Peak Travel in a Megacity: Exploring the Role of Infrastructure Saturation on the Suppression of Automobile Use

by

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ABSTRACT

Contrary to many previous travel demand forecasts there is increasing evidence that vehicle travel in developed countries may be peaking. The underlying causes of this peaking are still under much debate and there has been a mobilization of research, largely focused at the national scale, to study the explanatory drivers but research focused at the metropolitan scale, where transportation policy and planning are frequently decided, is relatively thin. Additionally, a majority of this research has focused on changes within the activity system without considering the impact transportation infrastructure has on overall travel demand. Using Los Angeles County California, we investigate Peak Car and whether the saturation of automobile infrastructure, in addition to societal and economic factors, may be a suppressing factor. After peaking in 2002, vehicle travel in Los Angeles County in 2010 was estimated at 78 billion and was 20.3 billion shy of projections made in 2002. The extent to which infrastructure saturation may contribute to Peak Car is evaluated by analyzing social and economic factors that may have impacted personal automobile usage over the last decade. This includes changing fuel prices, fuel economy, population growth, increased utilization of alternate transportation modes, changes in driver demographics , travel time and income levels. Summation of all assessed factors reveals there is at least some portion of the 20 billion VMT that is unexplained in all but the worst case scenario. We hypothesize that the unexplained remaining VMT may be explained by infrastructure supply constraints that result in suppression of travel. This finding has impacts on how we see the role of hard infrastructure systems in urban growth and we explore these impacts in the research.

DEDICATION

This work is dedicated to my parents, Greg and Teri, for giving me time and space and allowing me to decide my future.

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CHAPTER 1

INTRODUCTION

In many developed countries, there has been a plateau, and in some case a decline, in automobile travel in the past decade. Cumulative annual vehicle miles of travel (VMT) and annual VMT per capita steadily increased in most developed countries following the introduction of the personal automobile in the first half of the twentieth century but VMT in many countries have not increased since the early 2000's (Millard-Ball & Schipper, 2011). To date, the research seeking to unpack the underlying causes of this trend has focused primarily at the national level but transportation planning and policy is largely decided at the regional and local levels where research surrounding this phenomenon is relatively thin. If this trend holds there are significant implications for how mobility is planned for growing urban populations.

The demand for automobile travel is the result of the physical network (both roads and parking) and the activity system (social and economic activities) (M. Chester, Horvath, & Madanat, 2010; Manheim, 1979). Activities induce demand for travel and the design of the infrastructure results in mobility mode options (auto, transit, bike, walk, etc.), and the interaction between the two produces flow patterns that, in the many places, have resulted in peak auto use. As such, the recent trend of plateauing VMT is either the result of: i) total system stagnation, ii) changes in the transportation system, iii) changes in the activity system, or iv) changes in both transportation and activity systems. This research focuses on exploring the four possible system explanations, using Los Angeles County (LAC), California as a case study.

Previous analysis of the roadway network in LAC indicated that infrastructure deployment has slowed in recent decades. During that time network congestion increased and annual VMT has followed a similar trajectory to the one seen at the national scale (Figure 1). The confluence of these events suggests that infrastructure saturation may be suppressing vehicle.

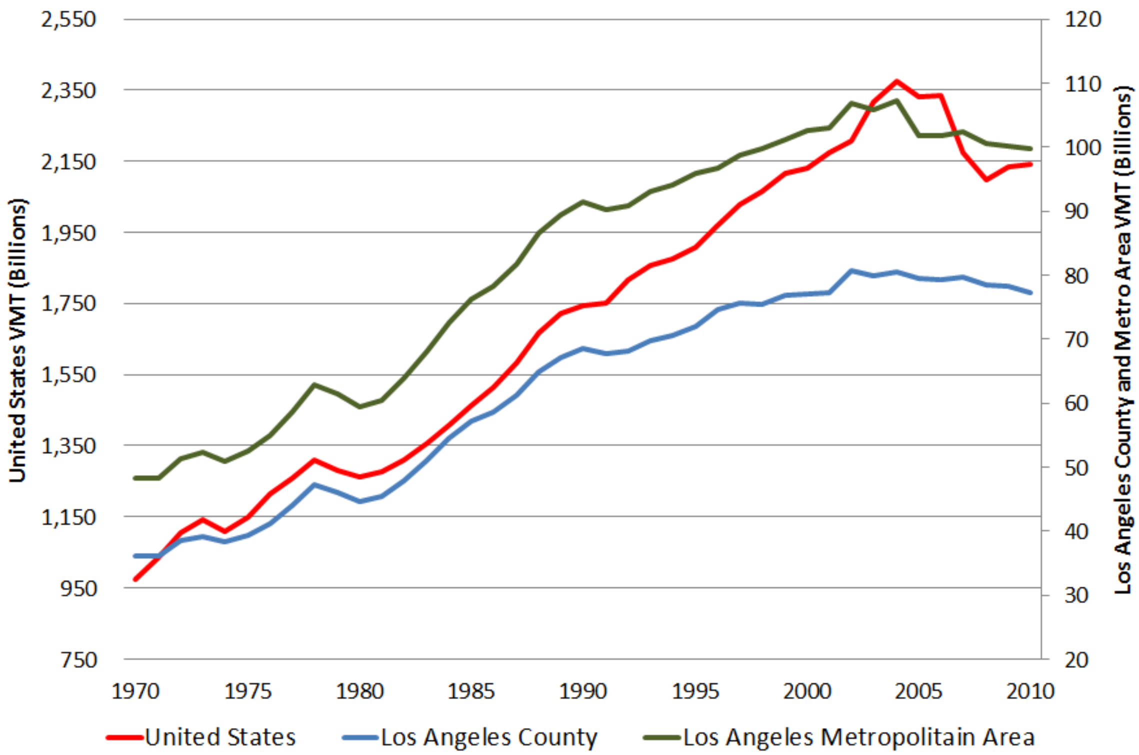

Figure 1: Annual VMT in the United States, Los Angeles County and Los Angeles Metropolitan Area 1970-2010. The recent nationwide trend of Peak Car can also be seen in both Los Angeles County and throughout the Los Angeles Metropolitan Area.

CHAPTER 2

PEAK TRAVEL BACKGROUD

In 2013, Goodwin and Van Dender published an overview of Peak Car research that focused on recent research and we add to this additional literature focused on peak car theory development.(Goodwin & Van Dender, 2013)

Evidence supporting the Peak Car theory is relatively recent but theories that an absolute limit to vehicle travel exist have been around since the early 1960's in the United Kingdom. Published in 1963, the authors of *Traffic in Towns* hypothesize that following a rapid adoption of the automobile, vehicle ownership levels and use will ultimately reach a plateau by 2010 (Buchanan, 1963). Additionally the book asserts that the absence of new infrastructure in the form of roads and parking facilities in urban areas will largely restrict the growth of vehicle travel naturally shifting it to outlying suburbs where a surplus of infrastructure exists. Conversely, the deployment of any new infrastructure will enable demand that was previously restrained by a lack of infrastructure. In 1973, the theory of automobile saturation was included in official vehicle travel forecasts for 1973-2010 which have proven to be relatively accurate (Tulpule & Litt, 1973). The saturation approach in vehicle travel forecasting was abandoned in the late 1980's in the United Kingdom (Goodwin & Van Dender, 2013). During the same time period the stability of travel time budgets were first explored. Early research found that the total expenditure of time used for daily travel remained relatively constant across space and time (Chen & Mokhtarian, 1999). Travel time budgets were first applied as a constraint in travel forecasting by Zahavi (1974). Travel time budgets were later applied to establish saturation in overall mobility. Schafer and Victor (2000) proposed a strong elasticity to total distance traveled with respect to income but suggest that total distance traveled is ultimately constrained by a stable travel time budget. The research concluded that per capita car use would reach a peak in 2010. Metz (2010) also used travel time budgets in conjunction with decreasing marginal utility of more distant locations to conclude that an overall limit to personal mobility exists.

