existing structures. Therefore, separate models were developed for each, resulting in 24 total models.

Population-weighted density was used as a measure of land use. To calculate weighted density, the density of each Census block group in the city was first calculated. Then a weighted average of the block group densities was calculated, with each block group weighted by its population. The population-weighted density provides a more accurate description of the density where people live, as compared to the conventional population density.

Population data were obtained from the 2012-2016 5-year ACS data. Population change was measured as the percentage difference from the 2010 Census to the 2012-2016 5-year ACS data. Data for per capita income and median house age were also obtained from the ACS. Because wage data were correlated with income, and appropriate wage data for each municipality could not be obtained, it was excluded from the model.

Two sets of models were run. The first included all municipalities from the data set with a population above 25,000. The second was limited to cities with populations ranging from 25,000 to 250,000. The final model included log forms of the dependent variable and for population, density, and per capita income. The equation is as follows:

$$lnME_{ij} = \theta_0 + \theta_1 lnPOP_i + \theta_2 POPCH_i + \theta_3 lnWDEN_i + \theta_4 lnPCI_i + \theta_5 HAGE_i + u_i \quad (6)$$

where $lnME_{ij}$ = log of per capita municipal expenditures in city i for spending category j
$lnPOP_i$ = log of population for city i
$POPCH_i$ = percentage change in population for city i from 2010 to the 2012-2016 5-year estimate
$WDEN_i$ = log of weighted population density for city i
$lnPCI_i$ = log of per capita income for city i
$HAGE_i$ = median house age in city i

There were 1,102 cities in the data set (cities with population below 25,000 were excluded), but not every city provided data for every category. Most cities provided data for operations spending for most categories, with the exception of library expenditures, which had 535 responses. Fewer cities provided data for construction or for land and existing facilities, and some categories had very few responses, such as libraries and solid waste. Table 3.5 provides descriptive statistics for per capita spending for each category. Per capita expenditures for operations ranged from $0.037 for libraries to $0.253 for police. Capital expenditures were greatest for streets and highways, sewer, and water. As Table 3.6 shows, average per capita expenditures do not change significantly when the largest cities, those with population above 250,000 are excluded.

Table 3.5 Per Capita Municipal Spending Data, Cities with Population Greater than 25,000

	N	Mean	Median	Standard Deviation	Minimum	Maximum
		--------------------dollars per capita--------------------				
Operations						
Fire	942	0.1646	0.1571	0.0765	0.0020	0.5680
Streets/highways	994	0.0933	0.0811	0.0552	0.0026	0.4573
Libraries	535	0.0370	0.0305	0.0282	0.0001	0.2066
Parks and recreation	954	0.0889	0.0741	0.0782	0.0006	1.3319
Police	998	0.2531	0.2327	0.1083	0.0021	1.0780
Sewer	902	0.1112	0.0982	0.0724	0.0006	0.6195
Solid waste	814	0.0697	0.0617	0.0484	0.0001	0.5948
Water	826	0.1395	0.1214	0.0847	0.0001	0.7469
Construction						
Fire	114	0.0077	0.0054	0.0073	0.0000	0.0389
Streets/highways	593	0.0876	0.0680	0.0771	0.0000	0.5789
Libraries	58	0.0093	0.0036	0.0141	0.0001	0.0814
Parks and recreation	382	0.0330	0.0181	0.0797	0.0001	1.4065
Police	120	0.0133	0.0067	0.0188	0.0000	0.1119
Sewer	418	0.0719	0.0441	0.0830	0.0000	0.6737
Solid waste	68	0.0164	0.0071	0.0378	0.0001	0.2948
Water	416	0.0797	0.0523	0.1123	0.0005	1.3568
Land and Existing Facilities						
Fire	357	0.0074	0.0054	0.0079	0.0000	0.0533
Streets/highways	362	0.0146	0.0070	0.0248	0.0000	0.2192
Libraries	84	0.0033	0.0017	0.0042	0.0001	0.0242
Parks and recreation	373	0.0088	0.0044	0.0124	0.0001	0.0984
Police	471	0.0077	0.0060	0.0069	0.0000	0.0531
Sewer	222	0.0259	0.0092	0.0619	0.0001	0.6941
Solid waste	138	0.0078	0.0056	0.0082	0.0000	0.0522
Water	218	0.0197	0.0098	0.0287	0.0001	0.2174

Table 3.6 Per Capita Municipal Spending Data, Cities with Population 25,000 to 250,000

