Technical Appendix 3
Geography and Neighborhood Type
in Support of Chapter 3

LIST OF FIGURES AND TABLES

INTRODUCTION AND STRUCTURE

This Technical Appendix is presented in three major sections.

- Part One reviews important relationships between trends in the patterns of domestic land use; residential development and travel behavior -- focusing on but not exclusive to the use of transit.
- Part Two then examines the settlement patterns of jobs and employment.
- Part Three presents a brief discussion of the nature of the workplace, the incentives offered there, and the options of working at home.

The Technical Appendix starts with an overview of the trends in development since the mid-20th century, which may be broadly characterized as a movement from rural to metropolitan areas, but also a dispersion of both population and employment outward from historical central cities to the suburban areas surrounding those cities. This pattern of growth, substantially enabled by the popularity of the automobile and programs of major roadbuilding, are shown to have resulted in patterns of development most suited to travel by automobile and unfavorable to transit. Part 1 shows how these development trends closely align with a decline in the share of trips made by transit. These trends pose a strong challenge to the design, performance and utilization of transit service moving forward.

Part two of the Technical Appendix then focuses more closely on the destinations aspect of travel, namely patterns in the location of employment and the goods and services needed by households. These trends closely followed on a slightly lagged time cycle those of residential settlement patterns. Importantly, jobs and commercial activity also located under the shaping influence of the automobile, resulting in employment settling into single-use business parks or research campuses, and retail/service activity locating in strip shopping centers along arterial highways, or eventually in regional shopping centers or malls. Such spatial separation of land uses, combined with the longer distances associate with lower densities, posed further critical challenges to transit and non-motorized travel over the same period.

Interestingly, events occurring at the beginning of the current (21st) century, appear to be challenging these powerful trends of the past 50-plus years. Urbanized living has found a new attractiveness among various population segments: those of the Millennial and Gen X cohorts who appear to be attracted to the vitality of cities and the opportunity to live without or with less dependence on a car, single professionals or those married without children, and increasingly empty-nesters and retirees who no longer want the maintenance burden of a large single-family house in the suburbs. To serve these evolving markets, cities have been undergoing major revitalization and infill, drawing a new class of developers to the marketplace. And since the working version of this often highly educated population is regarded as the more highly skilled “creative class,” employers are also trending back into the center city and surrounding city-like urban centers. These trends, whose effect remains to be quantified, offer a promising lift to transit in overcoming the challenges of the past half century.

PART ONE: GEOGRAPHIC TRENDS IN RESIDENTIAL DEVELOPMENT AND URBAN FORM

Transit is at its most effective and attractive as a transportation mode when it can provide frequent on-time service, have few restrictions on its travel speed, serve a finite number of stops (to not overly diminish average speed), and be readily accessed on foot at both the origin and destination of a trip. In that way, it can provide service that is competitive with – or even superior to – the private automobile, and thus become a preferred choice to travelers. Obviously, the setting in which these performance criteria are maximized is an urbanized region with moderate to high densities along the route and service to one or more nodes with significant attractions, through which it can realize a sufficient "mass" of potential trip flows to justify a high quality of transit service, with frequent headways and adequate speeds.

Clearly this does not describe the growth patterns seen in the United States over the last half century, and hence it should be of little surprise to observe the corresponding decline in the *share* of person trips that are made by transit over that period (even though total transit trips have increased with overall growth in travel). While the land area of the U.S, is still substantially rural (only about 5% has been "developed"), the proportion of the population living in metropolitan areas has grown from 46% in 1910 to more than 80% in 2010. Significant differences exist in *where* that metropolitan growth has occurred, and the form it has taken. Most metropolitan growth over the last 60 years has gone into the areas outside of central cities. The area at suburban or exurban densities (one dwelling unit per 1 to 40 acres) covers 15 times the land area developed at urban densities (National Land Cover Database 2016).

UNDERSTANDING GROWTH TRENDS

In Figure 1, data from the Washington-Baltimore region are used to offer a graphic illustration of the development trends that have been underway in the United States over the last century (Maryland State Data Center). The graphic shows how growth has trended out of the central cities of Baltimore (center of the map) and the District of Columbia (the unshaded rectangle at the bottom left of the map) into the surrounding metropolitan hinterland. The shift between 1930 and 1970 shows the first real boom in suburbanization following WW II, but also how that outward explosion continued unabated through 2000, pushing growth into even lower density areas at the metropolitan fringe. This trend has been replicated across the country and has been even more pronounced in newer cities in the south and west that saw most of their growth under the shaping influence of the automobile in the latter half of the 20th century.

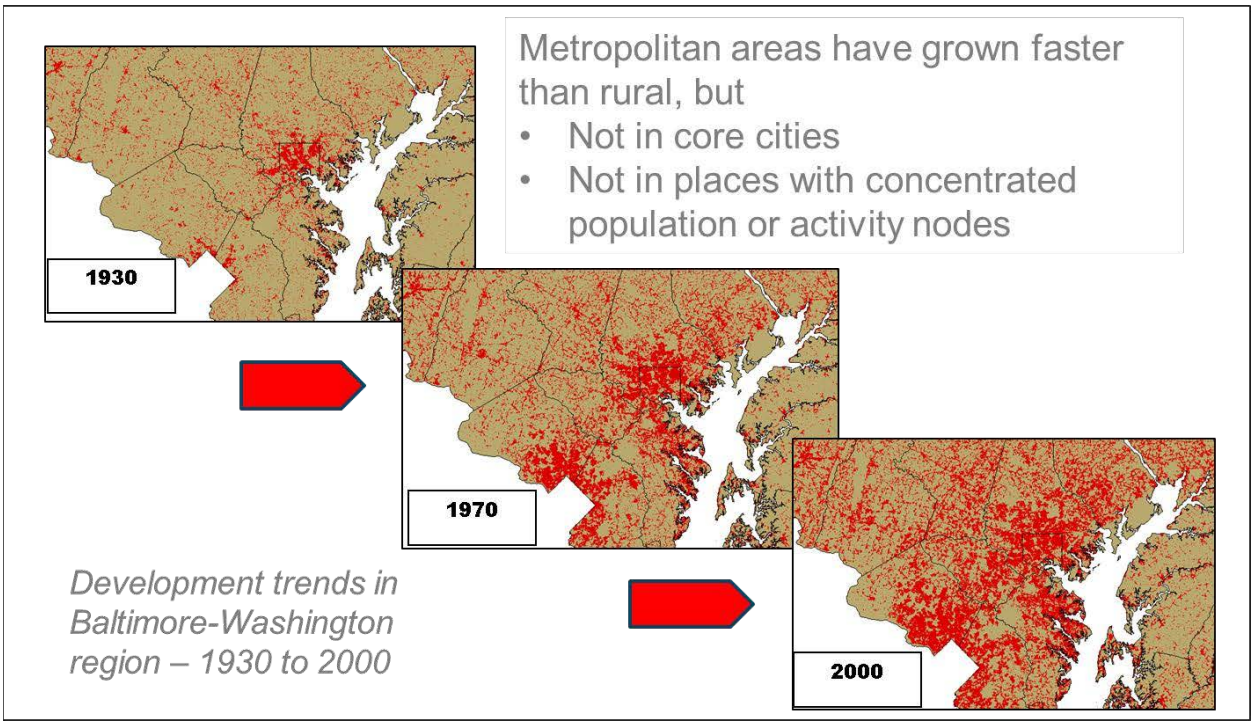

FIGURE 1. CHANGING FOOTPRINT OF DEVELOPED AREA: MARYLAND, 1930 TO 2000.

The dispersion of growth out of central cities is attributed to several factors, including:

- The return of service members following the war, looking for affordable housing and the desire to start families
- Introduction of single-family housing in planned subdivision developments in suburban areas now made accessible through auto ownership and accelerated road building
- A desire of dwellers of older, industrial cities to relocate to new communities perceived as more spacious, comfortable, and less impacted by noise, crime, and pollution
- Beginning of a period of road building that would include the interstate highway system and freeways that created easy access to outlying areas via automobile
- Federal participation in the long-term home mortgage loan market, coupled with interest tax deduction as an incentive for home ownership (Prante 2006).

Figure 2, taken from *Commuting in America 2013,* vividly shows not only the growth nationally in metropolitan areas occurring between 1950 and 2010, but the ever-expanding proportion of that growth occurring in the suburbs outside of the central cities (Pisarski and Polzin 2013). From a share of only about 20% of all population in 1950, suburbs grew to be the location of over 60% of all the U.S, population by 2010.

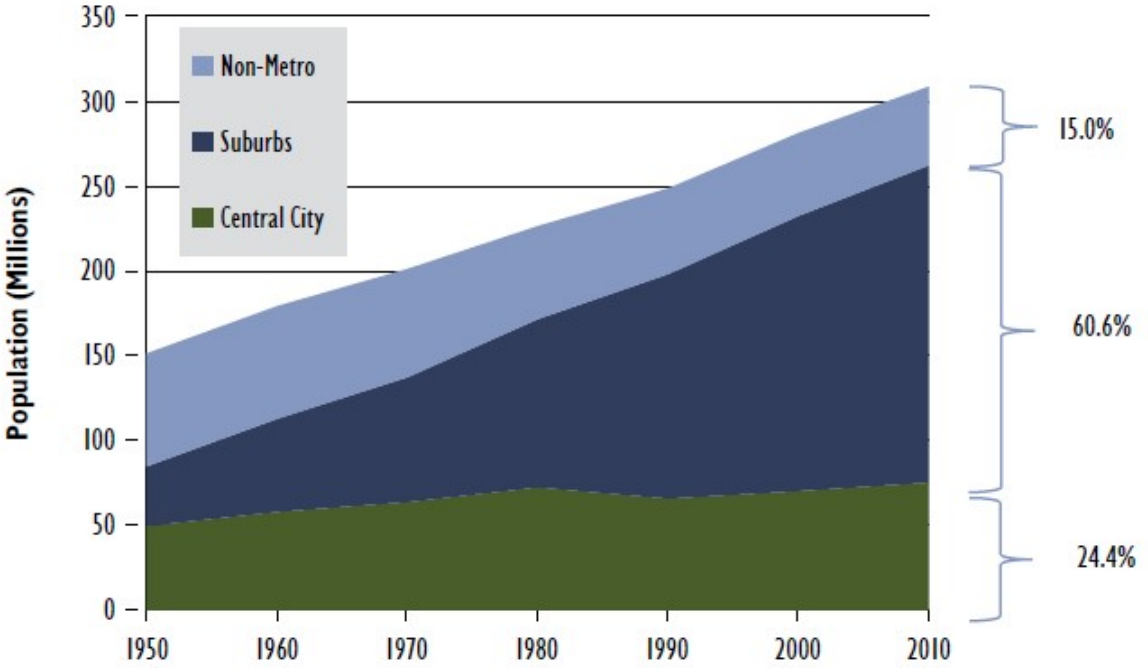

FIGURE 2. POPULATION GROWTH WITHIN METROPOLITAN AREAS, 1950 TO 2010
Source: U.S, Census Bureau. (as cited in Pisarski and Polzin 2013, Brief 4, Fig. 4-10, 2013).

