Vehicle-Miles Traveled (VMT) Impacts on the Environment, Human Health, and Fiscal Health

ABSTRACT

A review of a wide range of literature shows that as Vehicle-Miles Traveled (VMT) increases, greenhouse gas and other emissions rise, highway collisions and deaths increase, physical activity decreases, and mental health outcomes worsen. Additionally, higher VMT requires more roads to be built, which increases construction emissions and leads to more surface runoff, in turn exacerbating flooding and water pollution problems. Because of the association between VMT and compactness/dispersion of development, VMT levels are also associated with building energy and water use; consumption of agricultural land, habitat, and open space; and infrastructure construction and maintenance cost to local municipalities. Further, low VMT development may be essential to correcting a looming supply-demand mismatch in housing. In sum, VMT is a useful summary metric with broad coverage for measuring a project's impact on a jurisdiction or region.

1 INTRODUCTION

Planners and decision-makers are placing increasing importance on environmental and human health implications of land use and transportation planning decisions. A fast-growing body of research illuminates an array of impacts associated with projects and plans. Many of these impacts are caused by or correlated with the amount of vehicle travel associated with the project or plan.

At the same time, planners and decision-makers increasingly recognize the limitations of attempting to build our way out of automobile congestion, and the fiscal challenges that result from such efforts. Many planning efforts have refocused on reducing, rather than accommodating, automobile travel. Some cities, regions, and states have begun to deemphasize delay metrics (such as automobile Level of Service (LOS)) and increase focus on metrics that measure the loading of vehicle travel onto the regional roadway network. Vehicle Miles Traveled (VMT) is becoming a common metric in transportation and land use planning, and practitioners have developed many different models to estimate the effect projects and plans will have on it.

In California, the passage of the climate-change focused Senate Bill 375 in 2008 coincided with the advent of climate action planning, bringing about widespread calculation of VMT for projects and plans. Climate planning requires estimation of greenhouse gas emissions (GHGs), and VMT is a necessary interim step. In 2013, the passage of Senate Bill 743 prohibited use of LOS in estimating transportation impacts under the California Environmental Quality Act (CEQA, California's environmental review law), and directed the development of a replacement metric, recommending consideration of VMT.

This paper reviews researched associations between VMT and a broad array of impacts to the environment, human health, and fiscal health. We find a variety of negative impacts resulting directly from increases in VMT, resulting indirectly from increases in VMT, and associated with increases in VMT. Because of the multiple connections between VMT and various types of impacts, VMT is a useful first-cut metric for characterizing the impacts of a project. VMT may also be a useful metric of transportation efficiency, providing insight into a project's accessibility and its effect on regional accessibility, but assessing that claim is beyond the scope of this paper.

2 EMISSIONS

As VMT increases, so do emissions. This is both because of tailpipe exhaust, and because of the extra energy that must be used to build roads to accommodate more car travel. Such emissions impact the environment and human health.

2.1 Greenhouse Gas Emissions

In California, transportation tailpipe emissions produce 36.5% of total greenhouse gas emissions — more than any other sector *(1)*. As VMT increases, so do carbon dioxide (CO2) *(2)*, methane (CH4), and nitrogen dioxide emissions (N2O) *(3)*. The EPA estimates that model 2005 passenger vehicles in the US emit an average of .0079 grams of N2O and .0147 grams of CH4 per mile *(4).*

Additionally, emissions from fuel refining, vehicle manufacture, and roadway construction and maintenance increase indirectly from with increases in VMT *(2).* The construction of roadway infrastructure expends energy and results in greenhouse gas emissions. Annually, 400 million tons of asphalt is produced in the United States *(5),* and manufacture of each ton produces 570lbs of CO2 *(6).*

2.2 Other Air Pollutants

Other air pollutants also directly result from increased VMT. Per VMT, California's light vehicles emit *(7)*:

- 2.784 grams of CO
- 0.272 grams of NO_X

- 0.088 grams of $PM_{2.5}$
- 0.237 grams of ROC (reactive organic gases, similar to volatile organic compounds)

These emissions have substantial impacts on human health and agriculture. A 1997 study calculates the annual national costs of air pollution to public health to be between $40.5 and $748 billion, and crop damage $3.5 to $6.5 billion (all adjusted to 2014 dollars) *(8).*

3 OTHER PUBLIC HEALTH

VMT is tied to public health outcomes. Automobile collisions increase with VMT, and these frequently result in injury or death. Higher rates of automobile use are associated with lower rates of walking and bicycling for transportation, which is shown to result in higher rates of obesity and related illnesses. Long driving commutes are associated with stress, including depression and other poor mental health outcomes.

