The Transportation Crossroads: Influence of Urban Area Form And Composition on Mass Transit [1]

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ABSTRACT

In the wake of economic restructuring and decentralization of cities America has come to rely on automobiles, contributing to high levels of traffic congestion, carbon emissions, poor quality places, and a declining public infrastructure. Policymakers and planners recognize that mass transit, an 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 the significance and magnitude of large scale forces on travel behavior gauging the influence of demographics, urban area characteristics, and certain dollar values on mass transit travel particularly bus, light/heavy rail systems. In regressing per capita transit trips and per capita miles from the National Transit Database on U.S. Census data across urban areas and over time (2000-2007), significant variables include higher share of young and old age populations, larger household size, car ownership, higher commute times, denser central places, higher government funding, and higher gas prices. These findings illustrate how responsive the use of public transit is to urban area environments and demographic composition. Policy should acknowledge these relationships for environment sustainability, economic competitiveness, and social vibrancy.

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INTRODUCTION

Scholars, policymakers, and the general public universally agree that the contemporary transportation system of the United States is at a crossroads.[1] Traffic congestion increasingly impairs economic performance with delayed time and wasted resources and productivity.[2] The disproportionately large number of private vehicles relative to available roadways contributes to high amounts of carbon emissions and poor air quality from pollutants of combustion engines;[3] high energy costs with reliance on insecure, imported fuels;[4] high number of automobile fatalities;[5] and a costly public infrastructure of roads, bridges, water, and sewer lines.[6]

How exactly the U.S. developed this strained transportation system results from a steady progression of macro-level forces particularly transformations in urban development and demographic composition. This study aims to measure and evaluate the effect of these two transformations on travel demand for one mode of travel –public transit.

In essence, transportation is a crucial element in both the social and economic system. It connects the concentrations of people to urban outlets, influencing human activity, the built environment, urban growth, and metropolitan linkage of a national system.[7] It also facilitates access to employment, residences, schools, recreation, and other social endeavors.[8] However in the last several decades, social and economic impacts have shaken the urban landscape, straining U.S.'s transportation system.

Among many factors, urban form and demographic composition have been two consistent forces affecting transportation. Sociologist Saskia Sassen asserts that starting in the 1970s the U.S. underwent a global economic restructuring shifting from a manufacturing sector to a service-sector economy. Foreign direct investment in overseas manufacturing grew substantially, moving industrial jobs abroad.[9] Subsequently, a new form of service-based urbanization developed along with changes to institutional arrangements. American cities became complex, human-intensive knowledge-based economies with the growth of the corporate complex including banking, finance, insurance, advertising, law, food and accommodation, and nonprofit.[10] With the increasing globalization of the economy, production becomes decentralized while control and administration remained centralized. Finance, information, and communications industries magnified this trend as economic activity became geographically dispersed.[11]

Consequently, the urban landscape evolved from the pedestrian city to the streetcar suburb to the auto metropolis and from star-shaped axial patterns to circular structures.[12] This resulting suburban decentralization of jobs and housing from traditional central cores to outlying suburbs altered commute patterns and reinforced automobile dependence. Because services tended to be smaller, more dispersed, and varying in nature, fixed-route transportation such as bus routes and rail systems became inconvenient forms of travel. Furthermore, the loss of smokestack industries, the drop in central city population and employment, and the migration of people from northern, industrial cities to southern, Sunbelt cities marginalized mass transit as a viable form of transportation. As a result, car ownership and vehicle miles traveled exceeded population and employment growth, squeezing out other modes of travel including carpooling, public transit, and non-motorized alternatives. [13, 14] Then, escalating home prices driving development to cheaper land, subsidies for homeownership with the introduction of the long-term 30-year mortgage coupled with federally subsidized mortgage insurance and interest deduction continuously pushed development to the fringe of metropolitan areas.[15] With the interstate highway system in place, commercial development stretched out along highway corridors.[16] Eventually, the sprawled urban form necessitated the used of the automobile. In this study's model, population, central place density, occupations, and region will be used.