Vehicle travel trends supporting the peak car theory began appearing in the mid-2000s in several developed countries and since 2008 the quantity of research and publications dedicated to the phenomenon have dramatically increased. Puentes and Tomer (2008) were the first to publish a report highlighting the peaking of vehicle travel in the United States. They showed that total VMT peaked in 2004 before beginning to decline in 2007. The report also highlighted that VMT per capita had plateaued in 2000. At the time of publication the drivers of the trend were not known but the authors hypothesized that vehicle ownership saturation may play a role in its occurrence. In a follow-up publication Puentes (2013) cited travel time budgets, increased public transit utilization, telecommunication and social networking, the economic recession, the decreasing trend of car ownership and use in younger demographics, increased urban density, and a return to urban living as possible contributing factors to the trend. Millard-Ball and Schipper (2011) found trends of plateauing automobile use in six industrialized countries: U.S., Japan, United Kingdom, Sweden, Australia, and Canada. Like Puentes and Tomer, they cited saturation in vehicle ownership but also included aging population, increasing fuel prices, and constraints imposed by geography, urban form, and transport infrastructure as possible causes of peak car. Newman and Kenworthy (2011) found that trend also existed in Australia and cited travel time budgets, increased public transit utilization, rising fuel prices, the decreasing trend of car ownership and use in younger demographics, urban density, and an ageing population. Goodwin (2012) and Metz (2012) focused on VMT trends in the United Kingdom with both citing increased public transit utilization, an increase in urban living and density, and saturation of destination alternatives. Goodwin also cited increasing fuel price and the declining influence of income and Metz additionally cited an aging population and declining car ownership and use in younger demographics. The underlying peak auto travel drivers identified by each study are summarized in Table 1.

Table 1 Influential Peak Car Studies

Author	Puentes and Tomer (2008), Puentes (2012)	Millard-Ball and Schipper (2011)	Newman and Kenworthy (2011)	Goodwin (2011)	Metz (2012)
Country	United States	U.S. Japan, U.K., Sweden, Australia, Canada	Australia	U. K.	U.K.
Scale	National, State and Metropolitan Regions*	National	National	National	National
Identified Potential Causes of Peak Car					
Travel Time Budgets	X		X		
Saturation of Vehicle Ownership	X	X			
Public Transit	X		X	X	X
Telecommunication	X				
Economy	X				
Declining Car Use in Younger Demographics	X		X		X
Urban Density	X		X	X	X
Self-Selection Car Light Lifestyle	X		X	X	X
Ageing Population		X	X		X
Fuel Prices		X	X	X	
Geography		X			
Urban Form		X			
Transportation Infrastructure		X			
Freight					X
Saturation of Destination Choices				X	X
Declining Influence of Income				X	

CHAPTER 3

PEAK AUTO TRAVEL IN LOS ANGELES

When the peak car theory was first developed in the 1960s and 1970s, the effect of infrastructure saturation was heavily included in the conversation but most recently attention has shifted to factors influencing the activity system. While Los Angeles is a relatively young city by developed country standards, its roadway infrastructure growth appears to have slowed (California Highway Performance Monitoring System, 1996-2011). Given that automobile travel is the equilibrium result between the activity and infrastructure systems, the effects of an increasingly saturated physical transport network should be explored. Furthermore, past studies have also tended to focus at the national scale and their results may not be representative of what is happening with vehicle travel at a more granular scale.

Worldwide, Los Angeles, California is synonymous with the automobile and the city's struggles with traffic congestion are well documented (Schrank, Eisele, & Lomax, 2012). The sprawling suburbs and polycentric design has resulted in the heavy reliance on the automobile (Wachs, 1984). The roots of the modern transportation system can be traced back to 1924 when the first regional transportation plan was passed in response to growing inner city congestion caused by the rapid adoption of the automobile (Wachs, 1993). The passage of the "Major Street and Highway Plan" was the beginning of a pattern of preferential funding for automobile related infrastructure (Wachs, 1993). The roadway network in Los Angeles has become one of the largest and most congested in the country today with 93% of peak travel and 62% of lane miles congested (Schrank et al., 2012).

The congestion conditions in Los Angeles indicate that there are portions of the transportation system that have reached a saturation point for vehicle travel and the impact of constrained capacity on vehicle travel across the system is not understood. An analysis of individual driving characteristics using the 2001 and 2009 National Household Travel Surveys (NHTS) reveals that there have been significant changes in annual VMT at the individual level (Table 2) (Federal Highway Adminstration, 2001, 2009). These changes mirror those seen at the national level but are more pronounced in Los Angeles. While weekday (Monday-Thursday) and weekend (Friday-Sunday) vehicle trip totals for individuals have remained relatively stable, declining 1% and 5% respectively, there have been significant reductions in trip lengths for all activity types except family and personal business and overall trip lengths have decreased by 10%. But what other activity and exogenous factors have changed that might explain these drops and when these factors are assessed, do they sufficiently capture the reductions that have been seen or might saturated infrastructure also be contributing? We explore this question.

Table 2 Changes in Annual VMT and Automobile Trip Characteristics Means in the United States and the LA-MSA. Changes in annual VMT by Age Group and Average Trip Length are more pronounced in the LA-MSA than they are nationwide. There has been relatively little change in the automobile trip frequency for both the US and LA-MSA

	United States			Los Angeles-Long Beach-Aneheim MSA		
Annual VMT By Age Group	2001	2009	% Δ	2001	2009	% Δ
16-19	7,590	5,670	-25%	7,400	5,100	-31%
20-29	14,830	13,550	-9%	15,880	12,480	-21%
30-39	16,150	15,420	-5%	14,600	13,680	-6%
40-49	15,620	15,420	-1%	15,650	13,870	-11%
50-64	13,590	13,380	-2%	12,600	12,610	0%
65+	7,970	8,330	5%	6,990	7,540	8%
Average Trip Length (miles)						
Total	9.6	9.8	2%	9.9	8.9	-10%
Home	9.6	8.7	-10%	9.6	7.8	-20%
Work	12.0	13.9	16%	14.4	13.8	-5%
School/Daycare/Religious Activity	6.0	6.7	11%	8.3	5.7	-31%
Medical/Dental Services	10.9	10.8	0%	10.9	8.4	-23%
Shopping/Errands	6.9	6.3	-9%	6.1	4.8	-21%
Social/Recreational	16.0	14.6	-9%	17.0	13.9	-18%
Family Personal Business/Obligations	7.8	10.4	34%	8.2	9.8	19%
Transport Someone	7.9	8.3	5%	9.7	6.5	-33%
Meals	7.9	7.9	-1%	7.3	7.3	-1%
Average Daily Vehicle Trips Per Driver						
Week Day (M-Th)	4.1	4.2	3%	4.2	4.2	-1%
Week End (F-SUN)	4.0	4.0	-2%	4.25	4.0	-5%