This trend must be leavened somewhat by accounting for urban places that are outside the central city but have grown to a scale to be regarded as "principal cities," a designation introduced by the Office of Management and Budget in 2003. As shown in Figure 3, when added to the central city population, these principal cities raise the "urban" share from 24.4% to 32.2% and account for most of the urban growth between 1980 and 2010 (Pisarski and Polzin 2013). While this reduces the suburban share from 60.6% to 52.8%, suburban areas still account for the clear majority in metropolitan area growth since 1950.

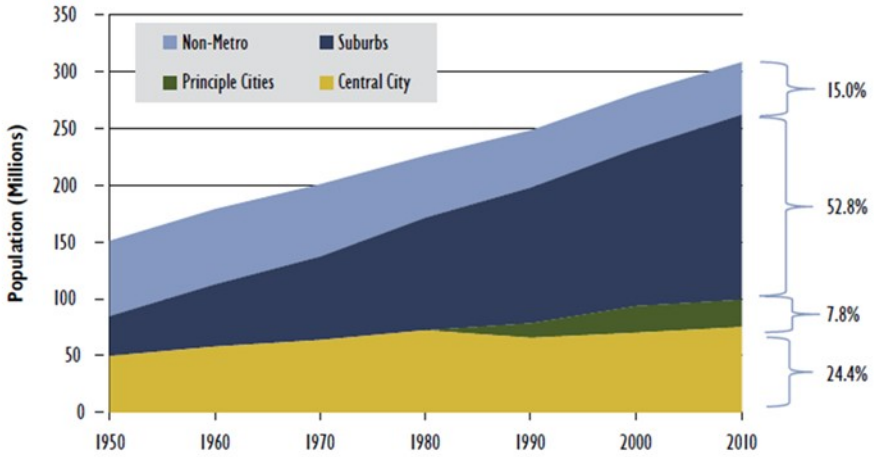

FIGURE 3 ACCOUNTING FOR PRINCIPAL CITIES IN METROPOLITAN AREA GROWTH
Source: U.S, Census Bureau. (as cited in Pisarski and Polzin 2013, Brief 4, Fig. 4-11, 2013).

Table 1 presents similar information in a slightly different format, beginning in 1940 (Giuliano et al. 2008). It shows how central city population as a proportion of total metropolitan population fell from 0.61 in 1940 to 0.38 by 2000. This is also reflected in a decrease in metro area density from 8,654 persons per square mile to 5,581 – a decline of 36%. This pattern of growth also had the impact of flattening the *density gradient* from core to periphery – often referred to as the "circus tent" by urban planners –from -0.72 to -0.32.

TABLE 1. URBAN POPULATION SPATIAL TRENDS, 1940-2000: 87 U.S, CITIES

Year	Central City/Metro Population Ratio			Average Metro Density			Density Gradient		
		Chg	%		chg	%		chg	%
1940	0.61			8654			-0.72		
1950	0.57	-.04	-6.5	8794	140	1.62	-0.64	-0.08	-11.1
1960	0.50	-.07	-12.2	7567	-1227	-14.0	-0.50	-0.14	-21.9
1970	0.46	-.04	-8.0	6661	-906	-12.0	-0.42	-0.08	-16.0
1980	0.42	-.04	-8.7	6111	-550	-8.3	-0.37	-0.05	-11.9
1990	0.40	-.02	-4.8	5572	-539	-8.8	-0.34	-0.03	-8.1
2000	0.38	-.02	-5.0	5581	9	0.2	-0.32	-0.02	-5.9

Source: Kim S. (2007) "Changes in the Nature of Urban Spatial Structure in the United States, 1890–2000" *Journal of Regional Science*, Vol.47(2), pp. 273–287 (as cited in Giuliano et al. 2008).

Commuting in America 2013 (Pisarski and Polzin 2013) also points out that where this growth occurred is also related to metropolitan area size and region of the country. As seen in Figure 4, most of the growth between 1990 and 2010 appears to have occurred in large metropolitan areas with populations of 5 million or more.

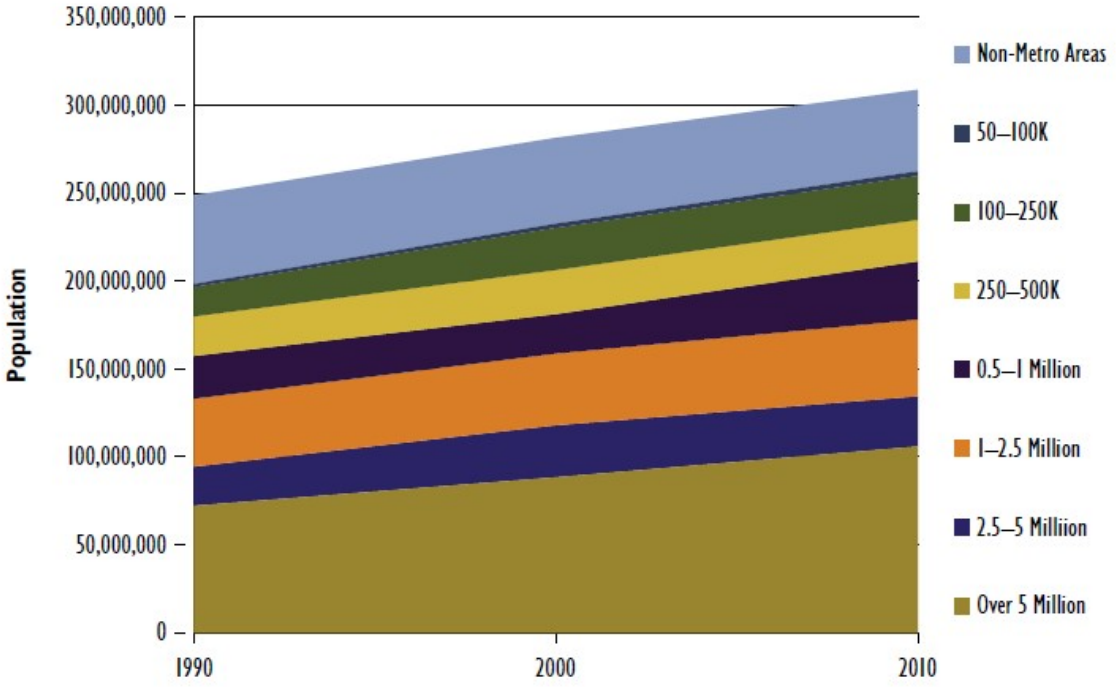

FIGURE 4. METROPOLITAN SIZE TRENDS
Source: U.S, Census Bureau. (as cited in Pisarski and Polzin 2013, Brief 4, Fig. 4-12, 2013).

Patterns in residential development and densities are only part of the challenge for transit, however. Employment also pushed out to the suburbs: first retail and service activity to serve early residents in the 1950s and 60s, and later—in the 70s and 80s – office and other professional employers in pursuit of lower rents and (seemingly) greater access to employees. The retail and service activities found it most effective to locate in shopping centers or commercial strips adjacent to major highways to serve visitors arriving by auto. Meanwhile, office and other professional activities gravitated to office parks and isolated campus locations, presuming that employees would drive to their jobs and be provided with free parking.

Sometime in the late 1980s, the trends in outward movement of employment reached a tipping point, to where most metropolitan area employment nationwide was now located outside central cities. Table 2 indicates that as of 2010, about 30% of all jobs (35% of metropolitan area jobs) were in central cities, while about 42% (50% of metro area jobs) were in the suburbs (Pisarski and Polzin 2013).

Whereas transit routes connecting inner suburbs to major employment concentrations in regional central business districts (CBDs) could offer reasonable levels of service and be competitive with auto travel, the dispersion of both population and employment has made it increasingly difficult to “connect dots” and compete in this many-to-many marketplace efficiently with transit.

TABLE 2. GEOGRAPHIC DISTRIBUTION OF POPULATION, WORKERS, AND JOBS, 2010

Geography	Population	Workers	Workers per Capita	Jobs	Jobs per Worker
Metro–Central Cities	75,283,196	27,899,370	0.37	40,536,506	1.45
Metro–Other Principal Cities	24,065,670	9,340,785	0.39	13,267,941	1.42
Metro–Suburbs	163,103,266	71,420,007	0.43	57,306,197	0.80
Metro–All	262,452,132	108,660,162	0.41	111,110,644	1.02
Non-Metro (by Subtraction)	46,293,406	28,280,848	0.61	25,830,366	0.91
Total U.S.	308,745,538	136,941,010	0.44	136,941,010*	1.00
Central City Share	24.3%	20.3%		29.6%	
Other Principal City Share	8.8%	6.8%		9.7%	
Suburban Share	52.8%	52.2%		41.8%	
Non-Metro Share	15.0%	20.7%		18.9%	

Source: Summary of ACS data. (as cited in Pisarski and Polzin 2013, Brief 5, Table 5-1, 2013).

GROWTH AND NATIONAL REGIONS

Figure 5 illustrates how the greatest population growth since 1990 has occurred in the Southeast and Southwest regions of the U.S, These areas have historically had the lowest rates of transit use attributable to having grown under the shaping force of the automobile. With some important exceptions (e.g., Chicago, Minneapolis, and Milwaukee), the Midwest shares these land use characteristics and the low rates of transit use; however, population growth in the Midwest has occurred at even lower rates than the Northeast.

TRANSIT-SUPPORTIVE CONDITIONS

Analysts have studied these relationships to try to categorize activity level thresholds necessary to support types of transit service. Zupan and Pushkarev famously developed a set of screening criteria back in the early 1980s, suggesting the appropriate levels of residential density and destination activity levels to support several types of transit, from simple bus to heavyrail/subway service (Pushkarev and Zupan 1982). Table 3 extracted from TCRP Report 95, Chapter 15, presents a more recent effort sponsored by ITE (Institute of Transportation Engineers) that provides a similar and slightly simpler classification. It suggests that for even a basic transit service consisting of a local bus with 1 hour headways, a density of 4 to 6 dwelling units per acre is needed, and the bus route should be serving an activity center of at

least 5 to 8 million square feet of attractions (office and commercial space). To justify a bus with 30 minute headways requires a minimum of 7 to 8 dwelling units per acre and a destination activity level of 8 to 20 million square feet. Of course, this is a minimalist transit service, with rail transit systems providing peak period headways of 10 minutes or less.

