CAMBRIDGE SYSTEMATICS

Emerging Technology, Demographic Changes, and Travel Behavior

Trends, Key Parameters, and Scenarios

technical

report

prepared for

Florida Department of Transportation

prepared by

Cambridge Systematics, Inc.

February 19, 2016

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500 East Broward Boulevard, Suite 1160
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Table of Contents

List of Tables

List of Figures

1.0 Introduction

This report is part of a continuing regional travel demand trend analysis for the Florida Department of Transportation (FDOT).

Building on a literature review performed for the first phase, this report:

- Compiles additional information on emerging technologies from identified sources and case studies;
- Gathers regional and national trends in a manner to support discussion of potential scenario testing; and
- Provides definition to specific scenarios that could be tested with the SERPM 7 model to support policy analysis.

This report is organized as follows: Section 2 compiles regional and national travel demand trends; Section 3 identifies key parameters and data needs for autonomous vehicles (AVs) and information and communications technology (ICT); Section 4 discusses potential scenario testing that could be performed with the travel demand model; and Section 5 describes potential next steps.

2.0 Trends of Interest

Historical and projected changes in transportation related issues make up travel demand trends. In this section, we focus on the key factors affecting vehicle miles traveled (VMT) and mobility, including population, employment, vehicle and transit availability, commuting mode, peak car travel, generation effects, and secondary effects. Analysis of regional, Florida, and national trends allows further exploration on how anticipated future conditions might affect travel demand forecasting, potential scenario testing using a demand model; and how to better achieve Florida Transportation Plan goals for over the next 50 years: safety and security for residents, visitors, and businesses; efficient and reliable mobility for people and freight; transportation solutions that support Florida's global economic competitiveness; transportation solutions that enhance Florida's Environment and Conserve Energy; agile, resilient, and quality transportation infrastructure; more transportation choices for people and freight; transportation quality places to live, learn, work, and play[1].

2.1 Demographic Trends

2.1.1 Population Trends

Traffic is produced by people engaging in activities such as employment, shopping, school, and recreation. The level of economic activity thus contributes to vehicle miles travelled per capita, and growth in travel demand relates to population growth. Figure 2.1 illustrates the continuous and rapid population growth in Florida since 1990 (and the U.S. baseline). In 2014, Florida became the nation's third most populous state with nearly 20 million people. It was the 6th fastest-growing (1.5 percent) state in the 12-month period ending July 1, 2014. Only during the recession did Florida's population growth slow down relative to national population growth. In the future, the Bureau of Economic and Business Research (BEBR) at the University of Florida has projected faster growth in population from 2015 to 2040 (also shown in Figure 2.1)[2]; BEBR expects a 32 percent increase in population, reaching 26 million by 2040.

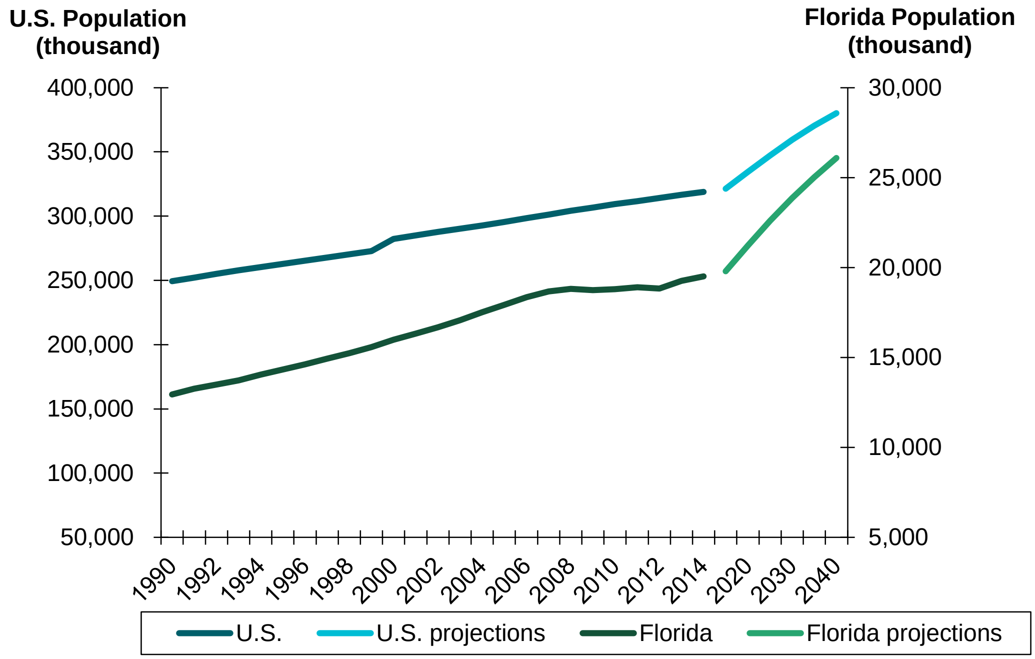
Concurrent with the rapid population growth has been growth in demand for travel.

Figure 2.2 presents the parallel trends of Florida population and VMT. VMT showed a bump up relative to population growth between 2002 and 2006, concurrent with impacts from economic growth and hurricane recovery activities, but otherwise, VMT tracks in the same way as population changes.

[1] Florida Department of Transportation (2015) Florida Transportation Plan Vision Element. http://www.floridatransportationplan.com/pdf/FDOT_FTP-SIS_VisionElement.pdf retrieved January 21, 2016.

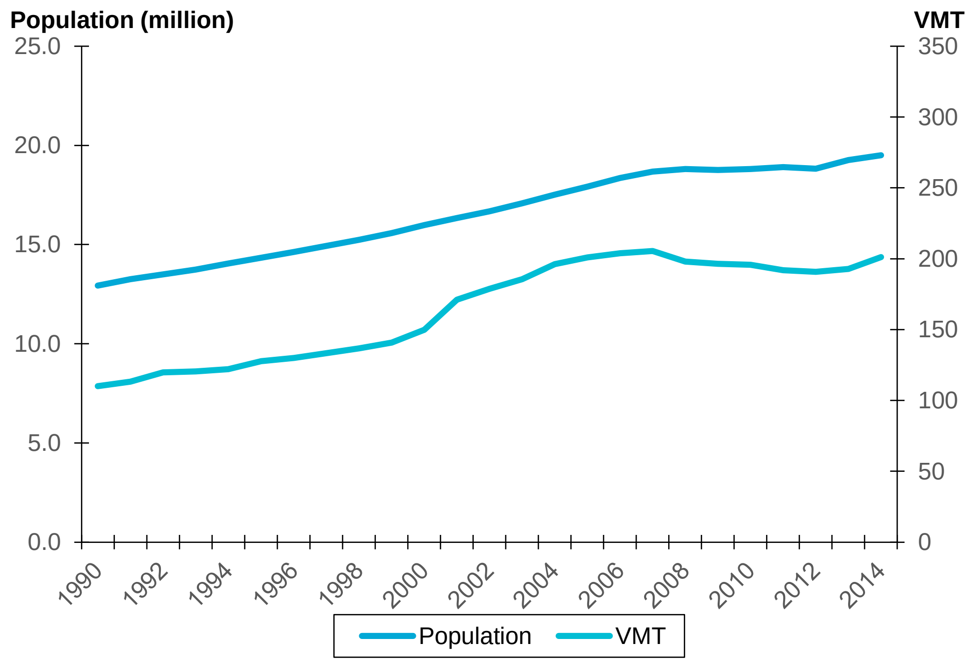
[2] Rayer, S. and Y. Wang (2015) Population Projections by Age, Sex, Race, and Hispanic Origin for Florida and its Counties, 2015–2040, with Estimates for 2014.

Figure 2.1 Regional and National Historical and Projected Population



Source: 1990-2014 estimates: FDOT; 2015-2040 projections: Bureau of Economic and Business Research, University of Florida.

Figure 2.2 Florida Population and VMT

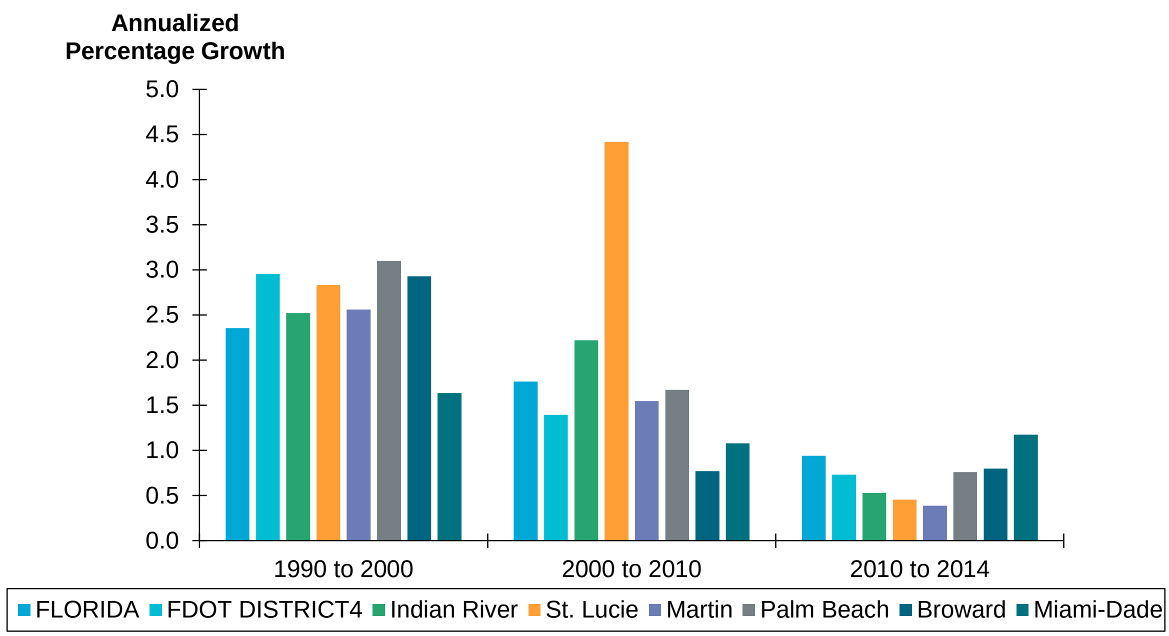


Source: 1990-2014 estimates: FDOT; FHWA.

Among all Florida counties, Palm Beach County, Broward County, and Miami-Dade County remain the three most populous from 1990 to present. Sumter County, Osceola County, and St. Johns County have had the most rapid population growth between 2010 and present. The geography covered by FDOT District 4 (which includes Martin, Palm Beach, and Broward counties), includes about one fifth the total Florida population.

Table 2.1 presents snapshots of population for Florida, FDOT District 4, and southeastern Florida counties along with projections for 2040 from BEBR. Figure 2.3 presents the average annual population growth rate at the state, district, and county level over each of three time periods. Noteworthy, a significant portion of future growth in population is expected to come from new immigration. It is therefore may be important to understand any differences in travel needs and behavior among immigrants when projecting future travel demand.

Figure 2.3 Annual Percentage Change in Population by Period



Source: Bureau of Economic and Business Research, University of Florida.

Table 2.1 Population and Population Distribution by Year

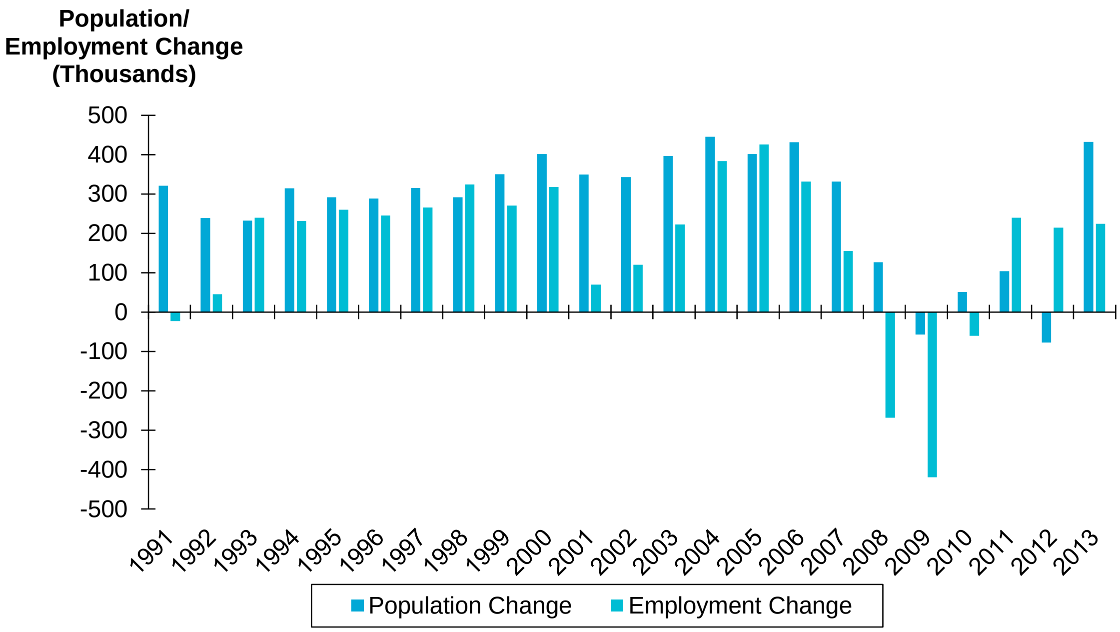
State, District, or County	Population (thousands)					Percent of State Population				
	1990	2000	2012	2014	2040	1990	2000	2012	2014	2040
FLORIDA	12,938	15,983	18,801	19,507	26,081					
FDOT DISTRICT 4	2,460	3,187	3,630	3,737	4,672	19.0	19.9	19.3	19.2	17.9
Indian River	90	113	138	141	195	0.70	0.71	0.73	0.72	0.75
St. Lucie	150	193	278	283	455	1.16	1.21	1.48	1.45	1.75
Martin	101	127	146	149	180	0.78	0.79	0.78	0.76	0.69
Palm Beach	864	1,131	1,320	1,360	1,737	6.67	7.08	7.02	6.97	6.66
Broward	1,256	1,623	1,748	1,804	2,106	9.70	10.15	9.30	9.25	8.07
Miami-Dade	1,937	2,254	2,496	2,614	3,344	15.0	14.1	13.3	13.4	12.8

Source: Bureau of Economic and Business Research, University of Florida.

2.1.2 Employment Trends

Employment is a major generator of transportation needs and travel demand. As shown in Figure 2.4, the pace of employment growth slowed down after 2006 and retreated during the recession years 2008 through 2010. Overall, however, from 2000 to 2013, more than 1.6 million new employment opportunities were created in Florida.

Figure 2.4 Florida Population and Employment Trends



Source: Bureau of Economic and Business Research, University of Florida;
U.S. Department of Commerce. Bureau of Economic Analysis.

The Florida Department of Economic Opportunity projects a 12.4 percent increase in total jobs, which is 1.0 million new jobs, for the next eight years (from 2014 to 2022). The three fastest-growing industries will be construction (34 percent), education and health services (22 percent), and professional and business services (16 percent). Indian River, Okeechobee, St. Lucie, Martin, and Palm Beach counties are forecast to experience 13.2 percent growth in employment. Broward County employment growth is projected to be 11.5 percent, only slightly lower that the rest of the state.

Table 2.2 presents employment projections for southeast Florida counties in 2040 from local Metropolitan Planning Organization (MPO) data. Compared to American Community Survey estimates on employment, St. Lucie County is going to have the highest growth in jobs (85 percent) between 2013 and 2040. Both Indian River County and Martin County will also experience significant growth in employment during this period (79 percent and 80 percent, respectively). Miami-Dade County will remain the largest employment center in southeast Florida, followed by Broward and Palm Beach counties. Since growth in employment is correlated with commuting needs, the continued growth in employment points to future demand for transportation infrastructure and services.

Table 2.2 Future Florida Projected Employment

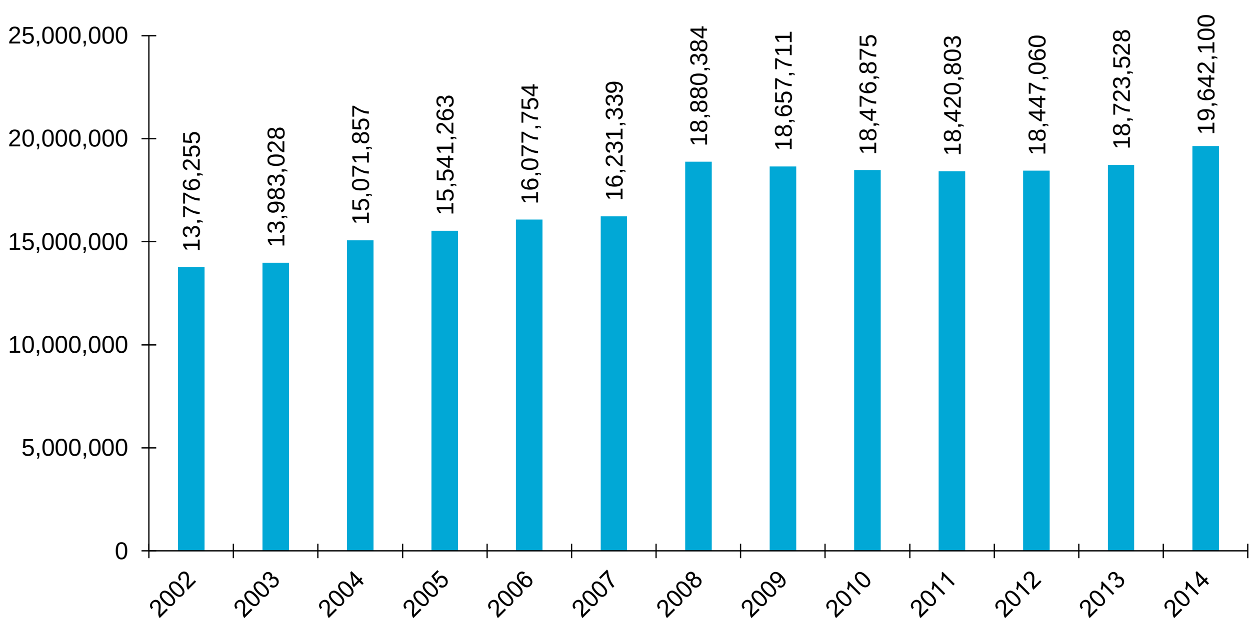
Region	2013	2040
Indian River County	51,007	91,226
St. Lucie County	81,933	151,692
Martin County	59,365	107,058
Palm Beach County	591,409	837,467
Broward County	766,025	921,019
Miami-Dade County	1,187,520	1,636,614

Source: American Community Survey, 2009-2013 5-year.
Florida Metropolitan Planning Organizations population projections.

