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An Analysis of State Policies on the Environmental Impacts of State Surface Transportation: Considering Land Development Patterns

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An Analysis of State Policies on the

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Surface Transportation:

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1.0 INTRODUCTION

Automobile-oriented transportation contributes to pollution, land consumption, and material waste. A sustainable transportation system, which is transportation that "meets the needs of the present without compromising the ability of future generations to meet their own needs," must be created in order to mitigate these negative effects (1). This research examines the relationship between state policy decisions and travel behavior and the corresponding environmental impacts of automobile-oriented transportation. We utilize urban development patterns in the United States to better understand key differences of automobile transportation between similar states.

Climate change is an issue that many government and non-profit organizations have begun to address. The United Nations Framework Convention on Climate Change drafted an environmental treaty called the Kyoto Protocol in 1997. Although most countries signed the treaty, the US has not committed to its binding obligations to reduce GHG emissions. However, the US is taking steps to address climate change in other ways. In 2009, the US Department of Transportation (DOT), Department of Housing and Urban Development (HUD) and Environmental Protection Agency (EPA) formed the Partnership for Sustainable Communities to coordinate transportation policy with housing and environmental protection. That same year, the EPA declared that increasingly high levels of carbon dioxide and five other greenhouse gases are negatively affecting the health and safety of the American people. The implications of long-term greenhouse gas emissions in the atmosphere have brought about more discussion of sustainable transportation and policies to promote sustainability.

As a result of the recent focus on climate change, the concept of sustainable transportation has increasingly become a topic of discussion in transportation and land use planning in the US. While some surface transportation decisions are made at the federal level, many decisions made at the state level through state DOTs, rather than at the regional level, county level or city level. The US EPA requires state DOTs to show that planned transportation activities conform to the air quality goals in the State Implementation Plans (SIPs) (2).

State's land development patterns, and policy towards transportation and land development have the ability to influence transportation habits of the state's residents. These travel habits directly

impact the environmental costs associated with surface transportation. This connection may inform policy makers of additional ways to make transportation systems more sustainable within the context of urban development.

The DOT and EPA are highly concerned with six criteria air pollutants (CAPs) from motor vehicles, which is why the EPA set National Ambient Air Quality Standards and requires states to submit State Implementation Plans. Some of these plans are aimed at reducing CAPs generated by motor vehicles. Directives include parking mandates, transit improvements, high occupancy vehicle facilities and emissions testing for vehicles. However, our research paper does not measure these directives.

In this paper, we investigate characteristics and environmental indicators associated with automotive transportation and evaluate select policies that could influence these indicators. Two other researchers at the University have assessed similar transportation measures. Garceau et al assessed economic, social and environmental indicators without considering land use patterns (3). Zheng et al used land development patterns for looking at select sustainability measures without exploring government spending (4). This paper goes further by evaluating government spending on transportation, travel characteristics, and the resulting environmental implications between states with similar land development patterns.

This paper contains a literature review to help further understand the impetus for research on environmental indicators of sustainable transportation. Following the literature review is the methodology section explaining how our research was conducted. Next, the results section contains the findings of the research. The subsequent discussion section explains the significance of the results. Finally, the conclusion examines the effectiveness of policies that are used by states to help create more sustainable transportation systems.

2.0 LITERATURE REVIEW

This literature review contains sections on the environmental impacts of automobile-oriented transportation and the emergence of the sustainable transportation concept, as well as how this concept is being applied within the US. We also review how land use and transportation are

intertwined. Lastly, the literature review discusses the research for this thesis and how this work develops the understanding of sustainable transportation.

2.1 Global Environmental Impacts of Automobile Transportation

Automobile transportation has a significant effect on an important global environmental issue - climate change. Greenhouse gases from automobile engines are one of the primary causes of our warming planet. The US is responsible for about 19 percent of all CO_2 emissions from fossil fuel combustion globally (5). While transportation is responsible for 32 percent of US CO_2 emissions (5).

Scientists have determined that the safe upper limit for the globe to warm is 2°C from pre-industrial times. Above this limit, human habitation becomes compromised (6). It is estimated that it will take 565 Gigatons of CO_2 to raise the globe an additional 1.2°C from the already 0.8°C increase since 1880 (6) (7). Assuming historic 3% annual increases at the current annual emission rate of 30 billion tons, it will take only 15 years to surpass 565 Gigatons (6). Since the earth's fossil fuel reserves contain 5 times the amount of carbon required to raise global temperature by 2°C (2,795 Gigatons), we need to prevent four-fifths of all carbon reserves from being released into the atmosphere (6). Exploring the relationship between existing transportation policies, land development patterns and transportation sustainability can help inform policies to reduce CO_2 emissions generated by surface transportation systems.

2.2 Air Pollution Impacts of Surface Transportation

When the Environmental Protection Agency (EPA) amended the Clean Air Act in 1990 they also established a list of 188 hazardous air pollutants (HAPs) that may cause cancer, serious health effects, environmental or ecological effects (8). The EPA labels air pollutants that are of most concern to human health as criteria air pollutants (CAPs) (8). The CAPs are responsible for acid rain, ozone formation, respiratory illness and other environmental problems affecting plants and animals.

There are only seven criteria pollutants for which the EPA has set permissible levels: ozone, two types of particulate matter, carbon monoxide, nitrogen oxides, sulfur oxides and lead (8). The

EPA National Emissions Inventory (NEI) is a comprehensive inventory of the amount and type of air pollutants emitted by twelve major sectors. The emission estimates are based on monitored readings, levels of industrial activity, fuel consumption, vehicle miles traveled, and other measures of polluting activity (8). Computer models are used to estimate emissions rates for all on-road emissions. These models are used to develop State Implementation Plans (SIPs) and budgets (9).

Ground level ozone, commonly referred to as smog, is of high concern because it harms the respiratory system and can cause or aggravate asthma and other lung diseases. Volatile organic compounds (VOC) and nitrogen oxides are two CAPs that form ozone in the presence of sunlight. It is these two precursors that are measured, not ozone itself. In addition to forming ozone, VOCs are suspected to cause cancer in humans through direct inhalation. Some symptoms of acute exposure to VOCs are headaches and nausea.

Carbon monoxide (CO) is a byproduct of fossil fuel combustion used in motor vehicles. CO is a colorless, odorless gas that can prevent oxygen from getting to the body's organs.

NO_2 is the indicator gas for the group of nitrogen oxides (NO_x). This gas is also created by combustion. It contributes to ground level ozone and fine particle pollution. NO_x can have acute effects on the respiratory system especially for those with asthma and the elderly. High concentrations are generally found near roadways.

Sulfur dioxide (SO_2) is used by the EPA as the indicator for sulfur oxides (SO_x). SO_2 is derived from combustion of coal and oil. SO_2 dissolves in water vapor after being released into the atmosphere to create acid rain. Acid rain acidifies water bodies, harms animals, damages trees, degrades soil, and decays buildings and paints (10). SO_2 is a precursor to fine particle particulate matter (PM).

PM2.5 are particles that are smaller than 2.5 microns and are referred to as fine particles. PM10 are particles smaller than 10 microns, but larger than 2.5 microns, and are referred to as inhalable course particles (10). Particulate matter not only comes from combustion, but tire and brake

wear, and dust from unpaved roads. PM is the primary cause of haze. There are also secondary particles that form from reactions with sulfur and nitrogen compounds. Some of the worst health effects are from particles that are smaller than 10 microns. They can get deep into the lungs and even bloodstream.

2.3 Emergence of the Concept of Sustainable Transportation

Sustainable transportation is defined in numerous ways. One definition by the Centre for Sustainable Transportation is (11):

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them.

Climate change is brought about because humans are releasing stored carbon into the atmosphere as CO_2 faster than the carbon cycle can return those carbon molecules back to the earth for storage in plants and animals and (under the right conditions) back to fossil fuels stored beneath the earth's surface. Increasing greenhouse gas emissions brings about climate related destruction such as floods, droughts, species extinction and more, as the earth warms from the greenhouse effect.

Many state DOT environmental initiatives began in response to the National Environmental Policy Act (NEPA) or national transportation reauthorization acts, like the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2003 (SAFETY-LU) (12). Although NEPA established a broad national framework to protect the environment, no national sustainable transportation strategy has been implemented to guide development policy (13), (12).