Meanwhile, in the wake of economic restructuring, demographic makeup influenced travel patterns. Towards the end of the century, urban composition took a different face with greater inequality between low-wage, low-skilled individuals and high-level professional service jobs (i.e. legal, consulting); a disproportionate concentration of poor, blacks, and Hispanics in large cities; and a feminization of the job supply. Even housing practices altered with gentrified, unaffordable areas, decaying housing stock, social relations in housing markets such as racial steering, and reduction in federal support.[17] Soon, the majority employed in the service sector were two-earner households who faced the increased pressure of time and money. This made the car the only efficient travel means to accommodate the trip-chaining of work, shopping, recreation, daycare, and school. Moreover, commuting times increased as living near work became more difficult to obtain.[18] And with the prevalence of the automobile, middle-class households faced both decreasing travel costs and increased incomes which allowed them to afford homes in outlying areas.[19] In the data analysis, we measure the impacts of median area income, household size, and commute times.

Unfortunately, in these demographic upheavals, economically-disadvantaged and physically-disadvantaged groups who rely on transit faced serious implications. In post-WWII urban development with sprawl, exclusionary zoning, and government fragmentation, a rise of class segregation, a less extent of racial segregation, and poverty zone occurred. Usually higher income groups moved to the outer edges of metropolitan areas while middle-income groups moved into inner edges with blacks and Latinos in middle-class enclaves. This left a poverty-concentrated core in central cities. With the gentrification of downtowns, poverty-concentrated inner suburbs grow as metropolitan limits expand outward.[20] Consequently, low-income African-Americans became victims of spatial mismatch with no equal access to resources or opportunities such as transportation.[21] This echoes sociologist William Julius Wilson's casual argument that the flight of black middle class from inner cities led to poor black isolation from the labor market, resulting in poverty concentration, welfare dependence, and rising unemployment.[22] Then, the question of the physically-disadvantaged such as the elderly who tend to age in place becomes a social concern for their mobility issues and social integration.[23] In this study, the effects of the non-white population, poverty percentage, age groups, and home values are measured on transit ridership.

Finally, a cultural and commercial component took place in the transportation industry. Motorized vehicles particularly the automobile came to symbolize modernity and development, status and individual freedom. Soon, intense advertisement and enticements to purchase new cars dominated society.[24] Automobile monopolists sought the two-car garage in every home, a gas station on every corner, and ubiquitous streets, parking lots, and maintenance facilities across the cityscape.[25] The real challenge of transportation planners was how to build infrastructure around the car.[26] For this, the data analysis measures car ownership, gas prices, and road supply on transit use. The diagram below summarizes these large scale forces behind the transportation problem. While not irrefutable, casual arguments the literature suggests a positive relationship between figure's causes and effects.

Despite the transformations of urban form and demographic patterns, a renaissance has grown in city places. Empty-nester baby boomers, Generation X professionals, immigrants, childless couples, and single-person households have rekindled urban living. These inward-migrating subgroups seek out cultural facilities, amenities, and services bulking up the use of transit and non-motorized transportation. Businesses are now constructing corporate buildings and entertainment complexes near major stops, allowing them to take advantage of a large labor pool and customer market.[27] Because of these trends, many of the demographic variables in this data study are used. Furthermore, the idea of the post-industrial city has garnered attention. Land developers and urban planners are beginning to promote new compact, sustainable initiatives of city design including *smart growth*, *transit-oriented development*, and *new urbanism*. These community designs aim to reduce car trips, conserve space, encourage green spaces, avoid gridlock, promote technological innovation, improve air quality, and enhance social vibrancy.[28] Here central place share and central place density are used in the data model.

To reform our transportation system amidst global economic restructuring and sprawling communities, many understand that a balanced, mode-neutral system must be employed for a sustainable future. One transportation alternative yet infrequently used service is mass transit or buses and light/heavy rail systems. This empirical study seeks to measure public transit's use in hopes to improve its viability. The effects of urban area characteristics and demographic composition, two consistent forces affecting transportation, will be measured on transit ridership. The essential question addresses: what and how do demographic variables (race, age, education, income, household size), urban area characteristics (population, density, region, city age, median home value), and dollar amounts (government funding and gas prices) affect mass transit ridership? With robust findings in concert to other efforts, mass transit can then be used to mitigate our transportation system.

Literature Review

In the field of transportation research, travel demand is understood to be a multi-dimensional, complex activity, signifying more than a consumptive value but a derived demand to "facilitate a complex, spatially varied set of activities."[29] Generally, research on the relationship between travel behavior and people and urban form take a variety of methodologies. A few major methods in the field include disaggregate analyses, aggregate analyses, and land-use studies. Disaggregate models assert individual choices decide travel behavior while aggregate models and land-use studies emphasize urban environment and system design influence travel behavior. The recent work in the field and scholarship on the subject use disaggregate and choice models to study transportation decisions.[30] However, as economic restructuring and decentralization has developed out in urban areas, this study takes the traditional methodology of aggregate analysis while adding to it a recent time dimension (2000-2007) and larger sample of urban areas (N = 360).