2.2 Vehicle Availability

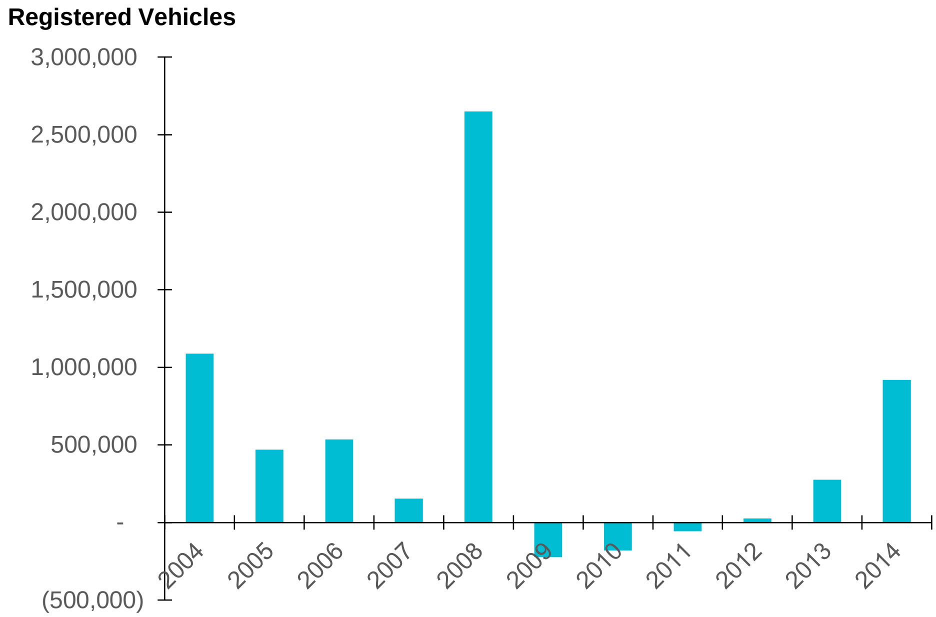
The number of registered vehicles, possessing a driver's license, and vehicle availability can all affect the number of trips taken, mode choice, and VMT. As seen in Figure 2.5, the number of registered vehicles in Florida has been growing in recent years and has increased by 4.5 million in the past 10 years, from 2004 to 2014. Meanwhile, the number of registered drivers have been also been growing overall. Figure 2.6 shows the change in registered vehicles each year, highlighting that over 1.2 million additional vehicles were registered from 2011 to 2014.

Figure 2.5 Registered Vehicles in Florida



Source: Florida Department of Highway Safety and Motor Vehicles (FLHSMV), Recurring/Periodic Reports.

Figure 2.6 Change in Registered Vehicles in Florida



Source: Florida Department of Highway Safety and Motor Vehicles (FLHSMV), Recurring/Periodic Reports.

Table 2.3 and Figure 2.7 present licensed drivers in Florida from 2003 to 2013 by age group. In the past ten years, Florida's total licensed drivers reached their peak at 14.1 million in 2007 and slightly decreased to 13.7 million in 2013.

Changes in the total number of drivers under 30 years old follow the same trends: the numbers peaked in 2007 at 3 million and dropped to 2.5 million in 2013. These drivers were 3.2 percent of Florida's total drivers in 2013 - down 1.6 percent from 2012 (4.8 percent), about half compared to their 6.3 percent in 2007 and 2008 – and their lowest share in past ten years. The reduction in driving among younger people could be the results of higher gas prices and tougher driver licensing laws, as well as the new "car-free" lifestyle. Additionally emerging technology and transportation options have played an important role in causing young people to delay or give up getting a driver's license. Younger people have had higher adoption rates of smartphone technology and social media, and have gravitated towards new ridesourcing services such as Uber and Lyft. In addition, bikesharing programs and transit service apps support a less personal car-centric lifestyle and are also popular among younger people.

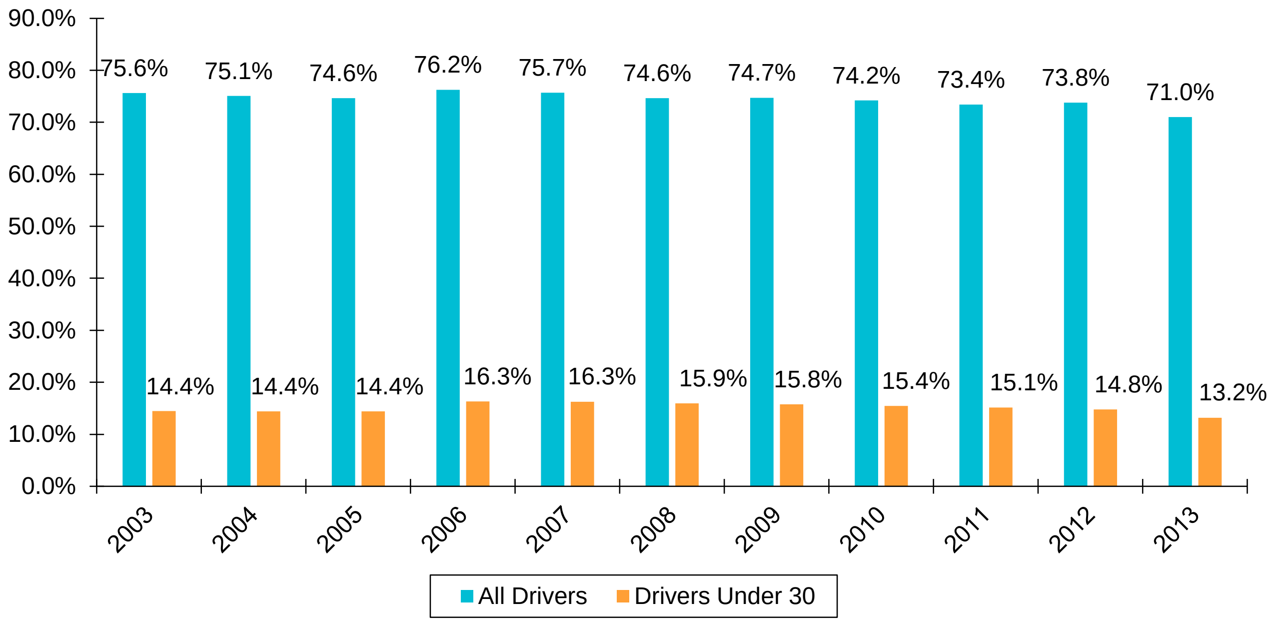
Table 2.3 Florida Licensed Total Drivers (in thousands) by Age Group

In Thousands

Year	19 and under	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85 and over	Total
2003	458	955	1,053	1,182	1,244	1,350	1,253	1,105	1,000	837	702	621	539	369	238	12,906
2004	468	978	1,076	1,178	1,237	1,375	1,290	1,146	1,051	878	721	615	527	377	230	13,146
2005	481	998	1,102	1,152	1,247	1,375	1,329	1,190	1,105	911	746	616	527	366	230	13,374
2006	770	1,080	1,148	1,138	1,269	1,367	1,365	1,235	1,131	968	773	625	523	363	234	13,989
2007	778	1,100	1,164	1,123	1,258	1,332	1,382	1,268	1,134	1,018	816	637	522	368	239	14,139
2008	760	1,095	1,140	1,083	1,206	1,271	1,375	1,278	1,139	1,040	852	656	516	374	249	14,034
2009	737	1,095	1,126	1,064	1,159	1,229	1,367	1,289	1,157	1,072	878	672	518	378	265	14,005
2010	706	1,085	1,111	1,061	1,105	1,213	1,344	1,304	1,175	1,101	892	685	516	381	270	13,950
2011	687	1,079	1,094	1,054	1,054	1,199	1,305	1,310	1,192	1,104	932	702	519	377	275	13,882
2012	621	1,077	1,088	1,057	1,037	1,187	1,268	1,322	1,218	1,100	980	742	531	379	289	13,897
2013	442	1,018	1,083	1,060	1,025	1,160	1,228	1,327	1,235	1,108	1,006	775	544	370	288	13,670

Source: FHWA, Highway Statistics Series, 2003-2013.

Figure 2.7 Licensed Drivers (Percent of Total Population) in Florida



Source: Federal Highway Administration's (FHWA) Highway Statistics Series.

Low vehicle availability can be related to income, disability, legal constraints, or lifestyle. Regardless of the reason, mode choice is affected as the option of using an automobile is curtailed if no vehicle is available. Florida's vehicle availability levels are higher than the rest of the country. Only 6.9 percent of Florida households have no vehicles (compared with a 9.0 percent average nationwide). FDOT District 4's vehicle availability levels are slightly lower than the reminder of Florida. As with the rest of Florida, the share of zero-vehicle households has been growing since 2010.

Table 2.4 provides detailed information on vehicle availability trends from 2009 to 2013 in the U.S., Florida, and southeast Florida counties. With increases in registered vehicles and licensed drivers, Florida households with no access to vehicles declined to 7.2 percent, which is below the national level of 9.1 percent in 2013. Florida households with no vehicle also declined 0.2 percent compared to 2012 (7.4 percent), and 0.1 percent compared to 2011 (7.3 percent). The share of households with only one vehicle in Florida is higher than the rest of the U.S., while the percent of households with more than one vehicle in Florida is lower than the rest of the country.

Table 2.4 Household Vehicles Availability Comparisons

Vehicles Available	2009 thousand	%	2010 thousand	%	2011 thousand	%	2012 thousand	%	2013 thousand	%
U.S.										
0	10,483	9.1	10,113	8.9	10,265	8.9	10,405	9.0	10,483	9.1
1	39,052	33.8	38,014	33.3	38,362	33.4	38,794	33.7	39,052	33.8
2	43,403	37.5	43,265	37.9	43,379	37.8	43,369	37.6	43,403	37.5
3	15,936	13.8	16,044	14.0	15,979	13.9	15,931	13.8	15,936	13.8
4 or more	6,737	5.8	6,800	6.0	6,776	5.9	6,727	5.8	6,737	5.8
Florida										
0	502	7.0	462	6.5	473	6.6	491	6.9	502	7.0
1	2,968	41.5	2,882	40.3	2,907	40.7	2,947	41.2	2,968	41.5
2	2,717	37.9	2,763	38.6	2,744	38.4	2,725	38.1	2,717	37.9
3	741	10.3	788	11.0	768	10.8	746	10.4	741	10.3
4 or more	232	3.2	257	3.6	248	3.5	237	3.3	232	3.2
FDOT District 4										
0	99	7.0	90	6.4	92	6.5	96	6.8	99	7.0
1	608	43.0	593	42.0	602	42.7	606	42.9	608	43.0
2	526	37.2	536	37.9	528	37.4	527	37.3	526	37.2
3	139	9.8	147	10.4	144	10.2	140	9.9	139	9.8
4 or more	43	3.0	46	3.2	44	3.1	43	3.0	43	3.0
Indian River County										
0	3	5.3	3	5.5	3	5.6	3	5.7	3	5.3
1	26	45.0	24	42.5	25	43.5	26	44.5	26	45.0
2	22	38.2	23	39.8	23	39.2	22	38.2	22	38.2
3	5	9.4	6	9.7	5	9.5	5	9.4	5	9.4
4 or more	1	2.2	2	2.6	1	2.2	1	2.2	1	2.2
St. Lucie County										
0	6	6.0	5	4.5	5	4.9	6	5.6	6	6.0
1	44	41.7	41	39.7	43	41.1	44	41.7	44	41.7
2	41	38.8	41	39.7	41	39.0	41	39.3	41	38.8
3	11	10.4	13	12.6	12	12.0	11	10.6	11	10.4
4 or more	3	3.1	4	3.5	3	3.0	3	2.9	3	3.1
Martin County										
0	3	4.9	3	4.6	3	4.5	3	5.1	3	4.9
1	26	44.0	25	41.9	25	42.2	26	43.1	26	44.0
2	23	37.8	23	39.0	23	39.3	23	38.4	23	37.8
3	6	10.4	7	11.1	6	10.5	6	10.2	6	10.4
4 or more	2	2.8	2	3.4	2	3.5	2	3.2	2	2.8
Palm Beach County										
0	35	6.7	32	6.2	32	6.2	33	6.4	35	6.7
1	231	43.9	227	43.4	231	44.1	231	44.0	231	43.9
2	198	37.6	199	38.0	196	37.5	198	37.8	198	37.6
3	47	9.0	49	9.3	48	9.2	47	8.9	47	9.0
4 or more	15	2.8	16	3.0	16	3.0	15	2.9	15	2.8

Table 2.4 Household Vehicles Availability Comparisons (continued)

Vehicles Available	2009 thousand	%	2010 thousand	%	2011 thousand	%	2012 thousand	%	2013 thousand	%
Broward County										
0	51	7.7	48	7.1	48	7.3	51	7.6	51	7.7
1	280	42.2	276	41.2	278	41.8	281	42.2	280	42.2
2	242	36.4	250	37.4	245	36.8	242	36.4	242	36.4
3	69	10.4	73	10.9	72	10.8	70	10.6	69	10.4
4 or more	21	3.2	23	3.4	22	3.3	22	3.3	21	3.2
Miami-Dade County										
0	93	11.3	92	11.1	91	11.1	93	11.3	95	11.4
1	324	39.1	324	39.1	326	39.5	330	39.9	331	40.0
2	293	35.4	292	35.3	290	35.1	289	35.0	288	34.7
3	87	10.5	88	10.6	87	10.6	84	10.1	85	10.3
4 or more	31	3.7	32	3.9	31	3.7	30	3.7	30	3.6

Source: Census Bureau. American Community Survey 2005-2009, 2006-2010, 2007-2011, 2008-2012, 2009-2013 5 year.

2.3 Commuting Mode

2.3.1 Commuting to Work

Work trips have traditionally been the most addressable by travel modes other than the single occupant automobile. With high personal vehicle availability both regionwide and nationwide, it is not surprising that in 2013 a large majority of Florida residents (89 percent) chose automobile as their travel mode to work, as do most Americans (85 percent) (Table 2.5).

Table 2.5 provides a comparison of Florida and U.S. travel modes for work trips. It reveals the fact that from 2010 to 2013 about 90 percent of Florida people drove alone to work, more than the national average (76 percent). Shared-ride commuting is the second most popular travel mode compared to other modes. From 2010 to 2013, fewer people carpooled to work or took transit to work, but the numbers for working at home increased. In 2013, transit carried 2.1 percent of the Florida population to work (the national average commuter transit share is 5.2 percent). However, Florida transit boardings have been growing since 2010, after a dip from the 2008 recession (Figure 2.9).

Table 2.6 presents commuting flows from/to counties in south Florida. Miami-Dade is the county that attracts the most trips. Approximately 1.2 million people travel to Miami-Dade to work. About 11 percent of these commuters live in Broward county. In the future, population and employment are expected to keep growing and will directly contribute to intra-county and inter-county trips in south Florida, potentially creating additional demand for new transportation infrastructure and services.

Table 2.5 Means of Transportation to Work

	2010		2011		2012		2013	
Mode	**FL**	**U.S.**	**FL**	**U.S.**	**FL**	**U.S.**	**FL**	**U.S.**
Car, truck, or van:	73,349	1,202,590	72,913	1,203,154	72,561	1,205,519	72,358	1,203,567
Drove alone	64,865	1,058,407	64,633	1,061,387	64,439	1,065,198	64,363	1,067,255
Carpooled	8,483	144,183	8,281	141,768	8,122	140,321	7,994	136,313
Public transportation	1,602	68,727	1,601	69,151	1,647	69,677	1,660	70,007
Bicycle	484	7,165	492	7,446	520	7,857	534	8,025
Walked	1,325	39,621	1,279	39,482	1,267	39,384	1,260	39,228
Other means	1,315	16,850	1,294	16,751	1,286	16,723	1,252	16,575
Worked at home	3,580	57,597	3,691	58,898	3,794	59,776	3,878	60,464

	2010 (%)		2011 (%)		2012 (%)		2013 (%)	
Mode	**FL**	**U.S.**	**FL**	**U.S.**	**FL**	**U.S.**	**FL**	**U.S.**
Car, truck, or van:	90.6	86.4	90.1	86.3	89.6	86.2	89.4	86.1
Drove alone	80.1	76.0	79.9	76.1	79.6	76.1	79.5	76.3
Carpooled	10.5	10.4	10.2	10.2	10.0	10.0	9.9	9.8
Public transportation	2.0	4.9	2.0	5.0	2.0	5.0	2.1	5.0
Bicycle	0.6	0.5	0.6	0.5	0.6	0.6	0.7	0.6
Walked	1.6	2.8	1.6	2.8	1.6	2.8	1.6	2.8
Other means	1.6	1.2	1.6	1.2	1.6	1.2	1.5	1.2
Worked at home	4.4	4.1	4.6	4.2	4.7	4.3	4.8	4.3

Source: Census Bureau, American Community Survey 5-year.

Table 2.6 Commuting Flow by County

Commuting flow			**Workplace**		
Residence	Martin	Palm Beach	Broward	Miami-Dade	Total work place
Martin	**37,296**	12,240	491	289	832,065
Palm Beach	3,133	**505,952**	46,183	4,859	57,043
Broward	371	52,535	**640,362**	126,681	1,122,339
Miami-Dade	121	3,898	68,970	**1,036,685**	575,037
All other counties	18,544	16,784	10,019	16,006	61,353
Total work place	59,365	591,409	766,025	1,187,520	

Source: 2009-2013 American Community Survey.