States have made policies aimed at reducing environmental impacts of transportation. For example, "Colorado's statewide transportation plan…[addresses] greenhouse gas emissions

reduction by finding ways to serve mobility needs without expanding roadways" (12). California's DOT (Caltrans) developed a Climate Action Program with four objectives. One objective is to "provide guidelines, procedures, performance measures, and a quantifiable set of reporting protocols to monitor GHG footprints." (12)

The federal government enforces reduced emissions by requiring states to submit SIPs to the US EPA that determine strategies for reducing emissions and improving air quality, as specified in the Clean Air Act (2), (12). When a state or part of a state, such as a metropolitan statistical area, does not meet a National Ambient Air Quality Standard (NAAQS), that area becomes a nonattainment area. A SIP is then required to be submitted to the EPA with a strategy for meeting the air quality standard. One strategy that was implemented in the consolidated metropolitan statistical area of Boston, MA in the 1990s, was the mandatory sale of higher oxygenated fuel with 2.7 percent by weight oxygen. This was to reduce CO formation during combustion and thereby meet the NAAQS. One way to achieve lower pollution from automobile transportation is through laws enforced by the EPA and other government agencies.

There are other state and federal sustainability initiatives that have begun to address GHG reductions in another way. One movement that addresses sustainable transportation is Smart Growth. The EPA is a partner in the Smart Growth Network (SGN), a program that has encouraged sustainable development. A report written by the SGN contains one hundred policies for implementing Smart Growth, many of which address transportation strategies, such as creating walkable communities. A few state level strategies that help create walkable communities are: develop a pedestrian master plan, encourage safe pedestrian routes to transit, and use transportation funds as an incentive to provide housing near transit (14). Several policies that can be implemented at the state level and provide a variety of transportation choices are: change state insurance policies to allow pay-as-you-drive, transform park-and-ride into multiuse facilities, and create comprehensive bicycling programs (14). The EPA recognizes exemplary communities with the annual National Smart Growth Achievement award to help showcase innovative policies and strategies that strengthen economies and protect the environment (15).

2.4 Application of Sustainable Transportation Concept in the United States

Over half of state DOTs have sustainability principles in their mission statements, but only two actually use the word sustainability (12). Whatever the terminology is, it is generally accepted that measuring outcomes is a good idea. Greenroads, a third-party certification organization that rates roadway and transportation infrastructure projects, predicts, "Sustainability is the next great game in transportation. The game becomes serious when you keep score." (16) This thinking has led researchers to create frameworks for measuring these outcomes. At the University of Connecticut there has been numerous research papers written about transportation sustainability and frameworks for ranking and measuring progress. The research that stimulated this work was conducted by several researchers at the University of Connecticut, most significantly Zheng et al and Garceau et al. Zheng et al developed the urbanization groups for the 50 states and D.C., while Garceau et al evaluated the costs of transportation from a sustainability perspective. Some of the costs that were assessed were CO_2 emissions per capita, household spending on transportation and automobile-related fatalities. Our research aims to determine which policy indicators have the most influence on travel behavior. Understanding this will help inform states how to best spend money to reduce automobile travel and road emissions.

2.5 Links between land use and transportation in the United States

There are a myriad of factors that promote urban sprawl including economic, housing, demographic, and transportation (17). Among the transportation factors are private car ownership, low commuting expenditure, transportation system improvements (including transit improvements), and availability of roads (17). Expansion of urban development into “rural areas that surround major cities, and leapfrogging of development beyond the city’s outer boundary into smaller settlements within rural hinterlands” is often referred to as sprawl (18). States do not enforce land-use zoning however, it is the local jurisdiction of the town or city to decide how land is used. “For the most part, state DOTs influence land use through access management policies, basically limiting the number of access points to state-supported roadways in order to manage growth” (12).

In 2012, the Federal Highway Trust Fund expenditures were $41 billion for highways and $8 billion for transit (19). The federal government does not “directly regulate development,” but many policies “related to the environment, transportation and housing affect how communities develop” (20). Some of the ways that the federal government influences local land use planning are through environmental law, tax codes, federal mortgage lending and transportation infrastructure policies (2). One example is the US Department of Agriculture’s Rural Communities Initiative. Two of its programs provide home loan assistance for people with low income, all across the country, to purchase homes in rural areas with no money down or reduced payments on their mortgages temporarily. Interest rates can be as little as one percent for families who are receiving mortgage assistance (21). There are no requirements to farm the land, in fact the properties receiving direct loans may not be designed for “income producing activities” (22). Qualifications are based on income, credit score, and debit to income ratio. The rationale is that by incentivizing people to live in these rural towns, it will spur the rural economy (22).

"Sprawling development forces us to drive more frequently and make longer trips" (23), and consequently increases VMT and the associated environmental costs. Sustainable transportation literature suggests that it is important to compare how different development patterns perform against each other. The amount of sprawl itself is difficult to quantify, however we use the degree of urbanization method developed by Zheng et al to provide us with a more comprehensive understanding of sprawl and its implications.

State's spending on transportation is one way that government policy can influence how people use transportation. The extent to which people are able to substitute transit, walking or biking, for driving a car, greatly impacts the environmental impact of the transportation system on a per capita level. Another way that governments can influence transportation decisions is through taxation. By increasing gasoline taxes it increases the costs for the automobile user. The gasoline tax is one of the major sources of revenue for State and Federal transportation budgets. Meanwhile there are other factors outside of policy or even gasoline prices that impact travel and the corresponding environmental costs. In a recent paper Doug Short writes:

> In the big picture, there are profound behavioral issues apart from gasoline prices that are influencing miles traveled. These would include demographics of an aging population in which older people drive less, continuing high unemployment, the ever-growing ability to work remote in the era of the Internet and the use of ever-growing communication technologies as a partial substitute for face-to-face interaction (24).

We have chosen not to focus on the factors that Short mentions, but instead assess how government policy impacts transportation systems throughout the country.

2.6 Summary of Literature Review

We have identified a need to explore the root causes of the environmental impacts of transportation and land use policy. This research uses transportation policy metrics and travel and economic characteristics to find key policies that will reduce the environmental impacts of state transportation systems.

3.0 METHODOLOGY & EMPIRICAL STUDY

This section begins by explaining how land development patterns are distinguished. The method of analysis is presented along with how the three types of indicators were selected to reflect policy decisions, examine travel characteristics and assess environmental impacts. This section explains where the data comes from, how the indicators are used, and the significance of the indicators. It also explains how states transportation systems are compared.

3.1 Degree of Urbanization

"…[T]he weight of the empirical evidence suggests that characteristics of urban form can be important factors in reducing VMT and emissions" (2). However the characteristics of urban form, which we are calling the degree of urbanization, are difficult to measure because states are not homogeneous in their population distribution and data is not available to easily characterize important differences in urban patterns. In our study, a state's level of urbanization is characterized by the population density and the population distribution. The method for characterizing states was developed by Zheng et al. In his research, the method outlined groups of states based on population characteristics of each state. Characterizing states in this way allows for the comparison of sustainability performance between states that are similar in terms of urban patterns. Zheng et al lay out the methodology for organizing the states into four urbanization groups. It is based on a method of hierarchical clustering described in, "Identifying Peer States and Implications of Urbanization Patterns on Transportation Policy". The urbanization clusters are based on the density and percent of people living in central cities, small towns, suburbs and rural areas.

This urbanization methodology developed by Zheng et al uses the population and land area data from the United States Census 2000 Decennial Census. The urban and rural definitions are those used by the US Census Bureau and US Office of Management and Budget (OMB). Using population and density criteria for geographic entities comprised of counties and census blocks, Zheng et al identified the percent of the states' population and density of that population living in each of four types of development patterns (central city, small town, suburb and rural). These types of places were derived from the US Census and OMB definitions (25). The US Census defines urban areas (UA) in metropolitan statistical areas (MSA) as central cities and all land outside a UA, within an MSA, as suburbs. Urbanized clusters (UC) are given alternative names

depending on whether they lie within a metropolitan statistical area, a micropolitan statistical area or neither, but Zheng et al called them small towns in his analysis (4). All remaining area that is not considered central city, suburbs or small towns is considered rural. (4) The metropolitan statistical area (MSA) and micropolitan statistical area (μSA) are based on the minimum population requirements of census blocks in a contiguous urban area. Gross land area is used to calculate population density, which includes undevelopable land, because Zheng et al were unable to identify data sources at the national level for analyzing net land area at this scale. After determining the percent of population and density for each type of development pattern, states are organized into groups using normalization, component analysis, and clustering. These steps are described below.

