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How Demographic and Urban Area Characteristics Influence Mass Transit Ridership

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OVERVIEW

America's reliance on automobiles persistently contributes to high levels of traffic congestion, carbon emissions, and a declining public infrastructure. A growing understanding among policymakers and planners recognizes the importance of alternative mode choices when it comes to passenger travel. Mass transit —one alternative mode of travel— can alleviate America's strained transportation system. However, public transportation is an infrequently used service for commuters' work and non-work related trips. The purpose of this study is to examine which particular demographic variables, urban area characteristics, and spending such as government funding and gas prices influence mass transit travel (particularly bus, light, and heavy rail systems). Correlating ridership statistics from the National Transit Database to U.S. Census data across urban areas, higher usage of public transit systems correlate to higher share of the working age population (18-64), larger household size, larger population, more densely populated central cities, and higher government funding for mass transit. These findings illustrate how responsive the use of public transportation is to urban area environments. As a result, future investment and implementation of cost-effective transit systems must work in tandem with urban planning decisions such as land-use policies and density studies.

INTRODUCTION

As we enter the 21st century in an ever-increasing global economy, the United States transportation system is essentially at a crossroads (Peters, 2007). One critical issue stems from the lack of travel mode choice for passengers. Without reliable, accessible alternative modes of transportation, Americans remain dependent on the private automobile. As a result, traffic congestion builds on interstate highways, city streets, and freight corridors. Furthermore, the disproportionately large number of cars for the limited roadway capacity contributes to greenhouses gases and poor air quality (Puentes, 2008). Private automobiles also tend to monopolize the public space, a key element of the social fabric, raising concern about quality places and social cohesion (Boarnet & Crane, 2001). To mitigate these circumstances, policymakers and planners should focus on increasing mode choices such as public transportation or mass transit and how these transportation choices fit into a broader pattern of metropolitan planning.

According to the Texas Transportation Institute's Urban Mobility Report, in 2004 traffic amounted to $63 billion in estimated congestion costs due to the 3.5 billion hours of travel delay and 5.7 billion gallons of wasted fuel from idling in traffic delays and traveling long miles. Hartford estimated that in this same period mass transit saved $20 billion in congestion costs (2006). Especially in large urban areas, many are acknowledging that public transportation is an important solution to traffic congestion (Zhao & Zeng, 2008). Through economies of scale in the automobile market, people gained greater access to cars due to increased affordability. In fact, Brendon Hemily of the American Public Transportation Association found that vehicle miles and car ownership exceeded the growth in population and employment. Consequently, this affected commuting patterns as the automobile became the principal means of transportation growing from 64.4 percent in 1980 to 73.2 percent in 1990 to 75.5 percent in 2000 at the expense of other means of travel such as carpooling, public transportation, and non-motorized modes (2004). David W. Jones, a transportation expert in the San Francisco Bay area, argued that these historical trends of solo-commuting strained the public ownership of mass transit, further marginalizing the service into a subordinate role to the car (2008). This is despite the fact that one bus can replace 60 cars from the road, one light rail vehicle car can replace 125 cars, and one subway line can carry 30,000 passengers in one hour (Cambridge Systematics, 2008). Yet it should be understood that automobile use responded to the spatial changes of employment dispersion and sprawling communities not just as a convenient and comfortable preference of individuals. The car suitably adapts to low density areas (Hemily, 2004).

However, there is growing evidence that private transit might not be environmentally sustainable. In a recent report Robert Puentes, a transportation specialist at the Brookings Institution, affirms: "the continued growth in driving cancels out both vehicle efficiency and fuel alternatives." The sheer volume of automobiles generates a large amount of carbon dioxide emissions due to low vehicle efficiency standards, idling in traffic, and traveling long distances. Since the mid-1990s, transportation became the leading source above all other sectors including industrial, residential, and commercial in contributing to United State's total CO_2 emissions (Puentes, 2008). If instead there existed a more balanced mode choice with mass transit, the carbon footprint could be alleviated. In terms of energy conservation, "public transportation saves more than 855 million gallons of gasoline or 45 million barrels of oil a year" (Cambridge Systematics, 2008). In addition, higher gas prices may be reversing the historical affordability of cars.

