Emerging Technology, Demographic Changes, and Travel Behavior

Literature Review

Task Report

prepared for

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1.0 Introduction

This literature review is the first phase of work on a regional travel demand trends analysis for Florida Department of Transportation (FDOT). It is anticipated to be followed by a second phase which will identify key parameters and data needs; and a third phase which will compile regional and national trends and discuss potential scenario testing that could be done with the regional model to support policy analysis.

This review explores prior studies and practitioner efforts on analyzing emerging technology from the travel forecasting and planning perspective. We provide an overview on two major fields: autonomous vehicles (AV) technology, and information and communications technology (ICT). We focus on studies that evaluate the potential impacts of technologies on travel behavior and regional travel trends, and analyze the factors and parameters that can be applied to model alternative scenarios.

The remaining part of this paper is organized as follows. Chapter 2 presents an overview of AVs, describes its potential impacts on travel demand, and underlying travel behavior factors. Chapter 3 follows a similar structure as that of Chapter 2, but emphasizes telecommuting, e-commerce and smart devices particularly. Chapter 4 provides case studies on AVs and ICT. Chapter 5 describes potential next steps of this task work.

2.0 Autonomous Vehicles

2.1 Autonomous Vehicles Overview

In the past decade AV technology has been developing rapidly. New technologies, including adaptive cruise control, traffic incident warning, and self-parking systems, have been adopted by new car models on the road today. It was reported that by providing safer and more efficient vehicle spacing, AVs can potentially bring significant increases in road capacity and reduction in collisions, offer expanded mobility to the disabled, and require less attention from the driver.[1] It is believed that as AV technology is adopted more widely, it has the potential to fundamentally change transportation engineering and planning.

The U.S. Department of Transportation (USDOT) National Highway Traffic Safety Administration (NHTSA) defines AVs as having five levels of autonomy:[2]

- No-Automation (Level 0): The driver has complete control of the vehicle;
- Function-specific Automation (Level 1): Vehicle provides one or more specific control functions, e.g., electronic stability control or pre-charged brakes;
- Combined Function Automation (Level 2): Automation of at least two primary control functions working together, such as adaptive cruise control and lane centering;
- Limited Self-Driving Automation (Level 3): Vehicle takes control of all safety functions under certain traffic and environmental conditions. The driver is expected to be available for occasional control; and
- Full Self-Driving Automation (Level 4): Vehicle controls all safety-critical driving functions and monitor roadway conditions. Driver only needs to provide destination or navigation information.

KPMG forecasted that by 2025 there will be widespread and after-market penetration for AV applications.[3] Nissan and Volvo expressed their intentions to implement AV driving capabilities by 2020. It would be only two decades since the Defense Advanced Research Projects Agency

[1] 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.

[2] NHTSA (2013) U.S. Department of Transportation Releases Policy on Automated Vehicle Development, May 30, 2013. Extracted in May 22, 2015 from: http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development.

[3] 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.

(DARPA) Grand Challenge, the first long-distance competition for driverless cars, was launched in 2004.[4]

States are preparing themselves for AV technologies by providing legislation to regulate AV operation and licensing. Florida enacted Bill CS/HB 1207 which provides for operation of autonomous motor vehicles on public roads. California and Nevada also have started proceeding with AV operation legislation.

AV testing facilities are available in multiple states including Florida, California, Michigan, and Virginia. In 2011, FDOT prepared a connected vehicle test bed at the Walt Disneyworld Speedway in Orlando. It was designed to test the use of wireless communications, vehicle sensors, and global positioning systems.[5]

2.2 Impacts on Travel Demand

Levin and Boyles[4] conducted a study using a multiclass travel demand model to analyze impacts of AVs on trip, mode, and route choice, on the Austin downtown network. They assumed that including AVs in the model network would provide drivers the option to avoid parking fees and increase road capacity.

Specifically, in the four-step model Levin and Boyles developed, travel demand was classified by value-of-time and AV ownership; mode choice was modeled by a nested logit model between driving, parking, repositioning, and public transit. Assignment was completed using a generalized cost function of time, fuel, and tolls.

For travel demand, the results show that transit ridership decreases as more value-of-time (VOT) classes have more access to AVs (i.e., there is greater market penetration). At full market penetration, transit ridership is reduced by over 60 percent and 83 percent of the modeled population chooses to use AVs round trip, increasing vehicle trips dramatically. For traffic, the model showed slightly lower average link speeds due to AVs compensatory contribution to link capacity.

The Atlanta Regional Commission (ARC) performed research on AVs using their activity-based model (ABM) with similar results.[6] Like Levin and Boyles, ARC anticipated potential growth in capacity (C) and decreases in travel time disutility (T), vehicle operating cost (O), and parking

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[4] Levin, M., and S. Boyles (2015) Effects of Autonomous Vehicle Ownership on Trip, Mode, and Route Choice. Paper presented at 94th Transportation Research Board Annual Meeting, Washington, D.C.

[5] Williams, K. (2013) Transportation Planning Considerations for Automated Vehicles. Center for Urban Transportation Research, University of South Florida. Prepared for Tampa Hillsborough Expressway Authority. Available at: http://www.tampa-xway.com/Portals/0/documents/Projects/AV/TAVI_2-PlanningWilliams.pdf as of May 22, 2015.

[6] 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.

cost (P). They assessed impacts under five different scenarios: no built base scenario (Base); C; C and T (CT); C, T and O (CTO); C, T, O, P (CTOP).

The model results confirmed that C, T, O, and P will contribute to growth of total daily trips and trip lengths. Compared to the Base scenario, in both the CTO and CTOP scenarios, 50 percent more capacity led to around a 2.5 percent increase in daily vehicle trips; average trip length increased from around 10 miles to 12 miles.

Vehicle miles traveled (VMT) and vehicle hours traveled (VHT) both increased in Scenario CT, CTO, and CTOP, as an outcome of higher roadway capacity. ARC also predicted a drop in transit share (up to 42 percent for CTOP) and longer average in-vehicle travel time with AV implementation. Additionally, the model captured a significant increase in accessibility in rural areas.

Lutin and Kornhauser[7] looked at the impacts of AVs on transit by different levels of autonomy (as detailed in detailed in Section 2.1). They summarized potential effects of AVs at level 2 to level 4 (Table 2.1).

Table 2.1 Impacts of AVs on Transit

Level	Key Features	Potential Impacts
Level 2	• Pedestrian and Bicycle Detection • Autonomous Emergency Braking • Lane-centering • Blind-spot Monitoring • Adaptive Cruise Control	• Reduce Car Crashes • Reduce Injuries and Fatalities • Claims Reduction > $$
Level 3	• Cooperative Adaptive Cruise Control • Lane-centering • Precision docking	• Increased capacity in high-volume bus corridors
Level 4	• Bus capable of fully automated operation	• Paired or bus "train" operation possible • BRT systems can emulate rail in capacity at lower cost

2.3 Underlying Travel Behavior Factors

As discussed in Section 2.2, ARC identified a series of factors related to AVs that influence travel behavior. ARC assumed that increased VMT and VHT lead to longer in vehicle time (IVT). Accordingly, ARC reduced the IVT coefficient for autos by 50 percent to reflect this assumption.

[7] 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.

This adjustment implies that people tolerate longer IVT time, and possibly have longer trips distances. Travel time was assumed to be reduced by 35 percent from current travel times.

Decreased parking costs stimulated vehicle trips in the testing scenarios. Cost per mile traveled greatly affected mode shares in the testing scenarios (e.g., transit mode share doubled when a high cost per mile of $1.65 per mile was tested).