Region	# Metro Areas	Population (mil)		Change		Transit
		1990	2010	Increase	%	Work Share
Northeast + Mid-Atlantic	6	41.5	50.7	9.2	22%	12%
Southeast	9	14.7	26.1	11.4	78%	2%
Midwest	11	30.2	36	5.8	19%	3%
Southwest	8	17.4	28	10.6	61%	3%
Northwest + West	6	28.4	38.5	10.1	36%	7%
All	40	132.2	179.3	47.1	36%	

- Highest growth rates in Southeast and Southwest
- Newer areas developed after the automobile
- Much lower rates of transit use

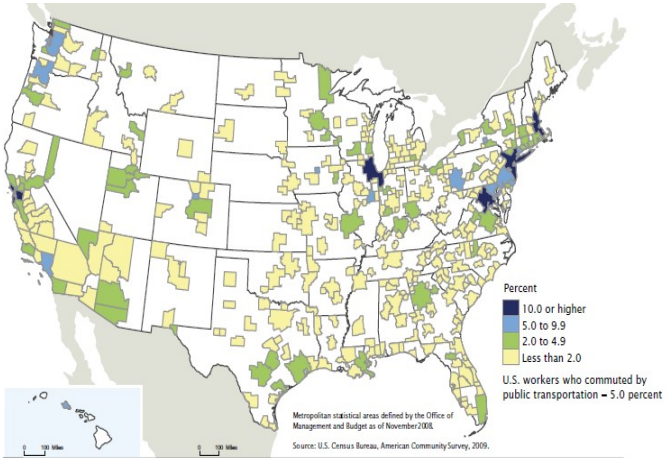

FIGURE 5. POPULATION GROWTH TRENDS AND TRANSIT USE RATES BY REGION
Source: U.S, Census Bureau. American Community Survey, and Pisarski and Polzin 2013, Brief 4, Table. 4-10, 2013).

TABLE 3. ITE RECOMMENDED MINIMUM DENSITIES TO SUPPORT TRANSIT SERVICE

MODE AND SERVICE LEVEL	RESIDENTIAL DENSITY	EMPLOYMENT CENTER SIZE
1 bus/hour	4-6 dwelling units/ residential acre	5 -8 million square feet of commercial/office space
1 bus/ 30 min.	7-8 dwelling units/ residential acre	8-20 million square feet of commercial/office space
Light Rail/ Feeder Buses	9 dwelling units/ residential acre	35 to 50 million square feet of commercial/ office space

Source: Holzclaw (1994). (as cited in TCRP Report 95, Chapter 15, 2003).

Most of suburban America does not achieve such densities, however, nor do activity centers outside of the regional CBD have attractions of that caliber. Commuting in America 2013 Brief 7 provides a breakdown of the percent of the metropolitan population that reside in four different residential density categories, as shown in Table 4. These categories are illustrated with photo examples in Figure 6 (Pisarski and Polzin 2013). Because the densities in the Commuting in America study are presented in terms of persons per square mile, it is necessary to convert to dwelling units per acre to get a comparison with the size categories in Table 4 shown above.

TCRP 95/Chapter 15 also presents a method for converting gross residential densities (persons per square mile) into dwelling units per acre, incorporating information about actual land area, which is roughly 35 to 65% after accounting for nonresidential land uses, parks, infrastructure, and undevelopable area. Using an average household size of 2.6 members (from 2009-2013 census), a gross residential density of 5,000 persons per square mile would be comparable to three dwelling units per gross acre*. The implication is that a substantial portion of the U.S, population does not reside in densities that are readily served by transit – and this is without also accounting for the appropriate destination activity levels in Table 4.

TABLE 4. POPULATION DISTRIBUTION BY DENSITY CATEGORY (2009)

DENSITY CATEGORY (PERSONS PER SQUARE MILE)	DWELLING UNIT EQUIVALENT (DU PER GROSS ACRE)	PERCENT OF METROPOLITAN POPULATION
0 to 2,000	0 to 1.2	46%
2,000 to 4,000	1.2 to 2.4	19%
4,000 to 10,000	2.4 to 6	23%
Over 10,000	Over 6	12%

Source: Pisarski and Polzin 2013, Brief 7, p. 11 (This table was created using information from the source document, but the source document did not present its information in the form of a table).

FIGURE 6. EXAMPLES OF POPULATION DENSITY USED IN ANALYZING COMMUTING
Source: Pisarski and Polzin 2013, Brief 7, Fig. 7-6, p. 11.

IMPLICATIONS FOR TRANSIT RIDERSHIP

The implications of these trends on travel behavior may be seen in Figure 7, also taken from *Commuting in America 2013, Brief 7*. Figure 7 clearly shows how private vehicles have dominated the growth in commute travel since 1960, with public transit and walk/work at home remaining almost constant in absolute numbers (Pisarski and Polzin 2013). Since 1980 the nonauto modes have declined, with walking dropping from 5.6% to 2.8% and transit from 6.2% to 4.9% (transit share was at 9% in 1970) (Pisarski and Polzin 2013). The only non-private vehicle option showing growth is working at home, which has increased from 2.3% to 4.3%, and, of course, is about foregoing travel entirely.

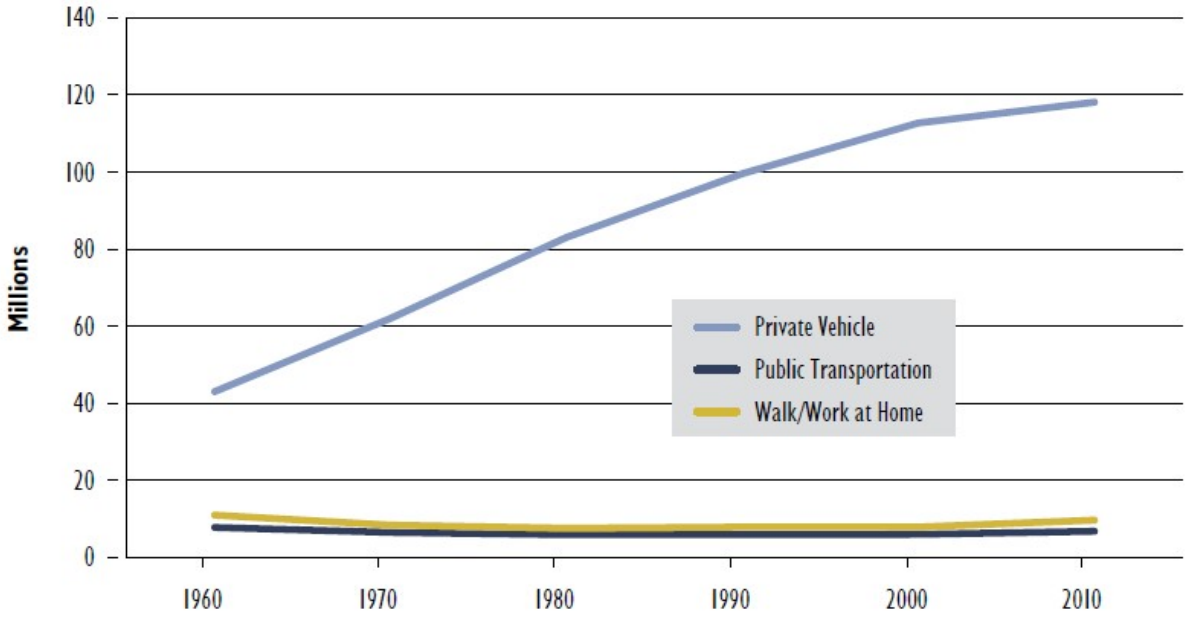

FIGURE 7. TRENDS IN COMMUTING BY MODE
Source: U.S, Census, ACS 2010 (as presented in Pisarski and Polzin 2013, Brief 10, Fig. 10-1, p. 5).

These commuting mode trends provide compelling evidence as to how continued large-scale shifts (new growth and dispersion) of both residents and jobs to the suburban and exurban areas of metropolitan areas have steadily reduced the market for mass transit. The movement of residents and jobs out of central cities has also limited the role of walking as a commuting mode. Too few circumstances exist where suburban workers live close enough to their jobs to realistically consider walking, assuming they can even safely do so.

A particularly crucial factor impacting transit service quality and use is access to and from the system. Travel behavior studies have long shown that the portion of the transit trip that involves time spent "out of vehicle" is much more important to the potential user than the time spent invehicle – more important by a factor of about 3 or 4 than the time spent riding. These out-ofvehicle components include the time to walk to and from the system at both trip ends, waiting time and transfer time. Perhaps the most critical element is the walk access (and egress) time. If

one cannot efficiently walk to the transit system at both ends of the trip, the appeal of transit is greatly diminished.

As illustrated in Figure 8 taken from Brief 7 of *Commuting in America 2013*, about half of U.S, households are within one-half mile of a bus stop, a little more than 40% within one-quarter mile (Polzin and Maggio 2007). Figure 9 paints a similar picture for employment, where (predictably) a somewhat higher proportion of employment sites are within one-half mile (about 60%) and one-quarter mile (about 52%) of a bus route. And these statistics come with the caveat that almost half of the nation's trips to work via transit occur in the Northeast, with the New York metropolitan area accounting for 39% of all such trips nationally (Pisarski and Polzin 2013). Along with Chicago, Washington, DC, Boston, Los Angeles, and San Francisco, these six areas alone account for over 65% of the nation's public transit commuters.

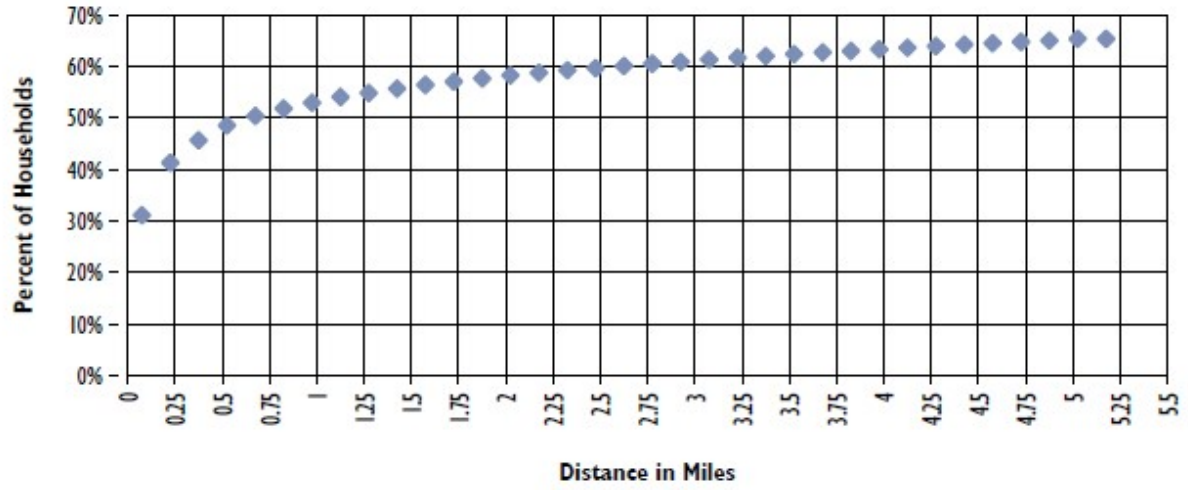

FIGURE 8. CUMULATIVE DISTRIBUTION OF DISTANCE FROM HOME TO BUS ROUTES
Source: Polzin and Maggio (2007) (as presented in Pisarski and Polzin 2013, Brief 7, Fig. 7-12, p. 20).