Disaggregate Models

Disaggregate models use microeconomic theory to explain the choice set and constraints of individual decision-makers weighing issues such as mode choice, destination, origination, time, distance, and travel costs. Such models capture the person-level preferences while still connecting travel environment with transportation decisions. The modeling structure takes into account both collateral and land-use decisions to determine transportation decisions. A host of benefits arise from disaggregate demand models including: larger number of observations for precise estimates and richer specification, larger variation between decision-makers' characteristics, and a complete set of service quality attributes such as comfort, crowding, and reliability.[31] Value of time and characteristics of service seem to be the most important behavioral parameters as travelers weigh time-money situations.[32] Choice models differ slightly in that urban form is implicit in the measurement of utility compared to disaggregate models.[33] Nonetheless, from this perspective, individuals can be regarded as rational, economic consumers with a derived utility function.[34]

While disaggregate models are the burgeoning trend in transportation research, modeling individual behavior leaves out the specific geographic and demographic features of metropolitan areas –the essential point of this study.[35] Consequently, this empirical study uses aggregate, regional statistics to measure the impact of urban form and demographics on travel behavior.

Aggregate Models

Additionally, aggregate analyses are conducted to measure transportation demand particularly in metropolitan planning organizations (MPOs) at the regional level and transit agencies at the route level. Transportation planners use mathematical travel forecasting methods and simulation studies to determine trip generation, trip distribution, mode choice, and traffic assignment usually obtained from household survey data in the areas of interest. Occasionally, these mathematical models integrate land-use/activity system models to furnish the proper estimations. Compiled maps, operator records, and field surveys as well as least squares and multinomial logit models are used in these efforts.[36] Not restricting to one particular metropolitan area, this study measures all known urban areas that receive Federal Transit Administration (FTA) funds pushing the sample size over 350. In addition, MPOs tend to focus on their particular localities possibly biasing their analysis compared to other localities. This study steers from that potential risk.

Other aggregate studies track urban travel demand through an historical and political lens highlighting significant national and state statistics. These studies illustrate the evolution of travel in American cities that ultimately led to the marginalization of transit to the automobile. Conclusions usually point to decentralization, government intervention, and inward migration as key contributors to transportation demand.[37, 38] A weaknesses of aggregate models is the simplification of urban form. Aggregate level data compare average travel characteristics across neighborhoods of different designs and cities of different densities. Simple comparisons, correlations, and regression procedures are estimated to determine trip frequency, average trip length, mode split, and total auto travel. These average values obscure significant amount of information that decision-makers face.[39] With this in mind, many variables are included in this study's model in order to harness the variation across and within urban areas. Urban form may be simplified but only to tell the story of its affect on transportation.

Land-Use Studies

Finally, some studies focus travel demand on the backdrop of urban planning. Transportation and land-use decisions often correlate and are used as the combatants to urban sprawl. Proponents of *smart growth* seek to channel new development to existing urban areas with the emphasis on compactness, transit-accessibility, and mixed-used zoning. Essentially, urban area development both affects transportation patterns and is affected by it.[40] Likewise, one study shows that *transit-oriented development* increases ridership, relieved traffic congestion, improved air quality, decreased tailpipe emissions, and increased pedestrian safety. With better management of land-uses such as connecting choice-riders (car owners who choose transit) from their offices and residences to entertainment complexes, costly rail services can yield appreciable returns.[41] Therefore, in this data model, population, density and other measure of urban design are estimated.

Additionally, some studies illustrate how transit use compares between compact and sprawl developments. People who live in more compact, dense areas tend to take fewer automobile trips and more transit trips as well as non-motorized travel. Moreover, mixed-used developments yield more walking trips and fewer vehicle miles traveled.[42] One study showed that walking and cycling depend on the environment of a locality. Low dense areas, longer commute journeys, and higher air pollution negatively correlates to active travel while higher human capital, wealth, and organizational structures yield more active travel.[43] Case studies of different cities also measure the effects of urban development and planning on transportation. Two large, dense cities Karachi, Pakistan and Beijing, China have recently adopted a decentralized urban form emphasizing the expansion of highways and expressways. These efforts negatively influence public transportation use.[44] In the U.S., Portland, OR with its aim for walkable neighborhoods and transit-oriented development was compared to Atlanta, GA with its focus on expanding road capacity. As population in both urban areas grew roughly the same, Portland witnessed a lower rate of vehicle miles traveled, shorter commute times, and fewer people commuting by single-occupancy vehicles.[45] Ultimately, place as this study will show becomes an essential factor when studying transportation.