In research performed by Gucwa[8] on AVs, the value of IVT and roadway capacity are considered as two primary dimensions influencing travel behavior. Travel time and cost factors are anticipated to have significant effects on IVT, while AV speed/traffic density relationships directly influence roadway capacity. Using San Francisco's Metropolitan Commission's Travel Model One, Gucwa developed a random utility model to analyze the difference across eight scenarios. As summarized in Table 2.2, 10 percent and 100 percent more capacity were added to low base and high base scenarios. With the implementation of AV, the model forecasted at least a four percent increase in VMT in the HL scenario, and an eight percent increase for the LH scenario.

Table 2.2 Model Scenarios

		Roadway Capacity		
		Base (B)	Low Base +10% (H)	High Base + 100%
In Vehicle Value of Time	Base (B)	BB	-	BH
	High Quality Rail	-	HL	HH
	½ Current Car (L)	-	LL	LH
	Zero Time Cost (0)	0B	-	0H

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

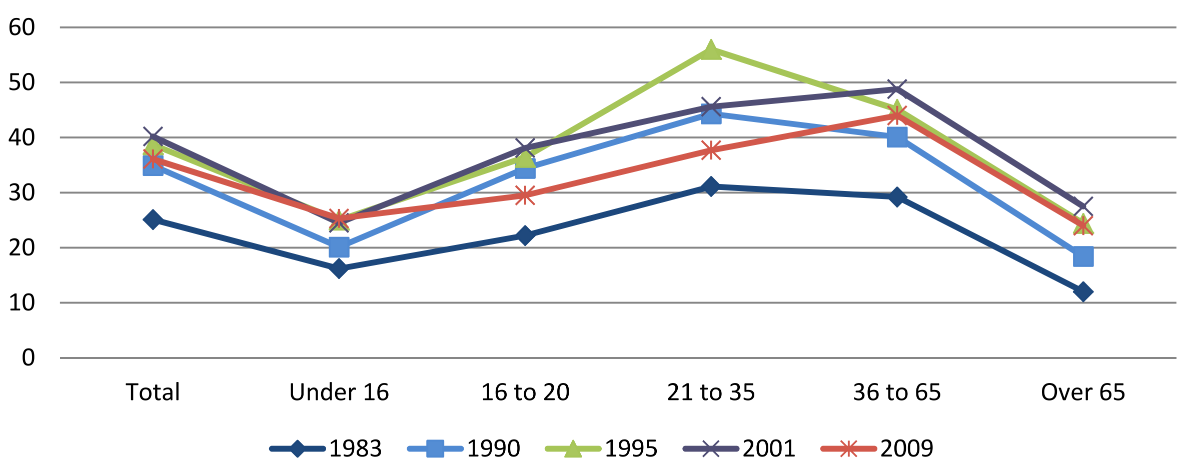
3.0 Information and Communications Technology (ICT)

3.1 ICT Overview

ICT plays an important and fundamental role in people's lives today. In fact, these digital technologies may be as effective as doubling or tripling the physical road capacity[9] and have already changed the way people work, shop, and travel. This section presents an overview of the established and emerging ICT technologies in the United States. We review studies on three main fields of ICT: telecommuting, e-commerce, and smart devices.

Attention is also paid on exploring the differences in travel behavior among millennials and aging populations. FHWA found that the next generation has tended to adopt new communication technologies earlier and more frequently.[10] Figure 3.1 and Figure 3.2 present an overview of differences in VMT and person daily trips by different age groups.

Figure 3.1 Person Miles of Travel per Person by Age

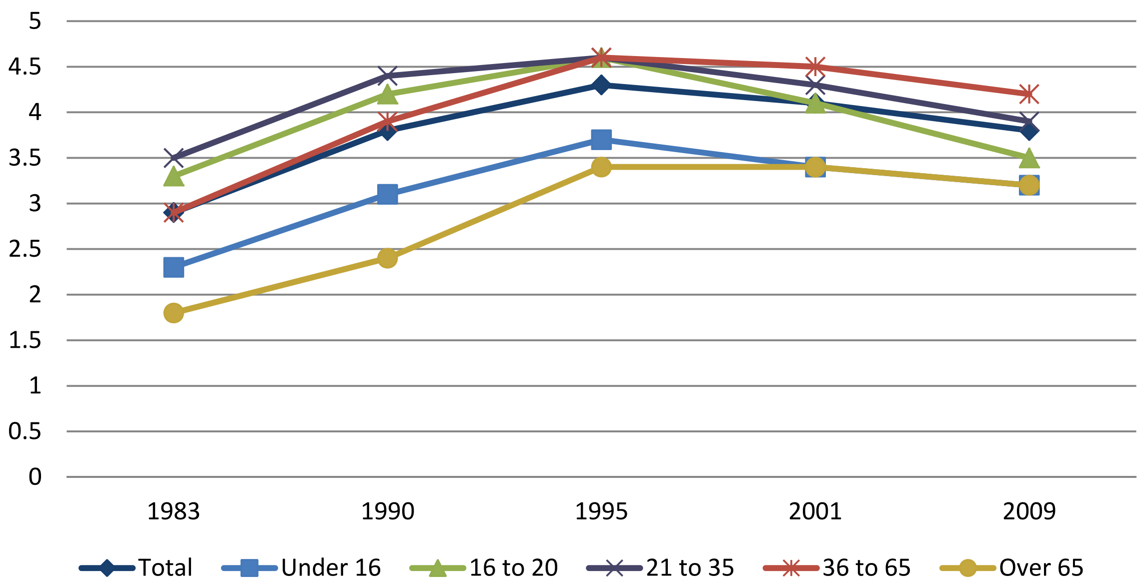


Source: 1983, 1990, and 1995 NPTS, and 2001 and 2009 NHTS.

[9] Ericsson and Imperial College London (2014) Horizon Scan: ICT and the Future of Transport. Available at: http://www.ericsson.com/res/docs/2014/ict-and-the-future-of-transport.pdf as of May 20, 2015.

[10] Blumenberg. E., B. Taylor, et al. (2013) The NEXT Generation of Travel Statistical Analysis. Institute of Transportation Studies, Lewis Center for Regional Policy Studies, UCLA Luskin School of Public Affairs. Prepared for Federal Highway Administration. Available at: http://www.fhwa.dot.gov/policy/otps/nextgen_stats/nextgen.pdf as of May 20, 2015.

Figure 3.2 Average Daily Person Trips per Person by Age



Source: 1983, 1990, and 1995 NPTS, and 2001 and 2009 NHTS.

3.1.1 Telecommuting

With the spread of high-speed internet, cheaper devices, and better remote systems, telecommuting expanded and became mainstream over the late 1990s and 2000s. However, through the latest recession, the number of Americans working at least one day a month remotely decreased nearly 20 percent from 2008 to 2010, down from 33.7 million in 2008 to 26.2 million in 2010. A combination of factors contributed to this decline: higher unemployment, higher anxiety surrounding job security, and lack of awareness of telework options.[11] Figure 3.3 shows the rise in telecommuting activities to 2008 and drop to 2010.