	N	Mean	Median	Standard Deviation	Minimum	Maximum
		--------------------dollars per capita--------------------				
Operations						
Fire	861	0.1634	0.1563	0.0773	0.0020	0.5680
Streets/highways	913	0.0943	0.0819	0.0554	0.0054	0.4573
Libraries	481	0.0377	0.0307	0.0290	0.0001	0.2066
Parks and recreation	875	0.0873	0.0716	0.0791	0.0006	1.3319
Police	916	0.2467	0.2286	0.1035	0.0021	1.0780
Sewer	828	0.1111	0.0981	0.0723	0.0006	0.6195
Solid waste	740	0.0694	0.0615	0.0489	0.0001	0.5948
Water	753	0.1402	0.1215	0.0862	0.0001	0.7469
Construction						
Fire	83	0.0087	0.0068	0.0081	0.0000	0.0389
Streets/highways	525	0.0885	0.0692	0.0767	0.0017	0.5789
Libraries	38	0.0110	0.0036	0.0166	0.0004	0.0814
Parks and recreation	320	0.0328	0.0169	0.0862	0.0001	1.4065
Police	86	0.0150	0.0073	0.0213	0.0000	0.1119
Sewer	363	0.0690	0.0415	0.0796	0.0000	0.5269
Solid waste	45	0.0145	0.0080	0.0182	0.0001	0.0842
Water	359	0.0759	0.0489	0.1053	0.0005	1.3568
Land and Existing Facilities						
Fire	320	0.0076	0.0057	0.0080	0.0000	0.0533
Streets/highways	325	0.0155	0.0074	0.0259	0.0000	0.2192
Libraries	65	0.0037	0.0021	0.0044	0.0001	0.0242
Parks and recreation	331	0.0088	0.0044	0.0123	0.0001	0.0984
Police	429	0.0079	0.0061	0.0070	0.0000	0.0531
Sewer	200	0.0275	0.0100	0.0648	0.0001	0.6941
Solid waste	115	0.0084	0.0057	0.0087	0.0000	0.0522
Water	192	0.0204	0.0102	0.0299	0.0001	0.2174

The average city in the data set had a population of 116,256, 5.3% population growth from 2010 to the 2012-2016 ACS 5-year estimate, a population-weighted density of 5,309 people per square mile, per capita income of 28,985, and median house age of 43 years (Table 3.7). Median values were 53,280 for population and 3,644 for population-weighted density. As Table 3.8 shows, if cities with population above 250,000 are excluded, average population drops to 66,723, with median population declining to 49,621, and average population density decreases slightly. Other variables are largely unchanged.

Table 3.7 Descriptive Statistics for Independent Variables, Cities with Population Greater than 25,000

	N	Mean	Median	Standard Deviation	Minimum	Maximum
Population	1102	116,256	53,280	336,038	25,031	8,550,405
Population change	1094	5.3%	3.9%	7.3%	-9.5%	83.3%
Population-weighted density	1097	5,309	3,644	5,830	602	74,473
Per capita income	1097	28,985	26,553	9,768	12,747	82,350
Median house age	1097	43	41	16	10	77

Table 3.8 Descriptive Statistics for Independent Variables, Cities with Population 25,000 to 250,000

	N	Mean	Median	Standard Deviation	Minimum	Maximum
Population	1020	66,723	49,621	46,818	25,031	249,042
Population change	1015	5.2%	3.7%	7.5%	-9.5%	83.3%
Population-weighted density	1018	4,933	3,497	5,141	602	63,364
Per capita income	1018	28,993	26,410	9,928	12,747	82,350
Median house age	1018	42	41	16	10	77

4. RESULTS

4.1 Impacts of Land Use on Transit

4.1.1 Relationship between Density and System-Wide Ridership

Table 4.1 shows the results of the regression model of transit ridership for small urban transit systems. The dependent variable, annual unlinked passenger trips, is in log form. Vehicle revenue hours, frequency, span, and population density are also in log form. Fare levels are not in log form because some agencies have a fare of zero. All variables have the expected signs, and all are statistically significant.

Density is shown to be positively associated with ridership. The estimated elasticity is 0.09, which is similar to those from other studies (Litman and Steele 2018). This indicates that a 10% increase in density is associated with a 0.9% increase in ridership.

Other results are as expected. Findings show that a 1% increase in vehicle revenue hours leads to roughly a 1% increase in ridership. Holding vehicle revenue hours constant, ridership increases with an increase in system-wide frequency or a greater span of service. Fare levels are shown to have a negative impact on ridership, as a $1 increase in fares reduces ridership by 20.7%. Given average fare levels, this would translate to a fare elasticity of -0.15. Ridership is shown to decrease as unemployment increases, and ridership increases in cities with a larger share of college students or people without access to a vehicle.

Table 4.1 Regression Results for Log of Transit Ridership

Variable	Parameter Estimate	p value
Intercept	0.472	0.5403
Log of vehicle revenue hours	1.006	<.0001***
Log of frequency	0.125	0.0239**
Log of span	0.587	0.0453**
Fare	-0.207	0.0123**
Unemployment rate	-0.031	0.0473**
College population	0.008	0.0015***
No vehicles	0.075	<.0001***
Log of population density	0.093	0.0030***

n = 110

System Weighted R^2 = 0.67

**p*<10%, ***p*<5%, ****p*<1%

The model was re-run using Walk Score in place of or in addition to population density, but the results were not statistically significant. Population density was shown to be a better predictor. The model used Walk Score data for the entire city, rather than a more clearly defined service area. If a more clearly defined service area is identified, or if ridership for specific routes are studied, Walk Score may prove to be a useful predictor of ridership.