Methods

Keeping with the larger story of economic restructuring and decentralization this study's sample universe moves upward from the smaller person and route level and downward from the aggregate state and national level to the regional level, particularly the urban area level. Because transportation patterns often cross local municipalities and at times over state boundaries, urban areas (a close equivalent to metropolitan areas) are the ideal units of analysis to measure the effects of urban shape and composition on transit use. In addition, the regional level is arguably the true geographic unit of the American economy. Metropolitan areas tend to concentrate the diverse key assets that sustain the country's economy including human capital, infrastructure, innovation, and quality places. The top 100 metropolitan areas out of more than 350, making up only 12 percent of land area, account for 65 percent of the U.S. population and 75 percent of GDP.[46] Thus, this empirical model captures middle ground trends that disaggregate models leave out and state and national statistics do not reach.

Hence, in using the regional level, the influence of urban area characteristics and demographic composition on travel behavior will be measured. From the Federal Transit Administration's National Transit Database (NTD) (2000-2007) per capita passenger trips and per capita passenger miles via mass transit systems (bus and light/heavy rail systems) are regressed on demographic variables from the U.S. Census at the urban area level and particular dollar values. Demographics, measured as proportions of entire population, include age, race, percent poverty, car ownership, education, household size, employment occupation, commute times, median income, and others (see Appendix for detailed listing of variables). Urban area characteristics include region of country, population, central place density, central place share of total urban area population, central city age, ratio of urban population to all public roads in state, and median home value. Finally, expenditure amounts include gas prices and government funding will enter the framework.

For six consecutive years (2002 to 2007), OLS will be run to illustrate and compare the year-by-year estimates of mass transit ridership across urban areas. The equation will take the following function:

$$y_i\{\text{per capita trips, miles}\} = \beta_0 + \beta_{1i}\{\text{demographic variables}\} + \beta_{2i}\{\text{spatial characteristics}\} + \beta_{3i}\{\text{dollar amts.}\} + \mu_i$$

In addition to estimating mass transit ridership in cross-sectional years, a panel regression will be run to capture the time dynamic trends for eight consecutive years (2000–2007) across urban areas. The equation with the time-dynamic variables will take the following function:

$$y_{it}\{\text{per capita trips, miles}\} = \beta_0 + \beta_{1it}\{\text{demographic variables}\} + \beta_{2it}\{\text{spatial characteristics}\} + \beta_{3it}\{\text{service population}\} + \beta_{4it}\{\text{service density}\} + \beta_{5it}\{\text{gas prices}\} + \beta_{6it}\{\text{govt. fund}\} + \beta_{7it}\{\text{city age}\} + \beta_{8it}\{\text{urban pop. per state rd.}\} + \mu_{it}$$

Because of the presence of heterogeneity, both fixed effects and random effects will be tested. Fixed effects assume unobserved heterogeneity is constant over time. Thus, time-constant variables are dropped from the model. Each regressor takes the difference of the urban area's observed value and the urban area's mean value. Random effects assume heterogeneity does exist over time. Each urban area is assumed to be randomly distributed from the population. Thus, regressors and error term are uncorrelated and the error is heteroskedastic (changes with each urbanized area). Many econometric studies agree that the random effects model is more efficient than the fixed effects model while fixed effects reduces chances of endogeneity. Yet, in this study we present both estimations. The time dynamic variables include service population, service density, gas prices, government funding, city age, and urban population per state road.

Limitations

It should be noted that though this study is generalizable of urban areas, it does not adequately measure demand for mass transit but only the use of it. The question of opportunity and behavior are unable to be separated. Only if adequate rail and bus service existed could transit trips and miles account for actual desired behavior. Household surveys are able to demonstrate travelers' intentional choices in deciding to use transit. In addition, this study's data cannot measure the quality of transit service in terms of frequency and availability which affect decisions. Thus, individuals who demand mass transit may not be able to do so. Essentially, our quantitative analysis illuminates the patterns associated between how an urban area is shaped and how it is demographically composed with the amount of public transit trips and miles. Lastly, the National Transit Database covers nearly every single public-operated agency but not all, particularly for some rural areas and urban clusters with populations under 50,000. Thus, only about 360 urban areas are used while a total of 452 urban areas actually exist.