In a related follow-up study in 2013, WorldatWork reported 34 percent of employer respondents offer full-time telework to some or all employees; 52 percent of employer respondents offer telework on a regular weekly basis of at least one day per week, and 83 percent on an ad-hoc basis.[12] Some organizations, such as the Federal government, have expanded their embrace of telework, while others, such as Yahoo! have recently curtailed it over concerns about the resulting workforce dynamics.[13] In the Federal government, over

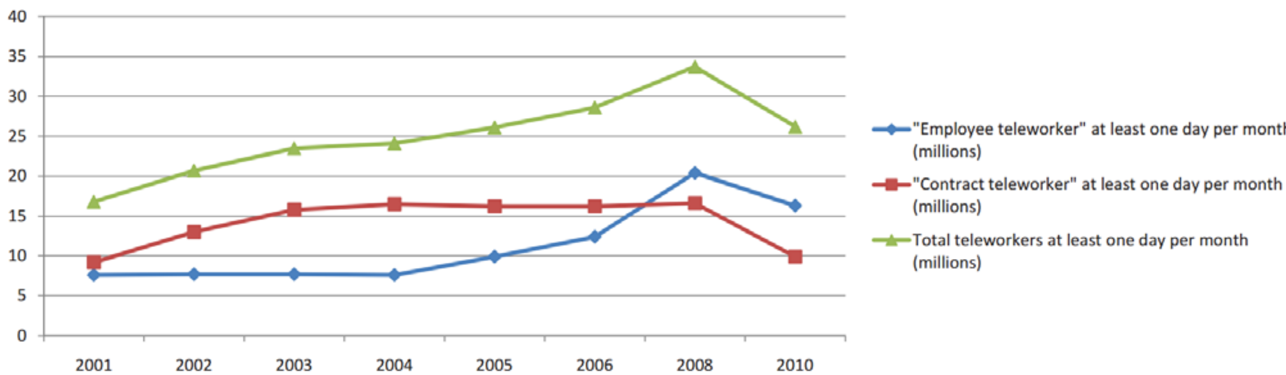
[11] The Dieringer Research Group Inc. (2011) Telework 2011: A WorldatWork Special Report. Available at: http://www.worldatwork.org/waw/adimLink?id=53034 as of May 5, 2015.

[12] WorldatWork (2013) Survey on Workplace Flexibility 2013. Available at: http://www.worldatwork.org/adimLink?id=73898 as of June 4, 2015.

[13] Krasny, J. (2013) Yahoo CEO: Why I was Right About Telecommuting. *Inc. Magazine*. Available at: http://www.inc.com/jill-krasny/marissa-mayer-twitter-telecommuting-policy.html as of June 4, 2015.

25 percent of eligible Federal workers have telework agreements in place, and 32 percent of teleworkers participate in telework three or more days a week.[14]

Figure 3.3 Trends in telecommuting[11]



Source: Telework 2011: A WorldatWork Special Report

Looking at the geographic distribution of people who work from home, San Francisco, Atlanta, and Phoenix are the top three Metropolitan Statistical Areas (MSAs) in the United States. Miami MSA ranked in the top eight MSA, with 4.2 percent of its population working from home, which is 1.6 percent less than San Francisco (5.8 percent). Table 3.1 presents the top 15 MSAs with the largest percentages of telecommuters to total population.

Table 3.1 Telecommuting in the top 15 MSAs

Metropolitan Statistical Area	Percentage Working from Home
San Francisco	5.76%
Atlanta	5.34%
Phoenix	5.23%
Seattle	5.04%
Minneapolis	4.65%
Los Angeles	4.59%
Washington	4.45%
Miami	4.20%
Dallas	4.19%
Boston	4.14%
Chicago	3.99%

[14] Top Telework Trends in 2015, A Conversation with Mika J. Cross and Dr. Rebecca Ayers, Office of Personnel Management, The Federal Manager, Spring 2015. Available at: https://www.fedmanagers.org/FMA/files/ccLibraryFiles/Filename/000000000613/FM%20MAG_SPRING%2015_WEB%20MAG.pdf as of June 4, 2015.

Metropolitan Statistical Area	Percentage Working from Home
New York	3.74%
Philadelphia	3.53%
Houston	3.33%
Detroit	2.97%

Source: 2006-2010 American Community Survey 5-year estimates.

As is shown in Table 3.2 highlighting the employee demographic profile of teleworkers, most teleworkers are people from 18 years old to 54 years old. The demographic results for the SCAG region (2002) are aligned with the national results from WorldatWork, which indicate that telecommuters tend to be older and have a college education.[15]

Table 3.2 Teleworker Demographic Profile: 2006, 2008, and 2010

	2006 (n=140)	2008 (n=130)	2010 (n=96)
Total teleworkers (United States)	28.7 million	33.7 million	26.2 million
Men	53%	61%	56%
Women	47%	39%	44%
Age			
18-34	38%	42%	42%
35-54	52%	48%	51%
55+	11%	8%	8%
Mean age	41.0	40.3	39.9
Median age	40.0	38.0	40.0
Educational Attainment			
High school or less	18%	23%	24%
Some college/vocational	25%	28%	32%
College graduate	57%	50%	44%
Post-graduate degree	22%	15%	25%

Source: Telework 2011: A WorldatWork Special Report

[15] SCAG (2011) 2012-2015 Regional Transportation Plan - Transportation Demand Management. Available at: http://rtpscs.scag.ca.gov/Documents/2012/draft/SR/2012dRTP_TransportationDemandManagement.pdf as of May 20, 2015.

The frequency of telework is on the rise in recent years. As is presented in Table 3.3, from 2008 to 2010, telecommuters who work almost every day have increased from forty percent to forty five percent of the total number of teleworkers. The percentage of teleworkers with the least frequency of teleworking have decreased by twelve percent to sixteen percent.

Table 3.3 Frequency of Teleworking

	Percent By Frequency		Cumulative Percentage	
	2008 (n=130)	2010 (n=96)	2008 (N=130)	2010 (N=96)
Almost every day	40%	45%	40%	45%
At least one day per week	32%	39%	72%	84%
At least once per month	28%	16%	100%	100%

Source: Telework 2011: A WorldatWork Special Report

3.1.2 E-Commerce

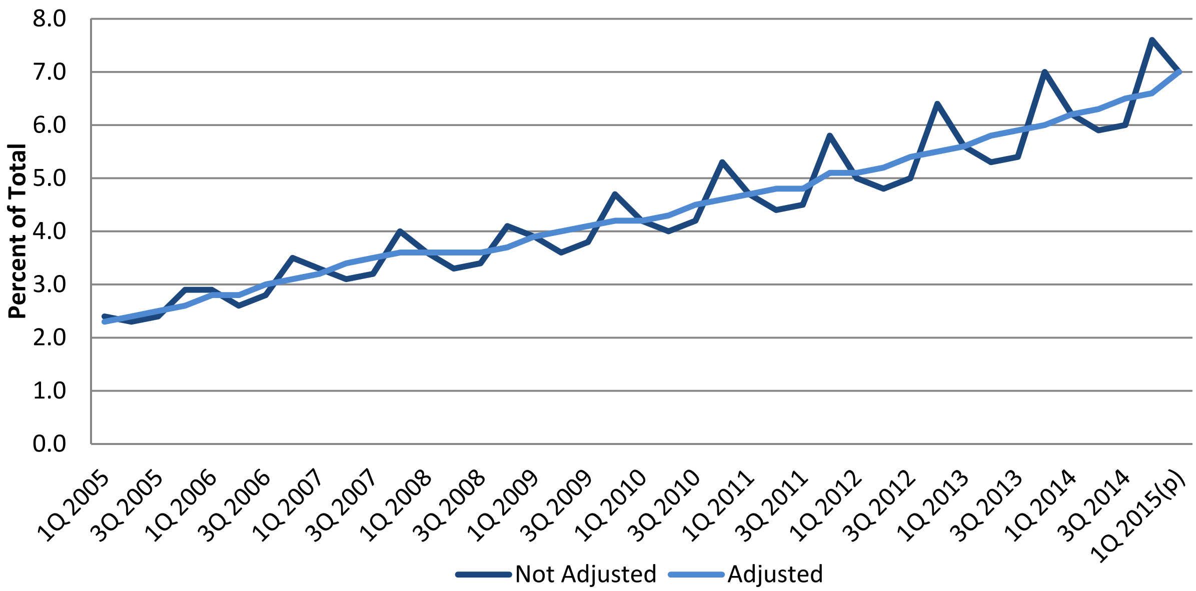
The growth of e-commerce has brought great changes to the transportation system and to travel behavior. Laudon and Traver[16] concluded the major trends in online retail are: mobile commerce has doubled; social commerce has had rapid growth; online retail remains the fastest growing retail channel; buying online is a normal, mainstream experience; selection of goods has increased; and shopping for information on high-priced items has expanded.