4.1.2 Relationship between Land Use and Transit Commuting

Results from the binary logit model predicting the likelihood of a Census block group having any transit commuters is shown in Table 4.2. Estimated coefficients all have expected signs and are statistically significant. Results show that block groups with greater population density are more likely to have at least one transit commuter, if everything else remains equal. Block groups with more workers, a higher percentage of carless households, or a greater share of college students are also more likely to have a transit commuter. Block groups located within a principal city are more likely to have a transit commuter, and block groups outside the principal city are more likely to have a transit commuter if they have a larger share of workers commuting into the principal city. Results also show that the total metro area population has a positive impact on the likelihood of someone commuting by transit.

Table 4.2 Results from Binary Logit Model Predicting Likelihood of any Transit Commuter in Census Block Group

Variable	Estimate	Odds Ratio	p-value
Intercept	-12.400		<.0001***
Log of workers	0.677	1.97	<.0001***
Households with no vehicles	5.117	166.75	<.0001***
College population	1.534	4.64	<.0001***
Live in principal city	0.301	1.35	<.0001***
Live outside work in principal city	0.217	1.24	0.0102**
Log of population density	0.322	1.38	<.0001***
Log of metro population	0.337	1.40	<.0001***

n = 45,211; *p<10%, **p<5%, ***p<1%

For those Census block groups with at least one transit commuter, the next model estimates the number of workers commuting by transit. Estimated coefficients from the negative binomial model all have expected signs and are all significant at the 1% level (Table 4.3). Results again show the positive effect of population density on transit use. The elasticity of transit use with respect to population density is found to be 0.15.

Table 4.3 Results from Negative Binomial Model of Number of Transit Commuters in Census Block Group

Variable	Estimate	Standard Error	p-value
Intercept	-5.231	0.090	<.0001***
Log of workers	0.664	0.010	<.0001***
Households with no vehicles	2.455	0.050	<.0001***
College population	0.559	0.048	<.0001***
Live in principal city	0.591	0.020	<.0001***
Live outside work in principal city	1.237	0.044	<.0001***
Log of population density	0.152	0.006	<.0001***
Log of metro population	0.173	0.005	<.0001***

n = 24,089; *p<10%, **p<5%, ***p<1%

Both models also show that the number of households without access to a vehicle is one of the most important determinants of transit use. College population is again found to have a positive impact on transit use.

Block groups within the principal city have a greater number of transit commuters than those outside the principal city if those areas outside the principal city do not have many commuters traveling into the principal city. Results, however, suggest that the number of transit commuters is greatest where there is a larger number of people who live outside the principal city but are commuting into the principal city. Because cities with a population of more than 200,000 were excluded from this analysis, those who live outside the principal city may be living in a suburb within a much larger metropolitan area. Therefore, they may face greater congestion and parking costs if they are commuting to the principal city, which would could explain their greater use of transit. Overall, transit use was lowest among areas outside the principal city that had a small percentage of commuters to the principal city, which is expected. The results also show that the number of transit users increases as the overall population of the metro area increases, if everything else remains constant. This may be because of better transit services in larger metro areas or because of congestion and parking costs contributing making transit commuting more attractive.

The models were re-run including only Census block groups located in metro areas with total metro population of less than 500,000. Results for the smaller metro areas is largely similar to what was found previously (Table 4.4 and 4.5). Population density is again found to have a positive impact on the likelihood of having any transit commuters and the overall total number of transit commuters, though the estimated coefficients are smaller. Total number of workers, households with no vehicles, college population, and total metro area population again have positive impacts, with mostly similar estimates. The main difference between these results and those estimated previously is that living in the principal city or commuting into the principal city do not have the same positive effect. In the smaller metro areas, though, most of the block groups are located within the principal city, especially because cities with population below 50,000 are not included, so the insignificant effect might not be unexpected.

Table 4.4 Results from Binary Logit Model Predicting Likelihood of any Transit Commuter in Census Block Group: Small Metro Areas

Variable	Estimate	Odds Ratio	p-value
Intercept	-10.145		<.0001***
Log of workers	0.614	1.726	<.0001***
Households with no vehicles	5.423	149.804	<.0001***
College population	1.786	4.489	<.0001***
Live in principal city	-0.153	0.663	0.2481
Live outside work in principal city	-0.800	0.272	0.0018***
Log of population density	0.213	1.189	<.0001***
Log of metro population	0.292	1.236	<.0001***

n = 12,974; *p<10%, **p<5%, ***p<1%

Table 4.5 Results from Negative Binomial Model of Number of Transit Commuters in Census Block Group: Small Metro Areas

Variable	Estimate	Standard Error	p-value
Intercept	-2.445	0.375	<.0001***
Log of workers	0.515	0.021	<.0001***
Households with no vehicles	1.942	0.106	<.0001***
College population	1.034	0.069	<.0001***
Live in principal city	-0.037	0.088	0.6731
Live outside work in principal city	-0.328	0.175	0.0608*
Log of population density	0.071	0.012	<.0001***
Log of metro population	0.129	0.027	<.0001***

n = 4,988; *p<10%, **p<5%, ***p<1%

4.2 Impacts on Household Expenditures

The H+T Index data show the relationships between density and household transportation use and expenditures. Table 4.6 shows correlations between two measures of land use – resident density and gross household density – and estimates for transportation use and costs and greenhouse gas (GHG) emissions for the 57 small cities in the Midwest and Upper Great Plains, using H+T Index data.