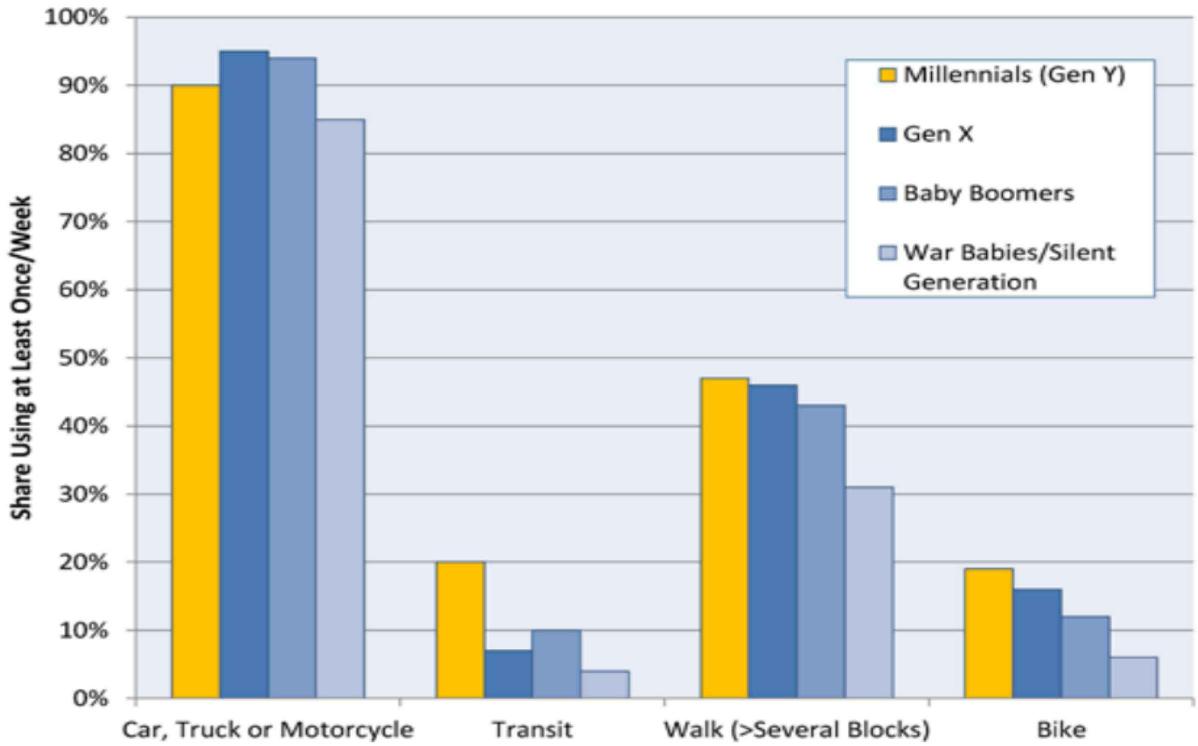
Figure 2.8 Florida Transit Boardings

Source: FTIS and Florida Transit Handbook (Fixed Route Transit Ridership only)

A 2013 survey by the Urban Land Institute (ULI)[3] found that Millennial commuters are less dependent on cars than older generations. 77 percent of Millennials travel by car, compared to 90 percent of Baby Boomers and 92 percent of Generation X. Millennials also tend to choose transit, biking and walking: 20 percent of Millennials take transit every week, while only 7 percent of Generation X and 10 percent of Baby Boomers use transit every week (Figure 2.9). Younger generation mode choices are leaning more towards transit and other non-driving alternatives. Between 2006 and 2013, trips by car by young people (16 to 24 years old) dropped by 1.5 percent, greater than older age groups (Figure 2.10).

[3] Urban Land Institute (2013) America in 2013: ULI Survey on Housing, Transportation and Community, Appendix A.

Figure 2.9 Millennials' Day-to-Day Transportation Experience from Other Generations[4]

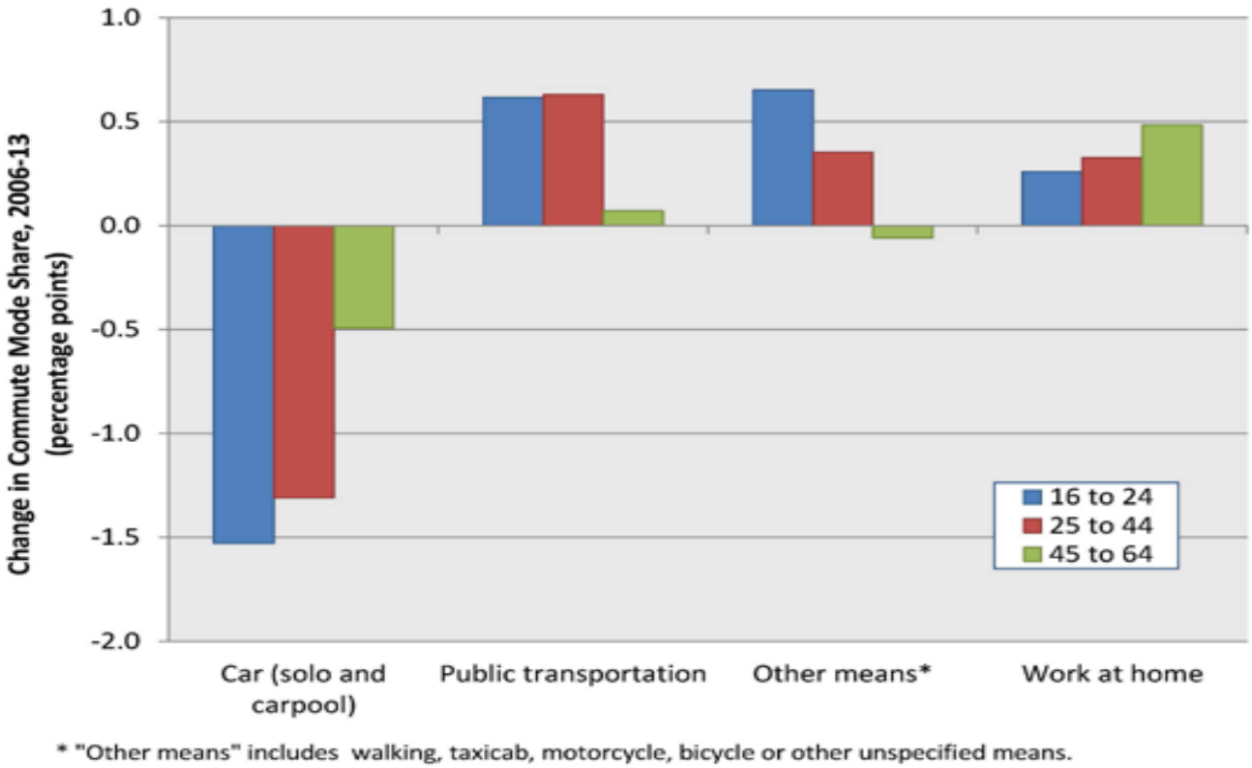


Source: Dutzik et al., 2014 citing data from ULI, 2013[5]

[4] Dutzik, T., J. Inglis and P. Baxandall (2014) Millennials in Motion: Changing Travel Habits of Young Americans and the Implications for Public Policy, U.S. PIRG, Boston. http://www.uspirg.org/sites/pirg/files/reports/Millennials%20in%20Motion%20USPIRG.pdf Accessed October 1, 2015.

[5] ULI (2013) America in 2013:A ULI Survey on Housing, Transportation and Community.

Figure 2.10 Millennials' Day-to-Day Transportation Experience from Other Generations[3]



Source: Dutzik et al., 2014 citing data from National Household Travel Survey 2010 and 2009 data.

2.3.2 Ridesourcing

App-based, on-demand ride services such as Uber and Lyft, are becoming a new favorite among consumers. As do recent transportation researchers, we refer to these services as ridesourcing. These services allow a smartphone to be used to both summon a car and pay the expense. The services inform the user where the car is and when the car is arriving; are cheaper than conventional taxis; are convenient, clean, and reliable; and they free their riders from the hassles of parking.

A survey on ridesourcing users in San Francisco suggested that "ease of payment," "short wait time," and "fastest way to get there" are the most common reasons for people to choose ridesourcing instead of other commuting modes. The majority of ridesourcing users are members of the younger generation, 57 percent of them are 25 to 34 years old. 8 percent the survey participants reported that they would not have made the trip at all if Uber/Lyft/Sidecar was not available, suggesting that these services are expanding mobility[6].

Uber provides more than 1 million rides each day in 311 cities in 58 countries. Besides providing commuter rides, Uber has begun experimenting with local delivery services in logistics. UberEATS operates in five cities, including three cities in the U.S.: Chicago, Los Angeles, and New York. UberPool offers carpooling

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[6] Rayle, L., S. Shaheen, N. Chan, et al. (2015) App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco. 94th TRB Annual Meeting, Washington, D.C.

services in San Francisco and urges people to use its low-cost service (merely $7 around the city) instead of transit. Uber is also reported to be planning to start same-day delivery for various retailers in America[7].

As of December 2013, Uber provided 140,000 trips every week in New York City. It appears to be the substitute for taxis in areas outside Manhattan's central business district (CBD). Uber ridership has increased from 4.8 million to 7.3 million per year in two years while yellow-taxi rides have fallen by 600,000 per year. However, within the CBD, the 1.8 million Uber rides in the past two years turned out to be mostly new riders[8].

A survey of 630 Millennials (401 Florida residents and 229 non-residents who plan to visit Florida) indicates that Millennials (both Florida residents and non-residents) use ridesourcing services for recreational trips more than for work/school trips (2 percent versus 1 percent). Florida Millennials use ridesourcing services as often as a taxi services for recreational trips. 10 percent of Florida residents responded that they are intending to use ridesourcing more in the future, while 20 percent of non-residents responded that they intend to use ridesourcing services more. The study suggested that increased access to ridesoucing services will close the gap between the reported future intention to use and the reported actual use[9].

2.4 Peak Car Travel

The theory of peak car travel puts forth that vehicle use (vehicle miles travelled per capita) has peaked and will now fall in a sustained manner in the years to come. Garceau[10] studied the trends by looking at peak car travel at a state level and the relationship between driving and economy in the past two decades. Garceau found that car travel in America peaked in 2004 after continuous growth for over half a century. Presented in Figure 2.11, total VMT in the nation follows a similar pattern and peaked after 2005, total VMT and VMT per capita were both in decline from 2007 to 2013, but started increasing again after 2013.

At the state level, peak car travel first occurred at as early as in 1992 in Washington State while another 10 states peaked as of 2000. By 2011, 48 of the 50 states appeared to have peaked. Florida is one of 15 states that appeared to peak after 2000. Figure 2.12 indicates that Florida appeared to peak at 11,332 VMT per capita in 2005 and then experienced a decline in VMT per capita over the next several years.

From 2013 to 2014, however, as with national trends, Florida VMT and VMT per capita started to rise again. Garceau found a decoupled relationship between GDP per capita and VMT per capita when they are closely correlated at both the national and state level. In some cases this relationship was negative but in most states the relationship has been insignificant for the most recent time period.

Table 2.7 demonstrates that in the 1980s, Florida had an insignificant correlation between driving and economy. But during 1990 to 1999 and 2000 to 2011, like most states in the country, there was a strong positive correlation between driving (VMT per capita) and economy (GDP per capita) in Florida. This could

[7] ----- (2015) Uber: Driving Hard *The Economist*, June 13.

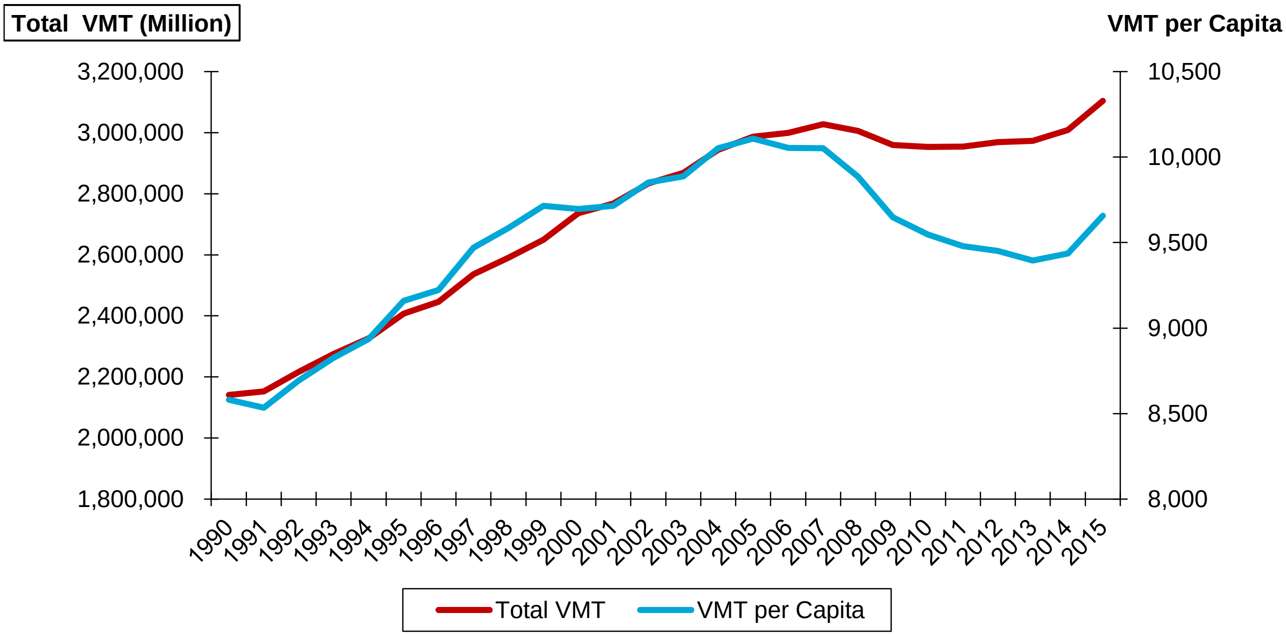
[8] ----- (2015) Taxis v Uber: A Tale of Two Cities *The Economist*, August 15.

[9] Future Users of Transportation: Final Report. Prepared for the Florida Department of Transportation by The Agency, College of Journalism and Communications, University of Florida. July 2015.

[10] Garceau, T., C. Atkinson-Palombo, and N. Garrick (2015) Peak Car Travel in the United States: A Two-Decade Long Phenomenon at the State Level. In Transportation Research Record: Journal of the Transportation Research Board, No. 2531.

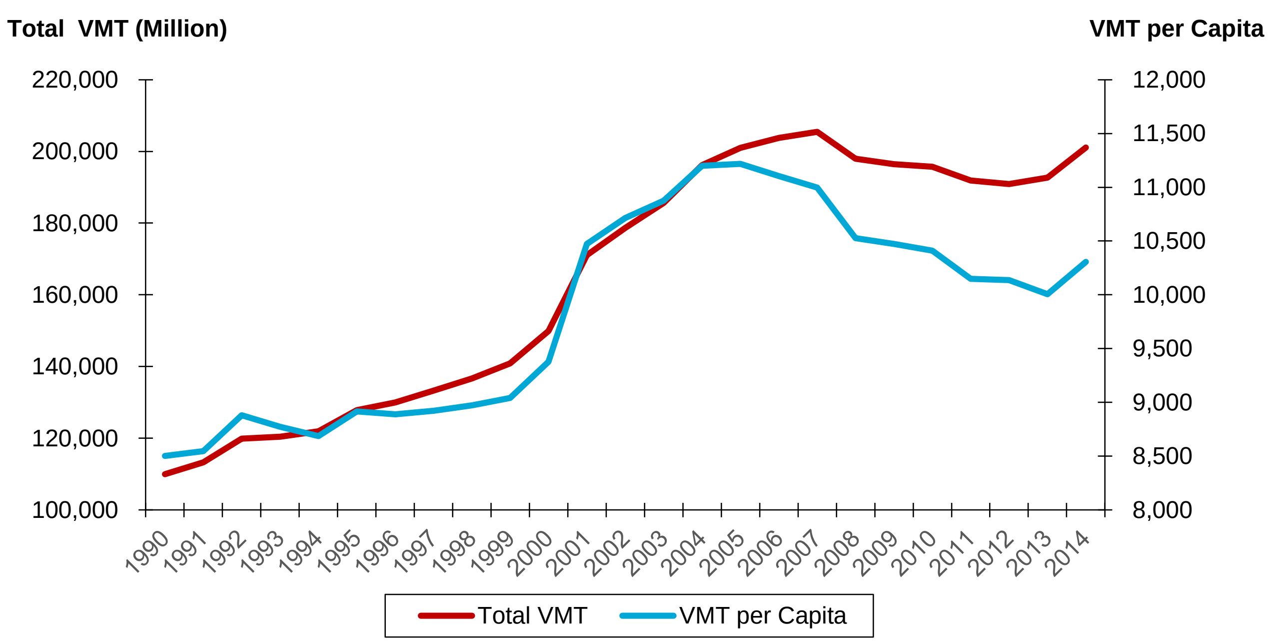
explain the dip and subsequent recovery in VMT per capita and suggests that further study is needed to assess if peak car travel has indeed occurred in Florida or the nation.

Figure 2.11 U.S. Peak Car Travel



Source: FHWA Traffic Volume Trends Report and Census Bureau.

Figure 2.12 Florida Peak Car Travel



Sources: Florida Highway Data Source Book; Florida Public Road Mileage Reports; BEBR, University of Florida.

Table 2.7 Florida Peak Car Travel Patterns and Regression Results

Travel Patterns	1980	2005	2011
VMT per Capita	8,106	11,332	10,054
GDP per Capita	27,420	44,119	39,168
Regression Results	**1980-1989**	**1990-1999**	**2000-2011**
R-Square (Slope direction)	0.34*(+)	0.85***(+)	0.70***(+)

Note: *** Significant to 1% level; ** Significant at 5% level; * Significant at 10% level.

Source: Timothy J. Garceau, Carol Atkinson-Palombo, Norman Garrick, University of Connecticut.

2.5 Millennials' Behavior Trends

As discussed in previous sections, Millennials (normally defined as people born between 1983 and 2000) appear to make different travel choices than older generations: they are driving less and biking and walking more. Dutzik and Inglis's[11] suggest that there are many factors contributing to these apparent shifts:

- Socioeconomic changes, like the Great Recession, which has led to high unemployment and low income among young people, has forced young people to live with their parents, and consequently to drive less;
- Technology changes and new transportation services like bikesharing, real-time transit apps, and ridesourcing provide a range of new options for transportation besides driving. Millennials have been the first to adopt these new technologies and become less car focused; and
- Location preference changes are evident among young people 20 to 29 years old – this demographic has been less likely to locate in the suburbs (unlike previous generations) and is instead living in transit-served environments.

Millennials are also engaging in different timing of their life cycles, further contributing to the changes observed in their traveling behaviors. As shown in Table 2.8, more young people (age group 15-19 years and 20-34 years) are entering marriage later. Both male and female Millennials showed 4 percent growth in the total number of singles from 2009 to 2013. The median age for first marriage of men increased from 27.5 to 29.0 years old in 2013; the median age for the first marriage of women increased from 25.6 to 26.6 years old[12]. Later marriage has resulted in delayed childbirth and enhanced the appeal of continuing to live with parents. Both due to the higher costs of housing and these phenomena, Millennials have a lower rate of homeownership than other generations[13].