As shown in Figure 3.4 e-commerce retail has been growing from 2000 to 2014 (with a short recess in 2009). According to the Census Bureau of the Department of Commerce quarterly e-commerce report, since the 4th quarter 2009 to 1st quarter 2015, e-commerce has been increasing by around 15 percent from same quarter a year ago.[17] Figure 3.5 indicates that drugs, health aids, and beauty aids; clothing and clothing accessories; computer hardware; and electronics and appliances are the top four merchandise lines with the most sales estimates.

[16] Laudon, K. and C. Traver (2014) E-Commerce 2014: Business. Technology. Society. Ninth Edition. Upper Saddle River, New Jersey: Prentice Hall.

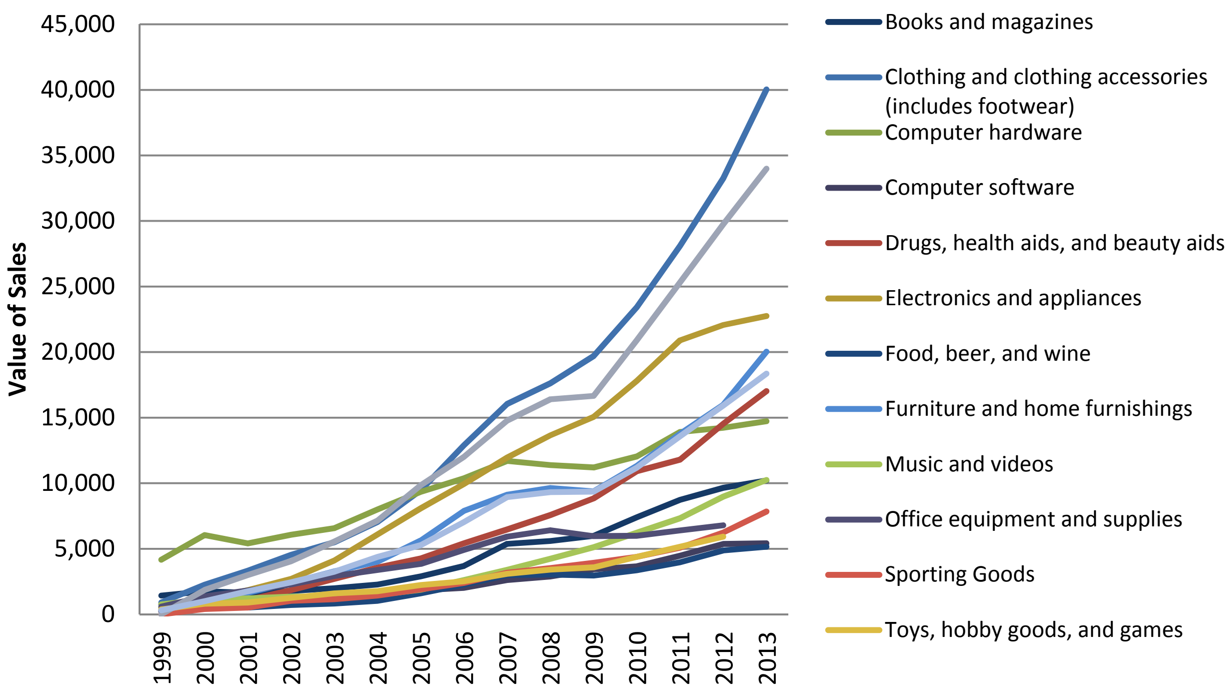
[17] U.S. Census Bureau (2015) The 1st Quarter 2015 Retail E-Commerce Sales Report. Washington, D.C. Available at: https://www.census.gov/retail/index.html#ecommerce as of May 20, 2015.

Figure 3.4 Trends in E-Commerce



Source: U.S. Census Bureau, 1st Quarter 2015 Retail E-Commerce Sales Report.

Figure 3.5 E-commerce Sales by Merchandise Line



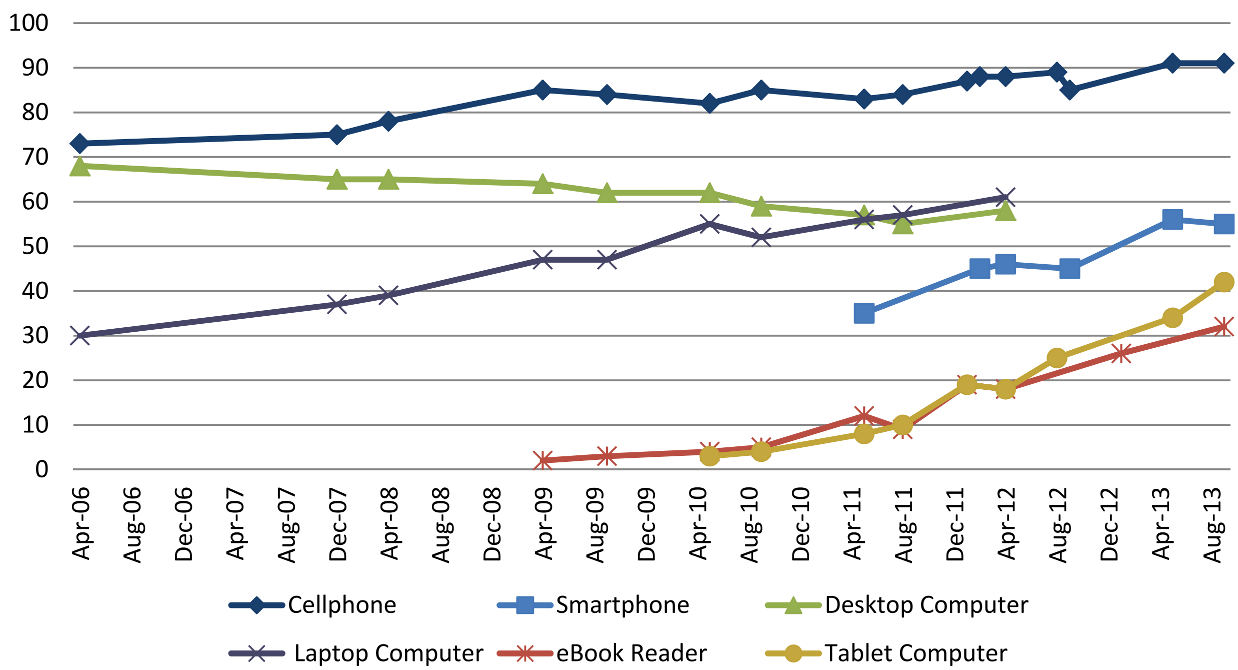
Source: U.S. Census Bureau (2015) Electronic Shopping and Mail-Order Houses (NAICS 4541) - Total and E-commerce Sales by Merchandise Line (1999-2013), *2013 Annual Retail Trade Report*, Washington, D.C. Available via http://www.census.gov/retail/index.html on May 20, 2015.