Residential density and gross household density are shown to be negatively correlated with number of automobiles per household, annual vehicle miles traveled (VMT) per household, GHG emissions per household, and annual transportation cost for a typical household. Housing and transportation costs combined, as a percentage of income, is also negatively correlated with residential density. In summary, household automobile ownership, VMT, GHG emissions, and total transportation costs are lower in higher-density cities, and even if higher-density cities have higher housing costs, it is more than offset by the lower transportation costs.

Table 4.6 Correlations between Density and Transportation Use and Cost for Small Midwest Cities, based on H+T Index Data

	Residential density		Gross household density	
Autos per Household for the Regional Typical Household	-0.58	(<.0001)	-0.39	(0.0029)
Annual Vehicle Miles Traveled per Household for the Regional Typical Household	-0.75	(<.0001)	-0.67	(<.0001)
Annual GHG per Household	-0.72	(<.0001)	-0.64	(<.0001)
Annual Transportation Cost for the Regional Typical Household	-0.56	(<.0001)	-0.37	(0.0047)
Housing + Transportation Costs % Income for the Regional Typical Household	-0.35	(0.0069)	-0.15	(0.2655)

Note: *p* values in parentheses

The results of the model of household transportation expenditures, based on CE data, are shown in Table 4.7. All explanatory variables are significant at the 1% level, except for the urban dummy variable, which is significant at the 10% level. The results show that those living in high rises spend the least on transportation, everything else equal (the dummy variables for the other housing types are all positive in comparison to high rises, which is the reference). Based on the magnitudes of the estimated parameters, results suggest that those living in single-family detached structures spend the most on transportation.

Table 4.7 Regression Results for Log of Household Transportation Expenditures

Variable	Parameter Estimate	p-value
Intercept	1.89	<.0001***
Single-family home	0.37	<.0001***
Townhome	0.23	<.0001***
Garden apartment	0.28	0.0007***
Mobile home	0.27	<.0001***
Population	0.04	<.0001***
Urban	-0.06	0.0553*
Log of after-tax income	0.39	<.0001***
Family size	0.08	<.0001***
Age <25	-0.12	0.0072***
Age 65-74	-0.15	<.0001***
Age 75+	-0.61	<.0001***
Male	0.07	<.0001***

n = 24,231; R^2 = 0.1824;
*p<10%, **p<5%, ***p<1%

Estimated results indicate that households in single-family detached homes spend 37% more on transportation than those in high rises, if everything else remains constant. The difference between single-family homes and other housing types is smaller.

Results suggest that those living in urban areas spend less on transportation, but at the same time, population was found to be positively related to transportation costs. While those living in rural areas may experience greater costs because of longer travel distances and greater reliance on the automobile, those in urban areas are found to have greater costs if they live in a larger metropolitan area.

As expected, income and family size are positively associated with household transportation spending. The estimated elasticity of transportation spending with respect to income is 0.39, meaning a 1% increase in income leads to a 0.39% increase in transportation spending. Transportation spending was found to be greatest among those aged 25-64 and lowest for those over age 75, also as expected, and expenditures were found to be greater if the respondent was male.

Results in Table 4.8 show that, among households living in single-family detached structures, those in older homes spend less on transportation, if everything else remains constant. Compared to those living in homes built after 1999, those in homes built before 1945 spend 22% less on transportation, those in homes built from 1945 to 1969 spend 17% less on transportation, and those in homes built from 1970 to 1999 spend 10% less on transportation. These results provide additional evidence that those living in more urban, traditional neighborhoods, which tend to be denser, closer to the city center, and more accessible by walking, biking, and public transit, spend less on transportation. The results also show that transportation costs have continued to increase over time for newly built houses, as spending is the greatest in the newest neighborhoods, holding income and other variables constant.

Table 4.8 Regression Results for Log of Household Transportation Expenditures for Single-Family Homes

Variable	Parameter Estimate	p-value
Intercept	3.06	<.0001***
House built <1945	-0.22	<.0001***
House built 1945-1969	-0.17	<.0001***
House built 1970-1999	-0.10	<.0001***
Population	0.06	<.0001***
Urban	-0.09	0.0186**
Log of after-tax income	0.33	<.0001***
Family size	0.08	<.0001***
Age <25	-0.09	0.3754
Age 65-74	-0.14	<.0001***
Age 75+	-0.70	<.0001***
Male	0.08	<.0001***

n = 14,891; R^2 = 0.1798;
**p*<10%, ***p*<5%, ****p*<1%

4.3 Impacts of Land Use on Municipal Spending

Results of the municipal expenditure models show that density has a significant effect for many spending categories. The estimated coefficient for density is negative and statistically significant for six of the eight operational cost categories (Table 4.9). Density is shown to be negatively associated with per capita operational costs for fire protection, streets and highways, parks and recreation, sewer, solid waste management, and water. Density, on the other hand, was found to be positively related to police operational costs. A possible explanation for this positive effect is that denser areas may have higher crime rates due to increased interaction between people. The effect of density was not statistically significant for library operational costs.