CHAPTER 4

METHODS

The extent to which infrastructure saturation may be contributing to Peak Car is evaluated by joining an infrastructure growth model, vehicle travel data, and an assessment of explanatory socio-economic drivers for automobile travel demand. The objective is to explain how the recent plateau and subsequent decline in vehicle miles of travel (VMT) in Los Angeles County (LAC) can be explained by socio-economic and market conditions, and how a constraint on roadway supply may have contributed. There are two phases to this approach: i) the development of a historical inventory of roadway infrastructure growth with a comparison to annual vehicle travel, and ii) the evaluation of changes to specific socio-economic and automobile use factors and the impact they have had on travel demand in LAC. The first phase makes it possible to identify a point in time when the existing infrastructure may have reached a capacity limit and in the second phase an estimate of infrastructure saturation as a suppressive factor to overall travel demand is developed.

The analysis focuses on LAC through 2010, a region that is part of the larger Los Angeles metropolitan area, largely due to data quality. Data for the infrastructure and socio-economic analyses are widely available at the county level. While some data for the Los Angeles—Long Beach—Anaheim Metropolitan Statistical Area (LA-MSA) (which encompasses portions of 2 counties in the Los Angeles metropolitan area) are available, necessary infrastructure, travel, and socio-economic data at this scale were not universally available. As such, LAC is used as the region of focus and includes 9.8 of the 12.8 MSA residents in 2010 (U.S Census Bureau, 2012). 2010 was selected as year of the analysis.

To assess the impact of roadway supply on vehicle travel, a network growth model is needed. The historical deployment of interstates, freeways and highways in LAC is well documented but there is a poor understanding of when the majority of roadways (specifically local, collector, and arterial) were constructed (Taylor, 2000). Due to their size and scale most highways, freeways, and interstates (collectively referred to as highways here after) have rich documentation that details their designs and costs (Nelson, 1983; Taylor, 2000). In contrast, records detailing the deployment of arterial, collector, and local roads are not available in a consolidated database for the entire county. A network growth model is developed that assigns a year of construction to individual links in the network based on a statistical assessment of nearby building ages. It is assumed that the deployment of roadway infrastructure coincided with the construction of adjacent buildings. Using building construction years from the LAC Building Assessor's Office, a statistical analysis of structure ages in each travel analysis zone (TAZ) is developed and links in each TAZ are assigned a year of construction equal to the mean less one standard deviation (LA County Assessor, 2009; Thomas Brothers Map Company, 2009). TAZs are on average 3 square miles (Institute of Transportation Studies - UC Davis, 2001). The underlying assumption is that most roads were deployed when a majority of the buildings in a neighborhood were constructed. The result is a spatial-temporal analysis that details the historic deployment of roadways in LAC. For validation, aerial photos and maps were used to confirm the results (Cameron, 2004; Creason & DeLyser, 2010; Evanosky & Kos, 2010; Fogelson, 1993; Nelson, 1983). Road mileage totals for each road classification were scaled up to lane mileage assuming 2, 4, 6, and 10 lanes for local, collector, arterial and highways respectively.

Historical vehicle miles of travel (VMT) estimates were developed from regional and state datasets. Data on annual VMT in LAC were published by the California Highway Performance Monitoring System between 1996-2012 and based on average daily traffic counts and show that VMT in LAC peaked in 2002 (California Highway Performance Monitoring System, 1996-2011). LA-MSA VMT estimates are available from 1989 to present (Federal Highway Adminstration, 1989-1995). Prior to 1989, only statewide estimates were identified, beginning in 1967 (Federal Highway

Adminstration, 1967-1988). To capture a sufficiently long time period, a countywide to statewide population ratio was used to estimate LAC VMT 1967-1988 from the statewide VMT estimates (U.S. Census Bureau, 2014). Similarly, a countywide to LA-MSA population ratio was used to estimate LAC VMT from 1989-1995. The pre-1996 extrapolation method is validated with existing estimates that were found sporadically in the literature (California Department of Transporation, 2004).

A large body of research exists that explores the relationships between socio-economic drivers and passenger and freight travel and we leverage these findings to assess the range of contribution to historical changes in travel. To isolate the primary drivers of peak and declining travel, it is necessary to evaluate the potential range of contribution of socio-economic and market factors. A literature review was developed and identified the changes in population, transit use, driver demographics, licensure rates, vehicle availability, trips, trip lengths, income, employment opportunities, fuel price, fuel economy, and freight activity as key elements that are expected to impact vehicle transportation levels. These factors are either used directly or joined with travel elasticity estimates to calculate the significance of the variable in LAC's changing travel. The primary data used to determine changes in these factors are provided in Table 3. A range of elasticities is developed by evaluating studies from the United States, Canada and Western Europe due to a lack of studies focused on Los Angeles or Southern California. It is assumed that the drivers are not correlated and their impact on VMT changes are evaluated with the variability that appears in elasticity estimates Figure 2. The socio-economic analysis is focused on changes that occurred following a peak in vehicle travel in LAC concerned with explaining the deviation between observed VMT in 2010 and VMT projections made prior to the peak.

Table 3: Socio-Economic Database Sources. These sources were used to determine changes in socio-economic factors in Los Angeles County between 2002 and 2010

Socio Economic Factor	Source
Population	U.S. Census Bureau
Transit Use	National Transit Database TTI – Urban Mobility Report
Driver Demographics	Federal Highway Administration Highway Statistics Series Table DL-22 National Household Travel Survey 2001 & 2009Δ
Licensure Rates	Federal Highway Administration Highway Statistics Series Table DL-22 California DMV
Vehicle Availability	California DMV±
Automobile Trip Characteristics	National Household Travel Survey 2001 & 2009Δ
Income & Employment	U.S Bureau of Economic Analysis
Fuel Prices	U.S. Energy Information Administration
Fuel Economy	California Emissions Factors Model (EMFAC)
Freight Activity	Southern California Association of Governments – Regional Transportation Plans EMFAC California Department of Transportation – Average Daily Truck Traffic Counts

± Available only until 2008
Δ 2001 & 2009 NHTS are used to estimate travel characteristics in 2002 & 2010