[11] Dutzik, T., J. Inglis and P. Baxandal (2014) Millennials in Motion: Changing Travel Habits of Young Americans and the Implications for Public Policy, U.S. PIRG, Boston. http://www.uspirg.org/sites/pirg/files/reports/Millennials%20in%20Motion%20USPIRG.pdf Accessed October 1, 2015.

[12] U.S. Census Bureau, Families and Living Arrangements: Marital Status, Table MS-2.

[13] Jed Kolko. (2014) More Millennials Leave Parental Nest, Without Lifting Housing Market. Huffington Post.

Table 2.8 Marital Status by Age and Gender

	United States						Florida					
	Total (thousand)		Now married (%)		Never married (%)		Total (thousand)		Now married (%)		Never married (%)	
	2009	2013	2009	2013	2009	2013	2009	2013	2009	2013	2009	2013
15 years and over	240,147	250,403	50.3	48.8	30.8	32.2	14,879	15,794	49.9	47.0	28.3	30.5
AGE AND GENDER												
Males 15+	117,167	122,004	52.3	50.6	34.1	35.4	7,241	7,648	52.1	49.2	32.1	34.2
15 -19	11,067	11,144	1.0	0.7	98.8	99.1	604	619	1.1	0.7	98.5	99.2
20-34	31,463	32,301	32.8	29.0	62.0	66.2	1,785	1,834	30.2	24.7	63.6	69.9
35+	74,637	78,559	68.2	66.6	12.8	13.8	4,853	5,195	66.5	63.6	12.3	13.9
Females 15+	122,980	128,399	48.4	47.0	27.7	29.1	7,638	8,146	47.8	45.0	24.6	26.9
15-19	10,476	10,571	1.9	1.4	97.7	98.4	567	583	1.8	1.3	97.8	98.5
20-34	30,144	31,510	39.7	36.0	52.1	56.5	1,683	1,789	38.2	31.8	52.2	59.3
35+	82,361	86,318	57.4	56.6	9.8	10.6	5,389	5,773	55.7	53.5	8.3	9.7

Source: Census Bureau, American Community Survey 5-year.

Case and Schipinski's research results for the Hampton Roads MPO in Virginia support the assumption that Millennials behave differently, especially with respect to travel behaviors, as compared with other generations. They analyzed 2009 National Household Travel Survey (NHTS) data in Hampton Roads, and found that 4 percent of Millennials used alternative modes like transit and bicycle compared to 2 percent of other generations. However, their study also suggests that the apparent inclination of Millennials toward driving less will likely not endure. They ascribe much of the observed differences in Millennial behavior to the economic effects of the era in which this generation has been introduced. Despite the acknowledged current increase in demand for alternative transportation by Millennials in Hampton Roads, Case and Schipinski do not expect a continuous leap in demand in the future.

2.6 Trends of Secondary Effects

2.6.1 Environmental Trends

Emissions associated with combustion engines used to power motor vehicles lead to environmental impacts related to air quality. Emissions may take the form of "criteria pollutants," such as carbon monoxide (CO), lead (Pb), nitrogen oxides (NOx), ozone (O3), particulate matter (10 microns or less in diameter (PM10) and 2.5 microns or less in diameter (PM2.5)), and sulfur dioxide (SO2), which are addressed with national air quality standards that define allowable concentrations of these substances in ambient air. Emissions may also take the form of greenhouse gas emissions, such as carbon dioxide (CO2).

The U.S. Environmental Protection Agency (EPA) Motor Vehicle Emission Simulator (MOVES) can be used with travel demand forecasting models to estimate vehicle emissions. MOVES uses model output about travel demand, including vehicle miles of travel and speed conditions, and inputs about the vehicle fleet composition to arrive at its emission estimates.

Vehicle fleet factors such as age, type, fuel economy, fuel composition significantly affect vehicle emission estimates. Prevalence of technologies such as hybrid vehicles and electric vehicles can also be considered. Similarly, the presence of connected and autonomous vehicles can influence emissions characteristics. For example, more efficient operating practices could improve fuel efficiency. Such connected and autonomous vehicles could avoid rapid acceleration and braking thereby minimizing fuel use. Closer vehicle spacing into platoons could reduce highway fuel use by 20 percent. Additionally, autonomous vehicles could eliminate the need for some safety features, reducing overall vehicle weight and further improving fuel economy. One study has found that connected vehicles have the potential of reduce emissions by 37 percent[14].

Less overall driving is another dimension to potential future emission reductions which could be explored under evaluations of demographic and travel behavior changes. Millennials are shown to prefer to live in denser areas which can lead to shorter trips to address activities and can facilitate greater use of public transportation. Public policy shifts towards greater investment in improved public transportation service, coupled with the apparent preference of Millennials to drive less than other generations, can magnify the potential of changes in travel demand, especially reduced driving, to contribute to a reduction in transportation emissions.

With these potentials introduced, it is worthwhile to consider greenhouse gas emission levels over time in the U.S. and in Florida. Figure 2.13 shows U.S. sector and total greenhouse gas emission since the early 1990's.

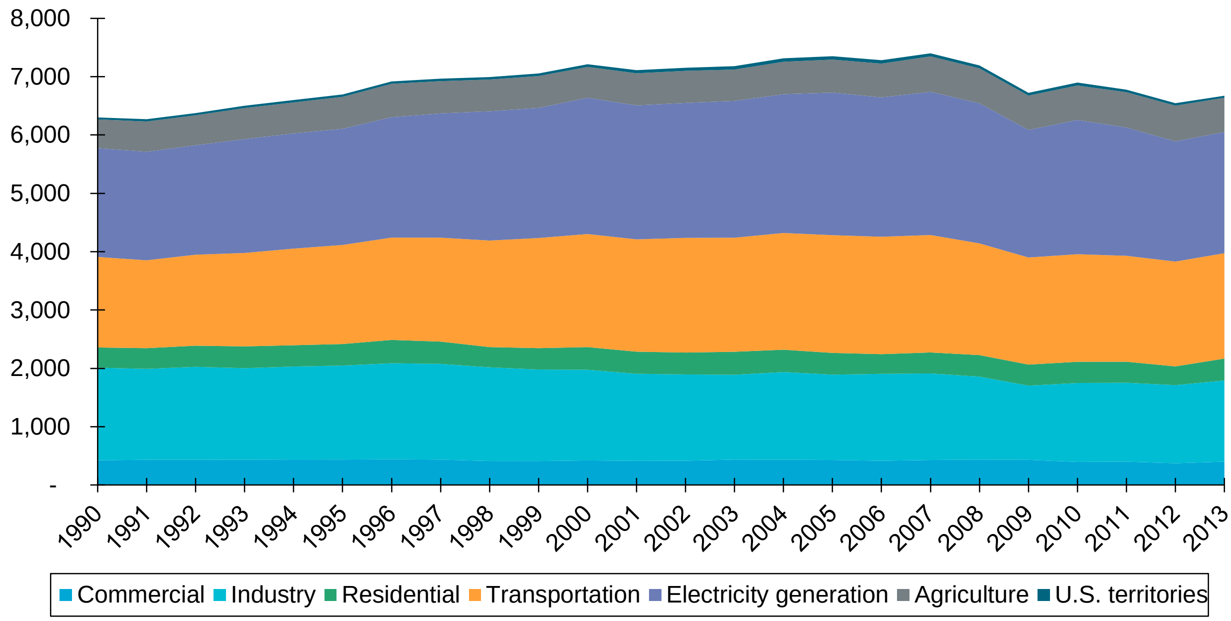
Figure 2.14 shows the same for Florida.

Figure 2.15 indicates that in the U.S., greenhouse gas emissions produced by the transportation sector represent 27 percent of the total, compared with 31 percent of the total produced by the electric power sector. In comparison, for Florida, the transportation sector accounts for 46 percent of greenhouse gas emissions. Reducing greenhouse gas emissions in the transportation sector in Florida could thus significantly impact the state's total greenhouse gas emissions. Accordingly, one of the major goals of Florida Transportation Plan (FTP)[15] to have "transportation solutions that enhance Florida's environment and conserve energy."

[14] Olia, A., H. Abdelgawad, B. Abdulhai, and S. Razavi (2015) Assessing the Potential Impacts of Connected Vehicles: Mobility, Environmental, and Safety Perspectives. Journal of Intelligent Transportation Systems, 1-15.

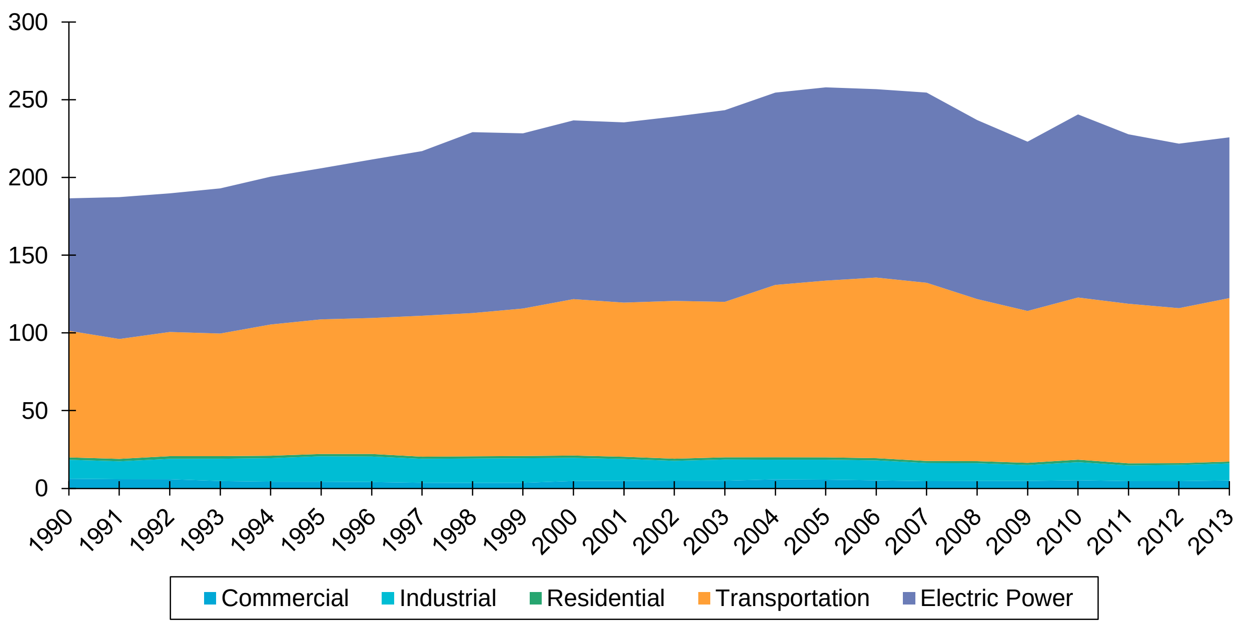
[15] Florida Department of Transportation (2015) Florida Transportation Plan Vision Element. http://www.floridatransportationplan.com/pdf/FDOT_FTP-SIS_VisionElement.pdf retrieved January 21, 2016.

Figure 2.13 U.S. Greenhouse Gas Emissions by Economic Sector, 1990-2013



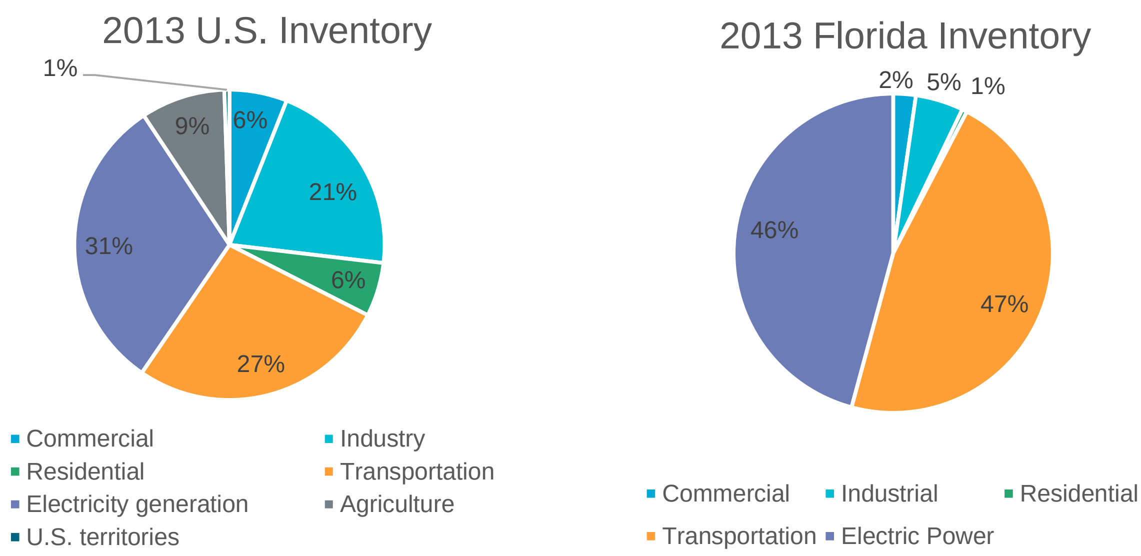
Source: U.S. Environmental Protection Agency

Figure 2.14 Florida Greenhouse Gas Emissions by Economic Sector, 1990-2013



Source: U.S. Environmental Protection Agency

Figure 2.15 Greenhouse Gas Emissions by Economic Sector 2013

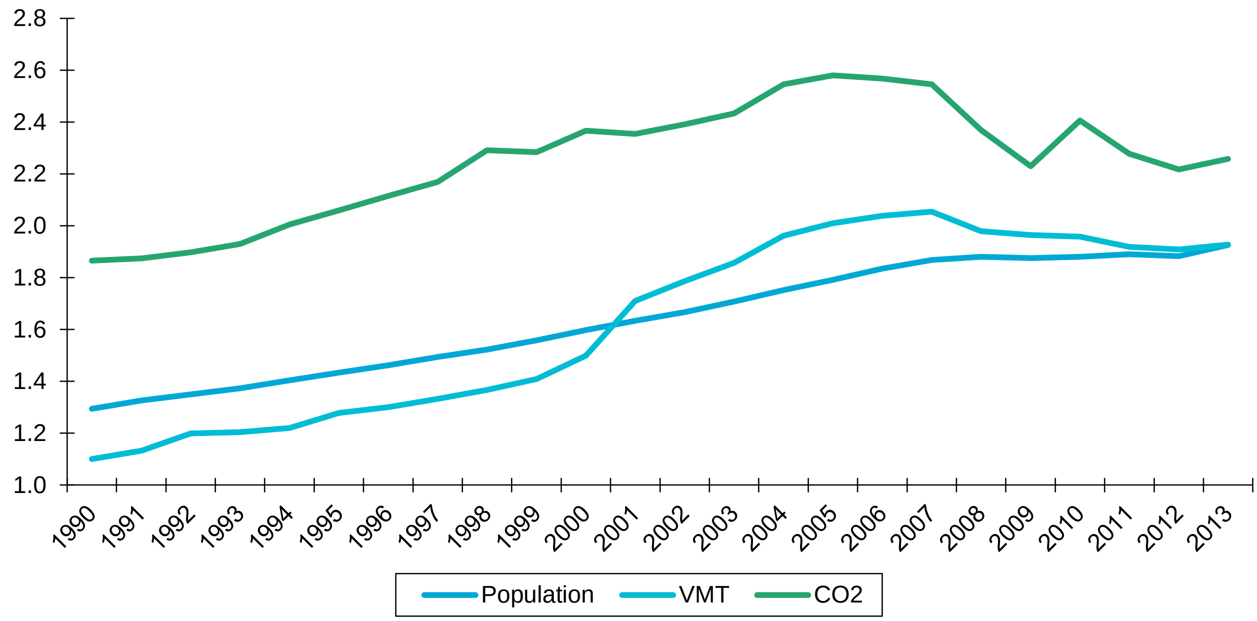


Source: U.S. Environmental Protection Agency

Figure 2.14 indicates the relative trends of CO_2 emissions, population, and VMT in Florida. Carbon dioxide emission levels generally track with population and VMT changes. However, emerging technologies and government regulations can be seen having pushed CO_2 emission levels down relative to population and VMT levels in recent years. Specifically, fuel switching; improving fuel efficiency with advanced design, materials, and technology; improving operating practices; and reducing travel demand contribute to reduced emissions from transportation[16].

[16] EPA. (Sources of Greenhouse Gas Emissions http://www3.epa.gov/climatechange/ghgemissions/sources/transportation.html#Trends

Figure 2.16 Relative Trends of Population, VMT, and CO_2

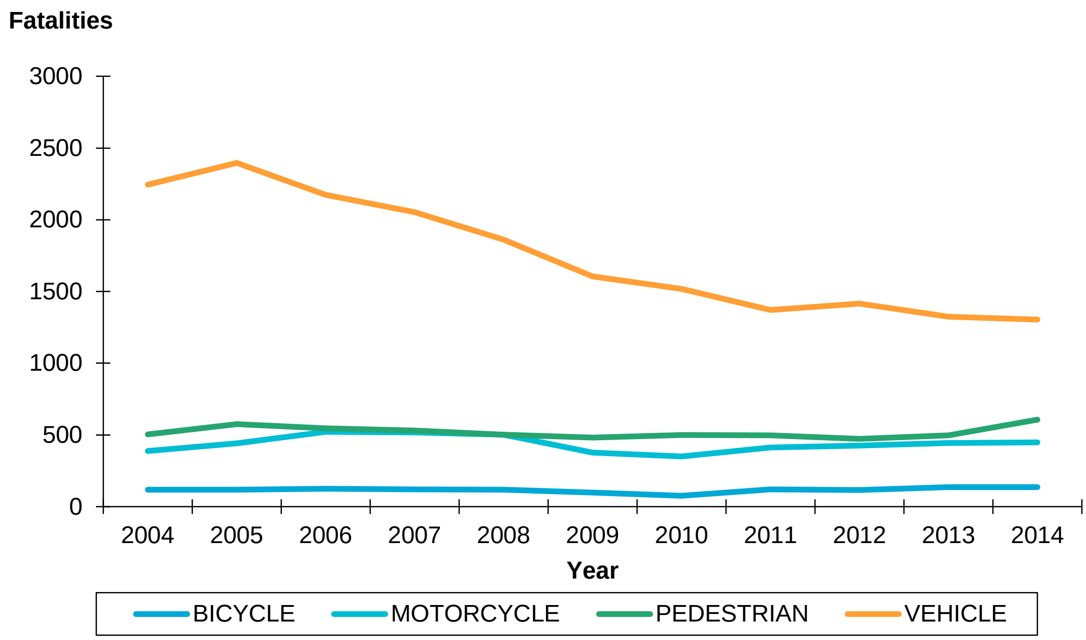


Source: EPA, FHWA, FDOT

2.6.2 Safety Trends

Total traffic fatalities have been dropping in the U.S. since 2006. In Florida, the five-year rolling average for total traffic fatalities decreased more than 26 percent (dropped from 3,3311 to 2,434) from 2007 to 2014, and remained below 2,500 fatalities. Figure 2.17 provides trends of Florida traffic fatalities by type from 2004 to 2014, it shows that in 2014 over 50 percent of Florida traffic fatalities are vehicle fatalities, around 24 percent are pedestrians and 18 percent are motorcyclists.