In the construction costs models, density is negative and statistically significant for streets/highways, parks and recreation, sewer, and water, while is it insignificant for the other cost categories (Table 4.10). In the land and existing facilities costs models, density is negative and statistically significant for police, sewer, and water (Table 4.11). For police costs, while the results show a positive correlation with operational costs, there was a negative relationship with land and existing facility costs.

Results were largely similar when the largest cities, those with a population above 250,000, were excluded from the analysis (Tables 4.12-4.14). In these models, density remains negative and statistically significant for the same cost categories.

Overall, the models clearly show a general negative relationship between density and per capita municipal expenditures for a number of cost categories. Since the dependent variable and density are both in log form, the estimated parameters can be interpreted as elasticities. Statistically significant elasticities of per capita costs with respect to population-weighted density are shown in Table 4.15, based on the overall results shown in Tables 4.9-4.11. Elasticities for operations costs ranged from -0.13 for fire protection to -0.31 for sewer, and was 0.09 for police. Greater elasticities were found for capital costs, where significant, such as -0.32 for streets/highways construction, -0.39 for water construction, and -0.54 for sewer construction.

Table 4.9 Results for Models of Municipal Expenditures, Operational Costs

	Fire		Streets/ highways		Libraries		Parks and recreation		Police		Sewer		Solid waste		Water	
	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value
Intercept	-4.424***	-6.25	-5.668***	-8.48	-16.007***	-10.37	-9.087***	-8.92	-4.685***	-9.56	1.800*	1.78	-2.405*	-1.94	-1.867**	-2.20
Population	0.163***	6.41	-0.014	-0.58	0.052	1.03	0.200***	5.54	0.088***	5.02	0.105***	2.88	0.108**	2.53	0.055*	1.84
Population change	-0.340	-1.06	-0.742**	-2.39	-1.926***	-2.68	0.084	0.18	-0.794***	-3.51	0.329	0.73	0.379	0.69	0.314	0.84
Density	-0.132***	-3.57	-0.266***	-7.61	-0.059	-0.78	-0.209***	-3.97	0.090***	3.54	-0.314***	-5.71	-0.203***	-3.25	-0.141***	-3.04
Per capita income	0.105	1.61	0.488***	7.89	1.160***	8.25	0.593***	6.27	0.124***	2.75	-0.311***	-3.3	-0.067	-0.58	0.001	0.01
Median house age	0.016***	9.15	0.013***	7.63	0.011***	3.01	-0.005*	-1.94	0.006***	5.12	0.008***	3.21	0.014***	4.60	0.006***	2.98
n	936		988		531		948		992		897		808		821	
R-square	0.1549		0.1475		0.1481		0.1187		0.1908		0.0554		0.0349		0.0148	

*p<10%, **p<5%, ***p<1%

Table 4.10 Results for Models of Municipal Expenditures, Construction Costs

	Fire		Streets/ highways		Libraries		Parks and recreation		Police		Sewer		Solid waste		Water	
	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value
Intercept	-11.65***	-2.75	-11.39***	-7.46	-3.401	-0.42	-15.20***	-6.44	-8.581*	-1.75	-4.637**	-2.13	-10.962	-1.26	-4.172**	-2.25
Population	-0.016	-0.13	0.047	0.93	-0.263	-1.46	0.231***	3.20	-0.066	-0.47	0.358***	5.08	-0.069	-0.39	0.195***	3.29
Population change	-0.071	-0.05	1.145	1.62	10.678*	1.76	0.453	0.45	0.778	0.41	1.435	1.55	-1.747	-0.34	4.033***	3.45
Density	-0.133	-0.61	-0.316***	-3.94	0.283	0.59	-0.259**	-2.02	-0.164	-0.59	-0.544***	-4.89	-0.395	-1.01	-0.391***	-3.83
Per capita income	0.679	1.64	0.993***	7.03	-0.175	-0.21	1.024***	4.56	0.495	1.00	0.100	0.48	0.911	1.02	0.121	0.69
Median house age	0.015	1.29	0.010***	2.63	-0.006	-0.24	0.002	0.25	0.012	0.98	0.019***	3.53	0.022	0.99	0.018***	3.60
n	111		589		56		379		117		414		66		411	
R-square	0.0352		0.0998		0.1525		0.0911		0.0235		0.0794		0.0737		0.0629	

*p<10%, **p<5%, ***p<1%

Table 4.11 Results for Models of Municipal Expenditures, Land and Existing Facilities Costs