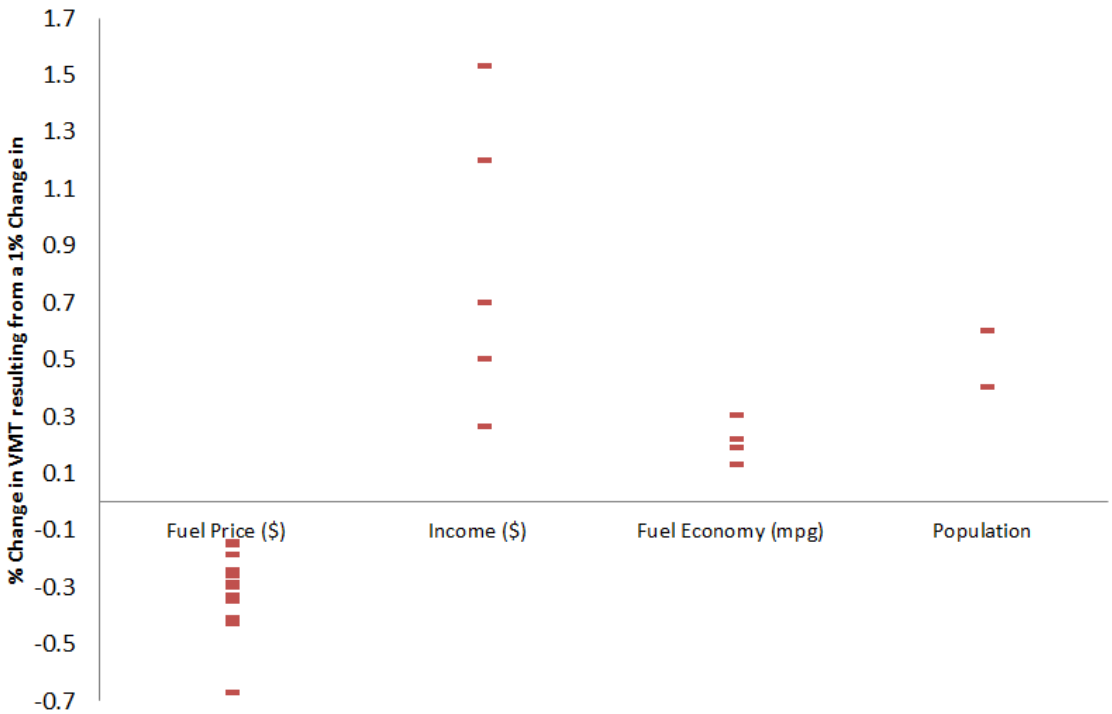

Figure 2 VMT Elasticities with Respect to Fuel Price, Income, Fuel Economy, and Population.

Increases in population have been shown to have a positive impact on VMT with elasticities measured between 0.4 - 0.6 (Hansen & Huang, 1997). LAC experienced little growth in population between 2002-2010 only gaining 108,900 new residents, an increase of ≈1% (U.S. Census Bureau, 2014). Expected increases in VMT as a result of population growth could be limited if not matched with equivalent growth in licensed drivers and available vehicles. A review of DMV records reveals that there was an overall increase in the total number of licensed drivers, 5,850,223—5,946,629, while drivers licenses per capita remained relatively constant, 0.602—0.605, from 2002-2010 (California Department of Motor Vehicles, 2014; Los Angeles Almanac, 2014a; U.S. Census Bureau, 2014). Similarly, there was an increase in total registered vehicles as well as vehicles per licensed driver between 2002-2008 (vehicle registration data are not available for 2009 and 2010) (Los Angeles Almanac, 2014b). These increases indicate that licensure rates and vehicle availability would not have limited VMT increases attributed to population growth over the assessed time period.

The peak and subsequent decline in annual VMT in LAC occurred before the beginning of the economic recession in 2007 yet changes in income and countywide jobs should be assessed. The extent to which economic and job activity influences travel demand is evaluated by analyzing changes in income per capita and countywide employment. Between 2002-2010 income per capita increased by 8% in LAC (U.S. Bureau of Economic Analysis, 2014a). VMT elasticities with respect to income range between 0.263—1.54 (Dargay, 2007; Gillingham, 2011; Johansson & Schipper, 1997; Parry & Small, 2005; Small & Van Dender, 2007). Despite an increase in per capita income, the total number of jobs in LAC decreased by approximately 250,000 (U.S. Bureau of Economic Analysis, 2014b). VMT reductions from a decrease in overall workforce is calculated by comparing worker and non-worker automobile travel characteristics derived from the 2001 and 2009 National Household Travel Survey (NHTS) (Federal Highway Adminstration, 2001, 2009).

Fuel prices have increased by 70% in LAC between 2002 and 2010 and has the potential to affect travel demand (Goodwin, Dargay, & Hanly, 2004; U.S. Energy Information Adminstration, 2014). Long run elasticities for changes in fuel prices range from (-0.67)-(-0.14) (Gillingham, 2011; Goodwin et al., 2004; Johansson & Schipper, 1997; Jong, Biggiero, & Coppola, 1999; Parry & Small, 2005; Small & Van Dender, 2007; Walls, Krupnick, & Hood, 1993). Commonly referred to as the rebound effect, increases in vehicle fuel economy can offset a portion of the increased costs associated with rising fuel prices (Small & Van Dender, 2007). The California Air Resources Board's (CARB) Emissions Factors model (EMFAC) is used to estimate changes in fleet wide fuel economy for passenger vehicles in LAC between 2002-2010 (CARB, 2011). Elasticities associated with fuel economy have been estimated to range from 0.13-0.3 (Greene, 1992; Greening, Greene, & Difiglio, 2000; Small & Van Dender, 2007; Wagner & Lee, 2012).

LAC has invested heavily in public transit in the past two decades and its growing transit ridership may be shifting travelers from automobiles. Public transit ridership is determined from the

National Transit Database (NTD) for all reporting agencies in LAC during the assessed time period (Federal Transit Adminstration, 1997-2010). There is a limited understanding of the effects of transit usage on VMT with very few published studies (Salon, Boarnet, Handy, Spears, & Tal, 2012). However, at the outside, if we consider average automobile trip occupancy derived from the 2001 & 2009 NHTS, 1.63 and 1.67 respectively, the relationship between passenger miles traveled (PMT) on transit and VMT based purely on occupancy is 1:0.59-0.61 (Federal Highway Adminstration, 2001, 2009). For trip distance shifts, some previous research has assumed a 1:1 relationship between transit PMT and avoided auto VMT (M. Chester, Pincetl, Elizabeth, Eisenstein, & Matute, 2013; Choo, Mokhtarian, & Salomon, 2005). Other research asserts that additional transit PMT can result in VMT reductions greater than one due to trip chaining, changes in route choice and destination, and transit use in combination with walking/biking. Existing research has found that transit leverages range from 1.4-9 avoided auto VMT for every transit PMT (Holtzclaw, 2000; Litman, 2004). Accounting for occupancy and transit leverage, increased transit utilization is evaluated with a range of transit leverages from 0.59-5.6.

Changes in driver demographics, specifically related to age, has been identified as a potential leading cause in shifts in auto VMT over the last decade (Kuhnimhof, Zumkeller, & Chlond, 2013). Data specific to LAC that detail the demographics of drivers are not publically available. California state distributions of driver age are used as a proxy for LAC and applied to the number of drivers licenses between 2002 and 2010 in LAC to estimate changes in driver demographics (California Department of Motor Vehicles, 2014; Federal Highway Adminstration, 1995-2010; Los Angeles Almanac, 2014a). The results are compared to changes in driver demographics in the LA-MSA between the 2001 and 2009 NHTS for validation (Federal Highway Adminstration, 2001, 2009). Only NHTS respondents who identified themselves as a driver were used in the validation. Average annual VMT totals for different age groups were computed by analyzing the vehicle use characteristics of persons who identified themselves as drivers in the 2001 and 2009 NHTS (Federal Highway Adminstration, 2001, 2009).