RESULTS

Least Squares Results

Cross-section results confirm the influence of urban form and demographics in the year-to-year analysis (2002-2007). As hypothesized, demographic variables, urban area characteristics, and dollar amounts do correlate significantly with per capita mass transit trips. Another consistent pattern involves percent of professional degrees in the urbanized area. Areas with highly-educated populations take more transit trips than high school graduates. This follows the fact that many fortune 500, high-tech jobs tend to be bubbled in transit-intensive metropolitan centers.[47] Furthermore, household size shows steady, substantive influence throughout the six years. Percent of smaller households and percent of larger households yield more transit trips than medium-sized households at least four out of the six years. White-collared occupations tend to take less transit trips than blue-collared occupations which cohere to the economic restructuring argument. Interestingly, commute times result significantly but at fluctuations. In 2005, areas with low commuters took fewer trips than areas with medium commuters. A year later, low commute areas took more trips, and then back to fewer trips in 2007. This discrepancy suggests the volatile choices of low commuters who in the short run can switch their travel patterns unlike other commuters.

Apart from demographics, urban area characteristics developed significantly as well. The northwest region urban areas consistently take fewer trips than the midwest. In addition, central place density, the density around the central cities of the urban area, yields appreciable, positive results. With every thousand person increase per square mile transit trips increase by 1-3 trips and with each year this trend remarkably decreases. Population also at times shows positive results. Finally, dollar amounts prove somewhat important. Government funding emerges significant only once while median income and home value to a less extent. Gas prices however, shows tremendous positive results suggesting some truth to the anecdotal evidence of recent gas price increases. The ratio of urban population for total public roads in a state remains significant across all six years. Thus, road networks do influence travel behavior. It should be noted that regressions have also been run on per capita miles which yielded similar significant results especially with young age, household size, and government funding.

Table 3. OLS Regression Results for Per Capita Trips, 2002-2007

	2002 PER CAPITA TRIPS	2003 PER CAPITA TRIPS	2004 PER CAPITA TRIPS	2005 PER CAPITA TRIPS	2006 PER CAPITA TRIPS	2007 PER CAPITA TRIPS
Mean	11.28	11.22	11.16	11.54	15.25	14.51
Median	5.42	5.33	5.51	5.87	7.06	8.30
Young Age	31.27	22.29	17.40	41.48	-35.68	49.39
	(64.17)	(56.28)	(54.57)	(52.25)	(70.56)	(50.17)
Old Age	95.26	95.75	88.61	**114.7***	-3.321	**143.2****
	(64.76)	(60.62)	(59.12)	(56.65)	(77.24)	(54.18)
Non-white	10.89	8.134	6.563	9.794	12.44	12.26
	(12.74)	(11.63)	(11.43)	(10.88)	(14.85)	(10.60)
Pct. Poverty	5.310	27.03	31.45	2.569	-5.249	18.28
	(53.40)	(48.21)	(46.89)	(44.90)	(60.19)	(43.24)
Car Ownership	-33.87	-36.45	-37.88	-41.52	-9.674	-39.44
	(29.66)	(27.72)	(26.30)	(25.31)	(35.26)	(25.00)
No HS Educ Lvl	-24.93	-38.70	-40.73	-36.74	23.77	-44.36
	(43.61)	(39.72)	(38.58)	(37.29)	(50.49)	(35.54)