Besides mitigating environmental and economic costs, in recent years mass transit has played an instrumental role in the development of quality places. Brendon Hemily (2004) acknowledges that: "mass transit is the lifeblood of cities, an essential multi-functional role that fosters livability and sustainability of urban communities." After decades of disoriented urban sprawl, land developers and urban planners have used public transportation in new compact initiatives of city design with *New Urbanism, Smart Growth,* and *Transit-Oriented Development*. These community designs aim to reduce car trips, conserve space, encourage green spaces, avoid gridlock, promote technological innovation, and improve air quality (Hemily, 2004). Understanding transit's economic cost-savings, business developers are now building corporate buildings, entertainment complexes, and sports facilities around transit stations (Cambridge Systematics, 2008).

RESEARCH QUESTION

As the above literature illustrates, mass transit can be regarded as an essential public good since it can reduce environmental and economic costs and improve quality places. While these effects of public transit have been acknowledged, what leads to a sustainable public transit system has not been fully explored. This study examines the link between metropolitan characteristics to public transportation ridership. And by identifying these factors, public transit systems can be better planned and installed.

Hemily (2004), like many other scholars, points out that inward migration and revitalization of city cores and inner suburbs starting in the last decade have been spurred by age groups. Empty nester baby boomers and young Generation X professionals have demanded urban living with lively downtown attractions and cultural facilities. Consequently, age may play a significant factor in the use of urban amenities and services such as mass transit. With professionals, education level may prove significant as well. Hemily also points out that immigrants as well have rekindled economic and residential life in urban cores suggesting that nonwhites may positively affect mass transit use. Moreover, household demographics have pushed for more patronage of public transportation as more single person households, childless couples, and non-family households choose to live in the city with accessible public transportation. Income has also played a role in commuters' choices. Higher income individuals are able to afford higher housing and commute costs, thereby discouraging mass transit. Also, because "sprawl is a sufficient but not necessary condition for automobile dependence," longer commute times may negatively affect mass transit ridership (Handy, 2005).

Studies have also shown area density or compactness encourages transit use and fewer privately owned vehicle miles compared to sprawl settings (Burchell et al., 2005). Additionally, mixed land use that combines housing, workplaces, and other urban activities bolsters transit ridership (Cervero, 2007). As a result, density and a mix of occupations may influence the use of public transit. The transportation industry has even acknowledged that network layout, service frequencies, and schedules in a proper design yields a positive impact on ridership (Zhao & Zeng, 2008). These components depend on urban area population and a central core density. To further explore these questions I examine how demographic and spatial characteristics such as population size and composition, commute times, region, and urban density affect transit use in places where such systems are available.

Beyond spatial or demographic characteristics, monetary items can also affect transit ridership such as gasoline prices and government funds. Increasing gas prices tend to encourage the use of alternative modes of travel away from the automobile as car usage becomes less affordable. In a recent Congressional Budget Office study (2008) a positive relationship exists between rail system ridership and gasoline prices in larger California cities. CBO estimated that a 20 percent increase in gasoline prices associated with a 1.9 percent increase in average system ridership. Furthermore, policymakers today continually invest in transportation infrastructure from federal, state, and local sources on highways and mass transit (Orszag, 2008). Consequently, government funding may yield a positive return on mass transit use.