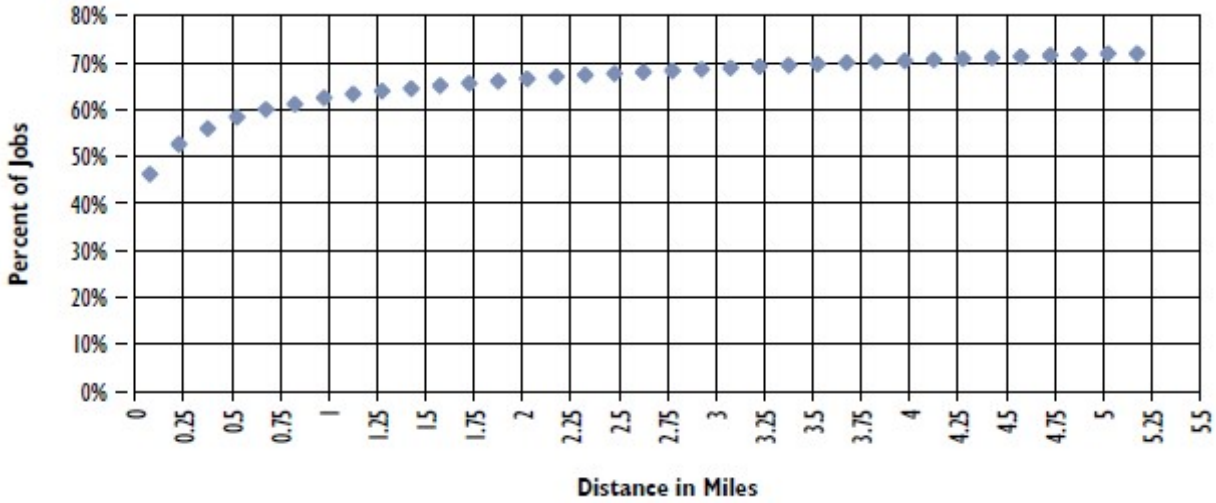

FIGURE 9. CUMULATIVE DISTRIBUTION OF DISTANCE FROM EMPLOYMENT LOCATIONS TO BUS ROUTES
Source: Polzin and Maggio (2007) (as presented in Pisarski and Polzin 2013, Brief 7, Fig. 7-13, p. 21).

Resulting Role for Transit, by Metro Area

As will be shown below in relation to the discussion on accessibility, what can be reached by transit must factor in these travel time components. In the case of walk access to transit, each quarter mile adds about 5 minutes of travel time to the transit trip, so if a person must walk ½ mile at both ends of their trip, they will experience 20 minutes of travel time, independent of the journey on board the transit vehicle. Considering that the average travel time for a work trip is less than 30 minutes, clearly many commuters will not find transit a competitive alternative under these circumstances. Moreover, it should be recognized that simply being near a bus stop has only partial meaning in whether the individual has a transit option, since the route servicing that stop may go nowhere near the person's destination. This is particularly true for most suburb to suburb trips, and even many trips from the suburbs to the core are outside reasonable walking distance and entail auto or feeder bus access. If one looks at overall travel conditions in the US, *Commuting in America 2013, Brief 7* cites Brookings research which reports that the typical job is accessible to only about 27% of its metropolitan workforce by transit in 90 minutes or less (Tomer 2012).

This may help explain the patterns seen in transit use among the nation's largest metropolitan areas -- seen in Figure 10.

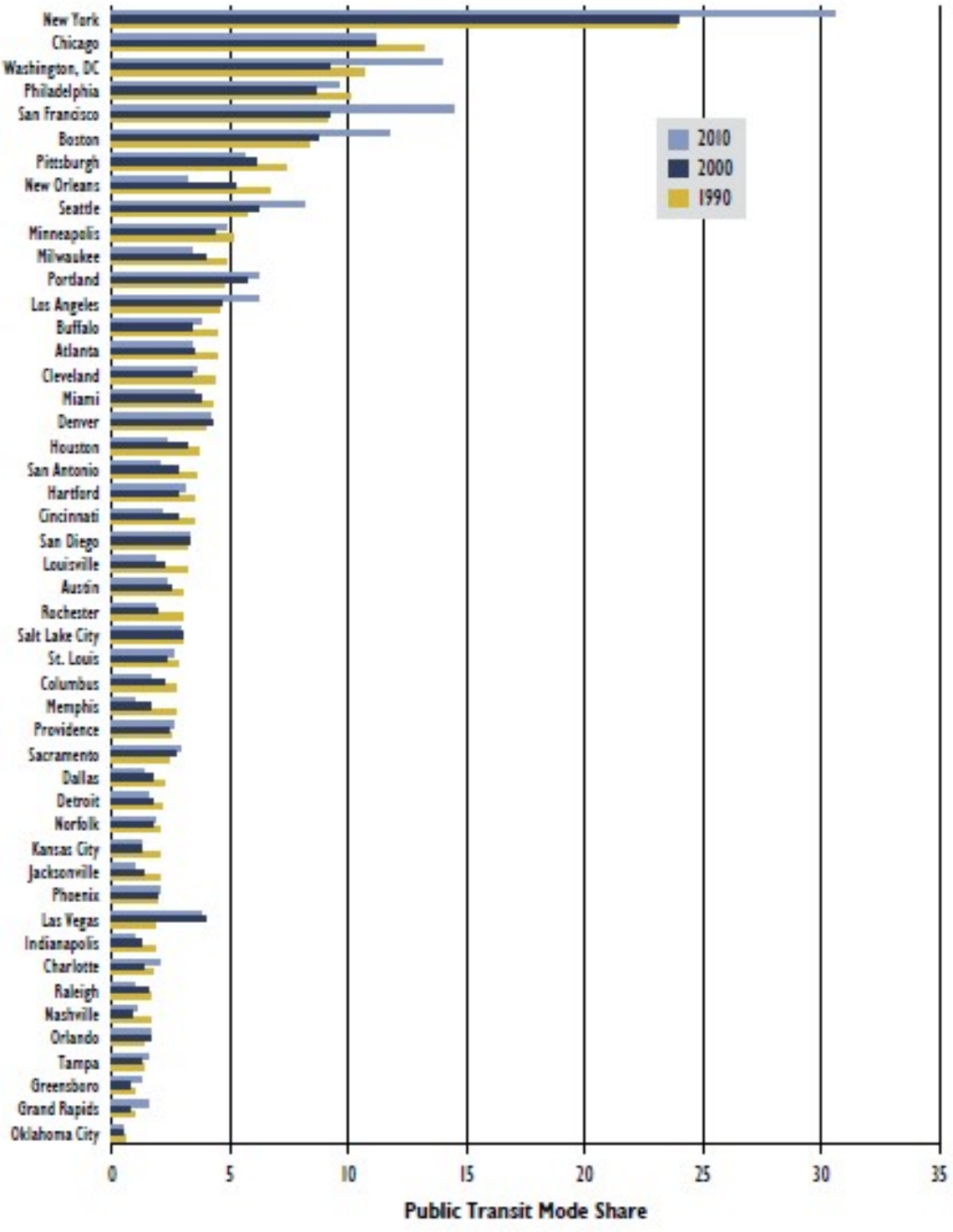

FIGURE 10. TWENTY-YEAR TREND PUBLIC TRANSIT SHARES AMONG METROPOLITAN AREAS

Source: Census, ACS 2010 (as presented in Pisarski and Polzin 2013, Brief 13 Fig. 13.5).

Geographic/Land-Use Implications for Total Trip-Making

The importance of the relationship between land use patterns and travel behavior extends well beyond commuting and transit, however. Per the 2009 NHTS survey, commuting to work makes up only about 16% of all person trips and 19% of all person miles of travel. According to *Commuting in America 2013 Brief 2*, for roadway travel, commuting constitutes 28% of all household vehicle-miles – largely because work trips are longer and because auto occupancy rates for work travel are much lower than for other purposes. As shown in Figure 12, the most substantial portions of household travel are associated with non-work travel, consisting of family business and errands (which includes shopping and personal services), and social/recreation, which account for 43% and 27% of all daily trips and 33% and 31% of all daily miles, respectively.

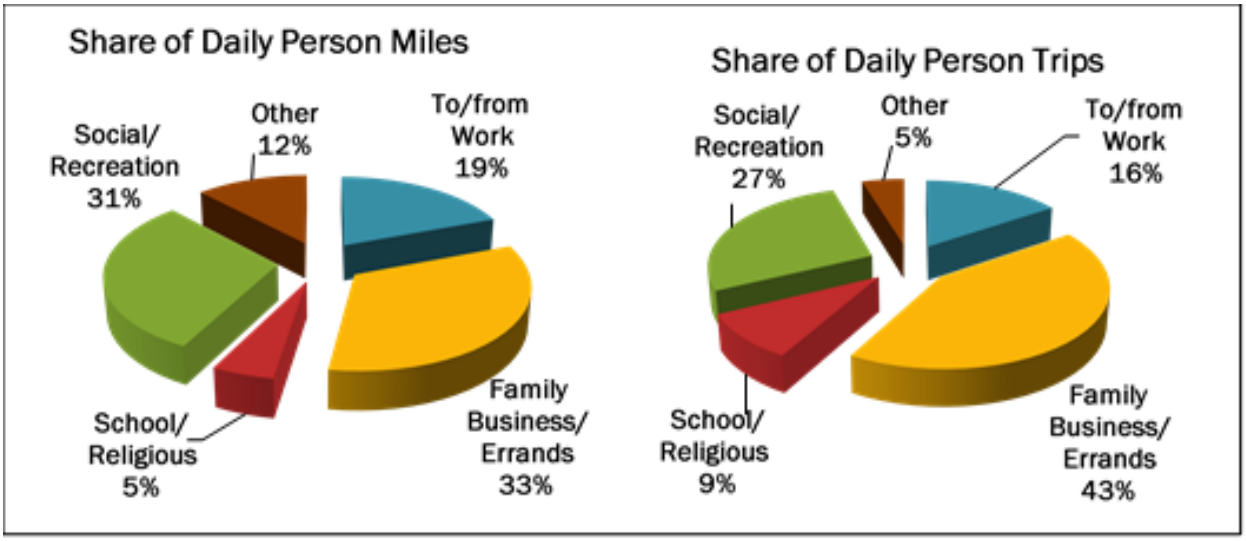

FIGURE 11. DISTRIBUTION OF PERSON MILES AND PERSON TRIPS BY TRIP PURPOSE, 2009
Source: U.S, Department of Transportation, FHWA, 2009 NHTS. http://nhts.ornl.gov.

While these proportions of person "trips" by purpose have remained stable over time, the amount of vehicle travel needed to accomplish these household needs has grown substantially, as illustrated in Figure 12 (National Travel Surveys). Using data from the NHTS and NPTS, Figure 12 shows that between 1969 and 2001, annual household VMT almost doubled, even though the average household size was steadily declining over this same period. Notice, however, that VMT related to commuting has generally declined as a percentage since 1969, while the proportions of VMT for shopping, family, and personal business, and "other" have grown substantially. The most realistic explanation for this pattern is the fact that in the suburban environment, activities (such as shopping, school, personal services, or child activities) that may have been accomplished by walking, biking or a short car trip in an urban setting are so spread out in the suburbs that private vehicle travel is the only realistic way to meet these needs.