As shown in Table 2, the four types of development patterns in each state are: central cities, small towns, suburbs and rural. The table shows two characteristics for each development pattern. The first is the percentage of the urbanization group's population living in each type of development pattern (central cities, small towns, suburbs and rural areas). The second is the average density of population in each development pattern in that state. The process used to determine the degree of urbanization includes:

- Principle component analysis (PCA) – PCA is a mathematical procedure of orthogonal matrix transformations. It is used, in this case, to transform nine variables into three components. The nine variables are the percent of population and density for each of the four development types (8 total) and a binary variable for states without any people living in rural areas. The three components are then used in hierarchical clustering.
- Hierarchical clustering (HC) – HC is used to group the states into urbanization categories that minimize within-group variance and maximize between-group variance of variables such as % population living in central city.
- Analysis of cluster solutions – This approach uses a Dendrogram Tree tool that provides visual cues to identify clusters and therefore appropriately size the urbanization groups "to enable meaningful comparisons" (4). Each group has a unique pattern of density and distribution of population across each of the four development patterns.

Using these steps, the states are combined into four urbanization groups defined as Low Density Rural – Suburban (LDR-S), Low Density Mixed (LDM), Medium Density Suburban (MDS), and High Density Suburban-Urban (HDS-U) (4). In Table 1, the states included in each group are presented along with the percent of the population living in each type of place and the density of each type of place.

TABLE 1 Population and Density by Type of Place and Urbanization Group (4)

Desc.	State	Central City(s)		Small Town(s)		Suburb(s)		Rural Area(s)	
		% Pop. Living in	Density[1]	% Pop. Living in	Density[1]	% Pop. Living in	Density[1]	% Pop. Living in	Density[1]
Low Density Rural-Suburb (LDR-S)	Alabama	26%	1,173	11%	535	37%	122	25%	32
	Arkansas	25%	1,272	20%	825	18%	67	36%	22
	Georgia	15%	1,262	8%	828	53%	372	25%	45
	Kentucky	16%	1,570	13%	1,143	28%	202	42%	52
	Maine	12%	1,034	12%	336	21%	216	54%	24
	Mississippi	13%	1,427	22%	812	22%	117	44%	30
	Montana	23%	2,644	22%	253	11%	12	45%	3
	New Hampshire	20%	1,948	14%	477	36%	379	30%	51
	Oklahoma	32%	1,044	22%	788	22%	85	24%	15
	South Carolina	14%	1,298	8%	1,000	53%	188	24%	54
	Vermont	6%	3,683	16%	691	21%	237	56%	40
	West Virginia	10%	2,061	10%	1,440	31%	149	49%	44
Low Density Mixed (LDM)	Alaska	36%	2,863	56%	74	6%	21	3%	<1
	Arizona	53%	2,267	24%	681	15%	17	9%	7
	Idaho	22%	2,712	17%	2,019	16%	81	44%	7
	Iowa	27%	1,812	22%	1,252	17%	83	34%	20
	Kansas	31%	1,949	25%	1,704	22%	113	23%	8
	Nebraska	36%	3,234	22%	2,058	16%	110	27%	6
	New Mexico	32%	2,166	22%	1,066	22%	35	24%	4
	North Dakota	30%	2,325	19%	1,663	14%	13	37%	4
	South Dakota	24%	1,819	25%	1,469	8%	16	42%	4
	Wyoming	21%	2,278	37%	1,270	9%	6	33%	2
Medium Density Suburb (MDS)	Colorado	34%	2,618	8%	1,168	48%	112	10%	5
	Florida	22%	1,800	3%	693	69%	387	6%	42
	Hawaii	31%	4,337	16%	631	40%	972	13%	29
	Louisiana	29%	2,296	11%	1,193	46%	141	14%	22
	Michigan	21%	4,452	6%	826	57%	439	17%	39
	Minnesota	19%	3,649	14%	750	47%	143	20%	16
	Missouri	22%	2,018	12%	1,116	43%	212	23%	23
	Nevada	33%	3,612	8%	181	50%	74	9%	2
	North Carolina	29%	1,900	9%	1,163	33%	177	29%	74
	Pennsylvania	22%	7,563	5%	674	60%	381	13%	67
	Tennessee	34%	1,444	10%	737	31%	167	26%	51
	Texas	46%	2,249	11%	1,005	34%	155	9%	9
	Utah	21%	2,354	8%	849	54%	163	17%	5
	Virginia	26%	1,643	5%	529	51%	269	17%	51
	Washington	28%	3,502	7%	1,256	52%	169	13%	17
	Wisconsin	30%	3,362	12%	617	34%	152	23%	31
High Density Suburb-Urban (HDS-U)	California	39%	4,752	5%	1,173	54%	207	2%	11
	Connecticut	27%	3,299	3%	499	67%	665	7%	171
	Delaware	17%	3,163	4%	1,158	61%	498	18%	149
	D.C.	100%	9,317	0%	n/a	0%	n/a	0%	n/a
	Illinois	35%	5,874	8%	1,681	48%	389	9%	30
	Indiana	30%	2,338	12%	1,798	36%	199	21%	54
	Maryland	15%	6,201	3%	1,522	76%	671	6%	93
	Massachusetts	32%	3,457	2%	834	63%	835	4%	103
	New Jersey	12%	4,240	1%	462	87%	1,057	0%	n/a
	New York	49%	14,890	4%	1,038	40%	405	7%	51
	Ohio	27%	3,410	10%	1,672	48%	363	14%	68
	Oregon	29%	3,573	15%	1,928	39%	95	17%	7
	Rhode island	36%	5,334	2%	484	62%	702	0%	n/a

[1]Density in people per square mile

Data Source: Census 2000 Decennial Census

TABLE 2 Population Distribution, Population Density, and States by Group (4)

Group Description	Central City		Small Towns		Suburbs		Rural	
	% Pop. Living in	Density[1]	% Pop. Living in	Density[1]	% Pop. Living in	Density[1]	% Pop. Living in	Density[1]
Low Density Rural-Suburban States	17%	1700	15%	760	29%	180	38%	34
	Alabama, Arkansas, Georgia, Kentucky, Maine, Mississippi, Montana, New Hampshire, Oklahoma, South Carolina, Vermont, West Virginia							
Low Density Mixed States	31%	2300	27%	1300	14%	50	27%	6
	Alaska, Arizona, Idaho, Iowa, Kansas, Nebraska, New Mexico, North Dakota, South Dakota, Wyoming							
Medium Density Suburban States	28%	3000	9%	840	47%	260	16%	30
	Colorado, Florida, Hawaii, Louisiana, Michigan, Minnesota, Missouri, Nevada, North Carolina, Pennsylvania, Tennessee, Texas, Utah, Virginia, Washington, Wisconsin							
High Density Suburban-Urban States	34%	5400	5%	1200	52%	510	8%	74
	California, Connecticut, Delaware, D.C., Illinois, Indiana, Maryland, Massachusetts, New Jersey, New York, Ohio, Oregon, Rhode Island							

[1]Density in people per square mile

The advantage to using the degree of urbanization groups in transportation sustainability analysis is that it allows us to compare states with similar development patterns by looking at the outcomes of those states in the same urbanization group.

3.2 Policy Indicators

The state DOTs and the federal government have a number of programs aimed at reducing environmental impacts of transportation. Many programs have budgets at the federal level and the funds are dispersed to the states. Some programs are designed to maintain roadways, reduce the air pollution or improve other transport modes. Spending reflects the policies in place. In order to understand how policies are affecting both travel habits and environmental impacts, we use four policy indicators for 2011 in Tables 4 and 5:

- State and Local Spending on Highways per Capita

- Congestion Mitigation and Air Quality (CMAQ) Improvement Spending per Capita
- The Percent of Total Surface Transportation Spending on Highways
- Gas Tax

For each policy indicator, we also graph the average for years 2008 to 2011 versus the average VMT per Capita (2008 to 2011) in Graphs 1-4. These years were chosen because they were the most recent years for which all data sets could be obtained for State and Local Spending on Transportation, Expenditures of Federal Funds Administered by the FHA and Gas Tax data.

State and Local Spending on Highways shows how state and local governments spend funds from the various programs. The FHWA administers funds in several categories such as National Highway System, Surface Transportation Program, Interstate Maintenance, and CMAQ. States report how they spend the funds, whether for highway, transit, air or water. Spending too small of a percentage on transit is seen as a policy decision that negatively impacts the environment.