Figure 2.17 Florida Bicyclists, Motorcyclist, and Pedestrian Traffic Fatalities



Source: Florida Department of Highway Safety and Motor Vehicles

Comprehensive crash-avoidance technology, augmented-reality windshields, network-based traffic alerts, and dynamic infrastructure are future automotive safety features that could improve vehicle safety[17]. The U.S. Department of Transportation (USDOT) National Highway Traffic Safety Administration (NHTSA) suggests that the evolution of vehicle electronics will improve crash avoidance and mitigate injuries[18].

The automotive industry has been focused on using sensor-based technologies and connected-vehicle communication technologies for collision avoidance, with an ultimate goal of producing vehicles that are crash-free. Sensor-based solutions use Advanced Driver Assist Systems (ADAS), such as lane-keeping and warning and adaptive cruise control, to improve vehicle safety in speed zones. Connected vehicles increase safety by using wireless communication among vehicles and between vehicles and infrastructure[19]. Connected vehicles could reduce the probability of an incident by up to 45 percent.[20]

When vehicle automation, which converges connected vehicle and sensor-based technologies, reaches Level 3 and Level 4, where the vehicle takes control of all safety-critical functions, monitors road conditions,

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[17] Sadlier, J. (n.d.) 5 Futuristic Vehicle Safety Features http://www.driverside.com/auto-library/5_futuristic_vehicle_safety_features-976. Retrieved November 10, 2015.

[18] Maddox, J. (2012) Improving Driving Safety Through Automation. NHTSA. http://www.roboticscaucus.org/schedule/2012/Automationforsafety-CongressionalroboticsCaucus-Maddox7-25-12.pdf. Retrieved November 10, 2015.

[19] KPMG (2012) Self-driving cars: The next revolution. Available at: https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-next-revolution.pdf as of May 5, 2015.

[20] Olia, A., H. Abdelgawad, B. Abdulhai, and S. Razavi (2015) Assessing the Potential Impacts of Connected Vehicles: Mobility, Environmental, and Safety Perspectives. Journal of Intelligent Transportation Systems, 1-15.

and communicates with other vehicles, safety threats could be greatly diminished. Automated vehicles could provide better vehicle operation practices and eliminate driver distraction, blind spots, drunk driving, and aggressive driving. Furthermore, pedestrian and bicyclist collisions, among the most catastrophic in terms of injury and loss of life, can be avoided.

3.0 Key Parameters and Data Needed for Scenario Testing

As discussed in the first phase of this work, Emerging Technology, Demographic Changes, and Travel Behavior – Literature Review:

- Information and Communication Technology (ICT) eliminates travel trips and therefore influences trip rates for modeling future travel demand; and

- Autonomous vehicles have the potential to provide an relaxing in-vehicle experience as well as safer and more efficient trips which affect the trip length distribution for modeling the future.

Building on the literature review, this section discusses potential parameters that can be changed to model alternative scenarios involving these emerging technologies.

3.1 Generational Effects

As discussed in Section 2.0, different generations, especially Millennials, behave differently. As shown in Figure 2.9, Millennials are shifting from car to other travel modes, and they are continuing to drive less. High gas prices, tougher driver licensing laws, lower income, and complex living arrangements all seem to contribute to their inclination to reduce driving[21].

Compared to other generations, Millennials are more easily attracted to emerging technology, and have adopted many of the new transportation options, such as ridesourcing, bikesharing, and transit tracking services. Emerging technology creates new mobility options and allows for reduced car ownership and, therefore, driving.

As introduced in Section 2.5, Case and Schipinski[22] performed an analysis for the Hampton Roads MPO, to address the questions of 1) how different Millennial transportation use is from that of other generations and 2) how enduring this different behavior is expected to be. For the first question, they discovered that from 2001 to 2009, workers aged 16 to 34 (Generation X plus Millennials) shifted somewhat from cars to public transit, walking, and biking; workers aged 16 to 24 (Millennials) shifted somewhat from cars to transit and other means between 2006 and 2013.

On the question of whether Millennial travel behavior differences will endure, Case and Schipinski concluded that they may not. They found that even though generational differences were positively correlated in terms of reduced driving and use of transit and other active travel modes, the effect of a "negative era" (poor economy, war period, etc.) is much greater. Their conclusion was that while Millennials have a moderately stronger inclination towards alternative transportation, it is reasonable to believe that as negative era influences are reduced, Millennial travel behavior will tend to be more like that of the preceding generation.

[21] Polzin, S., C. Xuehao, and J. Godfrey (2014) The impact of Millennials' travel behavior on future personal vehicle travel, Energy Strategy Reviews, Center for Urban Transportation Research, University of South Florida, vol. Tampa.

[22] Robert B. Case, P.E., Ph.D., S. Schipinski (July 2015) Mode Choices of Millennials: How Different? How Enduring? DRAFT. http://www.hrtpo.org/uploads/docs/Millennials%20Report%20DRAFT%20wo%20cover.pdf Retrieved October 1, 2015.

In developing future scenarios, the possibility that the current travel preferences of Millennials will evolve should also be considered.

3.2 Capacity of Freeway and Major Arterial Segments

Vehicle capacity, link length, and travel speed are highway network attributes needed by a transportation model to help describe the transportation supply. In traffic engineering, capacity traditionally represents the volume at Level of Service (LOS) E[23]. In terms of evaluating impacts of vehicle automation, one of the key parameters identified by previous literature and practices as an influenced parameter is the vehicle flow capacity of freeway and major arterials. Since automated vehicle (AV) technologies promise reduced spacing of vehicles, steady flow with limited traffic interruptions, and (potentially) higher speed limits, more vehicles could be allowed on a roadway in a defined period of time[24].

To date, a few literature and modeling efforts have addressed the potential impacts of AVs. Tientrakool found that using vehicle sensors could add an additional 43 percent of highway capacity; if using both sensors and vehicle-to-vehicle communications, the increase in capacity is about 273 percent[25].

Using "Travel Model One," the San Francisco Metropolitan Transportation Commission's (MTC) Activity-Based Model (ABM), Gucwa developed a random utility model to analyze the difference across eight scenarios. In his research, roadway capacity and the value of in-vehicle time are considered as two primary parameters influencing model outputs[26]. Gucwa applied three different factors for roadway capacity dimension: no change for "base scenarios"; 10 percent increase in capacity under a "low roadway capacity scenarios"; and a doubling of capacity under a "high roadway capacity scenarios" (see Table 4.19 for scenario look-up table).

The Puget Sound Regional Council (PSRC) used their ABM, "SoundCast," to test a series of alternative scenarios to evaluate the impacts of including automated vehicles into the roadway network. They assumed a 30-percent increase in roadway capacity. Additionally, PSRC modeled that not all costs of auto use were passed on to the user of automated vehicles[27].

Under the assumption that in 2040 automation of driverless cars has reached Level 4 (full-self-driving automation for which no driver involvement is needed), Atlanta Regional Commission (ARC) assumed that including AVs into the 2040 network would lead to 50 percent increase in roadway capacity in their study on AV impacts using their ABM[28].

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[23] Cambridge Systematics Inc., Vanasse Hangen Brustlin Inc., et al. (2012) Travel Demand Forecasting: Parameters and Techniques, NCHRP Report 716, National Cooperative Highway Research Program. Project 08-61: Chapter 3, Chapter 6.

[24] Bierstedt, J. et al. (2014) Effects of Next – Generation Vehicles on Travel Demand and Highway Capacity. Available at: http://orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf as of May 20,2015.

[25] Tientrakool, P., Y. Ho, N.F. Maxemchuk (2011) Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance. Vehicular Technology Conference, IEEE.

[26] Gucwa, M. (2014) Mobility and Energy Impacts of Automated Cars. Presented at the 2014 Automated Vehicle Symposium, San Francisco, California.

[27] Childress, S., B. Nichols, B. Charlton, S. Coe (2015) Using an Activity-Based Model to Explore Possible Impacts of Automated Vehicles. Presented at the 94th TRB Annual Meeting, Washington, D.C.

[28] Kim, K. et al. (2015) The Travel Impact of Autonomous Vehicles in Metro Atlanta through Activity-Based Modeling. Presented at the 15th TRB National Transportation Planning Applications Conference, Atlantic City, New Jersey.

3.3 Value of In-Vehicle Time (IVT)

Previous studies suggested that being driven by a full self-driving vehicle will be less onerous than driving in congested and frustrating traffic; therefore commuters would be willing to tolerate longer IVT, and possibly have longer trip distances. However, the actual influence of vehicle automation on travel time factors is still unknown. Additionally, comfort level and productivity are generally hard to represent in forecasting models. Instead, these factors can be represented by travel time, and modeled under the assumption that a relaxing and comfortable experience in AVs is equal to a reduction in travel time[8].

ARC assumed that AV technology eases travel time disutility by reducing stressful in-vehicle travel time, increasing in-vehicle productivity, and influencing mode choice utilities. To reflect this assumption, ARC adjusted IVT coefficients for autos to 50 percent of current value in their tour and trip mode choice utility expression calculators (UECs) files. In the MTC study, value of time (for IVT) was decreased 50 percent for the “L scenarios” and a zero cost was used for IVT for the “0 scenarios” (see Table 4.19 for scenario look-up table). PSRC used two scenarios to consider the impact on value of time (VOT): in one scenario, important trips are in AVs (only the highest-income households were influenced); in the second scenario, all cars are self-driving and none are shared -- VOT changes for households of all incomes. In both scenarios, for households that own AVs, trip-based VOT is reduced by 65 percent.

3.4 Parking Cost

Parking is one of the urban area characteristics that affects planning and modeling. In an AV transportation system, the need for nearby parking is potentially reduced -- cheaper parking farther away could potentially be utilized instead, significantly reducing parking cost. This change in travel behavior could, however, increase VMT considering the additional return trips from distant parking lots. With the resulting reduced parking cost, mode choice could be influenced – travelers previously encouraged to use transit by high parking costs may switch to using AVs.

Another potential AV phenomenon, sharing of vehicles, could also impact parking demand and infrastructure. AV sharing would keep vehicles in more constant use thereby reducing the need to find parking spaces at all.

To model the impact of parking cost reduction, ARC adjusted parking cost at the primary destination to zero, assuming that all AVs drop off passengers their destinations and park in a cheaper location farther away. PSRC similarly assumed that AVs help avoid parking in high parking cost areas and enable more efficient use of parking spaces. A 50 percent reduction in parking costs from current cost levels was assumed in all zones.

Modeling potential additional VMT generated from parking in secondary locations is much more complicated, requiring knowledge of alternative parking costs, parking locations, and trip tour timing[29].

[29] Childress, S., B. Nichols, B. Charlton, and S. Coe (2014) Using an Activity-Based Model to Explore Possible Impacts of Automated Vehicles. Transportation Research Board Annual Meeting 2015 Paper.

3.5 Auto Operating Cost

KPMG pictured a future network where AVs would decrease energy consumption in at least three primary ways: more efficient driving; lighter, more fuel-efficient vehicles; and efficient infrastructure. Efficient driving includes improved navigation along the best routes, closer spacing, and higher speed limits[30]. New Corporate Average Fuel Economy standards were put in placed in 2012, requiring automakers to raise the average fuel efficiency of new cars and trucks to 54.5 miles per gallon by 2025, double 2010's 27.5 mpg[31];

In work to explore these effects, ARC reduced 2040 auto operating cost (fuel) by 71 percent from present to test the impact of increased energy efficiency. PSRC addressed operating cost change due to AV adoption in a different way in one of its scenarios: the cost of auto ownership was incorporated into the operating cost per mile. By assuming people no longer own personal vehicles, but instead use AVs as a form of ridesourcing, the per-mile auto cost increases from $0.60 per mile to $1.61 per mile (similar to Uber at $1.65 per mile).

3.6 Daily Activity Pattern

As discussed in the literature review, ICT influences travel demand in various ways. For example, by working at home instead of commuting to work, telecommuting reduces both daily trips and vehicle miles traveled. While the effects of telecommuting on school trips and, indeed, total household travel are insignificant, telecommuting does help to mitigate congestion through shifting of work travel out peak hours[32]. E-commerce allows people to reduce non-work trips, e.g., in-store shopping and on-site banking. Smart device technology has stimulated the growth of shared-use mobility, and therefore helps reduce total tripmaking. Instead of modeling discrete ICT activities, the impact of ICT can be presented in the model by reducing out of home activities.

The MTC included a scenario considering the effect of increasing the rate of telecommuting among its testing. Instead of modeling how travelers can be induced to telecommute, it instead evaluated the travel changes that would occur if they did. To test this scenario, the alternative-specific constant on the stay at home pattern alternatives was increased in the coordinated daily activity pattern model[33]. The stay at home patterns do not need to be distinguished by any specific activities and can include teleworking activities.

[30] KPMG (2012) Self-driving cars: The next revolution. Available at: https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-next-revolution.pdf as of May 5, 2015

[31] Handley, M. (2012, August 29). 54.5 MPG For All Cars by 2025 With New CAFE Standards? Not Exactly. Retrieved August 3, 2015, from http://www.usnews.com/news/articles/2012/08/29/545-miles-per-gallon-for-all-cars-by-2025-not-exactly

[32] Turnbull, K., K. Balke, M. Burris, et al. (2013) Minnesota Urban Partnership Agreement: National Evaluation Report. Prepared by Battelle for USDOT RITA, FHWA, and FTA. Available at: http://www.dot.state.mn.us/rtmc/reports/hov/20130419MnUPA_Evaluation_Final_Rpt.pdf as of May 5, 2015.

[33] Greg, E., D. Ory, et al. (2011) MTC's Travel Model One: Applications of an Activity- Based Model in its First Year. Innovations in Travel Modeling 2012, TRB. Retrieved from http://onlinepubs.trb.org/onlinepubs/conferences/2012/4thITM/Papers-A/0117-000082.pdf.

Atlanta Regional Commission (ARC) assumed that the total number of telecommuters will double, and percent of time telecommuting will grow by 50 percent in the future-year, and tested the telecommuting scenario by adjusting daily activity pattern parameters[34].

A few other regions are also experimenting with exploring the impacts of ICT trends on regional travel. For example, the Fredericksburg Area Metropolitan Planning Organization (FAMPO) has designed Travel Demand Model (Version 3.0) to perform scenario analysis on telecommuter growth. Vehicle trip reduction factors are developed and applied to the model's home-based work origin-destination trip tables to reflect the effects of a significant increase in telecommuting[35]. Baltimore Metropolitan Council has planned to perform scenarios testing on emerging trends, including ICT, as part of its ABM travel demand model development effort[36].

[34] ARC 2014 Model Update. (2014, December 5). Retrieved August 5, 2015, from http://www.atlantaregional.com/File%20Library/Transportation/Travel%20Demand%20Model/tp_mug_arc2014modelupdate_120514.pdf.

[35] GWRC Scenario Planning Phase II. (2014, April 1). Retrieved August 1, 2015, from http://www.fampo.gwregion.org/wp-content/uploads/2014/04/FAMPO-Scenario-Planning.pdf

[36] BMC Regional Travel Demand Model Update: Development of Activity-Based Model. (2013). Retrieved August 5, 2015, from http://www.baltometro.org/TEMP/RFP_130219_ActivityBasedModelDevelopment.pdf

4.0 Potential Scenario Testing

To model potential impacts from AVs in the travel demand model, and evaluate influences from changes in key parameters discussed in Section 3.0, this section explores potential scenarios for modeling the impact of emerging technologies.

In developing the scenarios, the focus remained on and limited to addressing changes in emerging technology, demographics, and travel behavior. Impact of changes in future population and land use, for purposes of testing potential scenarios, will be held constant using available 2040 socioeconomic data and adopted local government future land uses.

All of the following scenarios can potentially be tested under the assumption that ICT affects travel behavior, eliminating work and non-work trips during both peak and non-peak hours. While the ICT impact can be represented in the model by increasing the constant on the stay at home pattern alternatives in the coordinated daily activity pattern model based on the expected growth of telecommuters, this is not included in the scenarios discussed below since it could be applied to any or all as a variation.