BA Educ Lvl	61.09 (66.10)	23.19 (60.90)	48.38 (58.53)	52.42 (55.51)	12.02 (75.54)	64.84 (52.26)
Prof. Educ Lvl	**164.8*** (68.08)	**143.5*** (63.09)	**160.1**** (60.73)	**161.7**** (58.75)	**288.3***** (81.54)	**153.0**** (57.32)
Household 1	**157.1*** (78.20)	**158.0*** (73.21)	**156.0*** (71.43)	**148.5*** (67.15)	-161.6 (90.73)	**175.4**** (65.29)
Household 4+	120.3 (67.99)	**126.2*** (62.09)	**124.0*** (60.23)	**119.7*** (57.57)	-82.94 (78.65)	**147.5**** (55.94)
Employ Status	19.73 (38.90)	37.28 (35.49)	25.84 (32.90)	21.69 (31.67)	33.95 (43.25)	25.74 (30.51)
White-Collared Occup.	-109.6 (58.65)	-80.41 (54.26)	**-106.6*** (52.79)	**-103.2*** (50.30)	**-143.7*** (69.49)	**-100.9*** (48.41)
Service Sales Occup.	-1.076 (40.19)	-9.364 (37.10)	-17.16 (35.87)	-11.10 (34.19)	68.84 (48.15)	-11.52 (33.07)
Low Commute	-28.33 (17.41)	-28.96 (16.19)	-29.43 (15.36)	**-31.98*** (14.81)	**64.88**** (20.09)	**-30.35*** (14.56)
High Commute	30.07 (30.59)	16.72 (28.04)	15.73 (26.24)	8.346 (25.01)	**80.72*** (34.12)	21.57 (24.15)
Really Hi Comm	-122.0 (100.3)	-69.96 (92.81)	-87.05 (79.81)	-101.3 (76.91)	-87.64 (105.0)	**-245.5**** (76.10)
Log Median Inc.	2.051 (3.616)	1.997 (3.318)	2.332 (3.270)	2.936 (3.216)	-1.674 (4.350)	2.091 (3.087)
northwest	**-10.67*** (4.121)	**-8.923*** (3.794)	**-9.023*** (3.704)	**-8.731*** (3.666)	-1.939 (4.956)	**-6.850*** (3.385)
south	0.694 (1.053)	0.512 (0.946)	0.314 (0.892)	-0.294 (0.821)	0.468 (1.125)	0.288 (0.841)
west	-1.471 (1.478)	-1.047 (1.423)	-0.965 (1.363)	-1.182 (1.319)	-0.818 (1.769)	-1.755 (1.204)
Population (per million)	0.915 (0.978)	1.294 (0.907)	**1.831*** (0.876)	**2.324**** (0.857)	-0.125 (1.206)	-0.472 (1.004)
Cntr. Pl. Dens (per thousand)	**4.836***** (0.910)	**4.004***** (0.835)	**3.650***** (0.764)	**3.076***** (0.739)	1.826 (1.070)	**1.793*** (0.728)
Cntr. Pl. Share	-1.586 (5.462)	-2.299 (4.977)	-1.538 (4.777)	-2.105 (4.614)	0.241 (6.305)	-3.805 (4.402)
Log Home Value	0.940 (6.562)	1.181 (6.105)	-0.644 (5.873)	-0.0171 (5.494)	4.069 (7.557)	1.231 (5.271)
Log Govt. Fund	-0.812 (0.807)	-0.490 (0.778)	-0.625 (0.758)	-0.849 (0.715)	**6.465***** (0.995)	1.131 (0.664)
Log Gas Prices	75.69 (40.86)	46.64 (27.76)	**57.76*** (28.58)	**90.43*** (39.03)	62.99 (53.43)	**135.2***** (37.14)
City Age	-0.0143 (0.0227)	-0.0166 (0.0204)	-0.0135 (0.0200)	-0.0223 (0.0193)	0.0443 (0.0259)	-0.0312 (0.0187)
Urban Pop. (per state rd.)	**0.119***** (0.0256)	**0.122***** (0.0244)	**0.129***** (0.0244)	**0.139***** (0.0241)	**0.127***** (0.0334)	**0.0423***** (0.00605)
constant	-454.7* (214.4)	-327.5* (160.7)	-355.1* (166.2)	-555.1* (220.0)	-464.4 (307.3)	-881.6*** (218.0)
N	336	350	355	365	367	370
adj. R-sq	0.469	0.470	0.479	0.495	0.405	0.464

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
Omitted categories:
working age (25-65), h.s. education level, households of 2 and 3, blue-collared occup., medium commute (15-44min.), midwest

Panel Data Study

The panel regression models capturing urban area characteristics and demographics over time (2000-2007) also yield interesting results, consistent with the OLS findings. Percentage of old age in urban areas correlated positively with per capita transit trips. Now, car ownership emerges as a significant variable, correlating negatively with transit trips. Higher education particularly professionally educated respond substantively positive. Household size keeps its significant trends. For trips and miles, households of four and more yield a strongly significant result. With each percent increase of such households in the urban area, transit trips increases by 118 trips and over 1,000 miles. Percentage of high commuters also shows strong correlation with an elasticity of 47 trips and 300 miles. Even median household income emerges significant despite a latent variable in the OLS results at nearly 7 percent response.