The federal government provides each state with money to help improve air quality and relieve congestion through the Congestion Mitigation and Air Quality program. The program was introduced in 1991 in the Intermodal Surface Transportation Efficiency Act. In 2011, under the SAFETY-LU legislation, the funds were allocated using a formula that considered state population and severity of ozone and carbon monoxide pollution. Some of the eligible projects that the funding could be used for include but are not limited to: projects that improve traffic flow, shift traffic demand, reduce particulates from diesel engines, and construct electric vehicle infrastructure. The Congestion Mitigation and Air Quality Spending indicator was introduced to assess which states require more funding for pollution.

The percent of total surface transportation expenditures on highways by state and local governments shows the extent to which states are focused on automobile transportation compared to other surface modes. Transit is the only other surface transportation expenditure in State Transportation Statistics Table 6-8 published by US DOT Bureau of Transportation Statistics (BTS). At this point in time, most states spend far more on highway projects than transit. Spending on bicycle and pedestrian facilities is not reported by the US DOT BTS. A higher percentage of spending on automobile transportation is seen as a negative in terms of environmental impact.

The state gas tax is the amount that each gallon of fuel is taxed by the state when purchased by the consumer. There is also a federal gas tax, which is the same for each state. The state gas tax is a policy indicator that shows the political climate in the state and their stance towards automobile transportation. High gas tax is perceived negatively by automobile users because it increases their cost of driving. States periodically increase gas taxes to meet the demands of maintaining the transportation system.

3.3 Travel and Economic Characteristics

States with different development patterns might use automobiles differently, which could result in different patterns of travel and consequently differing levels of environmental impact. Therefore to understand states' travel patterns, we analyzed the amount of travel, types of vehicles, and the amount spent on fuel. These characteristics may be influenced by government policy and government spending.

In this analysis, vehicle travel is measured in annual vehicle miles traveled (VMT) per capita. VMT is estimated with sample counts of vehicles using fixed and temporary counters on a

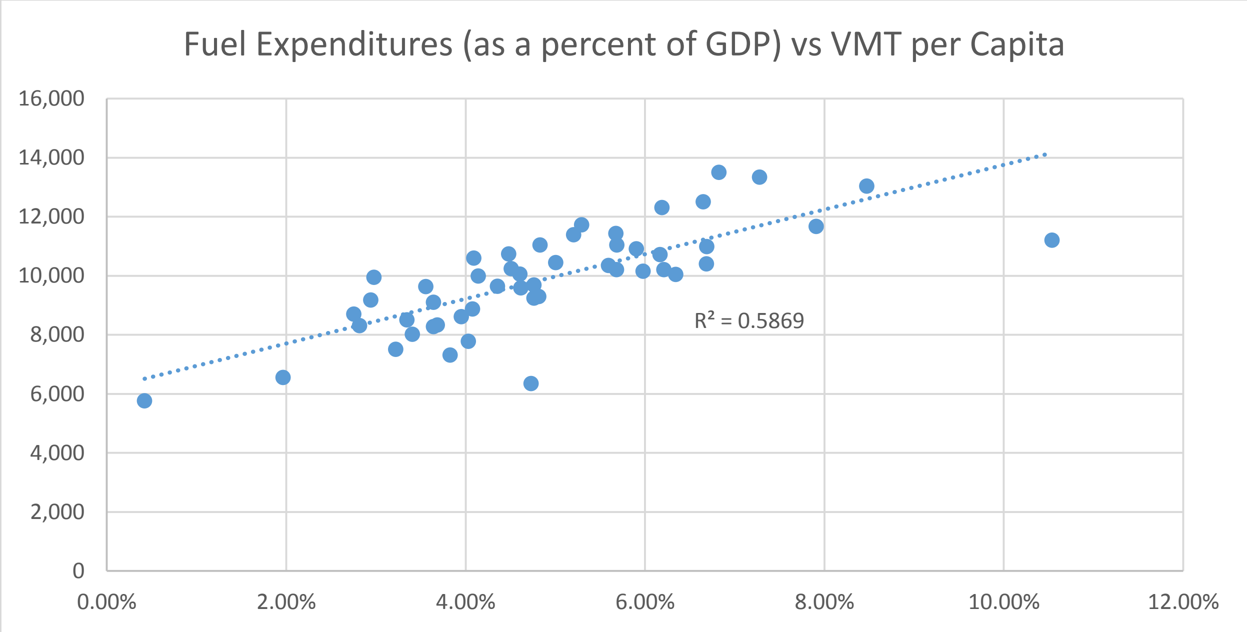
variety of road types and then extrapolated to the town, county and state levels (26). Combined with other metrics like environmental impacts, VMT per capita can be useful for analyzing transportation sustainability. Using VMT, we are able to analyze how environmental costs vary between states with similar and with different land development patterns. We use VMT per capita to assess how closely correlated our policy measures are related to a state's VMT per capita. The policies that are more highly correlated with VMT per capita will be more affective at changing a state's travel behavior.

The National Emissions Inventory MOBILE6 model uses VMT to calculate the total annual emissions for each criteria pollutant. Therefore, CAPs are a function of vehicle travel. VMT is not a factor in CO_2 emissions data. CO_2 emissions data is independent of VMT, but is instead calculated using gasoline consumption figures from each state.

The percent of total passenger vehicles that are pickup trucks, vans, and SUVs is a proxy for the level of fuel efficiency of vehicles people are driving in various development patterns. Trucks, vans and SUVs typically consume more fuel than cars, which are typically smaller, lighter and more aerodynamic. Fuel consumption is a function of how far vehicles drive and their fuel efficiency, usually expressed in miles per gallon. It is difficult to know the average fuel efficiency of all the vehicles in a state, so this indicates if trucks or cars are the predominant vehicle on the road. Together with VMT per capita, this measure explains fuel consumption differences between development types. Vehicle fuel consumption is a major cause of CO_2 pollution and other air pollutants. The percent of total passenger vehicles that are pickup trucks, vans and SUVs was calculated from vehicle registration data.

The fuel expenditures (as a percent of GDP) metric shows how much people are spending on fuel for highway transportation as a percentage of state GDP. This is important because it shows how efficient the transportation system is. States want to spend less money while being increasing their economic output. Efficient transportation is transporting more people and goods for less money and resources. Efficient transportation should not be confused with sustainable transportation, however. The metric Fuel Expenditures (as a percent of GDP) gives us some indication of how efficient the transportation system is in each state. Figure 1 shows that Fuel Expenditures as a percent of GDP are highly correlated with VMT per Capita. This relationship tells us that in states where people drive more per person they are also spending more on fuel in relation to their economic output.

Figure 1 Fuel Expenditures (as a percent of GDP) versus VMT per Capita



3.4 Environmental Indicators

Select environmental indicators are used to better understand how states transportation decisions impact the environment. We have chosen to focus on eight environmental indicators: CO_2 emissions, six criteria air pollutants, and lane miles of roadway used by automobile transportation. CO_2 emissions are used as an indicator of GHG emissions because they are the vast majority of the GHG emissions from the transportation sector. They directly relate to global implications of sustainable transportation. Criteria air pollutants (CAPs) are used as an indicator because they measure the harmful gases caused by on-road transportation. Lane miles of roadway are a proxy for the amount of land consumed for automobile transportation.

CO_2 is the primary greenhouse gas (GHG) emission of concern in the transportation sector. CO_2 is calculated from fuel consumption in FHWA (Federal Highway Administration) Table MF-21 for the year 2011. The data used from this table are the *total gasoline for highway use* and *special fuel for private and commercial highway use*. The data is reported by states' motor-fuel tax agencies. The amount of CO_2 emitted depends on the type of fuel burned. The conversion

factor for gasoline is $8.887\ \times 10^{-3}\ metric\ tons\ of\ CO_2$ per gallon of gasoline (27). The conversion factor for diesel is $10.15\ \times 10^{-3}\ metric\ tons\ of\ CO_2$ per gallon of diesel fuel (28). The carbon emissions from gasoline and diesel vehicles are added together and represented in units of metric tons.