METHODS

Essentially, this data analysis will gauge how public transportation relates to the demographic composition, spatial characteristics, and spending amounts across urban areas of the United States. Only those urban areas that employ existing transit systems will be analyzed. Because households often work across city and state borders and public transit serves intercommunity regions, the Census definition of urban area (a close unit to the more familiar metropolitan area) will be the unit of analysis. Transit ridership contingent to agencies reporting to the National Transit Database are measured in two consecutive cross-sectional years for comparison purposes: 2005 (N= 358) and 2006 (N=363). Through OLS regression, particular characteristics of residents, urban areas, and spending will be used to estimate their marginal influence on mass transit use. Despite the many modes of public transit, only three particular forms will be analyzed: motor bus, light/commuter rail, and heavy rail systems. Ridership will be measured in per capita passenger trips and passenger miles for these three modes of transit.

$$Y\{\text{per capita trips and miles}\} = \beta_0 + \beta_1\{\text{vector of demographic variables}\} + \beta_2\{\text{vector of spatial characteristics}\} + \beta_3\{\text{vector of spending}\} + \mu$$

Explanatory variables used from the 2000 U.S. Census data include age, race, poverty status, car ownership, household size, median income, education level, employment status, occupation, and commute time to work. All demographic variables reflect the proportions of total population in each category except median income, measured in dollars. Also from the Census, spatial characteristics include region of urban area, urban area population, central place density, and share of central place population to the total urban area population. We include 2005 and 2006 regional gas prices from the Energy Information Administration (EIA), a branch of the U.S. Department of Energy. Government funding includes total amounts allocated from the Federal Transit Agency (FTA). Table 1 summarizes all variables used.

Table 1. Definitions of Explanatory and Dependent Variables

Variable	Definitions/Categories
Explanatory Variables (all variables are measured as percent of population unless otherwise noted)	
Age	young age: 0-17yrs.; working age: 18-39; middle age: 40-64; old age: 65-older
Race	whites; nonwhites
Household Size	household size: 1; 2; 3; and 4 or more
Education	no high school; high school; some college; BA; Prof degrees
Income	urban area median household income in dollars
Occupation	white-collared occupations: includes management, professional related; service sale occupations: office-related; blue-collared occupations: includes farming, fishing, forestry, construction, extraction, maintenance, production, transportation material moving
Commuting Time	low: 15-29min; med: 30-44min; high: 45-89min; really high: over 90min.
Region	northwest, west, south, midwest (as defined by U.S. Census)
Population	total population of urban area
Central Place Density	density of any incorporated place or Census-defined place that has its name in the title of the urban area and has at least a pop. of 50,000 (Census.gov)
Gas Price Growth	percent change in retail gasoline prices for all grades (regular, mid-grade, premium) and formulations (gas and diesel) from a year ago (EIA.doe.gov).
Government Funding	total money from the FTA capital program, FTA urbanized area formula (uaf) fund, and other FTA funds (NTD).
Dependent Variables	
Per Capita Passenger Trips	total number of boardings on public transit vehicles, regardless of transfer on a one-way route; passengers are counted each time he/she boards a revenue vehicle
Per Capita Passenger Miles	total sum of the distances ridden by each passenger, calculated by totaling the passenger load times the distance between individual bus stop (ten passengers riding in a transit vehicle for two miles equals 20 passenger miles)

RESULTS

SUMMARY STATISTICS

Descriptive statistics here give an overview of per capita trips and per capita miles for both years. As illustrated in the tables below, mass transit trips and miles show considerable variability with the presence of outliers. Most urban areas have low numbers of trips and miles while there are a few urban areas with large central cities such as New York, Boston, San Francisco, and Chicago that show higher ridership numbers. Also, as can be noted more trips and miles were taken in 2006.

REGRESSION RESULTS

Multivariate regression results show the influence of demographic characteristics, spatial attributes, and spending activity on mass transit use. In Table 3, young age, single-person households, households of four or more, and annual gas price change show substantively strong correlation with passenger trips and miles in 2005. The young age population (under 17 years of age) correlates with fewer transit trips and miles than the working age population (18-64 years of age). Single households and households with four or more persons show higher numbers of transit trips and transit miles than households of two or three. Additionally, population correlates positively with ridership. As central place density – the density in the core cities of urban areas– increases public transit trips increase. Also, government funding –Federal Transit Administration (FTA) grants– increases passenger miles increase. Curiously, annual gas price change from 2004 to 2005 results in a strong negative correlation with trips and miles but this might reflect differences in regions and interactions with the proxy indicator. Nevertheless, this elasticity response comes well before the higher gas prices of the late 2000s. Finally, the northeast takes fewer trips compared to the Midwest. Differing occupations show no significant levels. Interestingly, car ownership and commuting time do not emerge as significant variables.