The state of the economy and recent trends in logistics may have impacted freight related travel. There is a dearth of high quality data at the county level, but several regional government sources provide insight into potential trends from 2002-2010. The Southern California Association of Governments (SCAG), a Metropolitan Planning Organization (MPO) which includes LAC, provides estimates of passenger VMT and heavy duty truck VMT (HDT VMT) in the 2004, 2008, and 2012 Regional Transportation Plans (RTPs) (Southern California Association of Governments, 2004, 2008, 2012). The estimates are developed by SCAG's proprietary travel demand model and provided at the regional level and for individual air basins. The urbanized portion of LAC is part of the South Coast Air Basin (SCAB) and the high desert area is part of the Mojave Desert Air Basin (MDAB). Linear interpolation is used to estimate 2002 and 2010 HDT VMT from the 2000, 2003, 2008, and 2012 RTPs. CARB's EMFAC model provides HDT VMT estimates at the MPO and county level for every year and are a based on a separate heavy duty truck travel demand model (CARB, 2011). In both SCAG's model and the EMFAC model, HDT VMT represents approximately 5-7% of the total VMT in the specified regions. The Annual Average Daily Truck Traffic (AADTT) report issued by the California Department of Transportation details average estimates for truck travel on various links in the state highway system (California Department of Transporation, 2004; California Department of Transportation, 2010). LAC highway segments that appear in both the 2002 and 2010 reports are analyzed to identify potential changes in HDT VMT.

CHAPTER 5

RESULTS

The roadway network was deployed largely between 1940 and 1970 and since 1980 this growth has significantly slowed. The region has the densest road network of any in the US and ranks eighth in lane miles per capita (Sorensen, Wachs, Min, Kofner, & Ecola, 2008). There are approximately 68,400 lane miles of combined highway, arterial, collector and local roads in the county and Figure 3 illustrates how this infrastructure was deployed over time. Local roads are the single largest roadway type in the network at 36,500 miles accounting for 53% of the total lane miles. The network experienced its largest rate of expansion during the late 1930s through the 1950s when between 620 and 2,900 lane miles per year were added. Over half of the network's lane miles were constructed between 1935-1960 coinciding with Federal Housing Administration (FHA) policies that encouraged low-density development of residential property, the widespread dismantling of the interurban rail lines, and the rise of the personal automobile as the dominant mode of travel (Nelson, 1983; Wachs, 1984, 1993; Whittemore, 2012). Expansion of the network has slowed since 1980 with lane miles being added at a decreasing rate. By 1990, 99% of the existing roadway network had been deployed.

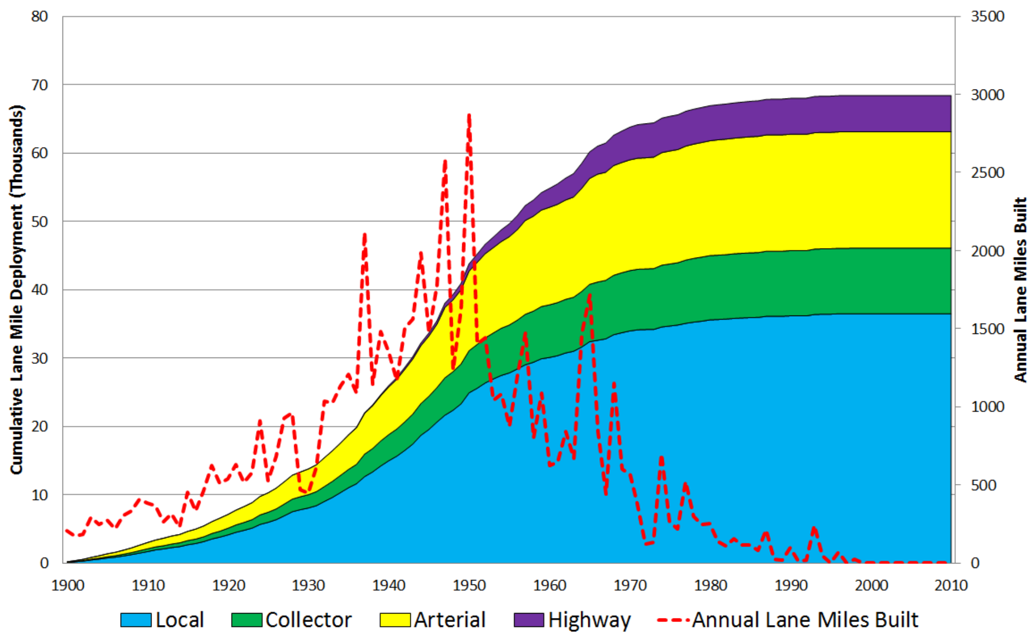

Figure 3 The Deployment of Lane Miles in Los Angeles County between 1900-2010. The red dotted line shows the annual deployment of lane miles and the colored stacked area chart depicts the cumulative lane miles in LAC.

Future expansion of the roadway infrastructure is limited by the extent of the existing built environment, natural topography, and isolation and protection of remaining open land Figure 4. The sprawling growth over the last century has consumed nearly all of the available public land in the Los Angeles Basin, San Fernando and Santa Clarita Valleys (Dear, 2001). The natural topography of the San Gabriel and Santa Monica Mountains makes them ill-suited for urban growth and a vast majority of this land is federally owned and set aside for conservation purposes (Dear, 2001). There is also available land in the high desert near the cities of Palmdale and Lancaster in the northeast portion of the county. However, the high desert's isolation from the rest of LAC, specifically its distance from major commercial and employment centers, and harsh climate makes significant development unlikely (Dear, 2001). Without future urban development it can be expected that there will be little to no significant future expansion of the existing roadway network through the addition of new road miles.