As discussed above, there are six criteria air pollutants (CAPs) that are measured by the EPA's National Emissions Inventory for 2002, which originate in the transportation sector: CO, NO_2, SO_2, VOC, PM2.5 and PM10. Lead is also a CAP, but is not tracked as a CAP for on-road emissions. These pollutants are mobile emissions from the highway sector estimated using a computer model. The 2002 NEI uses the National Mobile Inventory Model (NMIM) which is a consolidated emissions modeling system for the MOBILE6 modeling program. This program estimates criteria pollutants for on-road sources using local travel data and local parameters to estimate pollution rates in units of grams per mile. The data required to run the MOBILE6 model include: base emission rates, vehicle test conditions, fleet characteristics, fuel characteristics, and emission control programs (8). The emissions rate generated for each county was then multiplied by VMT to get the total emissions for each county. We added the totals from each county to compile state totals for each pollutant included in this study. All CAPs are reported in tons per 1000 people.

Lane miles are published in table HM60 by the FHWA for 2011 (29). We use the summation of interstate and arterial roadway types from both rural and urban areas. Although this metric excludes collectors, local roads and parking facilities, it is a proxy for the land required for on-road motor vehicle transportation system in each state, per capita. We report this metric in units of lane miles per one thousand people.

Table 3 Data Sources

Data	Source	Date
Carbon Dioxide	USDOT, FHWA, 2013. Highway Statistics 2011, Table MF-21: Motor Fuel Use. Retrieved June 2014 From: http://www.fhwa.dot.gov/policyinformation/statistics/2011/	2011
Congestion Mitigation and Air Quality	USDOT, FHWA, 2014. Highway Statistics 2008-2011, Table FA3: Retrieved June 2014 From: http://www.fhwa.dot.gov/policyinformation/statistics/2011/	2008-2011
Criteria Air Pollutants (CO, NO_2, SO_2, VOC, PM10, PM2.5)	U.S. Environmental Protection Agency, AirData Emissions by Category Report, Criteria Air Pollutants, 2002, Retrieved September, 2010 From: http://www.epa.gov/airdata	2002
Fuel Expenditures	U.S. Energy Information Administration, 2014. State Energy Data System, Expenditures. Motor Gasoline (Code MGACV) and Distillate Fuel (Code DFACV) From: http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US%23CompleteDataFile#CompleteDataFile	2011
Gross Domestic Product	U.S. Department of Commerce, Bureau of Economic Analysis, 2014. Table 1: Real GDP by State. Retrieved June 2014 From: https://www.bea.gov/newsreleases/regional/gdp_state/2011/xls/gsp0614.xls	
Highways Expenditure	USDOT, Bureau of Transportation Statistics (BTS), Research & Innovative Technology Administration, 2012. State Transportation Statistics 2012: Tables 6–8 Transportation Expenditure by State Governments, 2011. Retrieved June 2014 From: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/state_transportation_statistics_2012/index.html	2011
Lane Miles	USDOT, FHWA, 2013. Highway Statistics 2008-2011, Table HM-60: Functional System Lane Length. Retrieved June 2014 From: http://www.fhwa.dot.gov/policyinformation/statistics/2011/	2011
Population	U.S. Census, Annual Estimates for the Population of the United States, 2002, 2011, Retrieved Sept., 2010 & June 2014 From: http://www.census.gov/popest/data	2002, 2008-2011
State and Local Gov't Spending	USDOT, BTS, Research & Innovative Technology Administration, 2012. State Transportation Statistics 2012: Tables 6–8 Transportation Expenditure by State Governments, 2011. Retrieved June 2014 From: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/state_transportation_statistics_2012/index.html	2011
Vehicle Miles Traveled	USDOT, FHWA, 2014, Highway Statistics 2011, Table VM-2: Functional System Travel, 2011. Retrieved June 2014 From: http://www.fhwa.dot.gov/policyinformation/statistics/2011	2011
Vehicle Registrations	USDOT, FHWA, 2014. Highway Statistics 2011, Table MV-9: Truck and Tractor Trailer Registrations, 2011. Retrieved June 2014 From: http://www.fhwa.dot.gov/policyinformation/statistics/2011	2011
Gasoline Tax	USDOT, FHWA, 2014. Highway Statistics 2008-2011, Table MF-121T: Tax Rates on Motor Fuel. Retrieved April 2015 From: http://www.fhwa.dot.gov/policyinformation/statistics/2008/	2008-2011

Table 4 Indicators of Sustainable Transportation

Group		Policy Indicators				Travel Characteristics			Environmental Impacts							
Desc.	States	State and Local Gov't Spend. on HWY / Capita	CMAQ Improvements / Capita	Percent HWY to Total Surface Spend.	Gas Tax	Vehicle Miles Traveled / Capita	Percent Trucks, Vans & SUVs of Passenger Vehicles	Fuel Expend. (as % of GDP)	Metric Tons CO2 / Capita	Lane Miles / 1000 People	Tons CO / 1000 People	Tons NO2 / 1000 People	Tons SO2 / 1000 People	Tons VOC / 1000 People	Tons PM10 / 1000 People	Tons PM2.5 / 1000 People
Low Density Rural-Suburb (LDR-S)	Alabama	$460	$0.48	97%	$ 0.21	13,516	48%	6.8%	6.3	6.0	277	34	1.3	23	0.08	0.06
	Arkansas	$471	$2.46	97%	$ 0.22	11,216	54%	10.5%	6.2	7.0	272	31	1.1	21	1.49	1.09
	Georgia	$297	$1.55	81%	$ 0.21	11,050	51%	4.8%	5.4	4.6	262	36	1.3	22	0.99	0.74
	Kentucky	$522	$1.10	94%	$ 0.23	11,000	43%	6.7%	6.1	4.7	257	36	1.4	20	0.93	0.69
	Maine	$704	$0.37	98%	$ 0.31	10,728	50%	6.2%	5.8	4.7	279	36	0.9	20	2.51	1.75
	Mississippi	$566	$4.33	99%	$ 0.19	13,044	44%	8.5%	6.5	7.6	259	37	1.3	22	1.82	1.34
	Montana	$899	$2.84	96%	$ 0.28	11,681	59%	7.9%	6.8	17.6	312	40	1.2	22	1.00	0.76
	New Hampshire	$577	$3.37	97%	$ 0.20	9,649	47%	4.4%	5.3	3.4	232	31	0.7	17	1.36	1.03
	Oklahoma	$637	$2.38	97%	$ 0.17	12,518	48%	6.6%	6.2	7.1	307	38	1.5	25	1.01	0.74
	South Carolina	$331	$2.21	95%	$ 0.17	10,414	45%	6.7%	6.4	5.0	278	33	1.2	22	0.87	0.65
	Vermont	$947	$1.72	95%	$ 0.25	11,400	47%	5.2%	5.4	6.5	386	35	1.0	29	8.03	5.67
	West Virginia	$709	$3.37	96%	$ 0.32	10,221	50%	6.2%	5.4	5.6	279	33	1.5	21	2.49	1.84
LDR-S Average		$593	$2.18	95%	$ 0.23	11,370	49%	6.7%	6.0	6.7	283	35	1.2	22	1.88	1.36
Low Density Mixed (LDM)	Alaska	$2,353	$13.10	97%	$ 0.08	6,355	68%	4.7%	5.2	8.1	226	25	0.5	17	6.57	4.85
	Arizona	$386	$8.12	79%	$ 0.19	9,190	48%	2.9%	4.7	3.9	153	29	0.5	16	0.40	0.30
	Idaho	$632	$8.94	98%	$ 0.25	10,055	58%	6.3%	5.2	7.6	290	33	1.0	21	1.75	1.29
	Iowa	$695	$3.40	95%	$ 0.22	10,213	47%	5.7%	6.7	8.7	360	39	1.0	26	1.88	1.39
	Kansas	$613	$1.38	97%	$ 0.25	10,456	47%	5.0%	5.6	9.3	252	32	1.1	19	0.81	0.60
	Nebraska	$629	$4.47	97%	$ 0.27	10,362	49%	5.6%	6.2	11.0	275	38	1.2	21	3.78	2.83
	New Mexico	$574	$3.55	89%	$ 0.19	12,319	56%	6.2%	6.5	8.7	317	42	1.2	25	2.06	1.37
	North Dakota	$1,386	$14.72	99%	$ 0.23	13,350	49%	7.3%	9.9	22.4	326	39	1.1	24	12.72	8.76
	South Dakota	$1,104	$16.91	99%	$ 0.24	10,924	55%	5.9%	7.2	20.6	287	39	1.1	21	0.98	0.74
	Wyoming	$1,228	$24.72	99%	$ 0.14	16,272	66%	6.6%	10.7	20.3	495	66	1.8	36	1.61	1.22
LDM Average		$805	$9.93	95%	$ 0.21	10,949	54%	5.6%	6.8	12.1	298	38	1.1	23	3.26	2.33