	Fire		Streets/ highways		Libraries		Parks and recreation		Police		Sewer		Solid waste		Water	
	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value
Intercept	-3.699	-1.47	-5.651*	-1.81	-12.549**	-2.18	-5.103*	-1.87	-4.850**	-2.58	-3.917	-0.9	5.303	0.97	-5.248	-1.38
Population	-0.124	-1.48	-0.373***	-3.64	-0.303*	-1.97	-0.129	-1.4	-0.104*	-1.66	-0.140	-1.06	0.005	0.04	0.023	0.21
Population change	-2.744*	-1.89	-2.378	-1.35	-6.668**	-2.27	-2.306	-1.57	-2.328**	-2.32	0.829	0.55	0.261	0.09	1.643	1.03
Density	-0.119	-0.87	-0.202	-1.21	-0.148	-0.47	-0.013	-0.09	-0.243**	-2.38	-0.217	-0.96	-0.557**	-2.54	-0.542***	-2.77
Per capita income	0.171	0.73	0.663**	2.3	1.117**	2.04	0.219	0.84	0.314*	1.78	0.153	0.36	-0.659	-1.19	0.403	1.08
Median house age	-0.024***	-3.6	-0.008	-1.05	-0.006	-0.41	-0.024***	-3.41	-0.009*	-1.77	0.022**	2.34	0.011	0.91	0.013	1.48
n	353		359		83		368		466		221		135		215	
R-square	0.1103		0.1064		0.2159		0.0658		0.0863		0.0467		0.1098		0.0532	

**p*<10%, ***p*<5%, ****p*<1%

Table 4.12 Results for Models of Municipal Expenditures, Operational Costs, Cities with Population 25,000 to 250,000

	Fire		Streets/ highways		Libraries		Parks and recreation		Police		Sewer		Solid waste		Water	
	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value
Intercept	-5.395***	-6.72	-5.035***	-6.98	-17.295***	-9.87	-8.798***	-7.69	-4.602***	-8.54	2.684**	2.37	-2.333*	-1.7	-2.269**	-2.37
Population	0.258***	6.85	-0.046	-1.37	0.148*	1.9	0.215***	4.05	0.088***	3.5	0.079	1.48	0.151**	2.36	0.110**	2.44
Population change	-0.331	-0.99	-0.898***	-2.91	-1.989***	-2.7	-0.070	-0.14	-0.900***	-3.93	0.159	0.35	0.357	0.64	0.282	0.73
Density	-0.163***	-4.11	-0.241***	-6.78	-0.071	-0.89	-0.216***	-3.86	0.095***	3.58	-0.290***	-4.99	-0.228***	-3.47	-0.149***	-3.01
Per capita income	0.117*	1.7	0.451***	7.25	1.198***	8.15	0.558***	5.63	0.117**	2.52	-0.381***	-3.89	-0.101	-0.85	-0.012	-0.14
Median house age	0.018***	9.27	0.011***	6.19	0.011***	2.64	-0.005**	-2.03	0.005***	4.1	0.007**	2.49	0.014***	4.54	0.006***	2.85
n	858		910		479		872		913		825		737		751	
R-square	0.1615		0.1391		0.1516		0.1104		0.1601		0.0585		0.0388		0.0173	

**p*<10%, ***p*<5%, ****p*<1%

Table 4.13 Results for Models of Municipal Expenditures, Construction Costs, Cities with Population 25,000 to 250,000

	Fire		Streets/ highways		Libraries		Parks and recreation		Police		Sewer		Solid waste		Water	
	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value
Intercept	-11.572*	-1.99	-11.43***	-7.12	-3.200	-0.3	-13.52***	-4.79	-16.8***	-2.69	-4.322*	-1.7	-4.317	-0.4	-3.914*	-1.82
Population	0.311	1.12	0.163**	2.28	0.248	0.68	0.150	1.18	0.513*	1.76	0.395***	3.48	0.035	0.08	0.170*	1.83
Population change	0.095	0.06	0.931	1.38	6.771	0.9	0.295	0.27	1.255	0.67	1.061	1.11	-0.117	-0.02	3.570***	2.89
Density	-0.233	-0.85	-0.394***	-4.96	0.271	0.46	-0.337**	-2.28	-0.364	-1.21	-0.525***	-4.4	-0.891**	-2.03	-0.353***	-3.2
Per capita income	0.393	0.74	0.937***	6.81	-0.687	-0.67	1.015***	4.07	0.751	1.43	0.029	0.13	0.527	0.52	0.102	0.55
Median house age	0.016	1.07	0.011***	2.68	-0.014	-0.44	0.000	0	0.031**	2.09	0.016***	2.71	0.026	0.97	0.016***	2.93
n	82		524		37		319		85		361		44		357	
R-square	0.03		0.1139		0.1323		0.0861		0.0729		0.0626		0.123		0.0454	

*p<10%, **p<5%, ***p<1%

Table 4.14 Results for Models of Municipal Expenditures, Land and Existing Facilities Costs, Cities with Population 25,000 to 250,000