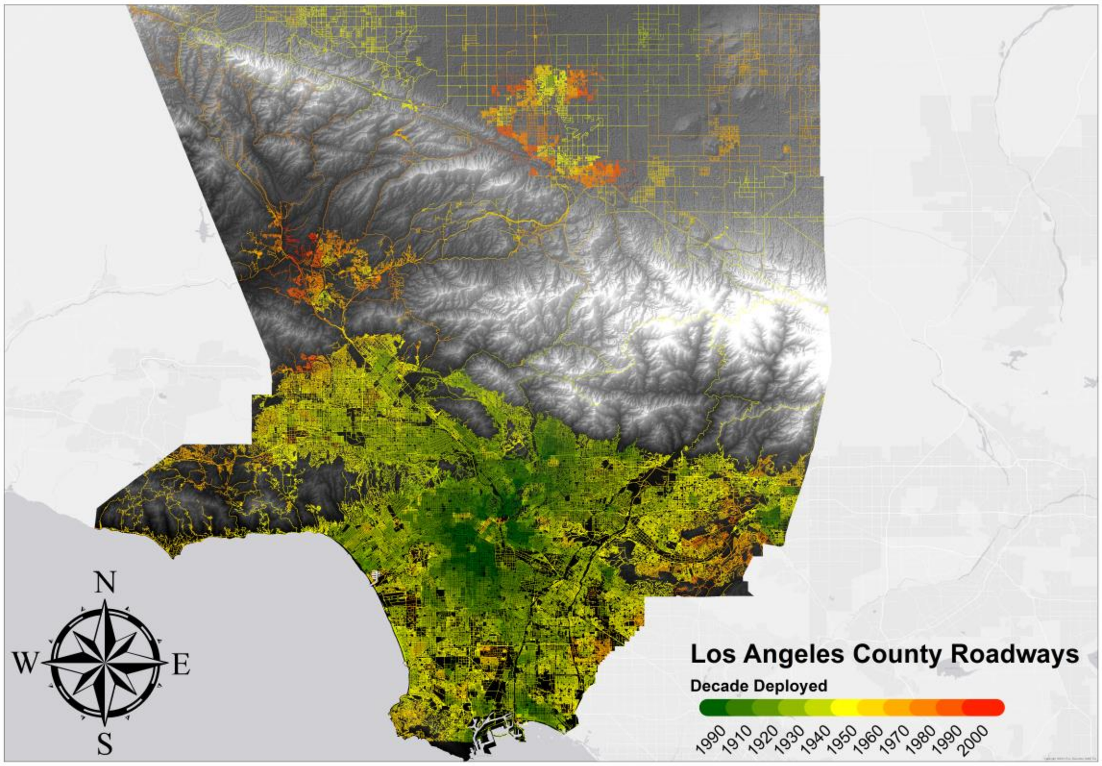

Figure 4 Spatial-temporal deployment of the Los Angeles County Roadway Network. Roads in older areas of the county (Downtown, Pasadena, Long Beach) are represented by green and yellow colors and the newer areas (Santa Clarita, Landcaster, Palmdale) are orange and red. The Los Angeles Basin in the southen part of the county is sperated from the high desert in the north by the San Gabriel Mountains. The grey scale topographic is provided for clarity of the natural land form. Areas of lower elevation are characterized by black shading which transitions towards to white as elevation increases. The highest point in Los Angeles County is Mt. San Antonio (10,068 ft)

LAC experienced a continuous rise in annual countywide VMT and VMT per capita until 2002 when travel peaked and then decreased. The peak in VMT occurred approximately 10 years after 99% of the network had been deployed and at a time when 85% of travel during daily peak periods experienced congestion (Schrank et al., 2012). In 2002, VMT and VMT per capita peaked at 81 Billion and 8,300 respectively. By 2010, annual VMT in LAC declined by 3.4 billion, a 4.1% drop, and VMT per capita declined to 7,900, a 5.2% decrease. The 2002 California Motor Vehicle Stock Travel and Fuel Forecast (MVSTAFF) predicted 98 billion VMT in LAC in 2010, 20 billion greater than what actually occurred in 2010 (California Department of Transporation, 2002). VMT in Los

Angeles County in 2010 fell short of all previous MVSTAFF projections (California Department of Transporation, 2013).

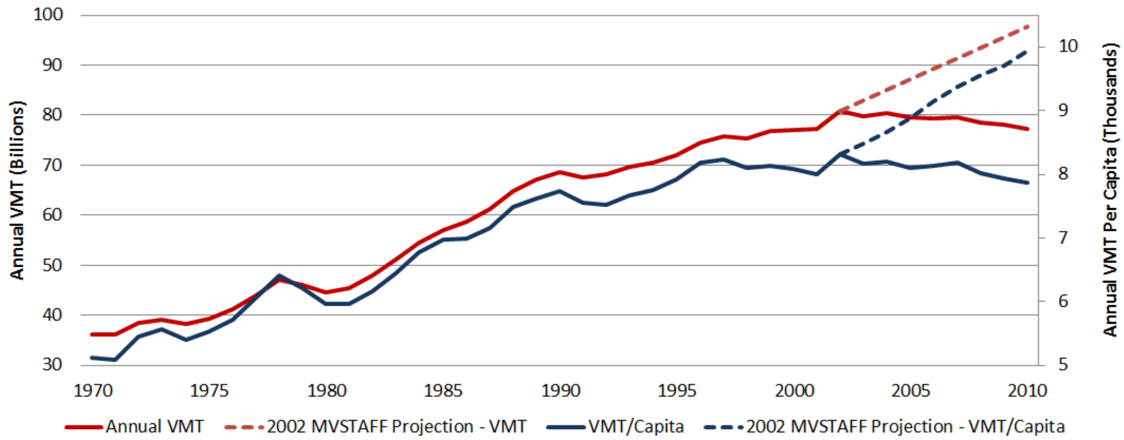

Figure 5 – Growth of VMT and VMT Per Capita in LAC 1970-2010. VMT and VMT per Capita experienced a fairly continuous rise in VMT until peaking in 2002. Between 2002 and 2010 both VMT and VMT per Capita declined. The red and purple dotted lines represent increases predicted by the 2002 MVSTAFF report for Annual VMT and Annual VMT Per Capita.

The slowing growth of the LAC Roadway Network has reached a peak and as the county experiences population growth the demand for automobile transportation may be outpacing the supply of infrastructure**.** The increasing demand without equivalent increases in the supply of infrastructure can result in congestion effects that have been well documented (Schrank et al., 2012). Destination accessibility, which has been identified as a predictor of travel behavior, may have been significantly impacted by increasing levels of congestion resulting in a suppression of overall automobile travel demand (Ewing & Cervero, 2001). By 2010, LA county was experiencing 20 billion fewer auto VMT than had been forecast in 2002 (California Department of Transporation, 2002).

CHAPTER 6

DRIVERS OF PEAK CAR IN LOS ANGELES

Since 2002 there have been socio-economic, fuel price, and fuel economy changes in LAC with some factors contributing to increases in travel and others decreases.

Incentives for Passenger Travel

Population growth, increasing income per capita and fuel economy since 2002 have likely contributed to more demand for personal vehicle travel. Vehicle use forecasts typically attribute a significant portion of the prospective increases in VMT to population growth (Polzin, Chu, & Toole-Holt, 2004). The population increase between 2002-2010 should have resulted in an overall increase of 360-540 million annual VMT when VMT elasticities with respect to population growth are applied (Hansen & Huang, 1997). These elasticities result in an additional 3,300-5,000 VMT per new resident annually. To a certain level, rising income increases discretionary spending and the consumption of goods and services, which manifests with increased vehicle travel (Millard-Ball & Schipper, 2011). There was a slight dip in income per capita in LAC between the onset of the recent recession and 2010 but there was an overall increase since 2002 from $38,880-$41,030 (U.S. Bureau of Economic Analysis, 2014a). Increasing income should have created demand for an additional 1-6.1 billion annual VMT, an increase of 100-620 annual VMT per capita. Furthermore, increases in vehicle fuel economy should reduce the costs of driving thereby creating demand for additional vehicle travel. Average fuel economy for passenger vehicles in LAC increased from 19.4-20. 1 mpg between 2002-2010 (CARB, 2011). Using VMT elasticities with respect to changes in fuel economy, the increasing fuel economy should have increased annual VMT by 274 – 714 million, an increase of 28-72 annual VMT per capita. In total, increases in population, income, and fuel economy should have resulted in an additional 1.6 – 7.4 billion annual VMT between 2002 and 2010.