Finally urban characteristics and dollar amounts emerge significantly in both the fixed effects and random effects models. Interestingly, service population yields a negative correlation while city age and ratio of population to urban roads yield positive results. Gas prices resulted with some ambiguity. In the fixed effects, gas prices results with negative transit trips and miles. Meanwhile, the random effects resulted with positive correlations. Random effects also show government funding correlates positively with both trips and miles.

Table 4. Descriptive Statistics for Per Capita Trips and Miles of Panel Data

Variables	Obs.	Mean	Median	Std. Dev.	Min	Max
PER CAPTIA TRIPS	3143	11.83	5.89	20.77	0	192.90
PER CAPTIA MILES	3143	56.82	22.44	130.50	0	1975.34

Table 5. Panel Regression Results for Per Capita Trips and Miles, 2000-2007

	PER CAPTIA TRIPS (2000-2007)		PER CAPTIA MILES (2000-2007)	
	FE	RE	FE	RE
Young Age	0	0.606	0	-24.73
	(.)	(48.09)	(.)	(295.9)
Old Age	0	**108.4***	0	227.0
	(.)	(50.89)	(.)	(314.1)
Non-White	0	11.41	0	14.51
	(.)	(9.992)	(.)	(61.33)
Pct. Poverty	0	-9.488	0	-145.9
	(.)	(41.62)	(.)	(256.1)
Car Ownership	0	**-68.78****	0	-192.7
	(.)	(22.59)	(.)	(138.7)
No HS Educ Lvl	0	14.68	0	146.6

	(.)	(34.50)	(.)	(212.2)
BA Educ Lvl	0	26.82	0	-167.8
	(.)	(48.92)	(.)	(301.3)
Prof. Educ Lvl	0	**203.7*** **	0	324.1
	(.)	(54.52)	(.)	(334.2)
Household 1	0	104.5	0	**1217.6** **
	(.)	(60.93)	(.)	(375.4)
Household 4+	0	**118.9* **	0	**1012.2** **
	(.)	(52.63)	(.)	(323.6)
Employ Status	0	12.30	0	62.16
	(.)	(29.50)	(.)	(181.3)
White-Collared	0	-71.25	0	166.3
Occup.	(.)	(45.74)	(.)	(280.7)
Serv Sales	0	44.64	0	247.1
Occup.	(.)	(32.24)	(.)	(198.6)
Low Commute	0	-15.76	0	-42.56
	(.)	(12.36)	(.)	(76.61)
High Commute	0	**47.49* **	0	**299.9* **
	(.)	(22.60)	(.)	(139.4)
Really Hi Commute	0	-59.56	0	446.5
	(.)	(71.53)	(.)	(442.0)
Log Median Inc.	0	**6.735* **	0	31.16
	(.)	(2.815)	(.)	(17.24)
northwest	0	-4.205	0	-5.890
	(.)	(3.205)	(.)	(19.70)
south	0	-1.339	0	-1.146
	(.)	(0.756)	(.)	(4.652)
west	0	-0.175	0	-1.558
	(.)	(1.068)	(.)	(6.553)
Service Pop	**-2.096*** **	**-2.230*** **	-6.337	**-5.046* **
(per million)	(0.418)	(0.325)	(3.455)	(2.356)
Service Density	-0.296	-0.0814	-2.386	-2.474
(per thousand)	(0.278)	(0.258)	(2.298)	(1.985)
Cntrl. Pl. Share	0	-5.251	0	-27.41
	(.)	(4.202)	(.)	(25.91)
Log Home Value	0	3.679	0	53.93
	(.)	(4.849)	(.)	(29.85)
Log Govt. Fund	0.279	**2.111*** **	0.142	**8.780*** **
	(0.301)	(0.231)	(2.491)	(1.813)
Log Gas Prices	**-24.82*** **	**3.021** **	**-96.26*** **	**28.73*** **
	(3.148)	(1.036)	(26.03)	(8.332)
City Age	**3.988*** **	-0.00310	**17.94*** **	**-0.246* **
	(0.424)	(0.0174)	(3.506)	(0.107)
Urban Pop	**0.0154* **	**0.0279*** **	0.0919	**0.168*** **
(per state rd.)	(0.00666)	(0.00627)	(0.0551)	(0.0483)
Constant	-448.8***	-197.3*	-2077.8***	-1820.7***
	(44.56)	(85.48)	(368.5)	(526.4)

N	2579	2579	2579	2579
R-sq	0.108		0.038	
rho	0.997	0.533	0.989	0.367
sigma_e	12.20	12.20	100.9	100.9
sigma_u	210.8	13.03	958.8	76.78

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

CONCLUSION

Overall, our estimation models illustrate that mass transit ridership does not exist in a vacuum. Per capita trips taken and per capita miles traveled via public transit systems respond to the shape and composition of the urban area environment as well as external dollar amounts. Age, education, household size, car ownership, commute times, region, service population, central place density, gas prices, government funding, and supply of public roads altogether influence mass transit ridership across urban areas and across time. Policymakers, planners, and the general public should acknowledge these relationships for a comprehensive transportation system.