3.1.3 Smart Devices

As of 2013, over half the adults in the U.S. own a smartphone, while tablet ownership has been growing dramatically since 2010 (Figure 3.6). In the meantime, social media usage has been climbing up since 2005; over 90 percent of the younger generation (age 18 to 29) use social media (Figure 3.7).

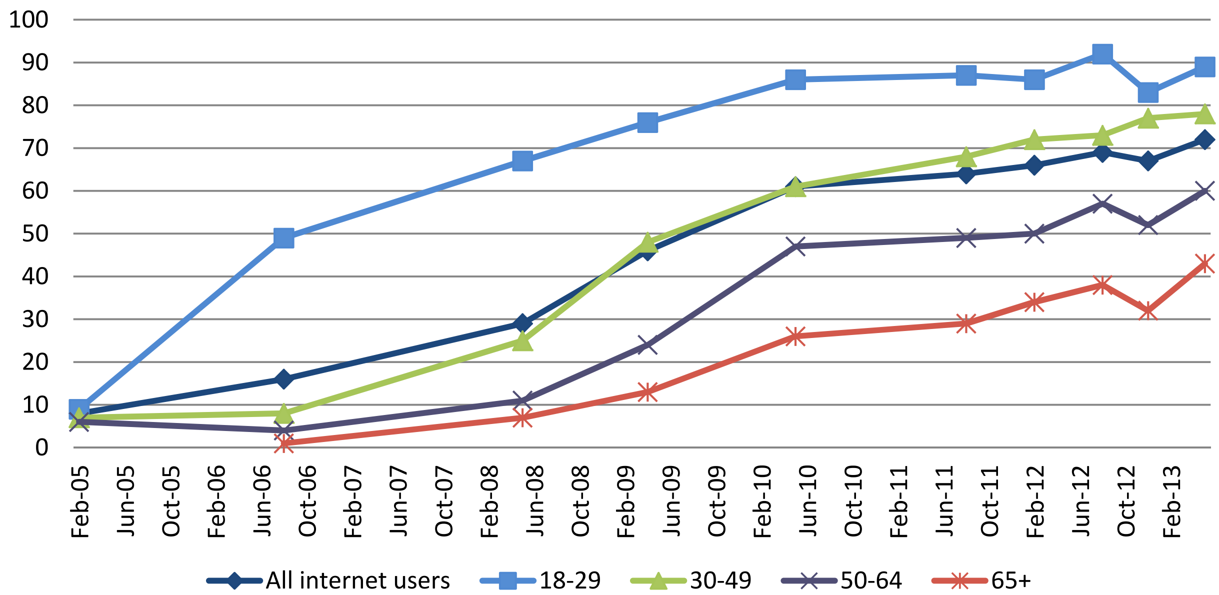
Expansion of high-speed internet, smart devices, and mobile apps has started affecting how people travel in various aspects, especially for the younger generation. Particularly, app-based, on-demand ride services (such as Uber, Lyft, Shuddle, etc.) have brought innovative changes in carsharing and rider services.

Figure 3.6 American Adults 18 Years of Age and Older Who Own Each Device (%)



Source: Pew Research Center (2014) Three Technology Revolutions. Available at: http://www.pewinternet.org/three-technology-revolutions/ on June 5, 2015.

Figure 3.7 American Adults 18 Years of Age and Older Who Use Social Media (%)



Source: Pew Research Center (2014) Three Technology Revolutions. Available at: http://www.pewinternet.org/three-technology-revolutions/ on June 5, 2015.

3.2 Impacts on Travel Demand

3.2.1 Telecommuting

The literature on impacts of telecommuting has grown significantly since 1970s. In this section, we review three studies that have this as their focus.

The Minnesota Urban Partnership Agreement (UPA) project includes[18] an extensive telecommuting program, eWorkPlace, which had 48 participating employers and 4,200 employees. The program results support three telecommuting impacts across hypotheses:

- Telecommuting reduces both daily trips and vehicle-miles travelled (VMT). The survey results indicate that an estimated 1,260 single-occupancy vehicle trips per week were removed during the peak hour due to the telework initiative on I-35W. A total of 570 of the 4,212 new telework participants are estimated to be from the I-35W study corridor, with 420 of these participants estimated to be single-occupancy drivers. Each of these participants teleworked an average of 1.5 times a week.

[18] 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.

- Telework can help to enhance congestion mitigation. Telecommuting initiatives as part of the UPA have resulted in regional as well as corridor-specific impacts in terms of VMT reductions. The local partners estimated an annual reduction of 7.5 million VMT from the eWorkPlace program. In the study corridor, the annual VMT reduction due to the eWorkplace participants is 520,000 vehicle-miles.

- The local partners reported that teleworkers take 80 percent fewer trips during the work day and 93 percent fewer peak-period trips compared to nonteleworkers. The eWorkPlace participants avoided making 11,350 additional vehicle trips per week in the region by teleworking based on these percentages. 75 percent of participating employers reported an increase in productivity and 93 percent planned to either continue or expand their telework program.

Another goal of the eTelework program was to shift the time of travel from peak to off peak times. Although there were no results from the program indicating a change in travel shifting to off-peak hours, the program places emphasis on eliminating overall trips, instead of shifting trips temporally from peak-hours to off-peak hours. An early study conducted by Kitamura et al.[19] used travel diary information from the State of California telecommuting study in the late 1980s. Kitamura et al. found that most of the reduction in trips occurred during peak periods: telecommuters made 73% fewer morning-peak departures after they began telecommuting and 54% fewer afternoon-peak departures.

Hu and He[20] studied the effects of telecommuting using data from the Chicago Regional Household Travel Inventory (CRHTI). Their hypothesis was that if a household has telecommuters, the decisions or considerations of telecommuting tend to precede their residential relocations. Their research results suggest that, for telecommuters, telecommuting increases one-way journey-to-work; but, for non-telecommuters in the household, it reduces journey-to-work durations as well as routine shopping trips. Effects of telecommuting on school trips and total household travels are insignificant.

Denstadlia et al.[21] looked at videoconferencing and its impact on business using data from a business air passenger survey. Small companies were found to be more willing to use new videoconferencing platforms; videoconferencing reduces business air travel. Results also indicated that respondents with access to in-house video conference rooms are of greater probability of substitution than those who only have access to new technologies, such as videoconferencing for personal computers.

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[19] Kitamura, R., P. Mokhtarian, R. Pendyala, and K. Goulias (1991) An Evaluation of Telecommuting as a Trip Reduction Measure. University of California Transportation Center. Berkeley, California: University of California.

[20] Hu, L., and S. He (2014) "Does Telecommuting Reduce Household Travel? A Case Study of Chicago Metropolitan Area." Presented at 93rd TRB Annual Meeting, Washington, D.C.

[21] Denstadlia J., M. Gripsrudb, R. Hjorthola, T. Julsruda (2013) Videoconferencing and business air travel: Do new technologies produce new interaction patterns? Transportation Research Part C: Emerging Technologies. Volume 29.

3.2.2 E-Commerce

According to a 2011 FHWA report, e-commerce affects travel behavior of consumers in the following aspects:

- Substitution – e-commerce reduces in-store shopping;
- Complementarity – e-shopping creates additional in-store shopping (e.g., batteries for new toy);
- Modification – e-shopping may change the characteristics of in-store trips (e.g., timing); and
- Neutrality – online shopping has no effect on in-store shopping activities.