	Fire		Streets/ highways		Libraries		Parks and recreation		Police		Sewer		Solid waste		Water	
	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value	Estimated parameter	t-value
Intercept	0.985	0.35	-2.492	-0.73	-10.875	-1.42	-1.823	-0.62	-2.209	-1.08	-2.741	-0.55	6.682	1.13	-6.579	-1.47
Population	-0.348***	-2.75	-0.600***	-3.94	-0.342	-1.16	-0.323**	-2.46	-0.253***	-2.73	-0.012	-0.06	-0.202	-0.95	0.070	0.38
Population change	-2.982**	-2.02	-3.502**	-2.01	-8.599***	-2.79	-3.543**	-2.51	-2.309**	-2.34	0.959	0.63	-0.640	-0.23	1.527	0.93
Density	-0.100	-0.69	-0.086	-0.51	-0.119	-0.34	0.073	0.49	-0.251**	-2.46	-0.331	-1.38	-0.556**	-2.62	-0.473**	-2.27
Per capita income	-0.039	-0.16	0.540*	1.88	1.056*	1.67	0.079	0.31	0.235	1.33	-0.018	-0.04	-0.527	-0.97	0.431	1.06
Median house age	-0.030***	-4.28	-0.016**	-2.00	-0.023	-1.35	-0.033***	-4.66	-0.012**	-2.53	0.024**	2.49	0.002	0.19	0.012	1.3
n	319		325		65		329		427		200		113		192	
R-square	0.1504		0.0979		0.1893		0.1011		0.1144		0.0448		0.1433		0.0378	

*p<10%, **p<5%, ***p<1%

Table 4.15 Estimated Elasticities of Per Capita Expenditures with respect to Population-Weighted Density

Cost Category	Operations	Construction	Land and Existing Facilities
Fire	-0.132		
Streets/highways	-0.266	-0.316	
Libraries			
Parks and recreation	-0.209	-0.259	
Police	0.090		-0.243
Sewer	-0.314	-0.544	
Solid Waste	-0.203		-0.557
Water	-0.141	-0.391	-0.542

Results also show significant relationships for other variables. Population was found to have a positive and statistically significant relationship for many of the operational costs and some construction costs, suggesting per capita costs increase with increases in population, but negative relationships were found for some land and existing facility costs. Population change was found to have a negative effect for some operational costs and land and existing facilities costs, consistent with findings from previous studies, suggesting per capita costs are lower for cities experiencing greater growth. On the other hand, population change was positively associated with per capita construction costs for water and libraries. Per capita income was found to be positively associated with per capita costs in a number of cases, as expected, though it was negative for sewer construction.

Median house age was positive and statistically significant in all operational cost models except for parks and recreation. This suggests older neighborhoods require increased operational expenditures, except that parks and recreation expenditures were higher in cities with newer housing. Construction costs for streets/highways, sewer, and water were also higher in cities with older housing, if everything else remains equal. There is some correlation between the age of a neighborhood and density, as older neighborhoods tend to be denser. The density contributes to lower costs, while the age of the buildings and infrastructure may contribute to higher costs.

5. SMART GROWTH PROJECTS IN SMALL COMMUNITIES

The analysis suggests that communities of all sizes could benefit from promoting smart growth principles. This includes promoting increased density and land use mix, creating walkable neighborhoods, providing options for transit and alternative modes, and limiting sprawl. These strategies could increase transit ridership and reduce household transportation spending, while also reducing costs for cities. While these principles are being pursued in large urban areas and many smaller metropolitan areas as well, less is known about the extent to which smaller communities are promoting smart growth projects or how they are attempting to accomplish these goals. This study provides some evidence on how smaller communities are pursuing smart growth strategies.

For this study, planning documents for 10 small cities within the Upper Midwest were studied to understand the extent to which these cities are pursuing these principles. Six different project types were considered: infill development, sidewalk/shared use paths, mixed-use development, downtown revitalization, multi-modal planning, and complete streets. Results in Table 5.1 show whether these 10 communities are engaged in these different types of projects. A specific project was acknowledged in Table 5.1 if the community planning document made particular reference to the project concept or developed the concept within the document. Smart growth project types that were not mentioned or only mentioned in passing without being developed within the planning document were not acknowledged.

Table 5.1 Smart Growth Projects in Small Communities in the Upper Midwest

		Smart Growth Project Types					
City	2018 population	Infill Development	Sidewalk/ Shared Use Paths	Mixed-Use Development	Downtown Revitalization	Multi-Modal Planning	Complete Streets
Mason City, IA	27,093		X	X		X	
Alexandria, MN	13,746	X	X	X	X		
Brainerd, MN	13,465		X		X	X	
Crookston, MN	7,806		X		X		X
Fergus Falls, MN	13,845	X	X				
Devils Lake, ND	7,278				X		
Dickinson, ND	22,739	X	X	X	X	X	
Brookings, SD	24,509	X	X	X		X	X
Pierre, SD	13,980	X			X		
Watertown, SD	22,153	X	X	X			

Infill development was highlighted by more than half of the communities considered. Alexandria, MN, for example, reported that 38% of the city is comprised of vacant land that may be developed as commercial or industrial land while allowing for defined wetlands. City officials found that development of this land would ensure prudent land management and would assist in preventing development beyond current city boundaries while ensuring maximum cost effectiveness for residents (City of Alexandria 2007).