Suppression of Passenger Travel

The increasing cost of fuel, public transportation access, and decreases in employment opportunities may have contributed to the recent plateau and decline in annual VMT. Increasing fuel prices are found to have the greatest potential influence on VMT reductions. In LAC, the average price per gallon of gasoline increased from $1.98 to $3.16 (inflation adjusted to $2010) (U.S. Energy Information Adminstration, 2014). Using fuel price elasticities, the increasing prices could have suppressed 4.8-23 billion VMT in 2010. Use of the LAC public transportation system (which includes bus, subway, light rail, and commuter rail) increased from 2.41 to 2.51 billion PMT from 2002-2010 (Federal Transit Adminstration, 1997-2010). Using auto VMT to transit PMT shift ratios, the increase in public transit usage may have displaced 54-533 million auto VMT. For the LA-MSA in the 2001 and 2009 NHTS, self-identified non-workers drove an average of 7,780 and 6,600 annual VMT less than workers (Federal Highway Adminstration, 2001, 2009). The recent economic recession has resulted in the loss of 250,000 jobs in LA and could have decreased annual VMT by 1.7-1.9 million (U.S. Bureau of Economic Analysis, 2014b). The combination of these factors may have suppressed 6.5-25.8 billion annual VMT in 2010.

Changes in Freight Travel

The extent to which HDT VMT may have changed is difficult to ascertain, but all three sources indicate that a decrease in freight traffic in LAC between 2002 and 2010 likely occurred. A dearth of data and geographic discrepancies make it difficult to assess accurate changes but because HDT VMT estimates range between 5-7% of total regional VMT even dramatic reductions in freight traffic are expected to have a relatively small impact. SCAG's RTPs estimate that HDT VMT in SCAB and MDAB decreased by 430 million from 2002-2010, a 4.3% decrease (Southern California Association of Governments, 2004, 2008, 2012). The asynchronous geographies make it difficult to estimate changes specific to LAC and the periodic estimates developed by SCAG (once every 4 years) does not allow for specific estimates to be developed around the recession which began in 2007. EMFAC estimates of HDT VMT in LAC also decreased from 2002-2010 by 91 million, a 2.3% reduction (CARB, 2011). A comparison of MPO level estimates reveals that the EMFAC model predicts 10-24% fewer HDT VMT than SCAG's model Figure 6. Analysis of the AADTT reports finds 173 highway links listed in both the 2002 and 2010 report of which 57% experienced a reduction in AADTT from 2002-2010. In total HDT VMT fell by 6.5%, a greater reduction than those estimated by either travel demand model (California Department of Transporation, 2004; California Department of Transportation, 2010). Using the reduction estimated by EMFAC as a lower bound and combining the overall reduction estimated by AADTT (6.5%) with the maximum ratio of HDT VMT to total VMT (7%) to define the upper bound, it is estimated that HDT VMT in Los Angeles County decreased between 91-370 million from 2002-2010.

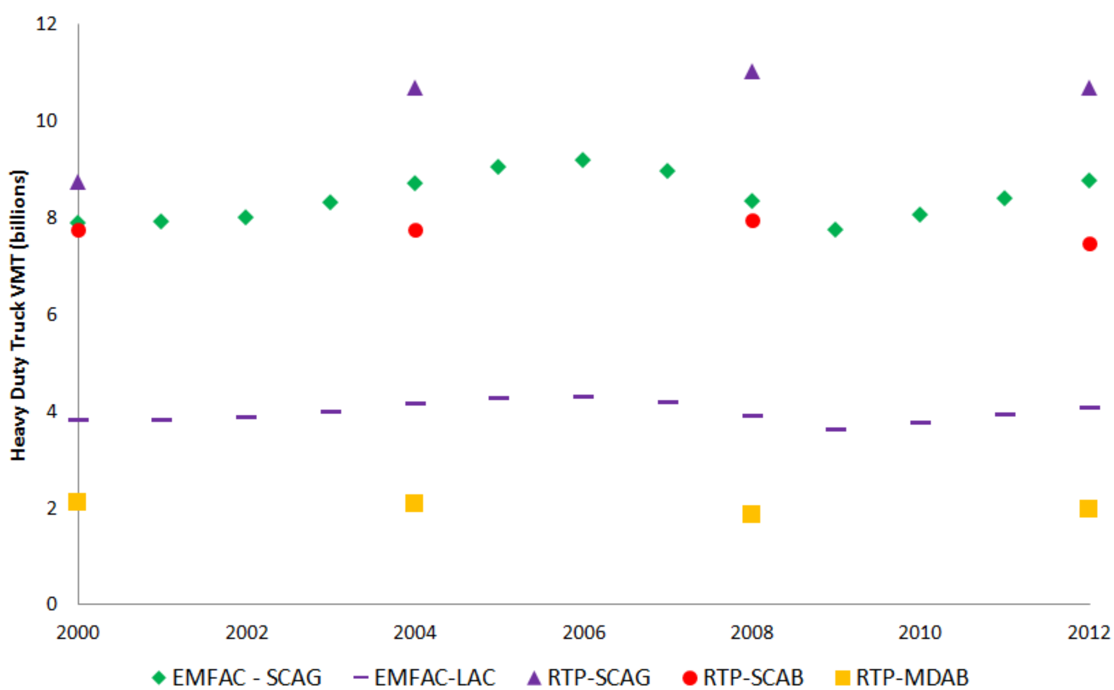

Figure 6: Heavy Duty Truck VMT 2000-2012 – There are obvious differences between the SCAG and EMFAC Heavy Duty Traffic Demand Model. There is a lack of data between 2008 and 2012 in SCAG's RTP and extrapolation may not capture the impact of the economic recession seemingly captured by EMFAC's model.

Driver Demographics

Changing driver demographics, specifically the general aging of the population, should impact overall vehicle travel demand (Table 2). Despite decreases in annual VMT for younger drivers and an increase for drivers older than 65 from 2001-2009, there is still a dramatic reduction in average annual VMT as individuals reach retirement age. The demand for vehicle travel has fallen at the individual level from 2001-2009 with reductions in annual VMT for most age groups and reductions in average trip length in LAC. The equilibrium and feedback relationships that exist between roadway supply and activity levels make it difficult to describe these changes to the activity system as independent contributors to Peak Car or changes that result from the influence of a saturated infrastructure system suppressing vehicle flows.

Cumulative Impacts

Given the uncertainty in the underlying methods, the degree to which the reduction in LAC VMT is explained by the factors analyzed is assessed through five bounding scenarios. The difference between observed VMT in 2010 and the 2010 forecast by 2002 MVSTAFF is 20 billion. For each scenario, the factors that increase and decrease VMT are shown in best and worst cases and are illustrated in Figure 7. Scenarios 1 and 2 capture the lower bound for all factors that may have suppressed vehicle travel combined with the upper and lower bound for those factors which may have had a positive impact on VMT. Similarly, in scenarios 4 & 5 the upper bounds for factors suppressing vehicle travel are combined with the upper and lower bounds for factors which may have had a positive impact on annual VMT. Scenario 3 captures the mean impact for all factors. Scenario 1 shows how if LAC experienced the minimum suppression (increasing cost of fuel, public transportation, job losses, and freight) and maximum incentivizes (population growth, income per capita and fuel economy) affects then a slight net increase in VMT would have been expected. For Scenarios 2 through 4, decreases of 5-18 billion annual VMT were expected which is less than the difference between the observed and projected VMT. In Scenario 5, however, the 24.5 billion annual VMT decrease is larger than the difference between the observed and projected VMT levels, fully explaining peak travel in LAC with socio-economic, fuel price, and vehicle technology changes. While it is possible that (at the outside of what is reported in the literature) these factors alone are responsible for LAC's change in personal vehicle travel behavior, Scenarios 1-4 show that there may be missing explanatory drivers.