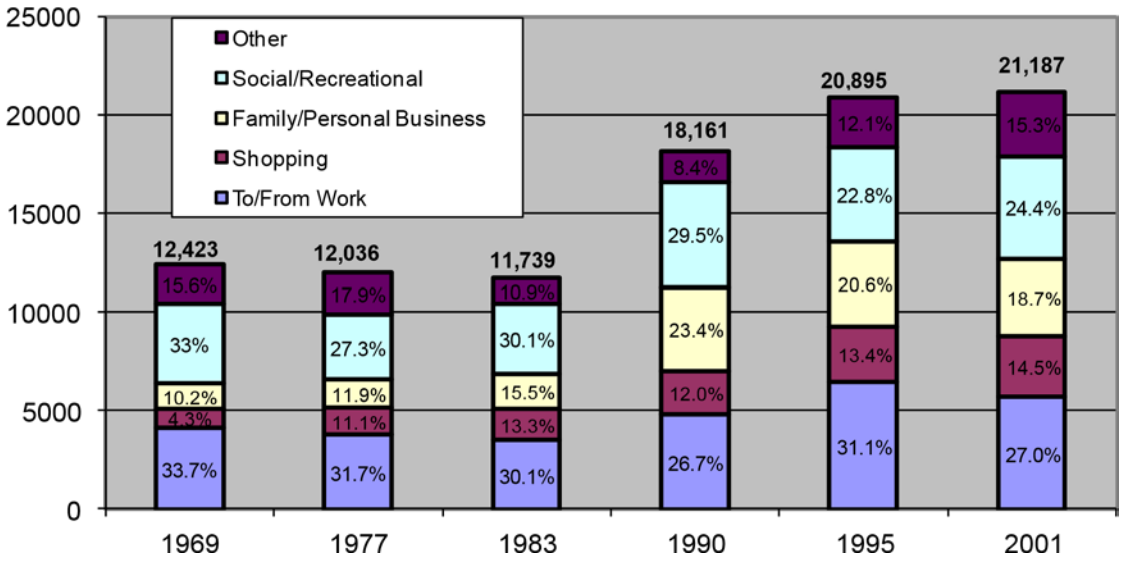

FIGURE 12 ANNUAL HOUSEHOLD VMT BY TRIP PURPOSE, 1969 – 2001
Source: Derived from National Person Travel (1969, 1977, and 1983) and National Household Travel (1990, 1995 and 2001) Surveys.

DEVELOPING THE TRANSIT/LAND USE CONNECTION

Going Beyond Density

While density is a widely used measure to describe the "urban-ness" of a setting, and correspondingly its suitability for transit service and use, research on the interplay between land use and travel behavior has shown that the influence of land use is considerably more nuanced than just density. Pioneering work by noted researchers Robert Cervero, Reid Ewing and Kara Kockelman back in the 1990s revealed that while density clearly played a role in terms of reflecting compactness and proximity, other contextual factors like the mix and balance of activities, the connectivity among those activities facilitated by design, and the level of accessibility to regional opportunities added critical insights in explaining travel behavior, such as vehicle ownership rates, mode choice and VMT generation.

These measures of land use have been widely referred to as the "4 Ds," representing *Density, Diversity, Design,* and *Destinations.* These advanced measures have been enabled by technological breakthroughs in tools such as geographic information systems (GIS), which make it possible to sharpen the spatial resolution of the built environment to create relationships that were previously lost in large-area aggregation of the characteristics addressed with the Ds. Traditional transportation planning models as used by metropolitan planning organizations were not designed to function at a level of detail fine enough to capture the critical interplay between the design of the micro environment and its effect on walking, biking, and even transit use (given the importance of walk access/egress). With the GIS methods, it is possible to focus the analysis at the level of individual households, employment sites, or any number of trip generators or attractors.

The strength of the accessibility measures in these many 4Ds (Density, Diversity, Design, and Destinations) modeling efforts raised attention to the dominant role played by the accessibility variable over the other Ds, and so subsequent research has placed greater emphasis on the relationship between accessibility and travel behavior. NCHRP project 08-78 (Report 770) opted to use accessibility as a major strategy for understanding bicycle and pedestrian travel behavior. One of the new procedures developed by the study focused on the calculation of accessibility "scores," for each mode and trip purpose, taking advantage of the recent proliferation of geospatial data on employment, households, travel networks and other contextual data. The procedure for calculating the scores is like the popular Walk Score on the internet, though the calculation is considerably more sophisticated. Geospatial layers of employment establishments are overlaid onto layers with the various transportation networks, and then sophisticated pathbuilding methods are used to locate the number of opportunities (jobs, grocery stores) which can be reached within a travel time budget. The number of such opportunities are added into a total for any given location (e.g., a residence address), with the value of each opportunity reduced (decayed) by the amount of time required to reach it. This is done for each mode and for work and non-work-trip purposes.

The U.S, Environmental Protection Agency's Office of Sustainable Communities Smart Location Database (SLD), which is a web-based resource, contains sociodemographic, employment, land use and transportation information for each census block group in the continuous 48 states. These data are for supporting coordinated transportation and land use planning, and EPA has also provided templates, tools, and media for using the data. Among the more innovative variables brought into this version of the database are various measures of accessibility, including scores for regional access (from each census block group) to jobs by auto and by transit, and conversely, employer access to workers, also by auto and by transit. In prior research. In working with these data, Renaissance found a strong relationship between the ratio of the transit and auto accessibility scores (TAR) and the transit/auto mode split for work trips (as captured in the American Community Survey). Figure 13 shows the nature of this relationship across 2,317 census block groups in the state of Virginia (American Community Survey 2016). While there is obviously statistical noise in the relationship based on only these two factors, the trend is nevertheless quite strong, with an R^2 measure of the goodness of fit of a straight-line curve being 0.5739.

We have been able to access and attach these measures to the travel survey database developed for this project, with the goal of having an objective measure of the quality of transit service at any of the respondent household locations. We have used this accessibility ratio as another potential explanatory factor when analyzing the range of attitudes and choices captured in the survey. These findings are reported in the second part of Chapter 5 of the Final Report.

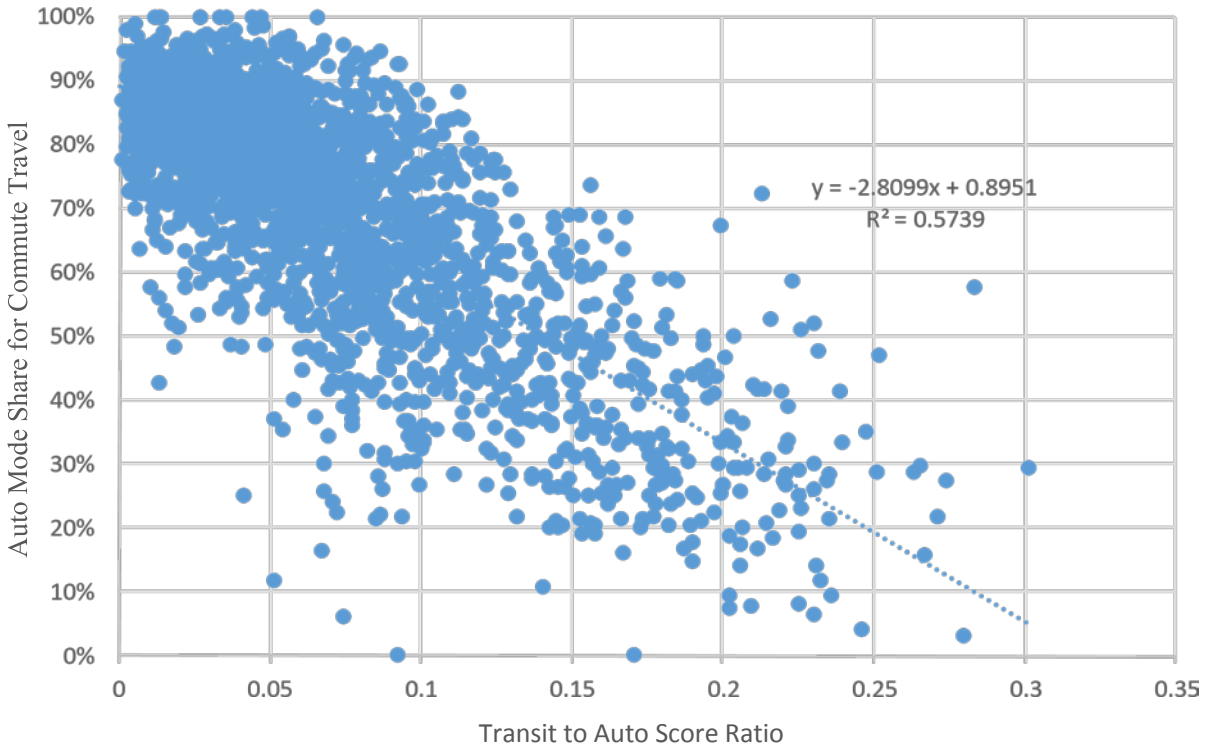

FIGURE 13. RELATIONSHIP BETWEEN TRANSIT AND AUTO ACCESSIBILITY SCORES AND AUTO MODE SHARE
Source: EPA Smart Location Database

PART TWO: TRENDS IN EMPLOYMENT LOCATION, AND IMPLICATIONS FOR TRANSIT

Part One of this Technical Appendix reviewed how growth trends in the U.S, since WWII have demonstrated a flow from cities to the suburbs. The importance of this trend on the diminishing viability of transit was explored, particularly in relation to residential growth patterns. The corresponding shift of employment growth to suburban areas, basically following residential out migration but on a slightly lagged time scale, was also discussed. Both trends have combined to reduce the number of productive node-to-node and corridor travel patterns that transit requires to be productive, and hence the share of regional trips that are made by transit. Part Two of this Technical Appendix now focuses on both empirical patterns in employment location, and more speculative considerations about their future.

The Outward Movement

According to Cortright in *Surging Center City Job Growth,* employment has been moving outward from the urban core for at least six decades. Some of the earliest sectors seeing an economic or logistic advantage in locating outside the urban core were manufacturing, retail, service, and wholesale trade. Data such as those displayed in Table 5 show that by 1963 these trends were well underway (Cortright 2015). Manufacturing and warehousing moved from city center locations close to ports and rail lines, to more suburban locations served by trucks.

Meanwhile, retail and service activities simply began to follow their residential customer markets.