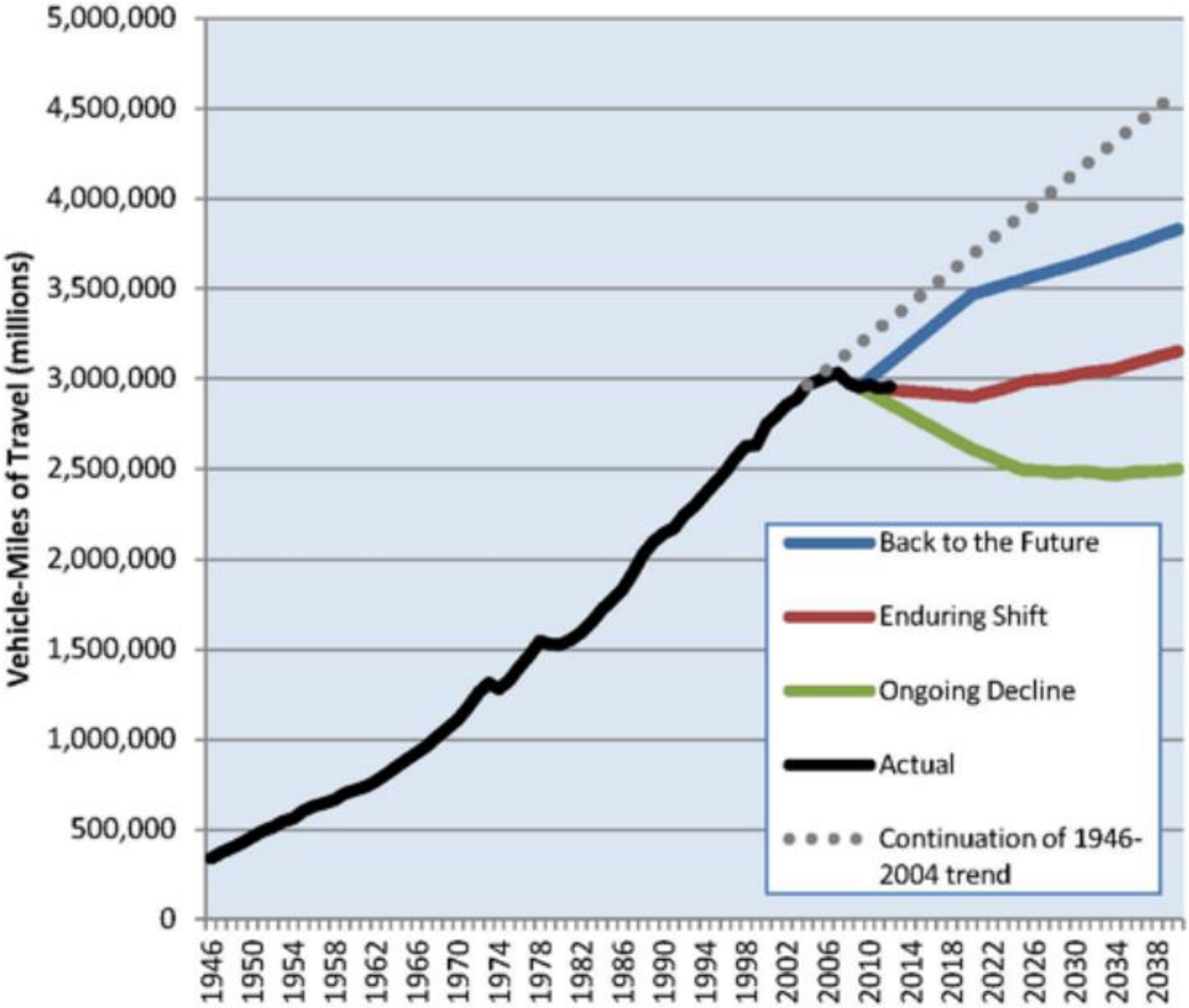
4.1 Scenario 1: Millennials Behave Differently

As already discussed, Case and Schipinski's study on Millennial transportation confirmed that Millennials travel differently than other generations, and affect future transportation needs. To understand the potential impact of Millennials on future travel trends, Dutzik and Baxandall have suggested three scenarios of future travel trends up to 2040[37]:

- *Back to the Future*: This scenario assumes that the U.S.'s decline in driving since 2004 is temporary. The recent decline in driving is due to poor economic conditions and higher gas prices. As these conditions reverse, the travel preferences of Millennials will increasingly mimic those of previous generations;
- *Enduring Shift*: In this scenario, the shift in travel behavior that has occurred over the last decade is assumed to be lasting. This is consistent with the view that the shift in preferences embraced by Millennials will be embraced by future generations as they reach driving age.
- *Ongoing Decline:* This scenario assumes that the decline in driving over the last decade is the beginning of a broader change that makes driving less necessary. The outcome of this scenario is that driving will stabilize at a much lower level per capita.

[37] Dutzik, T., and P. Baxandall. (2013). A New Direction: Our Changing Relationship with Driving and the Implications for America's Future, U.S. PIRG, Boston. Retrieved October 1, 2015.

Figure 4.1 Aggregate Vehicle-Miles Traveled in the U.S. under Three Scenarios of Future Travel Growth, 1946-2040



Implementation

The *Back to the Future* scenario is essentially the model baseline. The tour mode choice components include terms that increase the utility of non-auto modes for young adults. In this scenario, holding these terms constant implies that the next generation will behave similarly as Millennials do today and, similarly, as the Millennials age they will behave as older adults do today.

The *Enduring Shift* scenario implies that the Millennials hold on to their non-auto preferences throughout their adult lives. In 2040, Millennials will be 40 to 57 years old so this scenario would have adults between age 16 and 57 with the current auto preferences as the current 16-24 year olds.

The *Ongoing Decline* scenario implies that the preference Millennials hold for non-auto modes will increase in future generations. The increase will pivot off of the existing terms, with a 50 percent increase in the 25-40 year old generation and a 100% increase in the 16-24 year old generation in 2040.

The potential model parameter changes are summarized in Table 4.1.

Table 4.1 Scenario 1 Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	
Network Inputs	
Population Synthesis	Shift Millennial and later generations from suburban to urban areas.**
Long-Term Models	
Mobility	Create a term for a head of household in the Millennial generation or younger. Calibrate to reduce auto ownership.**
Daily	
Tour Level	Tour mode choice: Enduring Shift – carry forward age-mode terms Ongoing Decline – progressively increase age-mode terms by 50% and 100% for two generations following Millennials.
Trip Level	
Assignment	

Note: “**” indicates non trivial change in model.

The specific implementation approach is described below. Changes to the Tour Level models are discussed first, followed by the Population and Mobility model groups.

Tour Level

Changes to the Tour Level models are the most straightforward to implement because there are age terms already estimated in the model that can be transferred and pivoted off of for the scenarios. All changes require modifying and/or extending the Tour Mode Choice Utility Expression Calculator (UEC) file (ctramp\uec\TourModeChoice.xls), which is organized by tour purpose.

Table 4.2 shows the proposed changes to the age terms in the Tour Mode Choice model. Changes by tour purpose are based on the estimated values for the 16 to 24 age groups and only the non-auto terms are modified. The 16-24 age group terms are carried forward as is in the *Enduring Shift* scenario and, for the *Ongoing Decline* scenario, are increased by 100 percent and 50 percent for 16 to 24 year olds and 25 to 40 year olds respectively.

Where the non-auto mode term for 16 to 24 year olds has a negative coefficient, as with Discretionary non-motorized, the term is not propagated to other age groups. School and University tour purposes will not be modified because there are not many, if any, persons older than 25 with these tour purposes. Work Based tours also will not be modified because there aren’t any mode-specific terms estimated for 16 to 24 year olds. Note that the 25 to 40 age group was estimated as the reference value and hence does not have a row in the UEC. We will generate a new variable to represent 25 to 40 year olds and apply the coefficients listed in Table 4.2.

The effect of the new variables listed in Table 4.2 are translated into effective change in-vehicle travel time units and redisplayed in Table 4.3. The effective change to in-vehicle travel time can be interpreted as the difference between a person's mode preference, all else equal. For example, in the base scenario 16 to 24 year olds on work tours perceive non-motorized modes as 18.95 minutes shorter than 25 to 40 year olds. The Ongoing Decline scenario will increase the perceived attractiveness of non-motorized modes to 37.90 minutes for 16 to 24 year olds. In summary, a positive change to the effective in-vehicle travel time implies a lower preference and a negative change implies an increased preference.

Table 4.2 Millennial Scenario Changes to Tour Mode Choice Model Parameters

SCENARIO	MODE	WORK			MAINTENANCE			DISCRETIONARY		
		CURRENT	ENDURING SHIFT	ONGOING DECLINE	CURRENT	ENDURING SHIFT	ONGOING DECLINE	CURRENT	ENDURING SHIFT	ONGOING DECLINE
AGE 16 TO 24	shared-ride 2	-0.21388			0.00000			-0.51961		
	shared-ride 3+	-1.79023			0.00000			-1.31632		
	non-motorized	0.30322		0.60643	0.00000			-0.55570		
	transit	0.79472		1.58944	1.62111		3.24222	1.06375		2.12750
AGE 25 TO 40	shared-ride 2	0.00000			0.00000			0.00000		
	shared-ride 3+	0.00000			0.00000			0.00000		
	non-motorized	0.00000	0.30322	0.45482	0.00000			0.00000		
	transit	0.00000	0.79472	1.19208	0.00000	1.62111	2.43167	0.00000	1.06375	1.59562
AGE 41 TO 55	shared-ride 2	-0.30638			-0.82262			-1.04157		
	shared-ride 3+	-0.41025			-1.93552			-1.21044		
	non-motorized	-0.17752	0.30322	0.30322	-1.34146			-1.14969		
	transit	-0.42301	0.79472	0.79472	-1.39312	1.62111	1.62111	-0.48434	1.06375	1.06375
AGE 56 TO 64	shared-ride 2	-1.02962			-0.95497			-0.84295		
	shared-ride 3+	-0.85641			-2.16777			-0.96503		
	non-motorized	-0.64534			-1.34220			-0.97814		
	transit	-0.44991			-1.46184			-1.08450		
AGE 65 PLUS	shared-ride 2	-0.67111			-1.06222			-0.89435		
	shared-ride 3+	-1.43462			-2.14710			-1.11463		
	non-motorized	-1.45334			-2.32071			-1.69155		
	transit	-1.12310			-2.86495			-2.49829		

Table 4.3 Millennial Scenario Changes to Tour Mode Choice Model Parameters – Effective Change to In-Vehicle +Time (Positive = Longer Trip/Lower Preference)

	MODE	WORK (IVT -0.016)			MAINTENANCE (IVT -0.0125)			DISCRETIONARY (IVT -0.0125)		
SCENARIO		Current	Enduring Shift	Ongoing Decline	Current	Enduring Shift	Ongoing Decline	Current	Enduring Shift	Ongoing Decline
AGE 16 TO 24	shared-ride 2	13.37			0.00			41.57		
	shared-ride 3+	111.89			0.00			105.31		
	non-motorized	-18.95		-37.90	0.00			44.46		
	transit	-49.67		-99.34	-129.69		-259.38	-85.10		-170.20
AGE 25 TO 40	shared-ride 2	0.00			0.00			0.00		
	shared-ride 3+	0.00			0.00			0.00		
	non-motorized	0.00	-18.95	-28.43	0.00			0.00		
	transit	0.00	-49.67	-74.51	0.00	-129.69	-194.53	0.00	-85.10	-127.65
AGE 41 TO 55	shared-ride 2	19.15			65.81			83.33		
	shared-ride 3+	25.64			154.84			96.84		
	non-motorized	11.10	-18.95	-18.95	107.32			91.98		
	transit	26.44	-49.67	-49.67	111.45	-129.69	-129.69	38.75	-85.10	-85.10
AGE 56 TO 64	shared-ride 2	64.35			76.40			67.44		
	shared-ride 3+	53.53			173.42			77.20		
	non-motorized	40.33			107.38			78.25		
	transit	28.12			116.95			86.76		
AGE 65 PLUS	shared-ride 2	41.94			84.98			71.55		
	shared-ride 3+	89.66			171.77			89.17		
	non-motorized	90.83			185.66			135.32		
	transit	70.19			229.20			199.86		

Population and Land Use Data

Unless the scenario explicitly calls for a change in the population or land use, each scenario will be run using the base year data. The advantage of this approach is that the model sensitivities can be analyzed directly. Therefore, the base year population and land use inputs are unchanged.

Mobility

There are no age-specific terms available in the current auto availability model, which is defined in the ctramp\uec\AutoOwnership.xls UEC file. Therefore, a new term would need to be created and calibrated to make the model sensitive to the posited tendency for households with persons age 55 or younger to prefer non-auto modes and, hence, own fewer autos. This will be accomplished with a term that interacts the ratio of adults between 18 and 55 to all adults in the household with the number of cars:

(@numPersons18to55 / @numPersons18plus) * Auto alternative

This term would have a negative coefficient to reduce the number of cars chosen in households that have higher ratios of 18 to 55 year old adults. The term will be calibrated such that the difference between the average number of cars per 18 to 55 year old and 18 to 24 year old is reduced by 50 percent from the baseline to the *Enduring Shift* scenario and 100 percent shows an equal percentage decline in the *Ongoing Decline* scenario (i.e., average cars per 18 to 55 year old in the *Ongoing Decline* equals the average cars per 18 to 24 year old in the baseline). The observed vehicles per person by age group and targets for each scenario are shown in Table 4.4.

Table 4.4 Observed Vehicles per Person

	Observed		Scenario Targets	
Age Group	**Rate**	**% Difference from 18-24**	**Enduring Shift**	**Ongoing Decline**
18-24	0.79	-		
25-40	0.82	4%		
41-55	0.95	20%		
18-55	0.87	10%	0.83	0.79

Source: PUMS 2008-2012 Florida Data

Changes to the Mobility models will be made after the Tour Level changes have been implemented and tested to isolate model sensitivities.

Results

The output summaries to be generated from each scenario are identified in Table 4.5.

Table 4.5 Scenario 1 Output Summaries

Model Group	Output Summaries
Non-ABM Models	
Population Synthesis	
Long-Term Models	
Mobility	Autos per household Autos per 18-55 year old
Daily	
Tour Level	Average tour length by tour purpose and area type. Tour mode share by purpose and area type.
Trip Level	Trip mode share by person age group
Assignment	VHT and VMT of study area by facility type and area type Transit boardings Average congested speed by area type

4.2 Scenario 2: New Transportation Services Reduce Need for Driving

This scenario assumes that new technologies introduce newer forms of carsharing services like ridesourcing, such as Uber and Lyft, and one-way car sharing services like car2go reduce the need for driving, increase the number of zero-car households, and therefore reduce VMT in the future year.

A survey on ridesourcing users in San Francisco suggested that “ease of payment,” “short wait time,” and “fastest way to get there” are the most common reasons for people to choose ridesourcing instead of another commuting mode. The majority of ridesourcing users are members of the younger generation; 57 percent of them are from 25 to 34 years old. 8 percent the survey participants reported that they would not have made the trip at all if Uber/Lyft/Sidecar was not available, suggesting that these services are expanding mobility[4].

Implementation

This scenario implies that overall auto ownership would be reduced for residents and car rentals would be reduced for visitors. The amount of reduction depends on the degree to which these new services are available, the cost, and if they provide family-services (e.g., car-seats).

In this scenario, resident households that do not own any autos or have fewer autos than workers would not necessarily limit their mobility because auto travel is still available to them even though they do not own the vehicle in which they are traveling. Households using these new transportation services would be more likely to be composed of younger adults, as implied by the survey results, and higher income because the per-trip cost would be higher than travel by transit or personal vehicle. The visitor tour generation models are not sensitive to auto-availability and thus will be unchanged.

New transportation services essentially require a new mode in the model. This mode would be available for every interchange, although the waiting time may be higher in rural or suburban areas to account for the lower coverage. There would be no parking costs, but the operating cost would be substantially higher and should be calculated as a function of both time and distance. Finally, this mode would be available at the trip level for any auto or transit tour mode except drive-alone and would have similar availability as a shared-ride mode. The ridesourcing modes are similar to legacy taxi service and the "Taxi" mode in the Visitor tour mode choice model will be leveraged in the implementation.

Table 4.6 summarizes the parameter changes by model group. The detailed implementation approach is presented, first to represent the effects of the reduced sensitivity to vehicle availability and next to represent a new mode available in the model. Note that many of the proposed changes are non-trivial changes in the model and may require modifying the core codebase in the SERPM model.

Table 4.6 Scenario 2 Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	Visitor auto availability
Network Inputs	
Population Synthesis	Shift Millennial and later generations from suburban to urban areas.**
Long-Term Models	
Mobility	Auto ownership: reduce autos for Millennial and younger HHs. Include income in term and apply greatest reduction to wealthiest households in urban areas.**
Daily	Daily activity pattern: remove terms that differentiate hhs with insufficient autos
Tour Level	Tour mode choice: create new mode/extend taxi mode with higher operating costs, zero parking costs, waiting time in rural/suburban areas, available to all persons.**
Trip Level	Trip mode choice: create new mode/extend taxi mode with higher operating costs, zero parking costs, waiting time in rural/suburban areas, available to tours with shared ride or transit modes.**
Assignment	Highway assignment: assign as an HOV mode.**

Note: "**" indicates non trivial change in model.

Auto Ownership

The existing auto ownership model, which is defined in the ctramp\uec\AutoOwnership.xls UEC file, includes income and family type terms, but does not have an age-specific term. There is a direct relationship between income and number of autos, as shown in Table 4.7.

Table 4.7 Auto Ownership Household Income Terms

Term	0_Car	1_Car	2_Cars	3_Cars	4+_Cars
Household Income <30k	2.6549	0.6322	0.0000	-0.6012	-0.9361
Household Income 30-60k	0.9182	0.3426	0.0000	-0.3057	-0.2715
Household Income 100k+	-0.4431	-0.4431	0.0000	0.0870	0.1441

There are also terms for "non-family households" in the auto ownership model that represent adults living together, but not necessarily within the same family unit, e.g., roommates. The coefficients for these terms are shown in Table 4.8. Both terms favor fewer vehicles, which is interesting because non-family members are less likely to share vehicles. However, non-family members are even less likely to share incomes, so these terms may balance a collection of low-income workers, who collectively have a high household income, but are making decisions based on their individual incomes.

Table 4.8 Auto Ownership Non-Family Household Terms

Term	0_Car	1_Car	2_Cars	3_Cars	4+_Cars
Adjustment for Non-Family Household with 3 Workers	2.2422	1.3313	0.9209	1.4011	0.0000
Adjustment for Non-Family Household with 4+ Workers	6.1601	1.6936	-0.7288	-0.9065	0.0000

A term similar to the one proposed in Scenario 1 could be used to target households with younger members. However, the term should be refined to identify age groups by income segment. To avoid cases where many non-family workers add up to a high household income, the person-level average income (household income/adults) will be used as a filter. This term would have the following functional form and be filtered for person-level income of greater than $50,000 (~median income for Miami-Dade county).

(@numPersons18to40 / @numPersons18plus) * Auto alternative

The term will have a negative coefficient to reduce the number of autos owned by these households. The term will be calibrated to match an assumed target reduction of 10%. This is a reasonable target, based on the differences in auto ownership between age groups summarized in Table 4.4.

The non-ABM visitor model produces auto-availability shares, which represent auto rentals, by work, recreation, and other travel purposes. These are input to the ABM through the visitor_autoAvailable.csv file. The rate of auto rentals will be reduced by a similar degree (10%) as the auto ownership.

Daily Activity Pattern

The coordinated daily activity pattern (CDAP) component terms, defined in CoordinatedDailyActivityPattern.xls, include sensitivity to autos in the household for activity planning at the individual-level and in the generation of joint tours.

For the individual model (Table 4.9), the coefficients are generally positive for cases where there are more cars than workers for out of home travel and negative where there are zero cars or fewer cars than workers. This has the effect of limiting mobility based on the number of autos owned. However, in this scenario, mobility will actually increase for those segments that use the new transportation services. These segments are assumed to be 18 to 40 year old persons with individual incomes greater than $50,000. For those persons, terms will be added to the CDAP component to effectively cancel out the negative terms for zero or fewer vehicles than workers.