Table 5 Indicators of Sustainable Transportation

Group		Policy Indicators				Travel Characteristics			Environmental Impacts							
Desc.	States	State and Local Gov't Spend. on HWY / Capita	CMAQ Improvements / Capita	Percent HWY to Total Surface Spend.	Gas Tax	Vehicle Miles Traveled / Capita	Percent Trucks, Vans & SUVs of Passenger Vehicles	Fuel Expend. (as % of GDP)	Metric Tons CO2 / Capita	Lane Miles / 1000 People	Tons CO / 1000 People	Tons NO2 / 1000 People	Tons SO2 / 1000 People	Tons VOC / 1000 People	Tons PM10 / 1000 People	Tons PM2.5 / 1000 People
Medium Density Suburb (MDS)	Colorado	$472	$3.04	75%	$ 0.22	9,108	54%	3.6%	4.7	5.3	245	28	0.9	19	0.71	0.52
	Florida	$438	$0.54	83%	$ 0.34	10,067	45%	4.6%	4.4	2.8	228	27	1.3	22	0.75	0.54
	Hawaii	$413	$6.80	59%	$ 0.46	7,322	51%	3.8%	3.3	1.8	133	16	0.2	14	0.46	0.32
	Louisiana	$660	$0.88	93%	$ 0.20	10,167	53%	6.0%	6.0	4.3	211	28	1.0	17	0.76	0.56
	Michigan	$361	$4.15	85%	$ 0.38	9,594	45%	4.6%	4.8	4.5	273	31	1.3	21	0.78	0.59
	Minnesota	$674	$1.32	93%	$ 0.27	10,605	49%	4.1%	5.2	6.8	262	33	0.6	20	0.76	0.55
	Missouri	$541	$0.68	88%	$ 0.17	11,444	49%	5.7%	6.2	5.5	281	35	1.1	22	0.54	0.41
	Nevada	$517	$3.14	80%	$ 0.33	8,882	46%	4.1%	4.6	4.6	139	13	0.2	12	0.30	0.18
	North Carolina	$400	$2.76	89%	$ 0.33	10,746	42%	4.5%	5.0	3.6	215	29	1.0	17	0.08	0.05
	Pennsylvania	$713	$5.18	78%	$ 0.32	7,785	42%	4.0%	4.7	3.3	196	24	0.6	15	0.59	0.42
	Tennessee	$374	$2.24	91%	$ 0.21	11,049	46%	5.7%	5.8	4.9	290	41	1.3	24	1.06	0.80
	Texas	$427	$2.18	79%	$ 0.20	9,248	50%	4.8%	5.8	4.6	174	29	1.0	14	0.74	0.54
	Utah	$652	$2.73	71%	$ 0.25	9,308	49%	4.8%	5.1	4.9	328	33	0.9	24	0.71	0.51
	Virginia	$456	$3.21	87%	$ 0.20	10,001	41%	4.1%	5.3	3.9	237	29	0.9	17	0.09	0.06
	Washington	$595	$2.21	67%	$ 0.38	8,339	43%	3.7%	4.3	3.5	301	33	0.9	26	0.75	0.56
	Wisconsin	$654	$0.34	91%	$ 0.33	10,251	48%	4.5%	5.0	6.0	243	32	1.3	18	0.28	0.21
MDS Average		$522	$2.59	82%	$ 0.29	9,620	47%	4.5%	5.0	4.4	235	29	0.9	19	0.58	0.43
High Density Suburb-Urban (HDS-U)	California	$399	$5.72	59%	$ 0.48	8,511	46%	3.3%	4.1	2.7	166	20	0.1	10	0.79	0.60
	Connecticut	$446	$3.53	69%	$ 0.45	8,713	35%	2.8%	4.3	2.6	186	19	0.5	14	0.47	0.31
	Delaware	$602	$4.99	81%	$ 0.23	9,952	43%	3.0%	4.7	2.7	193	27	0.7	14	0.27	0.19
	District of Columbia	$433	$11.90	10%	$ 0.24	5,774	22%	0.4%	1.8	1.6	113	15	0.5	9	0.99	0.70
	Illinois	$556	$3.98	68%	$ 0.43	8,022	42%	3.4%	4.3	3.7	166	24	0.7	13	0.09	0.06
	Indiana	$416	$2.67	94%	$ 0.37	11,736	47%	5.3%	5.9	4.2	283	35	1.4	23	1.26	0.93
	Maryland	$516	$2.74	73%	$ 0.24	9,646	42%	3.6%	4.9	2.6	185	22	0.7	13	0.58	0.40
	Massachusetts	$392	$3.23	89%	$ 0.24	8,317	41%	2.8%	4.3	2.8	149	20	0.5	11	0.18	0.14
	New Jersey	$497	$1.52	66%	$ 0.15	8,286	40%	3.6%	5.0	2.3	155	19	0.4	12	0.11	0.08
	New York	$571	$3.88	37%	$ 0.47	6,562	39%	2.0%	3.2	2.3	147	15	0.4	11	0.10	0.08
	Ohio	$441	$4.57	87%	$ 0.28	9,700	42%	4.8%	5.0	3.5	228	29	1.1	18	0.70	0.52
	Oregon	$524	$1.43	76%	$ 0.31	8,619	49%	4.0%	4.7	5.1	307	31	1.0	26	0.77	0.57
	Rhode Island	$331	$2.05	59%	$ 0.33	7,516	39%	3.2%	3.7	2.5	177	16	0.4	13	0.32	0.20
HDS-U Average		$471	$4.02	67%	$ 0.32	8,566	40%	3.2%	4.3	3.0	189	22	0.6	14	0.51	0.37

4.0 RESULTS AND DISCUSSION

4.1 Data

The travel and environmental data sets were compiled at a state-wide level for 2011 with the exception of the CAPs. For the CAPS, 2002 was used because it was the only year that all the states submitted on-road emissions data to the US EPA AirData program. California used its own system in more recent emissions reporting. The four policy indicators were prepared for 2008-2011 and averaged for comparison in the discussion. Table 3 shows the sources of data compiled for this research.

4.2 Statistical Analysis of Groups

In order to draw conclusions from the datasets, we confirm that the indicators used in the study are statistically different for each of the four urbanization groups compared. In order to show that variation exists between groups, single factor ANOVA analysis with alpha equal to 0.05 is conducted on the variables of each policy, travel, and environmental indicator. The null hypothesis is that the mean values of the urbanization groups are equal. If the f > f-critical, we reject the null hypothesis and assume the means are statistically different. Table 6 shows the ANOVA results and group means for indicators used in this study. Zheng et al confirmed that the urbanization groups of states have statistically different land use patterns from one another. Our analysis confirms that the groups also have statistically different VMT. The F values in Table 6 are all higher than the F-critical of 2.80, which suggests that all groups are statistically different from each other, for all the indicators.

TABLE 6 ANOVA Results and Group Means for All Indicators

ANOVA Results		Means: Low Density Rural - Suburban	Means: Low Density Mixed	Means: Medium Density Suburban	Means: High Density Suburban - Urban	F Value
Policy Indicators	State and Local Gov't Spend. on HWY / Capita	$546	$940	$544	$496	6.27
	CMAQ Spending / Capita	$2.18	$9.93	$2.59	$4.02	10.25
	Percent of Total Surface Spending on Highways	95%	95%	82%	67%	12.74
	Gas Tax	$0.23	$0.21	$0.29	$0.32	5.24
Travel Characteristics	Vehicle Miles Traveled / Capita	11,370	10,949	9,620	8,566	7.61
	Percent of Passenger Vehicles that are Pickups, Vans & SUVs	49%	54%	47%	40%	11.59
	Fuel Expend. (as % of GDP)	6.71%	5.62%	4.54%	3.24%	18.70
	Average Daily Traffic / Lane	31,479	19,798	39,979	43,235	17.74
Environmental Impacts	Metric Tons CO2 / Capita	6.00	6.79	5.00	4.30	11.17
	Lane Miles / 1000 People	6.65	12.06	4.39	2.97	14.85
	Tons CO / 1000 People	283	298	235	189	8.10
	Tons NO2 / 1000 People	35.12	38.29	28.84	22.46	11.58
	Tons SO2 / 1000 People	1.19	1.06	0.91	0.65	6.11
	Tons VOC / 1000 People	22.03	22.65	18.95	14.49	8.34
	Tons PM10 / 1000 People	1.88	3.26	0.58	0.51	5.13
	Tons PM2.5 / 1000 People	1.32	2.33	0.43	0.37	5.24