In a study based on survey data from the Twin Cities, Minneapolis, Cao et al. found that e-shopping has a complementary effect on in-store shopping, instead of a substitution effect.[22] Zhou, whose study used the 2009 NHTS data and a structural equation model, also discovered that when in-store shopping activities suppresses e-shopping activities, e-shopping encourages in-store shopping trips.[23]

In their analysis of the Sydney Household Travel Survey (2003), Corpuz and Peachman[24] included observations on Internet activity versus alternate activity:

- In the case of Internet banking, were it not available, 71 percent of respondents would have undertaken a non-trip alternative (e.g., telephone, by mail); 29 percent would have undertaken a trip;
- In the case of Internet shopping, were it not available, 14 percent of respondents would not have shopped at all; 51 percent would have undertaken a non-trip alternative (e.g., telephone or mail order); 35 percent would have undertaken a trip;
- In the case of Internet browsing/research, were it not available, 24 percent would not have done it at all; 47 percent would have undertaken a non-trip alternative; 29 percent would have undertaken a trip.

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[22] Cao, X., Z. Xu, and F. Douma (2010) The Interactions between E-Shopping and Store Shopping: A Case Study of the Twin Cities. Prepared by Center for Transportation Studies, Humphrey Institute of Public Affairs, University of Minnesota. Available at: http://www.tc.umn.edu/~cao/Cao%20Douma,%20Cleaveland,%20Xu%202010_CTS10-12.pdf as of May 5, 2015.

[23] Zhoua, Y. and X. Wang (2014) Explore the relationship between online shopping and shopping trips: An analysis with the 2009 NHTS data. Transportation Research Part A: Policy and Practice. Volume 70.

[24] Corpuz, G., and J. Peachman (2003) Measuring the impacts of internet usage on travel behaviour in the Sydney Household Travel Survey. Presented at 2003 Australia Transport Research Forum Conference, Wellington, Australia.

3.2.3 Smart Devices

Smart device technology has stimulated the growth of shared-use mobility, include bikesharing and carsharing.[25] This section focuses on providing an overview of the impact of app-based, on-demand ride services, and app-based car sharing programs.

UberPool might be a good example of how app-based car sharing programs could affect travel demand and behavior. UberPool is one of the innovative rider splitting / carpooling programs. Since first adopted in San Francisco in 2014, UberPool has become a new mode choice – thousands of commuters use UberPool more than 5 times a week.[26] UberPool is designed to save up to 50 percent of regular cost, but users will have longer IVT. With high rates for matched trips (e.g., 90 percent from the Marina to the Financial District in San Francisco), UberPool has been contributing to VMT and vehicular emission reduction. The estimation of total daily miles (aggregation of individual rider routes and the UberPool rider routes) saved was 674,000 miles.

Rayle et al.[27] surveyed 380 ridersourcing users in San Francisco about both their ridesourcing and taxi experiences. They found that compare to taxi services, wait time for ridesourcing was markedly shorter. Around 90 percent of users reported they normally wait less than 10 minutes for a ridesourcing service. Ridesourcing wait time is also more stable and consistent as compared to taxi. Average ridesourcing vehicle occupancy (1.8 passengers per vehicle) was also higher than taxi (1.1 passengers) and San Francisco as a whole (the average vehicle occupancy for work trips was 1.1).

3.3 Underlying Travel Behavior Factors

3.3.1 Telecommuting

To look at factors that influence the future course of telecommuting, the USDOT Research and Innovative Technology Administration (RITA) released a report detailing the transportation implications of telecommuting. The report summarizes that uncertainty of benefits for employers and the time and effort inherently required to bring about significant changes in work styles will greatly affect the growth of telecommuting.[28]

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[25] Shaheen, S. (2015) Trends & Future of Shared-Use Mobility. 94th TRB Annual Meeting Workshop, Washington, D.C.

[26] Myhryold, C. It's a beautiful (pool) day in the neighborhood. Extracted in May 22, 2015, from http://blog.uber.com/uberpool-update

[27] 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.

[28] USDOT RITA. Transportation implications of telecommuting. RITA National Transportation Library. http://ntl.bts.gov/DOCS/telecommute.html. accessed May 3, 2015.

Zhou[29] used the Washington State Commute Trip Reduction (CTR) dataset in his dissertation to model the determinants of commuter's telecommuting choices. He categorized telecommuting into not telecommuting, telecommuting one day, two days, and three or more days per two weeks. A model was applied to estimate impacts of observed influences, including variables from both employer and employee surveys, on telecommuting choices.

Zhou found that commuters with a longer distance from home to work are more likely to make the transition from not telecommuting to telecommuting and to telecommuting more days if already choosing to do so. People consistently driving alone are more likely to telecommute compared with those consistently using transit or shared rides, as well as those using mixed modes.

Deng et al.[30] identified three types of telecommuting, including full-day, part-day, and overtime. They developed binary logit models and a trivariate probit model, using data collected from 1,864 commuters in Northern California, to explore impacts of different socioeconomic, attitudinal, and built-environment variables on three different types of telecommuting.

The results suggest that personal attitudes and built environment have significant impact on participants' decisions on whether/how to telecommute. Education and household also are factors that affect telecommuting decisions. The results also support Deng's hypothesis that with different employment density in residence area, same land use patterns have different influence on people.

3.3.2 E-Commerce

Age, education, and income were commonly reported as factors at play in the e-shopping decisions.[31] Cao et al.[32] used results from a survey of internet users in the Minneapolis-St. Paul metropolitan area to explore the interaction between online shopping and in-store shopping, and the influence of shopping accessibility (distance to shopping centers) on the e-shopping decision-making process. Structural equation models were used to explore connections between spatial attributes and e-shopping.

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[29] Zhou, L. (2008) Modeling the impacts of an employer based travel demand management program on commute travel behavior. Graduate Theses and Dissertations. University of South Florida, Tampa. Available at http://scholarcommons.usf.edu/etd/581.

[30] Deng, H., P. Mokhtarian, G. Circella (2014). Factors Influencing Full-day, Part-day and Overtime Telecommuting: An Investigation of Northern California Workers. 94th TRB Annual Meeting, Washington, D.C.

[31] Lee, R., I. Sener, S. Handy. (2015) A Picture of Online Shoppers: Specific Focus on Davis, California. 94th TRB Annual Meeting, Washington, D.C.

[32] Cao, X., Q. Chen, and S. Choo (2013) Geographic Distribution of E-Shopping: Application of Structural Equation Models in the Twin Cities of Minnesota. 92nd TRB Annual Meeting, Washington, D.C.

Lee, Sener, and Handy[31] analyzed variables include: online shopping binary variable, demographics, built environment, shopping attitudes, and online shopping perceptions from the shopping survey in Davis, California. The results confirmed that income and age have significant effects on online shopping decisions.

Cao et al.[32] found that shopping accessibility's influence on e-shopping is based on the geographic location. On one hand, Cao noted that since most residents in metropolitan area are better-educated and more experienced with internet, they are more likely to purchase online, even their residence is of higher shopping accessibility, compared to those who live in suburb areas. On the other hand, Cao found that limited shopping accessibility in exurban areas doesn't facilitate e-shopping activities. Cao[22] also found that high online searching frequency leads to more e-shopping and in-store shopping activities.