Conversely, a different scenario develops in 2006. The young age population continually travel less mass transit miles than the working age population. Yet, all other demographic characteristics including education levels and household sizes are no longer significant. Interestingly, commute times emerge with importance. Urban areas with more high commuters (45-89 min.) have higher numbers of transit trips and miles than areas with more medium commuters (30-44min). Areas with more very high commuters (over 90 min.) take fewer trips than medium commuters. This suggests that transit travel peaks at high commutes (especially since low commute has a negative tendency). Another interesting result is the change in sign with total urban area population one year later. An increase in population results in fewer transit trips and mile suggesting that public transportation may have increased in low populated urban areas since on the aggregate 2006 witnessed more transit travel. Moreover, the share of central place population relative to the total urban area population (not density) results in more transit miles traveled. Also a year later, government funding slightly increases its return and gas price growth magnifies its negative influence. Finally, instead of the northeast, in 2006 the south shows fewer transit trips and miles than the Midwest. Overall, urban area spatial characteristics tend to be more influential than demographic composition in 2006.

Table 2

Descriptive Statistics for Per Capita Trips and Miles in 2005						
Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Per Capita Trips	358	13.23	7.33	20.76	0	176.9
Per Capita Miles	358	56.3	26.93	102.67	0	826.1

Descriptive Statistics for Per Capita Trips and Miles in 2006						
Variable	Obs	Mean	Median	Std, Dev.	Min	Max
Per Capita Trips	363	23.9	9.61	45.13	0	378.9
Per Capita Miles	363	150	38.51	378.9	0	3222.9

Table 3

OLS Regressions for Per Capita Passenger Trips and Miles for 2005 and 2006.				
	2005		2006	
	Per Capita Trips	Per Capita Miles	Per Capita Trips	Per Capita Miles
Young Age	**-140.5*** (70.94)	**-766.8*** (382.0)	15.16 (171.7)	**-2968.7*** (1431.9)
Old Age	60.85 (56.87)	131.2 (306.3)	51.52 (139.6)	-1271.3 (1164.6)
Non-White	5.637 (11.18)	38.86 (60.22)	-21.09 (27.38)	13.92 (228.3)
Pov-Pct.	23.11 (36.23)	-104.1 (195.1)	6.506 (88.57)	-527.2 (738.7)
Car Owners	-11.84 (25.45)	-73.47 (137.0)	-31.82 (57.42)	689.2 (478.9)
No HS Educ Level	-56.26 (37.03)	-152.7 (199.4)	95.19 (91.57)	1000.5 (763.7)
BA Educ Level	-38.15 (55.98)	-104.5 (301.5)	142.4 (136.8)	-912.0 (1140.7)
Prof Educ Level	**171.0**** (62.23)	149.4 (335.2)	44.38 (152.5)	-1775.7 (1271.5)
Household 1	**161.9*** (65.22)	**1146.5**** (351.2)	-148.7 (161.2)	-758.5 (1344.2)
Household 4+	**220.2***** (63.56)	**1275.1***** (342.3)	10.58 (158.6)	1197.3 (1323)
Employ Status	38.62 (33.15)	64.63 (178.5)	12.43 (81.32)	502.9 (678.2)
Low Commute	-13.66 (13.97)	-95.36 (75.25)	-62.63 (33.85)	-117.0 (282.3)
High Commute	-27.42	-151.6	**187.3****	**1406.2****