3.1 Collisions

Vehicle collisions led to 2,835 deaths in California in 2011. Collisions between vehicles accounted for 72% of those fatalities, and vehicles striking and killing other road users accounted for 28% *(9).* Nationally, there were 32,479 roadway fatalities, and 1.10 deaths and 75 injuries per million vehicle miles traveled, in 2011 *(10),* and these fatalities and injuries are concentrated in places with high VMT *(11).* A 2008 study of road traffic fatality data by Mohan finds similar results, indicating that "city structure, modal share split, and exposure of motorists and pedestrians may have a significant role in determining fatality rates" in cities both inside and outside the United States with population greater than 100,000 *(12).* An extensive cohort study conducted in Spain shows that the likelihood of suffering motor vehicle injuries for adults increases with additional vehicle travel *(13).* Vehicle travel reduction, either by decreasing automobile mode share or reducing trip lengths, reduces risk and is an important approach to improving traffic safety *(14).*

3.2 Reduced Physical Activity

Areas with high VMT per capita also have poorer health outcomes resulting from reduced physical activity. Residents of counties in the United States with high VMT per capita are less likely to walk for leisure, more likely to be obese, have higher Body Mass Index (BMI), and have a greater prevalence of hypertension *(15).*

On a macro level, there are associations between the geography of VMT and the geography of obesity. Among California counties, those with the highest mean obesity also tend to have the highest mean VMT per capita *(16).* BMI is higher in areas with high VMT per capita, and the cardiovascular effects of VMT present more readily in people with high BMI, concentrating the negative impacts *(17).*

The relationship between high VMT and physical inactivity is in large part because an environment built to facilitate automobile travel tends to make walking for transportation more difficult. Saelens and Handy show a "positive relationship between walking for transportation and density, distance to nonresidential destinations, and land use mix" *(18).* Population density, overall neighborhood design, and Smart Growth practices are also important determinants of physical activity *(19, 20).*

As the neighborhood built environment becomes more conducive to walking and biking, resident physical activity tends to increase. According to Rahman, Cushing, and Jackson, these neighborhood features, as well as "mixed land use, accessible destinations, and transit," tend to increase resident physical activity *(21).* These same measures reduce VMT.

The increase in neighborhood walkability and physical activity has clear health benefits. Walkable neighborhoods are associated with lower self-reported obesity *(22).* Xia et al. find that replacing car trips with alternative transportation yields "a broad inventory of health and economic factors that could be improved with a shift away from automobile use towards walking," including reduced rates of diabetes and cardiovascular disease, along with a variety of social benefits *(23).*

3.3 Impacts to Mental Health

Long driving commutes have a negative impact on health, and are linked to stress and other negative mental health impacts *(24).* According to Hennessy, these health impacts include "increased blood pressure and heart rate, negative mood, emotional arousal, poor concentration levels, driving errors, lapses, and violations; traffic offenses, traffic collisions, and aggression *(25)*." Owning, driving, and maintaining a car are all associated with depressive symptoms *(26),* and the more total time a person spends driving per day, the more likely they are to smoke, be obese, experience high physiological distress, or other emotional problems that interfere with social functioning *(27).*

High VMT-type neighborhoods are linked to negative mental health outcomes. Social isolation, anxiety, increased blood pressure, headaches, and stress are associated with high VMT-type neighborhood design *(28),* as is depression *(22).* A built environment that reduces automobile dependence and promotes walking can result in lower rates of dementia *(23).*

4 ENERGY

High VMT development tends to be less dense, with larger units and a greater share of detached units. Because of these design features, high VMT development often result in higher building energy use once the units are occupied.

Counties in the United States with a low sprawl index score (associated with low VMT) were shown to use approximately 20% less energy for heating and cooling per household than counties with a high sprawl index score *(29).* Housing size is the main driver, because residential energy use is highly correlated with the square footage of the home *(29).* Energy consumption per capita can be as much as one and a half times higher in low-density areas than in high-density areas *(30).*

The 2005 California Energy Commission's Statewide Residential Appliance Saturation Survey shows the following differences in energy use by housing type *(31).*

Large lot single family	100 million Btu
Small lot single family	71 million Btu
Attached single family	54 million Btu
Multifamily	38 million Btu

5 WATER

High VMT communities tend to use more water per capita, as VMT and water consumption are both inversely correlated with development density. Most of this variation results from outdoor water use, typically from watering lawns or other landscaping. VMT reduction measures, such as building on smaller lots, can therefore reduce water consumption, by shrinking or eliminating the area requiring irrigation. Additionally, lower VMT development requires less roadway capacity be built to accommodate its vehicle travel. The smaller area of impervious surface decreases runoff, which in turn decreases flooding and reduces transport of pollutants.