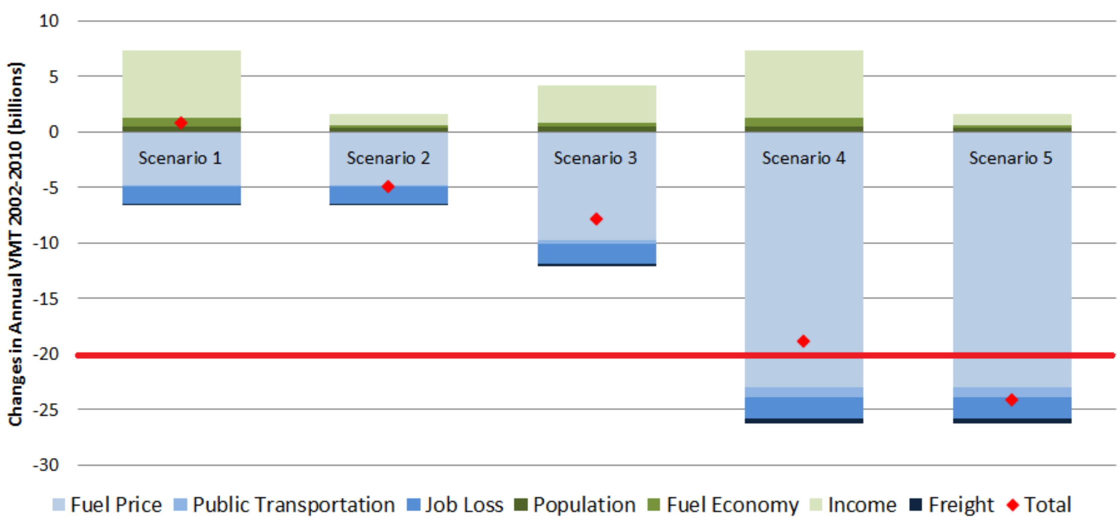

Figure 7: Total Changes in Annual VMT in LAC between 2002 and 2010 from assessed factors. The scenarios capture the upper and lower bounds of overall impact from seven overall factors. The red diamonds illustrate the summation of all impacts. In all scenarios, except for Scenario 5, the total difference is less than 20 billion annual VMT, the difference between 2002 MVSTAFF projections for 2010 VMT and actual 2010 VMT, depicted by the solid red line.

There is significant variation in the extent each factor may have influenced VMT in LAC from 2002-2009. The rising price of fuel over the last decade may have dramatically impacted travel in LAC. However, only at the outside and with little effect from income can it explain observed VMT's deviation from projections. It is generally expected that the price of fuel will continue to rise and that may have significant implications for future VMT in LAC. There has been VMT shifts resulting from job loss and VMT should be expected to rise slightly as economy recovers. Shifts to public transit and declining freight, both of which have been cited in the literature as potential drivers, likely have had little impact on VMT in LAC. With a mature roadway infrastructure and increasing congestion the possibility of infrastructure saturation suppressing personal vehicle mobility exists.

CHAPTER 7

DISCUSSION

The results indicate that the limits of auto-oriented transportation infrastructure supply should be considered when analyzing and predicting travel behavior and this has largely been ignored in the discussion of Peak Car. LAC has struggled with managing the demand for auto-mobility for many years and it is possible that current levels of demand have exceeded the capacity of the system resulting in congestion levels and increased travel times which may be shifting a portion of would-be auto travelers to alter choice of destination, elect to use alternate modes, or decide not to travel at all. It should be noted that the greatest reductions in trip lengths from 2001-2009 are found in activity types where the trip maker has significant flexibility in destination selection Table 2. In contrast trips types where there is less control of location destination, trip lengths have decreased slightly (work) or increased (personal obligations) over the same time period. An exception to these trends is trip length associated with meals which has remained relatively constant at 7.3 miles despite a high level of destination discretion. LAC may be unique for its relationship with the automobile but transportation infrastructure in many metropolitan areas is maturing and expectations of a consistent or increasing level of auto-related mobility may not be realistic as a result of a leveling off of roadway supply.

Projected population increases in LAC combined with limited transportation alternatives will likely increase demand for a roadway network that may already be saturated and could result in increasing levels of congestion and decreasing individual mobility. The population of LAC is expected to exceed 11.5 million by 2060, an 18% increase from 2010, increasing the demand for mobility (California Department of Finance, 2013). With limited greenfield land available it is probable that a portion of the projected growth will need to be accommodated through the redevelopment and the implementation of policies that encourage high-capacity transit, walking, and biking use. If the LAC transportation infrastructure has reached a capacity limit and annual VMT in 2002 reflects an absolute maximum, VMT per capita can be expected to fall to approximately 7000 by 2060. A reduction in individual auto related mobility coupled with the current urban form in LAC may greatly reduce individual access to necessary employment centers, goods and services especially in areas that may already be underserved. Though there has been significant investment in the public transportation system in LAC, current levels of service result in 1 transit PMT for every 31 auto VMT, illustrating how far the region is from breaking its automobile path dependence (California Highway Performance Monitoring System, 1996-2011; Federal Transit Adminstration, 1997-2010). The costs associated with increasing public transit service levels to adequately address the loss of individual mobility derived from automobiles are likely prohibitive.

Smart growth, which can focus on accessibility rather than mobility, and the integration of transportation and land use planning may help alleviate challenges created by an absolute limit to vehicle travel. The homogenous medium density suburbs that make up a large portion of LAC could transition to mixed use neighborhoods which provide many necessary goods and services reducing the requirement to travel. Accommodating population growth in close proximity to transit access has also been shown to decrease individual vehicle travel demand (Clower et al., 2011). There are significant upfront costs associated with these strategies and it may be tempting to reduce mobility limitations through roadway capacity expansion, a less expensive option, but any improvements to individual mobility are likely temporary (M. V. Chester, Nahlik, Fraser, Kimball, & Garikapati, 2013; Downs, 2004). The limitations of auto-centric infrastructure should be considered when evaluating infrastructure investment alternatives.

Behavioral changes and technological improvements may result in an increase in network capacity leading to increases in VMT but the results suggest there is likely a limit to auto-related VMT with current technologies in constrained networks. The LAC network experiences its highest levels of congestion during peak travel periods and the trends of flexible work schedules and working remotely have the potential to shift vehicle trips to less congested times of the day. Shifting trip start times would result in decreasing levels of congestion during peak periods which may incentivize additional vehicle trips (Downs, 2004). Analysis of the 2009 NHTS indicates that automobile trip frequencies remain at a relatively constant level from 8AM-7PM in LA-MSA meaning that trip start times would have to shift to overnight and early morning hours to have a substantial impact on decreasing overall congestion and subsequently increasing VMT in LAC (Federal Highway Adminstration, 2009). The increasing presence of smaller vehicles (Smart Cars, Fiats, Mini, etc) and increasing safe travel speeds and decreasing vehicle headway resulting from vehicle automation could increase lane capacity. However, there are natural limits to each and an absolute maximum capacity for any road network.

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