	(25.27)	(136.1)	(63.52)	(529.7)
Real Hi Commute	-116.4 (81.70)	-276.2 (440.0)	**-520.6*** (202.0)	2321.6 (1684.9)
Median Income Per Thousand	0.0267 (0.0441)	0.119 (0.238)	-0.0133 (0.108)	0.495 (0.904)
Population Per Million	**5.819***** (1.371)	**14.78*** (7.383)	**-13.54***** (3.611)	**-101.4***** (30.12)
Cntr. Pl Density	**1.677*** (0.797)	5.145 (4.292)	0.743 (2.106)	-3.845 (17.56)
Cntr. Pl Share	-2.451 (4.659)	-39.38 (25.09)	22.24 (11.50)	**233.2*** (95.88)
Govt Fund Per Million	0.0068 (0.00533)	**0.0888**** (0.0287)	**0.0759***** (0.0135)	**0.417***** (0.113)
Gas Growth	**-195.6**** (65.25)	**-838.7*** (351.4)	**-1581.3**** (596.3)	**-11102.6*** (4973.3)
Northwest	**-7.819*** (3.434)	-34.35 (18.49)	12.44 (9.361)	97.58 (78.07)
West	-0.556 (1.153)	1.677 (6.209)	-0.590 (2.452)	5.856 (20.45)
South	1.563 (0.921)	6.258 (4.962)	**-6.216**** (2.140)	**-45.41*** (17.85)
White Collar Occ.	-36.2 (58.41)	117.5 (314.6)	83.05 (146.8)	2271.2 (1224.5)
Blue Collar Occ.	45.89 (38.19)	246.6 (205.6)	-15.91 (98.62)	-1002.2 (822.5)
Constant	-30.65 (37.99)	-216.6 (204.6)	**220.4*** (112.0)	1165.9 (934.2)
N	350	350	349	349
adj.R-sq	0.481	0.385	0.292	0.348

Standard errors in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Omitted categories: working and middle age, white, h.s. educ and some college, households 2 and 3, medium commute, Midwest, serv sales occ.

DISCUSSION AND POLICY IMPLICATIONS

All in all, demographic, spatial, and external dollar amounts do influence the number of trips taken and miles traveled via mass transit systems across urban areas. Larger households, population, commute times, central place density, and government funding were key positive factors in mass transit use. The young, northwest, south and gas price growth resulted in negative correlations, though these results might reflect in the limitations of available data but will be further examined in future work.

In light of these findings, mass transit does not exist in a vacuum of costs and utility but responds to the nature of urban area environments. With this interplay of many factors, it is pivotal that coordination with land-use policies be used in installing and revitalizing mass transit systems. City and transportation planners as well as land developers should collaborate on projects to better girder a system that meets the needs of the metropolitan community. Given current economic uncertainty and federal and state budget strains, it is essential these agencies that once worked in isolation work now in collaboration on present and future cost-effective projects.

Furthermore, network routes and time scheduling should configure to the new spatial realities of the 21st century. Buses and rail lines should be made more accessible to residences instead of primarily to businesses. Additionally, tax credits can reward larger households. Low dense areas can provide rapid transit through spacious pathways, possibly alongside highway corridors or through suburb to suburb routes to reach the level of denser areas. Stakeholders should encourage young riders at appropriate ages to use transit and further install it in Sunbelt cities and revitalized it in the north. Agencies should regularly forecast gas prices to keep up at pace with demand especially during the summer months. Each government funding dollar should be accounted for at every stage of its use (capital or operating expenses, employee wages and benefits, infrastructure and facilities, etc.) to avoid waste and increase its return. More federal dollars can even help bolster the public service. Finally, longer commuters who take fewer trips should be encouraged to take transit through employment subsidies, tax rebates, and other incentives. Future research to study how patterns change over time would furnish more detailed information.

Essentially, a more integrated, comprehensive mass transit system in conjunction with better urban planning will help turn around the U.S. transportation system and lead to a more economically competitive, environmentally sustainable, and socially vibrant future.

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