All but two of the communities studied were implementing or had already implemented either sidewalk or shared-use path projects. Watertown, SD, is incorporating pedestrian sidewalks within reconstructed street projects and will use a new master trail and sidewalk plan in developing new pedestrian sidewalks and trails throughout the community (City of Watertown 2018). Mixed-use development was highlighted by half of the communities studied. Brookings, SD, for example, wants to encourage balanced and connected neighborhoods. Officials there have found that mixing compatible uses such as a corner store or school in a residential neighborhood creates a sense of community while promoting efficient infrastructure and travel times. Ideal balanced neighborhoods in Brookings will offer a variety of housing options, access to open space, and contain activity centers such as parks, civic centers, or commercial areas that are well connected to surrounding neighborhoods (RDG 2018).

Downtown revitalization was found to be of utmost importance to many small communities. Devils Lake, ND, for example, is focusing on downtown improvement project by updating its infrastructure and road network. Local landscapers are adding amenities, making the downtown area more visually appealing as well (City of Devils Lake 2019). Alexandria, MN, is improving its downtown by enacting building requirements that preserve the downtown and encourage pedestrian-traffic oriented businesses versus vehicle-traffic oriented businesses. The city is also encouraging participation in low-interest loan programs for downtown businesses with a focus on redeveloping and expanding the downtown community (City of Alexandria 2007).

Multi-modal planning was highlighted by only four communities studied. While multi-modal development is usually considered by urban communities, small urban communities that have experience considerable growth, such as Dickinson, ND, have made it a focus. Dickinson's transportation plan strives to provide the means to maintain a safe and functional multi-modal system. The specific objectives within the plan include identifying alternative approaches to address safety, congestion, and to preserve future barrier crossings for all modes of traffic (KLJ 2013).

Complete streets was a smart growth project addressed by two communities studied. Specifically, Crookston, MN, is making it a focus of its comprehensive plan. The city is building streets that are safer, more accessible, and easier to navigate for residents. The streets will be designed to enable safe access for pedestrians, bicyclists, motorists, and public transportation users alike. Crookston's plan acknowledges that complete street policies are important for aging adults who want to remain in their community as well as for millennials and young families who want to live in a community with a variety of transportation options to get to jobs, school, or for their daily needs. Their main goal within the complete streets concept is not centered on one specific project, but it is about changing the way the city approaches transportation projects on all streets throughout the community (KLJ 2016).

6. CONCLUSIONS

This study provides evidence that land use has an effect on transportation behavior, transit ridership, household transportation expenditures, and municipal expenditures in small urban areas. Specific results include the following:

- Transit ridership in cities with population of 50,000 to 200,000 is positively associated with service area population density. The estimated elasticity of ridership with respect to density is 0.09.
- The likelihood of anyone within a Census block group commuting by transit is greater in areas with greater density, if the area is within the metro area's principal city, if a larger percentage of workers commute to the principal city, and if the total metro area population is greater. Similarly, the total number of transit commuters within a block group increases with increases in density and total metro population and if the area is within the principal city or a large percentage of workers commute to the principal city. Within Census block groups with at least one transit commuter, the elasticity of transit use with respect to population density is found to be 0.15.
- Estimated household expenditures on transportation in small cities in the Midwest and Upper Greater Plains are negatively correlated with residential density and gross household density.
- Household transportation expenditures are greater for those living in single-family detached structures and lowest for those living in high rises.
- Among households living in single-family detached structures, those in older homes spend less on transportation. Compared to those living in homes built after 1999, those in homes built before 1945 spend 22% less on transportation. Those in homes built from 1945 to 1969 spend 17% less on transportation. And those in homes built from 1970 to 1999 spend 10% less on transportation.
- Weighted population density is significantly associated with many municipal spending categories. Density is shown to be negatively associated with per capita operational costs for fire protection, streets and highways, parks and recreation, sewer, solid waste management, and water, while being positively related to police operational costs. Density is also negatively associated with per capita construction costs for streets/highways, parks and recreation, sewer, and water and with per capita land and existing facilities costs for police, sewer, and water.

In summary, results provide evidence that more densely populated areas result in increased transit ridership and reductions in household transportation spending and per capita municipal expenditures. Much of the analysis is based on population density because of data availability. This study focused on large-scale, city-level analyses of cities across the country, where data for other land use variables are lacking. These other variables, including those discussed in Section 2, such as land use mix and accessibility, are also likely important. As previously noted, though, density tends to be correlated with other land use characteristics. Areas with greater density tend to have more land use mix, better accessibility, better transit services, shorter blocks, and better options for walking or biking. Results from this study, therefore, are likely capturing the effects of not just density but also these other characteristics that tend to be related.

Following from that, it is important to note that density alone cannot be assumed to result in increased transit ridership, reduced driving, and reduced expenditures for households and cities. Apartment complexes in suburban style, auto-oriented developments may provide greater density, but if they are located in single-use neighborhoods with poor accessibility, the expected benefits will not be realized. Further, households in single family homes in older, traditional urban neighborhoods with grid street networks, proximity to downtown, and greater accessibility by walking, biking, or transit may be less likely to drive and more likely to use transit, and as results suggest from this study, their transportation costs will be lower.

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