TABLE 5. EMPLOYMENT IN CENTRAL CITIES, BY INDUSTRY, 1947 AND 1963

	Central City			Suburbs		
	1947	1963	Annual Growth	1947	1963	Annual Growth
Manufacturing	3,750	3,250	-0.9%	2,449.0	3,791.0	2.7%
Retailing	2,032	1,667	-1.2%	811.0	1,756.0	4.8%
Service	673	826	1.3%	173.0	525.0	6.9%
Wholesaling	980	943	-0.2%	171.0	503.0	6.7%

Source: Mills, 1972 (as presented in City Observatory, February 2015).

Into the later 1960s and early 1970s, as the urban portions of the national Interstate Highway system were completed, vast new undeveloped fringe areas became accessible, adding fuel to the ongoing trends. In this wave of development, residential settlements extended even further away to formerly rural (now “exurban”) areas, while professional and white-collar employment began to follow the earlier lead of retail, service, and industrial establishments. While the retail and service activities settled into commercial strip shopping centers along major highways, and eventually malls surrounded with acres of surface parking, the white-collar employers opted for suburban office parks and campuses, and for some, into nameplate buildings along busy interstate corridors and near major interchanges. The motivations included ownership/prestige, lower cost per square foot of space, and presumed easier access to employees via high speed roads and free parking. The allure of this trend continued into the late 1980s, at which point overdevelopment of office space, the crash of the savings and loan market, and the sudden emergence of severe suburban traffic problems helped moderate the trend somewhat. This buildup of traffic in suburban areas became a sudden national transportation concern that consumed the attention of federal, state and metropolitan transportation and planning agencies, since the problems were occurring at the same time that the nation was facing a transportation infrastructure crisis (eventually leading to the passage of Intermodal Surface Transportation Efficiency Act in 1991), and also confronting the likelihood of strong new limitations on emissions (1990 Clean Air Act Amendments). The high-growth jurisdictions themselves rapidly mobilized toward adopting growth and traffic management ordinances to try to put brakes on overdevelopment and shift more of the responsibility for mitigating traffic impacts on developers and employers.

Continued Employment Decentralization

Regrettably, data are not readily available to examine these employment location trends in detail over this extended period (as they are with population). Table 6 shows that as of 1996, the share of metropolitan area employment located in the regional core (defined as within 3 miles of the city center) had dropped to 23.3%, from about two-thirds in 1950 and one-half in 1963 (Cortright 2015). A later study by Kneebone (2009) suggests that employment decentralization continued through at least 2006, showing the percentage of metropolitan employment located in the core reaching a low of 21.3% in 2006, with suburban job growth averaging 1.8 % annually over the 1996 to 2006 period, vs. only 0.1% in the city centers (of the largest 98 metropolitan areas).

TABLE 6. ZIP CODE BASED ESTIMATES OF CITY CENTER AND PERIPHERY EMPLOYMENT

YEAR	98 MSA TOTAL	3 MILE SHARE	CITY CENTER	PERIPHERY
1996	70,159,860	23.3%	16,347,247	53,812,613
2006	77,411,492	21.3%	16,488,648	60,922,844
Annual Growth Rate, 1996 -2006			0.1%	1.8%

Source: Kneebone, 2009, Appendix A, page 17 (as presented in Cortright [2015]).

The general sense among researchers and representatives of the development community is that a turning point in metropolitan employment trends – from suburban to urban – occurred somewhere in conjunction with the 2007 recession. Between 2007 and 2011, job growth in city centers grew at an average annual rate of 0.5%, while the suburbs lost jobs, shrinking by 0.1% annually (Smart Growth America 2015). Following the recession, jobs like construction and manufacturing – based outside cities – were hit much harder than urban jobs like business services. Jobs disappeared everywhere, but more rapidly outside cities (Miller 2015).

A Reversal of the Pattern?

Assorted reasons are given for the presumed reversal. A 2011 study by the Urban Land Institute served to provide its members in the international real estate industry with a prospective of key trends likely to shape the industry in the coming decades, particularly in the wake of the recent recession (Urban Land Institute 2012). The study cites several economic and demographic drivers that it suggests will dramatically influence future real estate investment and urban development decisions, including:

- *Global Networks:* The global economy will increasingly dominate business models and location decisions, with commercial activity continuing to organize around the network of innovative, gateway cities that constitute global pathways.

- *Rightsizing:* Real estate offers a way of reducing expenses, pushing office tenants and retailers to make do with smaller spaces, albeit "more interesting" architectural spaces located in a more vital 24-hour environment.

- *Shifting Job Generators:* While traditional manufacturing continues to relocate to places with lower labor costs/fewer restrictions, a new generation of "advanced manufacturing" jobs emerges built on knowledge industries of education, science, technology, and medical specialties.

- *Education Magnet*: Levels of education become a location driver both for employers and residents. Businesses choose communities with higher education rates, and recent graduates are attracted by the good jobs/salaries, industries, and specializations that are possible.

- *Changing Demographics:* Rapidly evolving social composition of communities triggers new markets, opportunities, products, and services, along with new residents competing for jobs, housing, and quality of life. The "barbell" population groups of Boomers and Gen Y are challenging where and how people live and work – in particular, the Gen Y Millennials who appear to want to distance themselves from the suburban lifestyle norms of their parents.

- *Evolving Technology*: More information is pushing into the marketplace, offering to both support more rapid and complex decision-making, but also to transform traditional models of business structure and management.

The Urban Land Institute report argues that these trends, in the wake of the Great Recession, are pointing the way to systematic changes in the way we perceive and how we should plan for our future cities. The report advises its members that the last decade provides an opportunity to rethink and evolve, reinvent, and renew. It asserts that nearly 100% of robust growth is in urban areas, and that growth is embracing a new mixture of land uses, new suburban centers, and intown reconfigurations.

The 2015 City Observatory study provides additional detail and insight into the changing shape of urban areas (Cortright 2015). The study explores what appears to be a *growing preference for urban living*, in which it cites:

- Some young adults are showing a clear preference for close-in urban locations. Cortright reports that between 2000 and 2012 the number of 25- to 34-year-old adults with at least a bachelor's degree who chose to live in city centers outnumbered those who chose the metropolitan area by a rate of 2 to 1. This suggest that many with high levels of education are choosing the city center. Examining the Millennials as whole, the 2016 survey for TCRP offered the options of preferring 'big city,' 'small city,' 'suburb,' 'town,' or 'rural': about 37% of those between 25-34 reported preferring the 'big city', leaving more than 60% reporting preference for less dense residential locations, as discussed in Chapters 1 and 5 of the Final Report. The results of that analysis support the general conclusion that preference for city living by Millennials *did increase* between 2004 and 2016.

- In 2010, college educated young adults were 126% more likely to live within three miles of the center of the central business district of a large metropolitan area than other metro residents, up from about 77% more likely in 2000 (Cortright 2015).
- This finding is important because this group of people constitutes an important source of labor for fast-growing knowledge-based firms, which seem willing to alter their growth or expansion plans to tap this labor pool (explored more below in conjunction with the Core Values study).

Cortright (2015) offers several other factors underlying resurging city growth:

- *Cities as Centers for Consumption*: Cities are consumption places, not just production places. The dense and diverse array of services and experiences that cities offer is a core advantage. He cites particularly the post 2007 growth rates in accommodation and food services, and arts, entertainment, and recreation industries.
- *Knowledge-based Industries*: Professional and business services including finance, insurance, engineering, accounting, business management, advertising, public relations, and planning, as well as many high-tech services are disproportionately concentrated in city centers.
- *Entrepreneurship:* Dense urban environments have become increasingly popular for startup firms, such as high-tech. As evidence for this claim, Cortright found that most businesses funded by venture capital are choosing central city locations.
- *Eds and Meds*: Education (Eds) and health care (Meds) are increasingly touted as drivers of economic growth in areas where they have a strong footing. These industries have consistently outperformed the overall economy in job growth, and they have accounted for much of the growth that occurred between 2007 and 2011 in city centers (though the city growth rate, during this time, continued to lag the rest of the metropolitan area).
- *Manufacturing and Distribution*: City centers have been less affected by downturns in these industries because they tend to prefer locations outside of the city.
- *Transportation*: While road building encouraged decentralization from cities, new road construction has been limited by resources and other constraints. As a result, traffic congestion continues to grow, disproportionately affecting travel outside cities where there are few viable options.

Why Companies Move to Downtowns

Perhaps the most definitive study of the changes underway in the shaping of metropolitan areas was performed by Smart Growth America, in partnership with Cushman-Wakefield and the George Washington University Center for Real Estate and Urban Analysis. The study report, *Core Values: Why American Companies are Moving Downtown*, summarizes a research project that identified almost 500 companies that relocated, opened new offices, or expanded in walkable downtowns and investigated their underlying characteristics, motives, and preferences (Smart Growth America 2015).

The study had the objective of better understanding what kinds of companies were making such moves, what competitive advantages these companies saw in those downtown locations, and what features these companies saw of greatest importance in their decision-making. The companies were of all types and sizes, covering over 170 specific industries, and were located across the country in a variety of areas. Global real estate advisors Cushman & Wakefield identified the sample of companies from a list of those known to have made a move within the past five years (2010 to 2015). Basic information was compiled on all the companies, and 40 were interviewed in detail.

The interviews revealed six major themes explaining the company's decision to locate downtown.

- *Workforce:* To attract and retain a talented workforce. As companies compete for talent, locating in a vibrant neighborhood was found to be a crucial selling point. Companies found that the employees with the skills they most desired had strong preferences to be in neighborhoods with restaurants, cafes, cultural offerings, entertainment and nightlife, and good access by public transportation
- *Brand Identity and Company Culture*: There was a belief that a downtown location projected an aura of innovation and uniqueness that would set companies apart from their competitors and inspire their employees to be loyal to the brand
- *Creative Collaboration*: Companies believed that by locating in dynamic, creative settings, they would inspire employees and encourage collaboration with coemployees and with employees at other companies and in other industries
- *Proximity to Customers and Partners:* Facilitating face-to-face meetings
- *Centralizing Operations*: A downtown location was seen as ideal for companies who wanted to consolidate multiple locations spread out across a single region
- *Triple-Bottom Line Business Outcomes:* A downtown location was seen as a way to demonstrate good citizenship, bringing with it the benefit of making companies more attractive as an employer

Types of Relocations

The "types" of relocation were explored by the Core Values study and are illustrated in Figure 14 (Smart Growth America 2015). Here, the largest number of cases involve a simple relocation from the suburbs to the downtown in the same metro area. In general, about half of the firms interviewed were coming from a suburban setting into a downtown setting, while the rest represent of cross section of reasons involving some previous downtown location.