Moreover, these results support the larger narrative of urban development in the last half-century. Economic restructuring of disaggregating firms and decentralization of cities have transformed U.S.'s workplaces and residential communities. Hence, the American transportation system must acknowledge the new spatial realities of the current post-industrial era and the relationships that emerge. Currently at a crossroads, private and public transport services must enact new models, new ideas, and new policies.

For instance, tax credits can reward larger households and encourage medium-sized households who use mass transit less. Car owners can supplement traveling with transit a few times a week with peak-spreading or staggered commutes. Low dense areas can provide rapid transit through their large lane streets, possibly alongside highway corridors or through suburb to suburb routes to reach the level of denser areas. Stakeholders should encourage ridership of differing age and education groups to use transit. Further systems should be installed in Sunbelt cities and revitalized in the north. Agencies should regularly forecast gas prices to keep up at pace with demand. 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. Longer commuters who take fewer trips should be encouraged to take transit through employment subsidies, tax rebates, and other incentives. Finally, paralleling road capacity relative to urban population would also incentivize more transit use.

These solutions along with others in the literature can help remedy U.S.'s strained transportation system. With better coordination among transportation and urban planners, land developers, businesses, public officials, and households, mass transit can help metropolitan areas become economically competitive, environmentally sustainable, and socially vibrant.

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APPENDIX

Table 4. Definitions of Regression Variables

Variable	Definitions/Categories
Dependent Variables (source: National Transit Database, 2000-2007)	
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)
Explanatory Variables (all variables are measured as percent of population and from U.S. Census (2000) unless otherwise noted, average values in parenthesis)	
Age	Young age: 0-17yrs. (0.37); working age: 18-39 (0.22); middle age: 40-64 (0.29); old age: 65-older (0.13);

Race	Whites (0.73); nonwhites (0.27)
Poverty Pct.	Percent living under the poverty threshold (0.13)
Car Ownership	Percent of population owning at least one automobile (0.63)
Household Size	household size 1 (0.27); 2 and 3 (0.49); 4 or more (0.24)
Education	no high school (0.18); high school (0.28); some college (0.29); BA (0.16) ; Prof degrees (0.09)
Log of Median Income	Urban area median household income in dollars ($47,100.34, log = 10.69)
Occupation	white-collared occup.: includes management, professional related (0.33); service sale occup.: health, education, food services, office-related (0.43); blue-collared occupations: includes farming, fishing, forestry, construction, extraction, maintenance, production, transportation material moving (0.23);
Commuting Time	low: under 15min (0.39); med: 15-44min (0.13); high: 45-89min (0.08); really high: over 90min. (0.02);
Region	Northwest (0.14), west (0.23), south (0.25), midwest (0.39)
Population	total population of urban area (425,526.8)
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 (3,278.747)
Central Place Share	proportion of central place population to urban area population (0.60)
Log of Home Value	Median home value ($119,524.30, log = 11.61)
Log of Government Funds	Total money from the FTA capital program, FTA urbanized area formula (uaf) fund, and other FTA funds (NTD). ($87.3 million, log = 15.83) (NTD)
Log of Gas Prices	retail gasoline prices for all grades (regular, mid-grade, premium) and formulations (gas and diesel) from a year ago ($1.97, log = 5.25) (EIA.doe.gov)
City Age	Age of central city from the year municipality was first incorporated either as a town or city (143 yrs.) (MSN Encarta)
Urban Are Pop/State Road	Ratio of urban area population to the total miles of public roads within the state including federal, state, county, township, municipality, and other jurisdiction roads (8.16) (FHWA)
Service Population	Population served by all transit agencies in the urban area per million (703,842.5) (NTD)
Service Density	Density (pop. per square mile) served by all transit agencies in the urban area per million. (2,034.49) (NTD)