Table 4.9 CDAP Individual Pattern Auto Ownership Terms

Term	Mandatory	Non-Mandatory	Home
Full-time Worker interaction with more cars than workers		-0.0870	
Non-working adult interaction with more cars than workers		0.2122	
Retired interaction with more cars than workers		0.8642	
Driving-age School child interaction with more cars than workers	0.0988		
Full-time worker interaction with zero cars	-0.3377		
Pre-driving-age child who is too young for school interaction with zero cars	-0.5917	-1.4389	
Full-time worker interaction with fewer cars than workers	-0.3377		
Pre-driving-age child who is too young for school interaction with fewer cars than workers	-0.4778	-0.5259	

The autos owned also influences the prevalence of joint travel (Table 4.10). Households with fewer vehicles than workers are more likely to have joint tours and vice versa. While the new transportation services will increase mobility, the cost per ride and ability to share cost across multiple passengers implies that the prevalence of joint travel would not necessarily be reduced. Therefore, the joint travel terms will not be changed in the CDAP component.

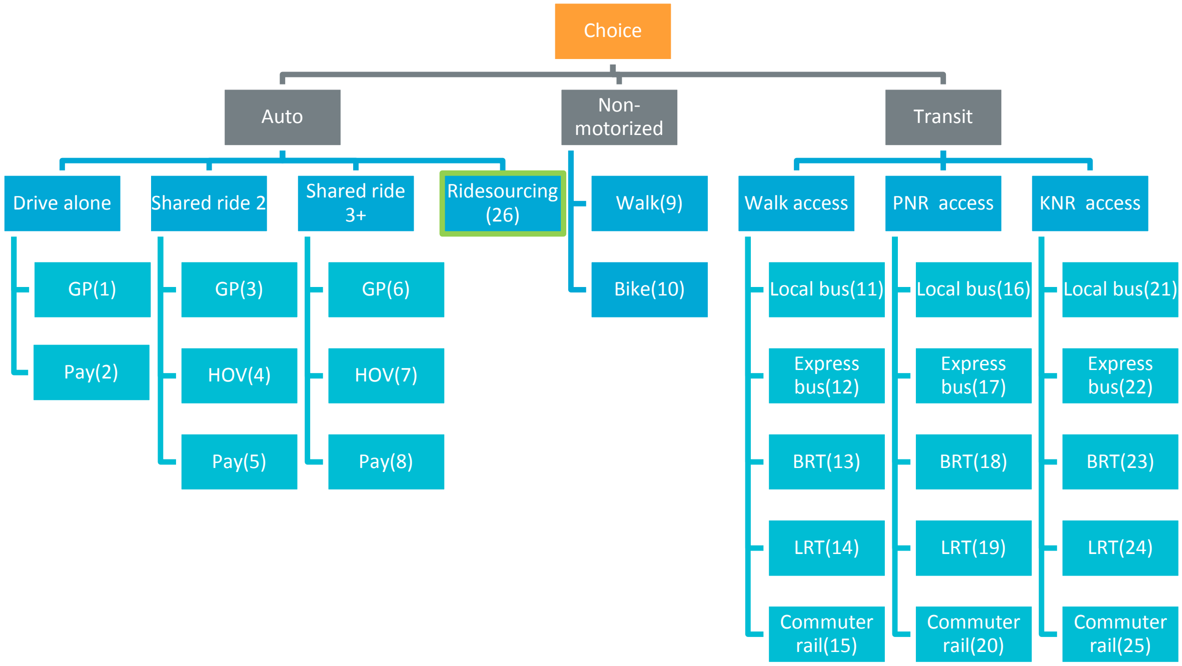
Table 4.10 CDAP Joint Tour Auto Ownership Terms

Term	Joint Tour
Cars Less than Workers	0.0884
Cars More than Workers	-0.0059

New Tour Mode

The SERPM 7 model has a deep, complex mode choice structure with 25 alternatives, as shown in Figure 4.2 with the new ridesourcing mode outlined in green. The visitor tour mode structure includes a taxi mode in a completely separate nest, which implies that there is no correlation between taxi and auto modes. To represent the similar passenger experience and point to point nature of travel, the new transportation services will be added as a new mode under the Auto nest for the resident and visitor model and the taxi mode would be removed from the visitor model. Given the higher costs, it is reasonable to assume that this mode would always use a tolled road as long as the travel time is shorter. Therefore, a pay/general purpose sub-nest is not needed.

Figure 4.2 SERPM 7 Mode Choice Model Structure



The new transportation services will share many attributes of an SOV. In some aspects, they will be more attractive because the traveler will not have to deal with the stresses of traffic or parking. But, the cost will be higher, there may be a long initial wait in suburban and rural areas, and the traveler is not able to use the car as storage during their tour, e.g. for golf clubs to hit the links after work.

The longer initial wait in suburban and rural areas will be represented by increasing the terminal time in those areas and reducing it in urban areas. This is essential an inverse relationship to the existing terminal time, which represents the walk access/egress to a vehicle. Therefore, rather than urban areas having the highest terminal time because parking is consolidated, they would have the lowest for RideSourcing because of a higher availability of service and vice versa for rural areas. Although waiting for a ride isn't the same as walking to a car in that the traveler could use the waiting time productively, as with a scheduled transit service. However, the waiting time would not necessarily be constant. Sometimes, the cars would be available immediately in rural areas and the terminal time should represent the expected waiting time. So the traveler would need to budget their time, i.e. be ready to go when initiating the car request.

It will be assumed that the disutility of traffic stress when driving alone is balanced out by the disutility of storage when using a ridesourcing mode. Therefore the alternative specific constant (ASC), which represents the unobservable aspects of the alternative utility, for the new mode would be equal to the SOV ASC.

The travel time, toll, and distance information for the new mode will use the SOV-pay skim inputs and the SOV time and cost coefficients will also be used for the new mode. Some of the key differences in the new mode utility can be represented by modifying the SOV inputs, as described in Table 4.11.

Table 4.11 SOV Mode Choice Changes for Ridesourcing Mode

Utility Term	SOV	Ridesourcing (New Mode)
Operating cost	toll + operating cost per mile	toll + fare per mile ($0.95) + fare per minute ($0.16) + base ($1.70)[38]
Parking cost	Parking cost at destination	N/A
Terminal time	At origin and destination	Inverse relationship to existing terminal time for origin only: urban areas will have short (<5 minutes), suburban areas will have longer (10-15 minutes), rural areas will have longest (20 minutes). At the destination, the traveler is assumed to be dropped off at the door.
Availability restrictions	Unavailable for persons < 16 and households with zero autos.	No availability restriction

Implementing the new mode alternative will require modifications to the Tour Mode Choice UEC file (ctramp\uec\TourModeChoice.xls and ctramp\uec\VisitorTourModeChoice.xls). Terminal time changes will be made to the zone.term zone terminal time input data file. Depending on the flexibility of the underlying codebase, modifications may also be necessary to the compiled software to support the new mode.

New Trip Mode

Trip mode choice is largely constrained by the select tour mode choice. Figure 4.3 shows the trip mode availability rules for the SERPM 7 model and with the new Ridesourcing mode. Note that the trip mode with a Drive Alone Toll tour mode can only be Drive Alone Non-Toll or Drive Alone Toll. The Ridesourcing tour mode would not have the same constraints because there is no requirement to get the family car back home at the end of the tour. The Ridesourcing tour mode is more similar to the Shared-Ride modes. Note that the Ridesourcing trip mode is not available on either PNR-Transit or KNR-Transit because tours with those modes do not have intermediate stops.

The changes described in the Tour Mode choice utility function would also apply here. Implementing these changes will require modifications to the Trip Mode Choice UEC file (ctramp\uec\TripModeChoice.xls and ctramp\uec\VisitorTripModeChoice.xls). Depending on the flexibility of the underlying codebase, modifications may also be necessary to the codebase to support the new mode.

[38] Uber X rates for Miami, FL. https://www.uber.com/cities/miami accessed November 18, 2015

Figure 4.3 Trip Mode Choice Availability Rules

Tour Mode	Trip Mode: Drive Alone Non-Toll	Drive Alone Toll	**RideSourcing**	Shared Ride 2 Non-Toll, Non-HOV	Shared Ride 2 Non-Toll, HOV	Shared Ride 2 Toll, HOV	Shared Ride 3 Non-Toll, Non-HOV	Shared Ride 3 Non-Toll, HOV	Shared Ride 3 Toll, HOV	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit
Drive Alone														
Non-Toll	•													
Toll	•	•												
RideSourcing			•							•				
Shared Ride 2														
Non-Toll, Non-HOV	•		•	•						•				
Non-Toll, HOV	•		•	•	•					•				
Toll, HOV	•	•	•	•	•	•				•				
Shared Ride 3														
Non-Toll, Non-HOV	•		•	•			•			•				
Non-Toll, HOV	•		•	•			•	•		•				
Toll, HOV	•	•	•	•	•	•	•	•	•	•				
Walk										•				
Bike										•	•			
Walk-Transit			•	•	•		•	•		•		•		
PNR-Transit													•	
KNR-Transit														•

Highway Assignment

The new transportation services will have at least two occupants; therefore, HOV facilities would be available for their use. However, any tolls charged to the vehicle would be the responsibility of the passenger alone, but the travel time cost is higher so the generalized cost function for HOV would be the most appropriate. This suggests that the new service mode could be assigned in the same group as the Shared Ride 2 Toll, HOV mode. Combining trips from the new transportation services and this mode will reduce the changes necessary in the model and maintain assignment run times.

The trip tables can be aggregated in Cube prior to highway assignment; however, outputting the Ridesourcing mode as a separate trip table may require changes to the core codebase.

Results

The output summaries to be generated from each scenario are identified in Table 4.12.

Table 4.12 Scenario 2 Output Summaries

Model Group	Output Summaries
Non-ABM Models	
Population Synthesis	
Long-Term Models	
Mobility	Autos per household Autos per person by age group and income
Daily	Out of home activity by age group, income, and auto ownership
Tour Level	Average tour length by tour purpose and area type. Tour mode share by purpose and area type.
Trip Level	Trip mode share by person age group
Assignment	VHT and VMT of study area by facility type and area type Transit boardings Average congested speed by area type

4.3 Scenario 3: Emerging Technologies Enhance Transit Systems

This scenario assumes that emerging technologies help to achieve FTP goal on transit for 2060, which aims at providing more transportation choices (emphasis on walking, bicycling, transit, and rail, as well as emerging mobility options) for people and freight[39]. It assumes that new technology does not only affect automobiles but also enhances transit systems; other technologies, such as high speed rail, will increase capacity and connectivity of urban transit systems.

[39] Florida Department of Transportation. (2015). Florida Transportation Plan Policy Element. http://www.floridatransportationplan.com/pdf/FDOT_FTP-SIS_PolicyElement.pdf Retrieved January, 2016.

Implementation

Table 4.13 indicates the potential model parameter changes required to implement this scenario in SERPM 7. Similar to Scenario 2, implementing this scenario might require changes to the SERPM core codebase.

Transit system technological improvements and the availability of new transit modes such as high speed rail will be represented through the forecast network, and these changes are already coded into the network. AVs could increase transit coverage by providing an auto connection on the non-home end of a transit trip (i.e., auto egress). Note that the impact of AVs are explored more fully in Scenario 5 and the combined effect will be explored in Scenario 6. For this scenario, the ridesourcing service as described in Scenario 2 is assumed to provide the auto egress connection.

To add an auto egress leg to transit modes, a new skimming procedure will need to be developed in the model and a new mode added to tour and trip mode choice. The attributes of the auto leg for this mode would be similar to those described by Scenario 2.

Table 4.13 Scenario 3 Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	
Network Inputs	Skim transit with drive-egress Recalculate transit accessibilities with drive-egress available
Population Synthesis	
Long-Term Models	
Mobility	
Daily	
Tour Level	Create new transit-drive mode with higher operating costs.**
Trip Level	Create new transit-drive mode with higher operating costs **
Assignment	Highway assignment: assign as a drive alone mode.**

Note: "**" indicates non trivial change in model.

Transit Skimming Procedure

The current transit skimming procedure assumes a walk-egress connection. There are currently 15 transit mode alternatives and associated skims in the model (3 access modes x 5 transit sub-modes). A full expansion of the transit alternatives to reflect a new access/egress mode would require 40 transit mode alternatives (4 access modes x 5 transit sub-modes x 2 egress modes). This is a substantial increase in model complexity and is likely to require excessive effort to implement. Instead, auto-transit-auto paths will be assumed to not be reasonable. Furthermore, the Ridesourcing mode will only be considered as an egress mode, and only be available on a walk-access path. Therefore, there will be 20 transit mode alternatives in this scenario.

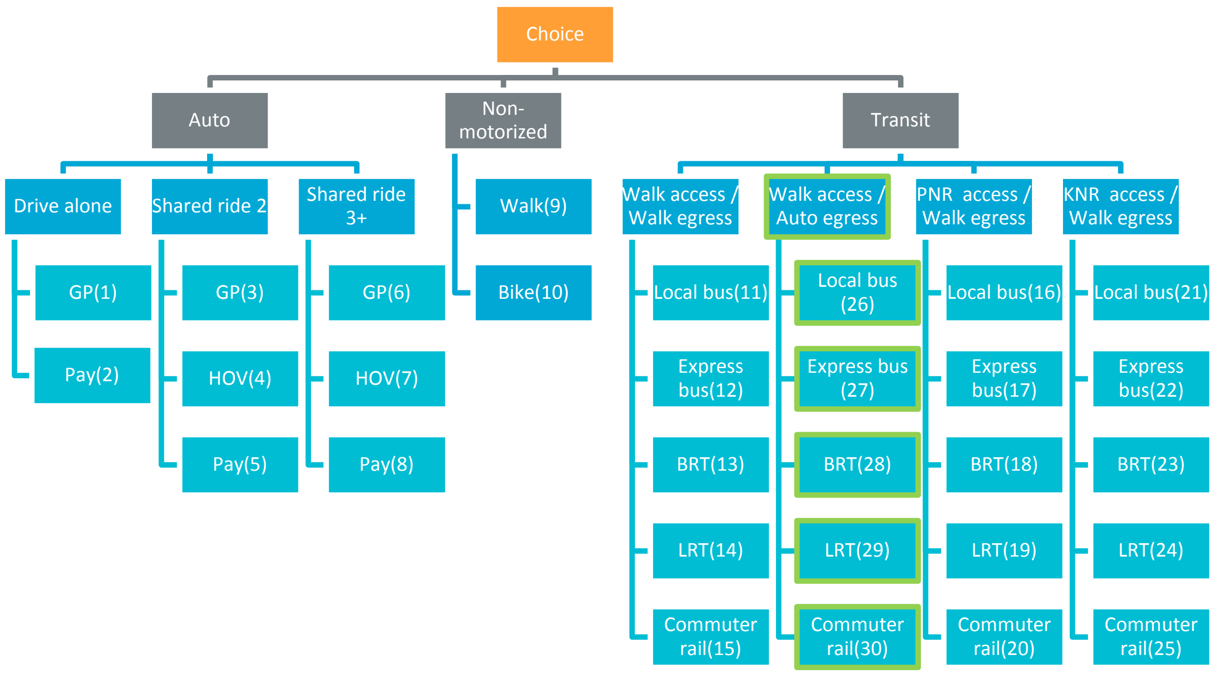
It is not necessary to run a separate set of skimming procedures. Rather, the kiss and ride skims can be transposed to represent a walk-access and drive-egress path.

Note that the transit zonal accessibilities, which are inputs to several of the Mobility and Daily components, will increase as a result of the drive-egress availability. The transit accessibility calculation procedure will be enhanced to include drive-egress transit modes.

New Tour Mode

The extension of the SERPM 7 model mode choice structure with 30 alternatives is shown in Figure 4.4 with the new transit modes outlined in green.

Figure 4.4 Mode Choice Structure with Drive Egress Modes



As described above, the walk access/auto egress modes will use the transpose of the KNR skims as data input. But, the experience of a walk access/auto egress mode will be considered to be more similar to the experience of driving and parking because the auto is more readily available whereas a kiss and ride requires some coordination with a household member or friend. Therefore, the PNR utility formulation and constants will be used for the new modes except as indicated in Table 4.14.

Table 4.14 PNR Mode Choice Changes for Ridesourcing Mode

Utility Term	PNR	Ridesourcing (New Mode)
Operating cost	toll + operating cost per mile	toll + fare per mile ($0.95) + fare per minute ($0.16) + base ($1.70)[40]
Parking cost	Parking cost at destination	N/A
Terminal time	At origin and destination	Inverse relationship to existing terminal time for origin only: urban areas will have short (<5 minutes), suburban areas will have longer (10-15 minutes), rural areas will have longest (20 minutes). At the destination, the traveler is assumed to be dropped off at the door.
Availability restrictions	Unavailable for persons < 16 and households with zero autos.	No availability restriction

Implementing the new mode alternative will require modifications to the Tour Mode Choice UEC file (ctramp\uec\TourModeChoice.xls and ctramp\uec\VisitorTourModeChoice.xls). Terminal time changes will be made to the zone.term zone terminal time input data file. Depending on the flexibility of the underlying codebase, modifications may also be necessary to the codebase to support the new mode.

New Trip Mode

Trip mode choice is largely constrained by the select tour mode choice. Figure 4.4 shows the trip mode availability rules for the SERPM 7 model. The walk access/auto egress tour modes would have the same constraints as the existing walk access tour modes.

The changes described in the Tour Mode choice utility function would also apply here. Implementing the new mode alternative will require modifications to the Trip Mode Choice UEC file (ctramp\uec\TripModeChoice.xls and ctramp\uec\VisitorTripModeChoice.xls). Depending on the flexibility of the underlying codebase, modifications to the codebase may also be necessary to support the new mode.

Highway Assignment

The new transportation services will have at least two occupants; therefore, HOV facilities would be available for their use. However, any tolls charged to the vehicle would be the responsibility of the passenger alone, but the travel time cost is higher so the generalized cost function for HOV would be the most appropriate. This suggests that the new service mode could be assigned in the same group as the Shared Ride 2 Toll, HOV mode. Combining trips from the new transportation services and this mode will reduce the changes necessary in the model and maintain assignment run times.

The trip tables can be aggregated in Cube prior to highway assignment, however, outputting the walk-access/drive-egress transit modes as a separate trip table may require changes to the core codebase.