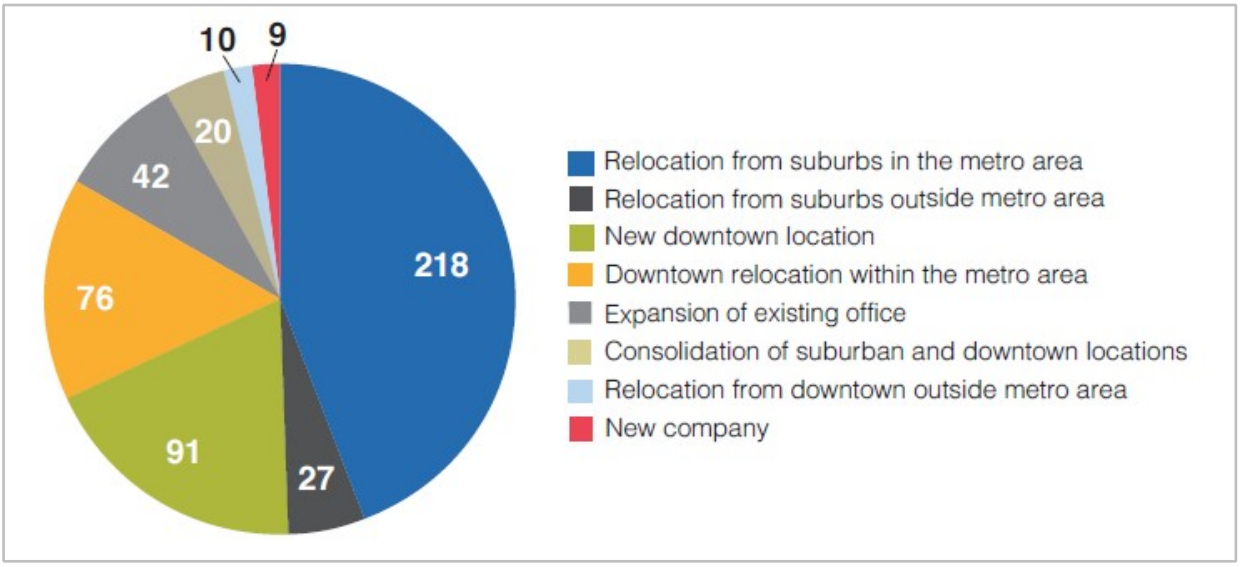

FIGURE 14. RELOCATIONS, EXPANSIONS, AND NEW OFFICE CREATION SURVEYED.)
Source: Smart Growth America (2015). (NUMBERS REFER TO NUMBER IN SAMPLE SURVEYED.)

The Core Values study did not address movements of firms into suburban centers with evolving urban characteristics. More of these places have emerged as transit-oriented development sites or "edge cities" over time, with many of the characteristics of mixed use, walkability, and accessibility of downtown, though perhaps not the full complexity of a metropolitan downtown. Still, it would be enlightening to ascertain the degree to which employers are locating (relocating) to these areas, and whether such a transformation is being accompanied by greater acceptance by Millennials.

Measuring the Change in Transit-Supportive Characteristics

The Core Values study undertook the calculation and comparison of the values of walk, transit, and bike scores prior to and following the relocation. As Figure 15 illustrates, it appears that companies that make a move to a more urban location in the center city realized significant gains in each measure, with the improvements in walk score and transit score being the most vivid (Smart Growth America 2015).

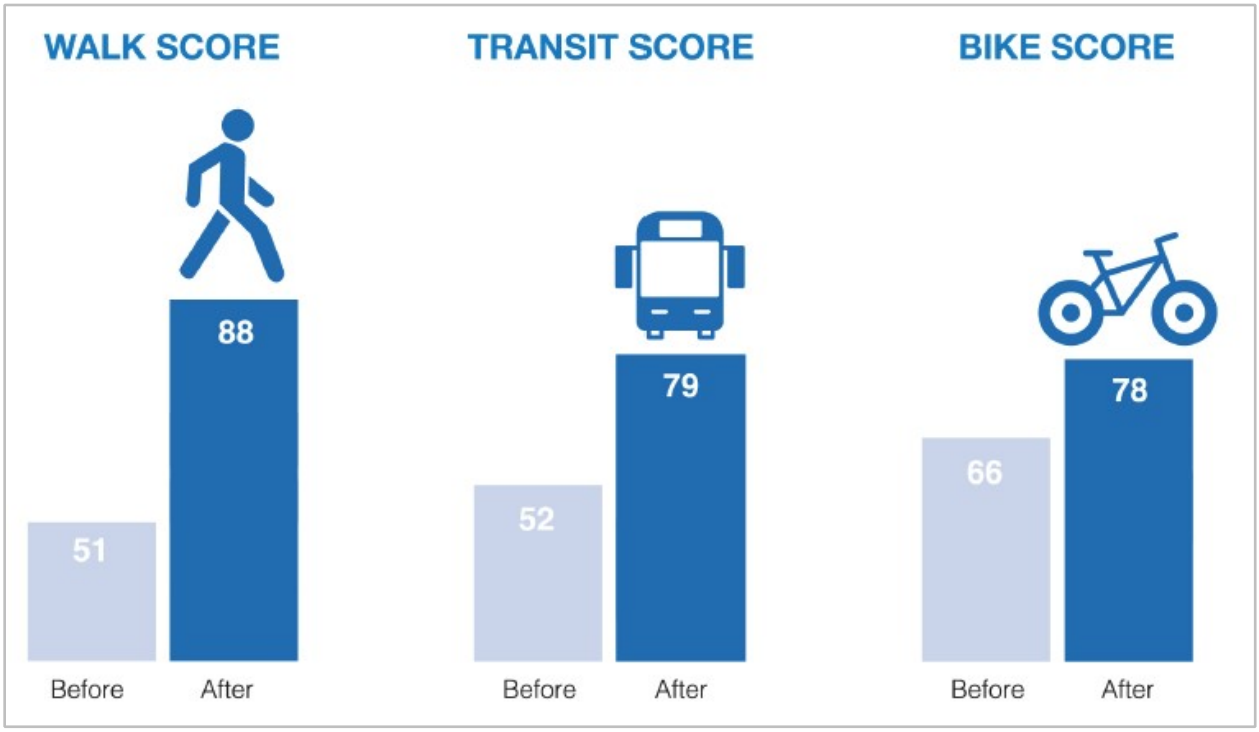

FIGURE 15. COMPARATIVE WALK, TRANSIT, AND BIKE SCORES BEFORE AND AFTER RELOCATION
Source: Smart Growth America (2015).

PART THREE: UNDERSTANDING THE IMPORTANCE OF WORKPLACE CHARACTERISTICS

WORKPLACE INCENTIVES, BY LOCATION

Just moving to an urban new location shows improvements in a company's workplace characteristics supportive of walking, transit, and biking. However, there is significant variation in the financial incentives companies offer to support pro-environmental commuting patterns to the workplace. The employer can influence behavior patterns that either do, or do not, support the marketability of transit services. Figure 16 shows that the propensity to offer transportation incentives at the workplace is influenced by the transit-accessibility level of the community in which the job is located.

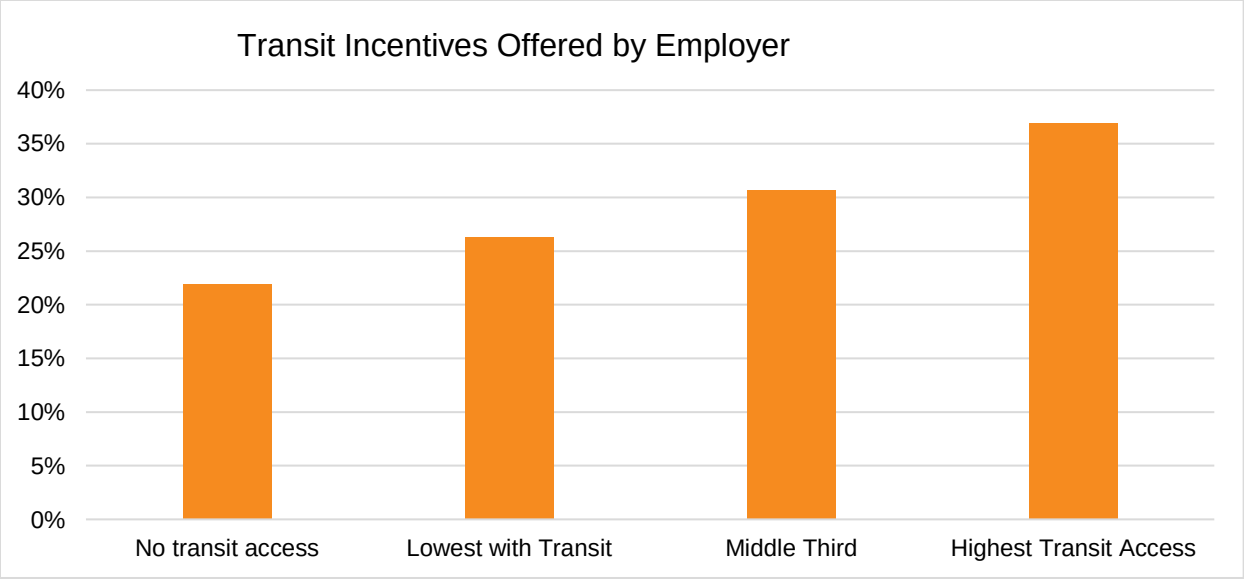

FIGURE 16. PERCENT OF EMPLOYERS OFFERING TRANSIT INCENTIVES, BY LEVEL OF TRANSIT ACCESSIBILITY
Source: TransitCenter, 2014

An example of how pro-environmental commuting options are offered is when the employer allows the employee to work from home, which theoretically could be offered in a location with no transit whatsoever. Figure 17 shows that the geographic areas with the highest transit accessibility have a higher rate of telecommuting than areas with less transit.

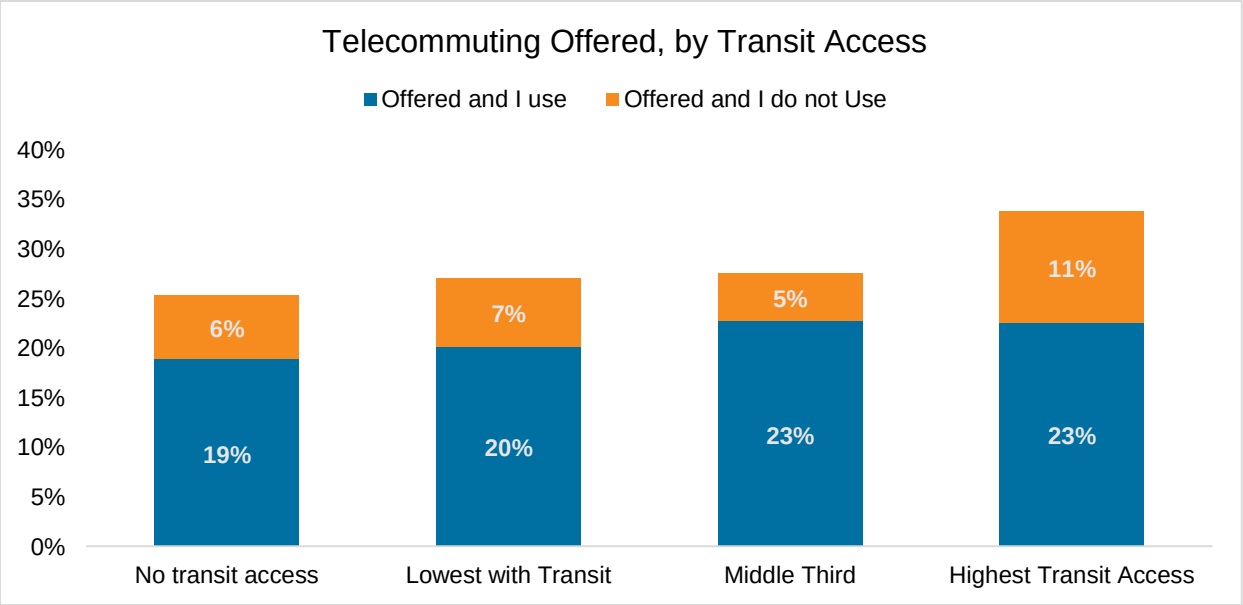

FIGURE 17. PERCENT OF WORKERS ACCEPTING TELECOMMUTING, BY LEVEL OF TRANSIT ACCESSIBILITY

Source: TransitCenter, 2014

Incentives Offered and Accepted, by Age of the Employee

Wide variation exists, and the amount of transportation commute incentives offered to employees. Figure 18 explores the percentage of TransitCenter respondents who reported that their employer was offering incentives. Millennials seem to be more likely to have a job where their employer is offering a bike subsidy, offering a shuttle to the transit station, or a subsidy on either the transit fare or vanpooling charges. Concerning the issues of flextime and telecommuting, the role of age is less dominant concerning options being offered.