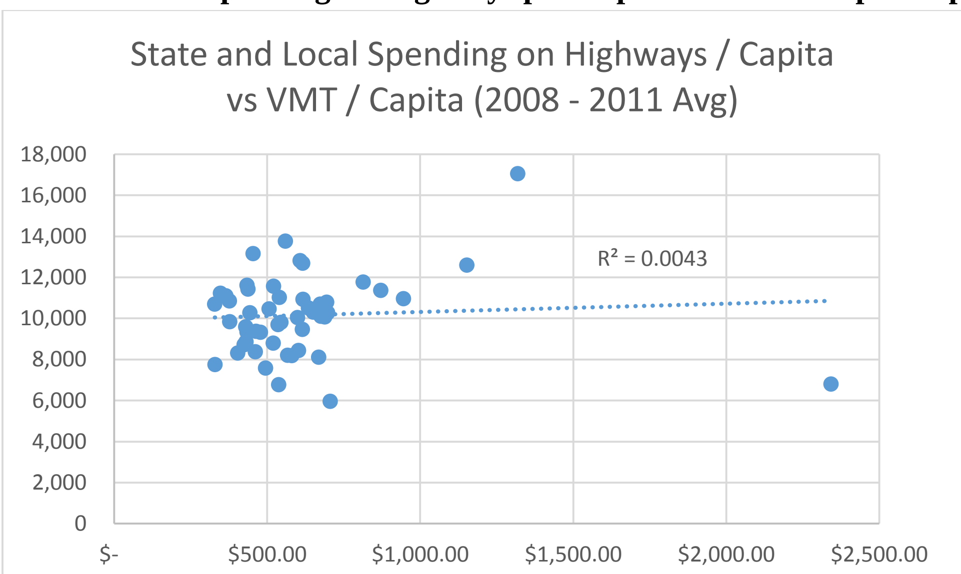
F-Critical = 2.80

4.3 Policy Indicators

In the following analysis, we determine the extent to which state and local policy decisions correlate with the amount of driving that people do. We compare each of the four policy indicators in this study to VMT per Capita.

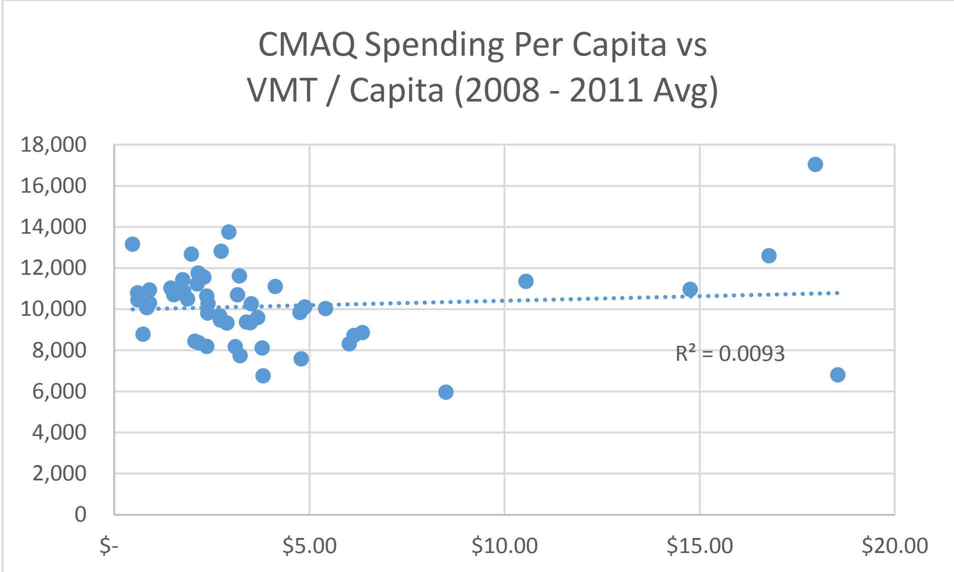
The first policy indicator that we analyze is State and Local Spending per Capita on Highways. This policy indicator does not have a strong correlation with VMT per Capita. The R2 value is 0.0043 for this plot located below in Figure 2. It is unlikely that the amount being spent on highways is influencing the amount people drive.

Figure 2 State and Local Spending on Highways per Capita versus VMT per Capita



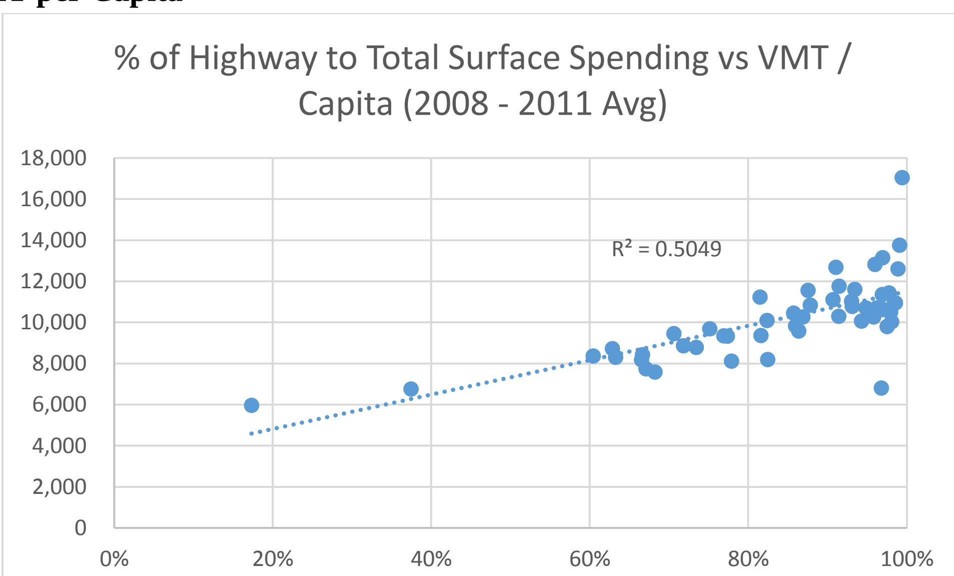
The second policy indicator is Congestion Mitigation and Air Quality spending per Capita. On a per capita basis, we discovered that the states with lower pollution per capita, have quite high levels of CMAQ spending per capita. This indicator has very little correlation to VMT per Capita. The R^2 value is 0.0093, as shown below in Figure 3. This means that regardless of how much states are spending on CMAQ, the VMT per Capita and consequently emissions are not influenced.

Figure 3 Congestion Mitigation and Air Quality Spending per Capita versus VMT per Capita



The third policy indicator is Percent of Highway to Total Surface Spending, which is graphed versus VMT per Capita in Figure 4. This indicator is highly correlated with VMT per capita. State and local governments that spend more per capita on highways generally have higher VMT per capita. States governments should spend higher portions of their budget on transit in order to lower VMT per capita.

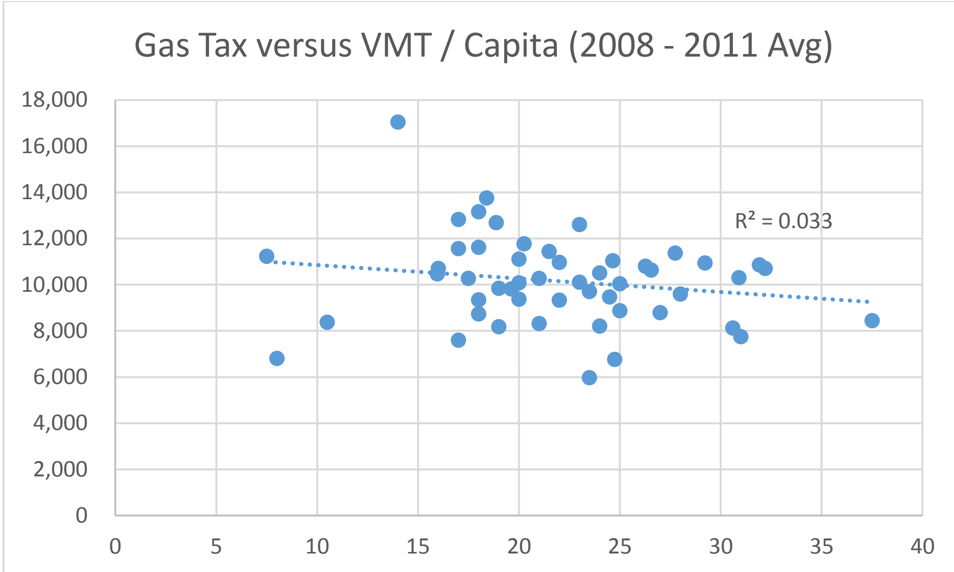
Figure 4 Percent of Total Surface Spending on Highways by State and Local Governments versus VMT per Capita