[40] Uber X rates for Miami, FL. https://www.uber.com/cities/miami accessed November 18, 2015

Results

The output summaries to be generated from each scenario are identified in Table 4.15.

Table 4.15 Scenario 3 Output Summaries

Model Group	Output Summaries
Non-ABM Models	
Population Synthesis	
Long-Term Models	
Mobility	Autos per household
Daily	
Tour Level	Average tour length by tour purpose and area type. Tour mode share by purpose and area type.
Trip Level	Trip mode share
Assignment	VHT and VMT of study area by facility type and area type Transit boardings

4.4 Scenario 4: Managed lanes used differently

The Florida Transportation Plan encourages development of enhanced transportation corridors that include managed or special-used lanes, and incorporate and support emerging technologies such as connected vehicles or alternative fuel sources, etc.[41] This scenario assumes that managed lanes will be enhanced with features like a statewide electronic payment and scheduling system and that more HOT, HOV lanes, and managed lanes for transit will be developed. The percentage of travel using transit and carpooling, accessibility to public transit facilities, person hours of delay, highway vehicle miles travelled could potentially be indicators of the growth of managed lanes usage.

Implementation

This scenario will be primarily represented through changes to the model inputs, specifically the model network and associated skims. Tolls and vehicle class exclusions are coded into the network. The managed lanes may implement dynamic tolls that adjust according to the level of traffic. The SERPM model currently supports a feature whereby tolls are recalculated based on the current volume to capacity ratio. This procedure will be reviewed depending on the specific dynamic toll approach proposed. The changes in the model are detailed in Table Table 4.16. Note that changes to the tolls require a recalculation of the accessibilities.

[41] Florida Department of Transportation. (2015). Florida Transportation Plan Policy Element. http://www.floridatransportationplan.com/pdf/FDOT_FTP-SIS_PolicyElement.pdf Retrieved January, 2016.

Table 4.16 Scenario 4 Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	
Network Inputs	Change coding of networks to represent managed lanes with truck/SOV restrictions and tolls. Recalculate accessibilities with tolls
Population Synthesis	
Long-Term Models	
Mobility	
Daily	
Tour Level	
Trip Level	
Assignment	Review and modify dynamic toll rate procedure for managed lane facilities.

Results

The output summaries to be generated from each scenario are identified in Table 4.17. In order to identify how the managed lanes effects cost-sensitive users, the tour level summaries will be segmented by household income group.

Table 4.17 Scenario 4 Output Summaries

ZModel Group	Output Summaries
Non-ABM Models	
Population Synthesis	
Long-Term Models	
Mobility	
Daily	
Tour Level	Average tour length by tour purpose and area type and income level. Tour mode share by purpose and area type and income level.
Trip Level	Trip mode share
Assignment	VHT and VMT of study area by facility type and area type VHT and VMT on managed lane facilities Transit boardings Average congested speed by area type

4.5 Scenario 5: AV Technology Affects How People Travel

As discussed in the literature review, there are 5 levels of automation, from no automation (Level 0) to full self-automation (Level 4). KPMG forecasted that by 2025 there will be widespread and after-market penetration for AV applications. One assumption is that about a decade after 2025, Level 4 AVs will have 100 percent market penetration. The other assumption could be that only people with high incomes could afford AVs. The latter assumption seems reasonable in a short time period: it was recently reported that the sensors (LIDAR) used in the Google self-driving car cost $70,000[42], the equipment in the Google AV costs $15,000; and higher income households tend to purchase high-tech vehicles, e.g., electric automobiles. But sensor technology prices are steadily dropping; Google expects the price of its sensor system to drop if the cars were ready for a mass market[43]. It is not unreasonable to assume that, by 2040, the sensors would be inexpensive enough to be present in all types of vehicles, including retrofit packages for legacy vehicles.

Another assumption would be that the proclivity to own vehicles also shifts such that AVs are most often used as part of a car-sharing/ridesourcing service. This assumption would have implications for the vehicle availability and vehicle sufficiency terms that are present in many models, such as daily activity pattern and tour/trip mode choice. Car-sharing/ridesourcing type services are the most attractive in urban areas or for occasional trips because the cost is experienced for each individual ride, rather than overtime as with car payments, insurance and maintenance. The Millennial scenario (Scenario 1: Millennials Behave Differently) the new technologies scenario (Scenario 2: New Transportation Services Reduce Need for Driving) and the transit technologies scenario (Scenario 3: Emerging Technologies Enhance Transit Systems) all explore cases where this is more likely. Scenario 5 will first hold those aspects constant and examine how the vehicle technology affects the road operations, in-vehicle experience, and parking costs. Overarching scenarios that combine the effects will be explored in Scenario 6: Comprehensive Scenario.

The following section discusses scenarios with full market penetration and assumes that all vehicles are AV but that the vehicle availability is consistent, i.e., households with vehicles less than workers would have the same preferences for non-auto modes with AVs as with conventional vehicles.

4.5.1 AVs Use Facilities More Efficiently

This scenario tests the assumption that adding autonomous vehicles into the road network expands capacity. It reflects operational improvements from vehicle automation. In this scenario, travel demand changes can be modeled by increasing the roadway capacity coded on roadway network links, and so the scenario captures one major impact of AVs on a roadway network.

Assuming that an autonomous vehicle requires smaller safe spacing, and can potentially have higher speeds, currently it’s still unclear what the magnitude of capacity increase should be. Based on case studies and previous literature, a wide range (from 10 percent to 100 percent) was applied. Gucwa considered two

[42] Google self-driving car. (n.d.). Retrieved December 23, 2015, from https://en.wikipedia.org/wiki/Google_driverless_car

[43] Behind the wheel: A look inside Google's self-driving cars. (2014, May 14). Retrieved December 23, 2015, from http://www.theverge.com/google/2014/5/14/5714602/photos-inside-googles-self-driving-cars

road capacity increase scenarios: the “Low Base” scenario included an additional 10 percent roadway capacity; the “High Base” scenario assumed a doubling of roadway capacity[44].

Implementation

Rather than set a fixed capacity increase across the network, it is more reasonable that the level of capacity increase be sensitive to facility type. The potential for AVs to improve freeway operation is greater than for arterials. Freeways will benefit from the reduced headways, higher speeds, and efficient merging and weaving AVs provide, while arterials cannot avoid turning traffic/driveway access and cannot increase the speed that much. Therefore, the capacity on freeways and divided highways can be assumed to increase on the high end of the range (80 - 100 percent) while arterials and local roads increase more towards the lower end (10 – 30 percent). Note that on-ramps and highway interchanges should be treated like a freeway (higher increase) because there isn’t any turning traffic ahead. But, off-ramps should be treated like an arterial/local road. These values were selected based on the range of increases in the previous research and the functionality of the existing Dynamic Traffic Assignment (DTA) tools will be reviewed and DTA may be employed to inform the capacity increase. The changes will be made by modifying the input network.

Table 4.18 Scenario 5a Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	
Network Inputs	Freeway facility types: increase capacity by 80-100% Other facility types: increase capacity by 10-30%
Population Synthesis	
Long-Term Models	
Mobility	
Daily	
Tour Level	
Trip Level	
Assignment	

4.5.2 Less Onerous In-Vehicle Travel Time

This scenario builds upon the first scenario by assuming that, along with capacity improvements from AV uses, driverless vehicles free people from the stress and tiredness that comes with driving and congestion, and time spent in AVs becomes less onerous and more productive. With high accessibility to AVs and greater value of time, transit ridership share decreases.

The IVT coefficient from the UECs files can be adjusted to reflect the improvement on value of in vehicle time. Based on research and practices discussed previously, a decrease in the IVT coefficient from 50 percent to 65 percent might be reasonable. A 50 percent reduction in the value of in-vehicle time was used

[44] Gucwa, M. (2014) Mobility and Energy Impacts of Automated Cars. Presented at the 2014 Automated Vehicle Symposium, San Francisco, California.

by Gucwa in the low in vehicle value of time scenario, and ARC reduced the IVTT coefficients for autos by 50 percent to test the scenario where autonomous vehicles have 100 percent market penetration[45]. Table 4.19 details the scenarios that Gucwa considered. PSRC assumed that for individuals who travel in AVs, trip-based value of times are 65 percent of non-AVs in assignment; travel time is 65 percent of skimmed travel time in the demand models[46].

Table 4.19 MTC Scenarios Considered[47]

	Roadway Capacity		
In-Vehicle Value of Time	(B) - Base	(L) - Low Base +10%	(H) - High Base +10%
(B) – Base	"BB"	-	"BH"
(H) – High Quality Rail	-	"HL"	"HH"
(L) – ½ Current Car	-	"LL"	"LH"
(0)– Zero Time Cost	"0B"	-	"0H"

Levin and Boyles's study shows that at full market penetration vehicle trips increase dramatically: transit ridership is reduced by over 60 percent, and over 80 percent of the modeled population chooses to use AVs round trip.

Implementation

Table 4.20 summarizes the parameter changes necessary to implement the scenario. This scenario builds on the changes implemented in 4.5.1.

PSRC and ARC assumed a rather large 50-65 percent decrease in IVT sensitivity and those assumptions may not be completely justified for this scenario. This level of change implies that, given an autonomous vehicle and all else equal, travelers would be willing to spend twice as long or more traveling. The reasons given for the reduction in previous research are that the traveler avoids the stress of driving and is able to productively complete other tasks. However, passengers in non-autonomous vehicles already experience both of those benefits, yet the shared ride modes do not have a reduced IVT coefficient. Moreover, taxi modes, which are included in the Visitor mode choice model also does not have a reduced IVT coefficient. Therefore, a smaller reduction (5-10 percent) to the IVT coefficient is more reasonable and consistent with the current model implementation.

The IVT coefficient is specified individually in the UEC files (TourModeChoice.xlsx and TripModeChoice.xlsx) by mode and ranges between -0.010 and -0.032 for tour mode and -0.020 and -0.0334 for trip modes depending on the activity purpose.

[45] Gucwa, M. (2014) Mobility and Energy Impacts of Automated Cars. Presented at the 2014 Automated Vehicle Symposium, San Francisco, California.

[46] Childress, S., B. Nichols, B. Charlton, S. Coe (2014) Using an Activity-Based Model to Explore Possible Impacts of Automated Vehicles. Presented at the 94th TRB Annual Meeting, Washington, D.C.

[47] Gucwa, M. (2014) Mobility and Energy Impacts of Automated Cars. Presented at the 2014 Automated Vehicle Symposium, San Francisco, California.

Table 4.20 Scenario 5b Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	
Network Inputs	*Freeway facility types: increase capacity by 80-100%* *Other facility types: increase capacity by 10-30%*
Population Synthesis	
Long-Term Models	
Mobility	
Daily	
Tour Level	Tour Mode Choice (all purposes and logsums): Reduce Auto IVT coefficient by 5-10%
Trip Level	Trip Mode Choice (all purposes and logsums): Reduce Auto IVT coefficient by 5-10%
Assignment	

Note: Previous changes are italicized.

4.5.3 AVs Significantly Reduce the Need for Paid Parking

Besides increased capacity, decreased in vehicle time of value, and reduced operating cost, the third scenario takes it a step further to assume that besides increased capacity and decreased VOT, parking cost will be reduced significantly. Since AV technology allows vehicles to return to a cheaper or free location after dropping off the passenger at his/her destination in a high cost parking area, there is less need for close-by parking; self-parking AVs also better utilize existing parking space (requiring fewer or no driver spaces).

Prior AV scenario testing studies conducted by ARC and PSRC set parking cost to be 50 percent of current cost with AV technology. These studies, discussed in Section 3.4, suggested that additional VMT and operating cost would be generated from round trips between the drop off and parking locations. However, the potential increase in VMT and operating costs cannot be captured directly by adjusting the parking cost parameter.

The previous studies did not propose a method to account for the additional operating time, which overstates the benefits of AVs on paid parking. Areas with paid parking are most likely dense, urban areas with congested streets and little open space nearby. Therefore, the AV would need to travel some distance to find free or lower-priced parking. There is an operating cost to this travel and also an inconvenience to the traveler because they need to call their vehicle back with enough advance warning. Moreover, for short duration tours, there may not be enough time to send the vehicle to a lower cost parking area. Finally, in a scenario of 100% AV penetration, it is not feasible for every vehicle to drive unoccupied for a potentially great distance to find free parking. This would be particularly untenable when serving spikes in demand, such as at the end of the work day or at the conclusion of a sporting event. But, the cost of parking could be reduced somewhat because travelers are less sensitive to the garage location and parking garages could be more efficient.

Implementation

Table 4.21 summarizes the parameter changes necessary to implement the scenario. This scenario builds on the changes implemented in 4.5.1 and 4.5.2.

The calculated parking cost for mandatory tours depends on the results of the parking provision model. In the existing model, parking costs are either set to zero if the person has free parking at work or they are reduced according to the reimbursement defined. In this scenario, the calculated parking cost will be reduced by 20% to reflect the additional efficiencies of autonomous parking.

The change in parking demand also implies that the traveler will be dropped off and picked up closer to their destination than if they had to park manually. Therefore, terminal times can also be reduced. The terminal times will be set to 1 minute, the minimum value, throughout the model area. Parking cost changes will be made to the TAP_Node.dbf parking input data file. Terminal time changes will be made to the zone.term zone terminal time input data file.

Table 4.21 Scenario 5c Model Parameter Changes

Model Group	Parameter Changes
Non-ABM Models	
Network Inputs	*Freeway facility types: increase capacity by 80-100%* *Other facility types: increase capacity by 10-30%*
Population Synthesis	
Long-Term Models	
Mobility	
Daily	
Tour Level	Tour Mode Choice (all purposes and logsums): *Reduce Auto IVT coefficient by 5-10%* Reduce parking costs by 20%; Set maximum terminal time to 1 minute
Trip Level	Trip Mode Choice (all purposes and logsums): *Reduce Auto IVT coefficient by 5-10%* Reduce parking costs by 20%; Set maximum terminal time to 1 minute
Assignment	

Note: Previous changes are italicized.

Results

The output summaries to be generated from each scenario are identified in Table 4.22.

Table 4.22 Scenario 5 Output Summaries

Model Group	Output Summaries
Non-ABM Models	
Population Synthesis	
Long-Term Models	
Mobility	
Daily	Out of home activity
Tour Level	Average tour length by tour purpose and area type. Tour mode share by purpose and area type.
Trip Level	Trip mode share by person age group
Assignment	VHT and VMT of study area by facility type and area type Transit boardings Average congested speed by area type

4.6 Scenario 6: Comprehensive Scenario

After each of the scenarios have been implemented and explored individually, they will be combined in a systematic manner to isolate complex interactions and produce a more comprehensive model result. The specific approach is presented in the following section.

4.6.1 Scenario 6a: New Transportation Services (2) and Transit System Technologies (3)

These two scenarios involve an extension of the mode alternatives with a new ridesourcing mode from Scenario 2 and auto-egress modes from Scenario 3. The implementations of the additional modes are independent, and the modified UEC files can be combined.

This scenario will have a complex effect, particularly with transit ridership. The reduced auto ownership from Scenario 2 will have a positive effect on transit ridership, but the ridesourcing mode will compete with transit modes.

4.6.2 Scenario 6b: Millennials (1) with New Transportation Services (2) and Transit System Technologies (3)

Scenario 6a will resolve the balance between ridesourcing and the new transit technologies. This scenario adds a layer of complexity by introducing the reduced auto ownership and non-auto preferences of Scenario 1.

Scenario 1 includes changes to model parameters and additional variables that favor non-auto modes, but ridesourcing should not be included with the legacy auto modes; therefore no additional terms are needed for tour mode choice.

This scenario should show an increased move from the legacy auto modes and towards transit as well as ridesourcing.

4.6.3 Scenario 6c: Autonomous Vehicles (5) with New Transportation Services (2) and Transit System Technologies (3)

The autonomous vehicle scenario (Scenario 5) assumed that the individual auto ownership paradigm is unchanged, but that all owned vehicles are now autonomous. In this scenario, pay-per-use ridesourcing modes are also autonomous, which will make that mode more attractive.

An autonomous ridesourcing mode should have a lower cost and be even more available than a human-operated service. The fare will be assumed to be reduced by 50% to reflect the savings by not having an operator. Also, the initial waiting time will be reduced by 50% to represent the greater availability. Although an autonomous ridesourcing vehicle can no longer be assumed to operate using HOV facilities, the substantial improvements to freeway capacity due to an autonomous vehicle fleet make this detail less critical.

Previous research[48] explored ways in which non-fixed guideway transit modes would benefit from autonomous operations, such as: reduced accidents; increased capacity in high-volume corridors: improved reliability; and higher off-peak service levels. In this scenario, the increased capacity in high-volume corridors will be represented through the highway network changes. There isn't a mechanism to control for reliability or accident likelihood in the model, and so these effects will not be represented. The shorter running times could allow for higher frequency with a constant vehicle fleet, but service levels are highly dependent on the transit agency targets and thus will not be included in this scenario.

4.6.4 Scenario 6d: Autonomous Vehicles (5) with Managed Lanes (4)

Scenario 5 includes substantial improvements to freeway capacity that will balance out some of the toll deterrent.

4.6.5 Scenario 6e: Comprehensive Scenario

This scenario will include the collective effects of full set of Scenarios 1 through 5. The ridesourcing and Transit System Technologies will be implemented as described in Scenario 6c.

[48] Lutin, J. and A. Kornhauser (2014) Application of Autonomous Driving Technology to Transit: Functional Capabilities for Safety and Capacity. 93rd TRB Annual Meeting, Washington, D.C.

5.0 Next Steps

To date, models are applied to gauge the demands for, and the sizes of, new facilities, using calibrated parameters. In other words, modeling parameters, such as trip production rates, trip length distribution, and other parameters found from travel surveys and calibrated in the model are assumed to remain the same when the models are applied for future forecasts.

In the real world, however, emerging technologies are positioned to disrupt traditional travel behavior paradigms. As discussed in previous sections, the intensifying of internet usage will expand the likelihood of alternate means being available to accomplish the same tasks that require making trips today. Trip rates for modeling the future could be different. On the other hand, autonomous vehicles, which relieve the burden and frustration of driving in congestion, could make people more willing to make longer trips more frequently. So, the trip length distribution for modeling the future could be different too.

After reviewing relevant literature, identifying key parameters and data needs, alternative scenarios can be tested to analyze the impact of emerging technologies on trends of travel behavior changes in the region. The findings can be applied to test and shape policies in regional and MPO Long Range Transportation Plans to achieve their goals and objectives. It can also help to project more accurate demands for projects.