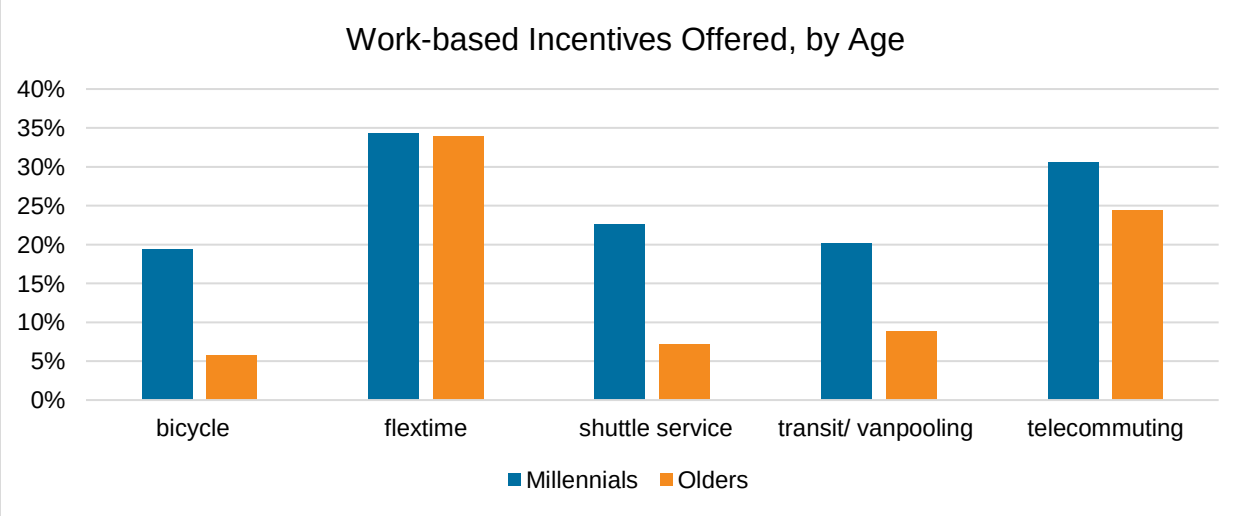

FIGURE 18. PERCENT OF WORKERS OFFERED INCENTIVES, BY AGE GROUP.
Source: TransitCenter, 2014

As expected, Millennials have a much higher propensity to use the bike incentives offered at (some) workplaces than their older colleagues. Consistent with Figure 18, Figure 19 shows that Millennials are far more likely than their older colleagues to *use* both the subsidized shuttle service and the subsidies for transit and vanpooling. Actual use of flextime occurs more often with those aged above 35 than those younger than 35.

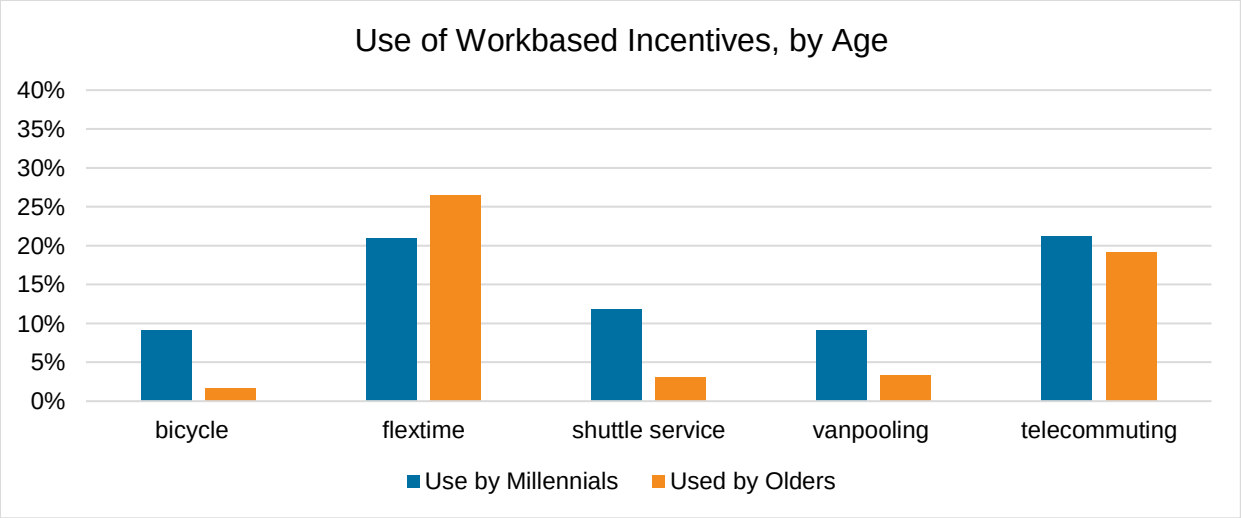

FIGURE 19. INCENTIVES ACCEPTED AND USED, BY AGE GROUP
Source: Transit Center, 2014

WORKING AT HOME

Another major trend affecting the number of commuting trips taken is the propensity to work at home, and thus have no trip to work. It is important to observe that the term 'telecommuting' refers to persons having a base location of work, with the option of connecting electronically for some portion of the work week; the term 'work at home' is a census-based category describing workers who do not have a predominant base outside of the home. The share of workers who report working at home has doubled between 1980 and 2013, according to the Census Journey to Work data shown in Figure 20.

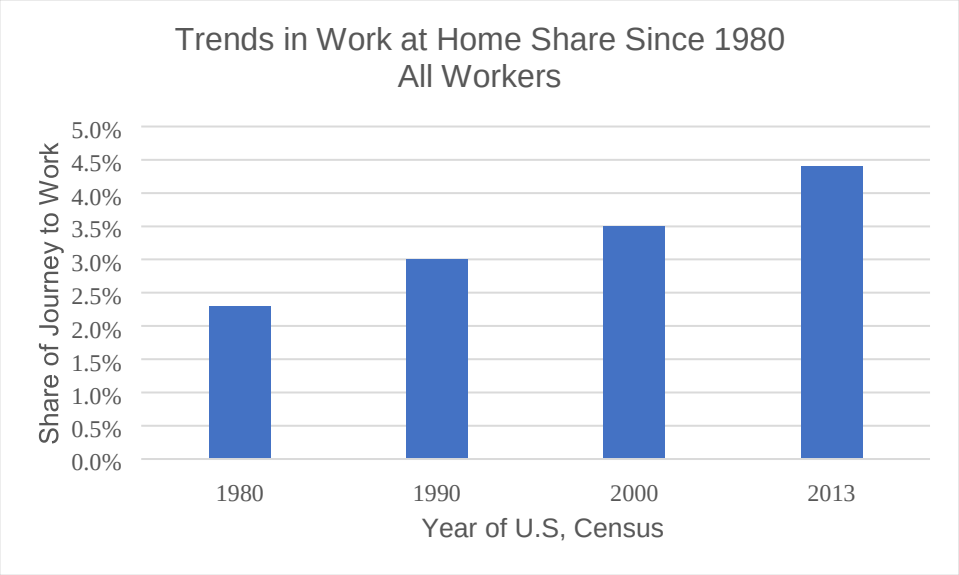

FIGURE 20. GROWTH OF WORK AT HOME SHARE OVER 33 YEARS.
Source: U.S. Census.

Figure 21 shows that the propensity to work at home *increases* directly with age. This is a pattern quite different from the propensity to have a job and telecommute for some days -- a pattern which decreases with age, as discussed in Chapter Seven of the Final Report, and Technical Appendix 7, concerning the future role of Information and Communications Technology. The propensity to work at home increases linearly with age, with the rate for those above 55 years more than twice the rate for those under 30, according to Census Journey to Work data in 2013.

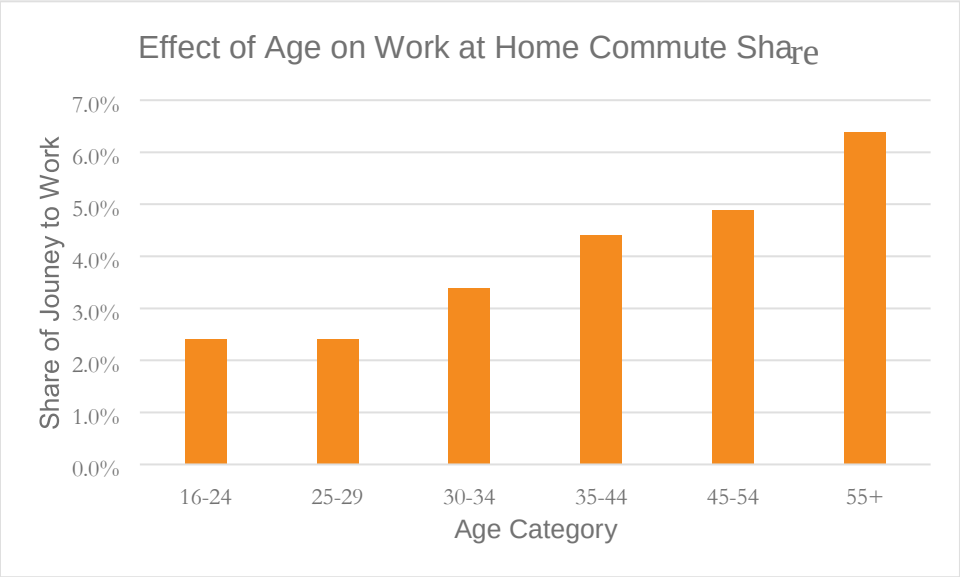

FIGURE 21. EFFECT OF AGE ON WORK-AT-HOME COMMUTE SHARE
Source: U.S. Census.