Survey results from Lee et al.[31] suggested inconsistent results compared to Cao's research in terms of shopping accessibility's impact on online shopping activities. They found that 90 percent of people with lowest shopping accessibility (2 miles or more away from nearest shopping center) have online shopping experience, while under 85 percent of survey participants live near shopping center (0 to 1 miles) shopped online.

3.3.3 Smart Devices

Rayle et al.[27] identified different basic characteristics of ridesourcing users and trips. Per the survey results, usage of ridesoucing can differ by people's age, education background, vehicle ownership, and trip purpose. The younger generation (15 to 34 years old) is 72 percent of total ridesourcing users (Table 3.4), and 81 percent of survey respondents have a bachelor's degree or graduate degree.

In terms of trip purpose, Rayle et al. noted that most ridersourcing trips were social/leisure trips (67 percent), including trips to bar, restaurant, concert, visit friends/family. Trips to work were only 16 percent; trips to/from airport and trips to/from transit were both 4 percent. Survey results also suggested that ridersourcing users own fewer vehicles (43 percent users have no vehicle available), and tend to travel with more companions.

Rayle et al. looked into home locations (reflected by ZIP code) for survey respondents. Most of the respondents live in three San Francisco neighborhoods. Only 6 percent of trips had at least an origin or destination outside San Francisco. It is possible that the high percentage of social/leisure trips are attributable to the survey time period. This survey was conducted in evenings and during PM peak hours (Thursdays from 5:30 p.m. to 8:30 p.m., Fridays 6:30 p.m. to 9:30 p.m., and Saturdays 7:30 p.m. to 10:30 p.m.); it included both intercept trips (trips just completed) and previous trips. The survey captured mainly evening trips to dining and entertainment venues (other types of trips were likely under represented). However, Rayle et al. stated that social and evening trips likely comprise a large part of the ridesourcing market.

Table 3.4 Age Distribution of Ridesourcing Users, Taxi Users, and City Population

Age	Ridesourcing (%)	Taxi (%)	San Francisco (%)
15-24	16	3	11
25-34	57	43	22
35-44	19	27	16
45-54	6	13	14
55-64	1	9	12
65-84	0	4	7
75+	0	2	7

Source: App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco.

4.0 Case Studies

4.1 Using an Activity-Based Model to Explore Possible Impact of Automated Vehicles (Puget Sound Regional Council)

Background. Widespread AVs have been predicted to become a reality within current future planning horizons. Regional planning agencies and Metropolitan Planning Organizations (MPOs) are beginning to prepare for the potential impacts within the time horizon of their long-range regional transportation plans. The Puget Sound Regional Council (PSRC) believes that AVs could have in their long-range goals established in the long-range regional plan. These goals include: improving safety and mobility; reducing greenhouse gas emissions and congestion; focusing growth in already urbanized areas to create walkable, transit oriented communities; preventing urbanization of rural and resource lands; and helping people live happier and more active lives.

Actions. To better understand the impact of AV technology, the Puget Sound Regional Council (PSRC) conducted research that uses modeling tools to forecast how AV affects transportation networks and travel behaviors. They used the Seattle region's activity-based model, SoundCast, to test potential impacts of automated vehicles.

Analysis. As is summarized in Table 4.1, PSRC adopted four scenarios, compared to the 2010 baseline, to model potential impacts from AV in Puget Sound region.

Table 4.1 Scenario Definitions

Scenario 1	Scenario 2	Scenario 3	Scenario 4
"AVs increase network capacity."	"Important trips are in AVs"	"Everyone who owns a car owns an AV."	“"All autos are automated, with all costs of auto use passed onto the user."
30% capacity increase on freeways, major arterials	30% capacity increase on freeways, major arterials Travel time is perceived at 65% of actual travel time for high value of time household trips (>$24/hr.)	30% capacity increase on freeways, major arterials Travel time is perceived at 65% of actual travel time for all trips 50% parking cost reduction	Cost per mile is $1.65

In Scenario 1 through Scenario 3, as a result of implementation of AVs, capacity was predicted to grow by 30 percent. Travel time was assumed to reduce for AVs by 35 percent in Scenario 2 and Scenario 3. Scenario 4 is where AVs are broadly used and travel cost per mile (1.65 dollars) is higher than the travel cost in base scenario (25 cents).

Results. As shown in Table 4.2, with a 30 percent capacity increase, Scenario 1, 2 and 3 all generated more VMT, with the increase ranging from 3.6 percent to 19.6 percent. With higher speed settings for these three scenarios, Scenario 1 and 2 showed decreases in VHT, despite having increases in VMT. With travel time being perceived at 65 percent of actual travel time for high value of time household trips in Scenario 2, and for all trips in Scenario 3, VHT grew by 17.3 percent in Scenario 3 and lightly decreased by about 2 percent in Scenario 2.

Note that VHT and delay were both increased in Scenario 3. PSRC suggested that commuters are more tolerant for longer delays and congestion when travelling in AVs. The SoundCast model also captured a decrease in public transit share (9 percent) and walk share (21 percent).

VMT and VHT were dramatically reduced in Scenario 4 (both by over 35 percent). Results from Scenario 4 indicate that with the high cost of driving, people tend to choose other modes of transportation (transit share increased by 140 percent and walk share increased by 50 percent). PSRC found that escort trips are the most sensitive to time and cost changes for all scenarios.

Table 4.2 Scenario Results, Base Year 2010, Summaries by Average Travel Day.

Measure	Value	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4
VMT	Total Daily	78.7 M	81.5 M	82.6 M	94.1 M	50.8 M
	% Change (Versus Base)	---	3.6%	5.0%	19.6%	-35.4%
VHT	Total Daily	2.82 M	2.72 M	2.76 M	3.31 M	1.67 M
	% Change	---	-3.9%	-2.1%	17.3%	-40.9
Trips	Trips/Person	4.1	4.2	4.2	4.3	4.1
Distance (miles)	Average Trip Length	6.9	7	7.2	7.9	5.8
	Work Trips	12.4	12.9	12.9	20	11.5
	School Trips	5.8	5.8	5.8	6.7	4.7
Daily (1000 hours)	Daily Average	846.0	700.0	727.2	996.1	350.2
	Freeways	288.1	201.2	218.3	338.7	56.4
	Arterials	557.9	498.8	508.9	657.5	293.8
Speed (mph)	Daily Average	27.9	30	29.9	28.4	30.4
	Freeways	40	44.7	44.2	40.8	49.2
	Arterials	22.5	23.2	23.1	22.3	24.3
Mode (%)	SOV Share	43.7	43.7	42.7	44.8	28.7
	Transit Share	2.6	2.7	2.7	2.4	6.2
	Walk Share	8.6	8.6	8.4	6.8	13.1

PSRC also performed a series of spatial analyses on distribution of potential AV effects. In these analyses, an accessibility metric (aggregate tour mode-destination logsums) was calculated for households grouped by income, vehicle availability, and transit accessibility by trip purposes, including escort, meal, personal business, school, shop, social, and work. With an increase in capacity and decrease in travel time in Scenario 3, Transportation Analysis Zone (TAZ) accessibility increases for all households, particularly for rural households. PSRC also found that AVs have similar effects on different income groups. From Scenario 1 to Scenario 3, the difference in aggregated logsums for the low income group (8.5 percent) and high income group (8.9 percent) is minor, if technology enhancements did not offset these impacts.

All of these results indicate that AVs could help enhance regional mobility due to the associated increases in system capacity and higher speeds. However, the extra VMT generated by AVs could also lead to more greenhouse gas emissions.

More… PSRC pointed out that modelers still need to work on how to define AV-related alternatives and variables for travel demand models. They suggested that a stated preference survey would help better understand impacts on travel demand and behavior. They also believe that this research is just a start; that more work on model improvement will be needed.