5.1 Household Water Consumption

Per household water consumption is significantly higher for large lot, single family homes than in smaller lot or attached homes. Housing type and density are related to the amount of water consumed by a residential development *(32).*

Some jurisdictions have used compact development as a strategy to reduce water consumption. In Utah, planners estimate that water demand falls by 50% when residential densities increase from two units per acre to seven *(33).* Based on California usage data, the following 2005 household usage rates are estimated for each housing type *(31)*.

Large lot single family	194,000 gal
Small lot single family	125,000 gal
Attached single family	93,000 gal
Multifamily	89,000 gal

The Northern California Water Association finds similar results, calculating the following daily usage rates per housing type *(34)*.

Very low density/rural residential	1-3 du/acre	625-980 gal/day
Low Density	4-8 du/acre	445-805 gal/day
Medium density	9-12 du/acre	315-580 gal/day
High density	13-25 du/acre	225-405 gal/day

Outdoor water use is responsible for almost all of the savings that accompany residential densification *(34).* Building more compactly as a means to reduce VMT would have the co-benefit of reducing water consumption. Even assuming no change in indoor water consumption, more compact development would save 150 million gallons of water and sewer demand per day in the United States between 2000 and 2025, because of reduced outdoor watering and shorter pipelines *(35).*

Because lot size is a key factor in determining outdoor water use, it plays perhaps the largest role in household water consumption. A 2006 report by the Environmental Protection Agency recommends compact neighborhood design, making maximum use of smaller lots. These lots would have "less landscaping and thus less demand for water *(33).*" Case studies show that a neighborhood of single family homes on compact lots uses 20-30% less water than single family homes on conventional lots found elsewhere in the same city *(36),*

Transporting water long distances also consumes water. Due to leaks and breaks, water pipes can lose six to 25% of finished water *(37).* Locating housing and businesses on smaller, more centralized lots, in addition to reducing VMT, can reduce the distance water has to be transported, thus reducing loss.

5.2 Runoff and Water Pollution

High VMT-generating development necessitates building more roadway capacity, covering ground with surfaces that are impervious to water, resulting in more runoff *(38).* Runoff in suburban landscapes can be 1.5 to four times greater than runoff in rural areas or undeveloped grassland *(39).* Urban runoff can contaminate the water supply by washing chemicals, metals, and other contaminants into rivers and lakes, and is one of the leading causes of water pollution in the United States *(40).* Increasing residential densities from one unit per acre to eight units per acre decreases surface runoff by as much as 74% *(41).* Zheng and Baetz also found that "sustainable designs with smaller total development areas can effectively reduce peak flows and total runoff volumes when compared with less sustainable designs," helping to reduce flood hazard *(42).*

6 AGRICULTURE AND OPEN SPACE

More dispersed, VMT-generating development can often come at the cost of consuming agriculture land, sensitive habitat, or open space. A comparison of various development scenarios across the Sacramento and San Francisco Bay Areas predicted that the most compact growth scenario would save nearly 50% of agriculturally sensitive land acreage and steep-sloped areas, and close to 100% of wetland areas *(43).* A 2013 study of various San Francisco Bay Area growth scenarios recommended an infill growth policy, finding that it would preserve 60% of the natural lands (including 88% of agricultural lands) that would be consumed by a more traditional, business-as-usual, growth scenario *(44).*

7 COST AND FISCAL IMPLICATIONS

High VMT development requires higher levels of infrastructure to support a more dispersed population. This less efficient use of resources places an increased financial burden on municipalities responsible for its maintenance. And because of shifting demographics and real estate preferences, building new high VMT development also contributes to a mismatch between projected housing supply and projected housing demand.