Source. 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.

4.2 Telecommuting in Southern California

Background. The Southern California Association of Governments (SCAG) considers telecommuting, along with flexible work schedules, as the transportation demand management (TDM) strategies that are expected to help reduce regional VMT (as is stated in the SCAG 2012 to 2035 regional transportation plan (RTP)). Meanwhile, SCAG is in the in the process of transitioning from a four-step model to an activity-based travel demand model (ABM), and needs to understand key factors in telecommuting behavior.

Actions. To better understand dimensions of telecommuting in the SCAG region, such as options, choice, and frequency, SCAG staff analyzed telecommuting activities using the SCAG-ABM. They classified telecommuting into two main types: work at home (WAH), for persons who work exclusively from home; and telecommute, for persons who telecommute regularly but not exclusively.

Analysis. In order to model WAH activities, a WAH submodel was developed as part of the work arrangement model for long-term choices procedure, using population synthesis. In the WAH submodel, person and household characteristics and industry are the primary factors that determine primary work place type (home or out of home).

In terms of telecommuters who only occasionally work at home, SCAG staff used both the 2012 California Household Travel Survey (CHTS) and the 2012 SCAG Travel Survey (CHTS add-on) to analyze each telecommuter's travel behavior and the impacts of telecommuting on travel demand. Questions in both surveys were designed to collect information on the availability and frequency of telecommuting.

Results. As is shown in Table 4.3, older males (65 years and over) with lower household income ($50,000 to $100,000) are more likely to work at home. People working in finance, investment, real estate, and information. Business services have a higher possibility of choosing to work at home.

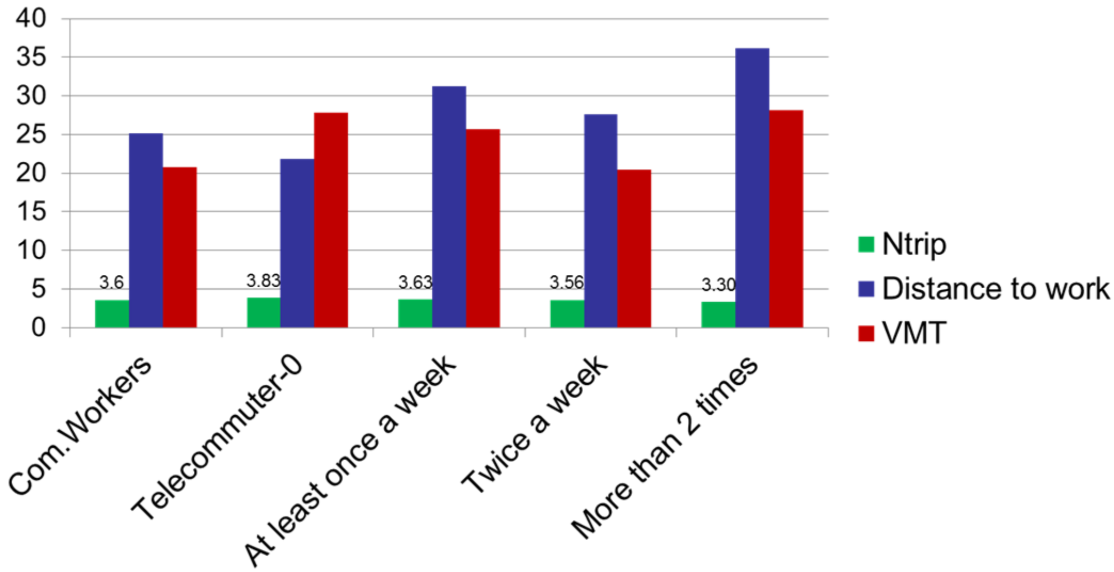
Table 4.3 SCAG-ABM Work at Home Model

		Beta – Specific to Choice Alternatives	
Constant	**Variable**	**0**	**1 (WAH)**
Constant	Constant		-3.44
Gender	Female		-0.07
Age	Less than 35		-0.514
	35-44 (reference)		
	45-54		0.239
	55-64		0.348
	65 and older		0.847
Household Income	50K-100K		0.235
	>100K		-0.283
Industry	Agriculture, Mining		-1.175
	Construction, Utility		-0.766
	Manufacturing, Wholesale		-0.929
	Retail, Other Service		-0.39
	Information, Business Service		0.201
	FIRE (Finance, Investment, Real Estate)		0.57
	Arts, Entertainment, and Hospitality, Food Service		-0.421
	Public administration		-1.699

Survey results from the CHTS and SCAG travel survey indicate that older workers are more likely of telecommute. 28 percent of people who are 60 years and older are provided with an option of telecommuting, only 3 percent of workers in the youngest age group (16 to 24 years old) are granted with the choice of working at home. Older workers also tend to choose telecommuting when they have the option (over 10 percent of people over 25 years old chose to telecommute, compared to 2 percent of people from 16 to 24 years who telecommute).

As shown in Figure 4.1, high frequency of telecommuting brings a reduction in the number of trips made, people who telecommute more than twice a week have fewest trips (3.3 trips); but no significant effects were found between telecommuting and VMT. SCAG has identified age, education, availability of a flexible working schedule or compressed working schedule, and industry as primary factors effecting the likelihood of having the option of telecommuting. Gender, age, household income, industry, presence of small children, smart phone ownership, and vehicle availability appeared to affect the decision on whether or not to telecommute.

Figure 4.1 Daily Travel Characteristics Telecommuters versus Commuters



More… WAH and telecommuting are considered as important TDM strategies to reduce roadway congestion and greenhouse gas emission. To gain a better understanding of key factors that affect WAH and telecommuting behavior, SCAG believes that the following future enhancements are necessary: more data and samples for telecommuting; consider land use and technology as additional factors; incorporate telecommuting into travel models.

Source. Aleksandr, B., H. Hu, G. Huang, M. Sangkapichai (2015) Understanding Dimensions of Telecommuting: Options, Choice and Frequency of Telecommuting in Southern California. Presented at the 15th TRB National Transportation Planning Applications Conference, Atlantic City, New Jersey.

5.0 Next Steps

5.1 Define Parameters and Data Needs

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, emerging technologies, however, are positioned to disrupt travel behaviors. As discussed in previous section, the intensifying of internet usage will expand the likelihood of alternate means being available to accomplish the same tasks that require trip making today (e.g., teleworking; GotoMeeting; online schooling, shopping, banking, and entertainment). 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 be more willing to make longer trips more frequently. So, the trip length distribution for modeling the future could be different too.

Therefore the next step is to provide limits of deviations for parameters that can be applied to model alternative scenarios. The findings can be applied to test and shape policies in regional and MPO Long Range Transportation Plans to achieve their goals and objectives.

5.2 Identify Regional and National Trends

Traditionally, increases in VMT have been projected across the United States, corresponding with population and economic growth. However, there is now empirical data indicating that this is not universally the case. Driving, as measured by national VMT, began to plateau in mid-2000, and actually dropped during the recession of 2008. Similar trends have been seen in per capita driving. Several studies that have used available data have shed light on the dominant modes of traffic, geographic areas, and whether growth is occurring on urban or rural roadways.

Thus the next step is to identify data sources that will help determine factors influencing, or that have the potential to influence these trends. The two aspects that we will focus on for this effort are: first, a review of available past VMT data; second, identification of VMT data sources that can be used to help determine factors that would allow an analysis of impacts on VMT trends by the emerging technology, demographics, and trend behavior.