7.1 Increased Cost to Local Government

More disperse, higher VMT development generally results in higher public costs than compact, lower VMT development. The amount of land consumed for development is directly related to road lane miles required to service that development *(32, 45).* Per dwelling unit road construction costs for compact development are 75% of analogous costs for disperse development *(32).* Nationally, local road spending between 2000 and 2025 could be reduced from $927 billion to $817 billion under a managed growth scenario *(35).* Further, "higher density, the clustering of land uses, and attached housing and linked nonresidential uses all contribute to a reduced number of infrastructure feeder lines and reduced cost *(35)."*

Between 2000 and 2025, local governments in the United States are projected to spend $190 billion in providing water and sewer infrastructure to new developments. However, this figure could be reduced by 6.6% if growth were to occur in a more compact fashion, within existing urban areas. *(35)* Construction of utilities such as pipes and sewers in compact development typically cost only 80% of what they do in disperse development *(35).* A doubling in residential lot size from .25 to .5 acres results in water and sewer costs increasing by 30%. Tract dispersion and distance are also associated with increases in water and sewer infrastructure costs *(46).*

In addition to higher capital costs, municipal operating costs also increase as a result of disperse development. Under more compact growth scenarios, overall school district and municipality operating budgets experience a compounding two percent annual savings *(32).* This is a result of administration and capacity sharing between schools, and of local jurisdictions sharing non-police resources. Capital cost savings also reduce the cost of debt service *(32).* Growing more compactly, local governments throughout the United States can expect to save $4 billion in local public service costs from 2000 to 2025 *(35).* Separate studies conducted in Michigan and the Delaware Estuary region report municipal operating budgets to be 5-6% lower under compact growth scenarios *(32).*

7.2 Housing Supply and Demand Mismatch

Matching long-run housing supply and demand is important to maintaining fiscal health. Conversely, a mismatch can lead to vacancies and blight. This is a cause for concern, because California's projected housing stock, given projected production, will result in a substantial oversupply of single family, large-lot units, and substantial unmet demand for transit station area, small-lot and attached units. Nelson finds that, as of 2010, "the four largest MPOs may have nearly 3 million more units on conventional lots (those larger than one-eighth acre) than the market may demand *(47)."* Nelson also shows that "about a third of American households want to have accessibility to transit, especially fixed-guideway systems; yet, fewer than 10% have this option *(48)."* A 2001-2002 set of surveys finds that 32% of Californians would prefer high density, multi-family housing if it meant being able to walk to shops, school, and transit. A 2003 survey, duplicated in 2005, shows that a majority of Californians would support Smart Growth communities in their neighborhood (55%) and would prefer to live in them (51%) *(47).*

Much of the shift in preference towards more urbanized neighborhoods is due to shifts in preferences between generations. Those born between 1979 and 1996 report a strong preference for walkability. A third of the respondents say they would pay more to be able to walk to work, shops, and entertainment; and more than half report they would accept small lot size in exchange for proximity to work and shopping. Even in suburban locations, these respondents prefer urban characteristics, such as walkability. This cohort also gives a positive response to living in Smart Growth communities, with 61% saying they would prefer to live in such places, compared to 47% of those born between 1934 and 1950 *(47).*

As this generation continues to age into the work force and make up a greater share of total households, their housing preferences will exert a greater pressure on the market. A national assessment estimates that 14.6 million households looking for housing between 2005 and 2025 will be looking to rent or buy within a half mile of rail or bus rapid transit. At the start of this period, only 6 million households lived in such locations *(49).* Thus, to accommodate future demand, the amount of housing near transit will need to be doubled — either by densifying near existing transit, building new fixed guideway transit, or a combination of both.

Even in the most robust years of housing development, total housing stock increases by only 2%. Given this slow expansion, all new residential units built in California "could be directed to TSAs [transit station areas] between now and 2035 and still not meet the demand for living in TSAs *(47)."*

8 SUMMARY

VMT correlates with a broad array of impacts to the environment, human health, and fiscal health. Increased VMT per capita increases emissions of greenhouse gases and other air pollutants, leads to high rates of vehicle collisions, driver stress and mental illness, and health outcomes such as obesity from lack of physical activity. Constructing roads to accommodate new VMT results in increased rainwater runoff, which worsens flooding and contaminates waterways. High VMT development leads to higher building energy and water use; greater consumption of agricultural land, habitat, and open space; and higher infrastructure costs. Finally, because of shifting demographics and real estate preferences, the continued development of built environments that encourage high VMT exacerbates a long-run mismatch in housing stock and consumer demand. While the traditional focus on minimizing delay (or improving LOS) leads to poor outcomes across these factors, a focus on minimizing VMT will benefit them.

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