The fourth policy indicator is Gas Tax versus VMT per Capita. This indicator has very little correlation with VMT per capita, as shown in Figure 5. State gas taxes have a negative correlation with VMT/capita, which indicates that states with higher gas taxes have lower VMT/capita. The R^2 value is only 0.033, which means that raising the gas tax would not have a great influence on people's travel behavior and therefore it would not reduce the environmental impacts of surface transportation. This may be because the price of gasoline remains mostly inelastic. When the gas price rises and falls, it does not significantly change how much people drive. If the tax is increased by a few cents per gallon, it will not likely impact the amount that people drive. Gas tax is included in the price at the pump, so it does not seem like an additional charge. However, the overall price of gasoline does not appear to influence VMT either. This may be why there is low correlation between gas tax rate and VMT per capita. Doug Short looks at the gasoline price to VMT relationship very closely. In the paper he states:

> [The gasoline price and VMT] correlation is fairly weak over the entire timeframe (1990 – 2015). And, despite the volatility in gasoline prices since the onset of the Great Recession, the correlation since December 2007 has been even weaker… (24)

Figure 5 Gas Tax versus VMT per Capita



Out of the four policy indicators, the Percent of Total Surface Spending on Highways by State and Local Governments is the only indicator highly correlated with VMT per Capita.

4.4 State Comparisons Within Urbanization Groups

In the analysis below we have chosen to compare two states in each urbanization group to see how similar states can have different transportation sustainability outcomes given different transportation policies. The states that we have chosen to compare are neighboring states that have significantly different levels of state and local government spending on highways per capita. We chose neighboring states to mitigate any climate and geographical differences that may otherwise cause differences between state's environmental impacts.

4.4.1 Low Density Rural-Suburban States

The two states chosen for comparison in this group are Vermont and New Hampshire. In Table 1 we see that New Hampshire had 20 percent of its population living in central cities, whereas Vermont had only 6 percent. Vermont had denser central cities at 3,683 people per square mile verse New Hampshire's 1,948. The small town percentages and densities are similar. Where the

larger difference lies is the percentage of rural area population. Vermont had 56 percent living in rural areas whereas New Hampshire had 30 percent of its population living in rural areas. In summary New Hampshire is more urbanized than Vermont.

In terms of policy, New Hampshire’s state and local government spends $531 per capita on highways versus Vermont’s $747 per capita. Both states spend similar percentages of their surface transportation budget on Highways (97 percent for New Hampshire and 95 percent for Vermont). This means that neither state invests heavily in transit. New Hampshire spends $3.37 per capita on CMAQ spending versus Vermont’s $1.72. The more urbanized a state is, the more spending may be required on congestion mitigation and/or air quality improvements. In 2011, Vermont had a $0.25 gas tax and New Hampshire had a $0.20 gas tax (30). New Hampshire and Vermont have both had gas tax increases since 2008. This shows that both states have the political will to increase the variable cost of automobile transportation and address the rising costs of roadway maintenance.

Vermont had higher VMT per capita than New Hampshire, 11,400 and 9,649, respectively. Both states have the same percentage of trucks, vans and SUVs of total passenger vehicles. Vermont spends more on fuel as a percent of GDP than New Hampshire (5.2 percent versus 4.4 percent).Vermont had 6.5 lane miles per 1000 people whereas New Hampshire had only 3.4 lanes miles per 1000 people. This means Vermont had more pavement to maintain per capita and more land consumed for surface transportation per capita than New Hampshire.

We can see from Table 4 that New Hampshire performs better than Vermont for every environmental indicator. Vermont emitted 5.4 MT CO_2 per capita versus 5.3 MT in New Hampshire. For the CO, indicator the difference was more drastic; Vermont emitted 386 tons of

CO per 1000 people versus 232 tons of CO per 1000 people in New Hampshire. The VOCs and PM values are much higher for Vermont, as well.

It appears that the higher percentage of rural population and lower percentage of central city population contribute to Vermont's higher environmental impacts of surface transportation. Vermont's policy makers should incentivize its rural residents, who are not farming, to live in towns or central cities. 56 percent of the population was living in rural areas, while only a small percentage of these people are actually farming. According to the U.S. Bureau of Labor Statistics, Vermont had 1,060 people working in Farming, Fishing and Forestry Occupations in 2014 (31). The majority of the rural residents are likely commuting to towns or cities many miles from where they live, for work each day. This is likely why Vermont's VMT per capita is much higher than New Hampshire's.

4.4.2 Low Density Mixed States

For Low Density Mixed states, we compared Arizona and New Mexico. Table 1 shows that Arizona had 53 percent of its population living in central cities versus New Mexico's 32 percent. Arizona's central cities are denser at 2,267 people per square mile, while New Mexico's are 2,166. Arizona and New Mexico have a similar percentage of their population living in small towns; 24 percent versus 22 percent, respectively. New Mexico had denser small towns at 1,066 versus 681 for Arizona. Arizona and New Mexico both have low density suburbs at 17 and 35 people per square mile, respectively. 24 percent of New Mexico's population lives in rural areas, whereas Arizona had only 9 percent. These two states have similar percentages for suburbs and small towns, but much different percentages for central cities and rural areas. It is these differences that reflect the differences of environmental impacts of surface transportation.

Arizona's state and local government spent $386 per capita on highways. New Mexico's state and local government spent $574 per capita on highways. Not only did New Mexico spend more per capita, but they also spent more on highways as a percent of the total surface transportation spending. New Mexico spent 89 percent of its budget on highways and only 11 percent on transit. Arizona spends 79 percent on highways and 21 percent on transit. Arizona spent $8.12 per capita on CMAQ funding. This is much more than New Mexico spent, at $3.55 per capita. Neither state had approved a gas tax increase since 2008. This shows that neither state had the political will to increase the road user's variable costs of automobile transportation (gasoline). New Mexico and Arizona both had a $0.19 state gas tax in 2011 (when the national average was $0.27).

The VMT per capita for New Mexico was 12,319 versus 9,190 for Arizona. New Mexico had a higher percentage of vehicles that are Trucks,

Table 4 shows that New Mexico emitted 6.5 MT of CO_2 per capita from gasoline and diesel fuel versus 4.7 MT for Arizona. New Mexico had higher CAP emissions for each indicator CO, NO_2, SO_2, VOC, PM10 and PM2.5. New Mexico had 8.7 lane miles per 1000 people, whereas Arizona only had 3.9 lane miles per 1000 people.

The factor that distinguishes Arizona from New Mexico is likely its decision to spend proportionally more of surface transportation spending on transit than New Mexico. This, coupled with the fact that Arizona also had a lower percentage of its population living in rural areas and a higher percentage in urban areas than New Mexico, makes transit more cost effective. Spending less on highway transportation facilities and more on transit, had contributed to Arizona performing better than New Mexico for every environmental indicator of sustainable

transportation. To reduce environmental impacts of surface transportation, New Mexico policy makers should spend more money on urban development and urban transportation infrastructure such as transit, bike and pedestrian alternatives in proportion to its highway spending.

4.4.3 Medium Density Suburban States

In this urbanization group, we compare Michigan to Wisconsin. Table 1 shows Michigan had a lower percentage of people living in the central cities (21 percent), it had higher density central cities (4,452). Wisconsin had 30 percent of its population living in central cities with a density of 3,362. Perhaps the most significant difference between these two states is that Michigan had a higher percentage of its population living in suburbs (57 percent) and at a higher density (439 people per square mile) than Wisconsin (46 percent and 152 people per square mile). The two states have similar percentages of their population living in small towns. Michigan had denser small towns and rural areas than Wisconsin and a lower percentage of the population living in these land development types. Michigan is more suburban with denser suburbs and had denser central cities, which makes it arguably more urbanized than Wisconsin.

State and local governments in Wisconsin spent $654 per capita on highways in 2011, as shown in Table 5. By contrast, Michigan spent $361 per capita on highways. Michigan spent $4.15 per capita on CMAQ improvements, whereas Wisconsin spent $0.34. Michigan spent 85% of its state and local budget on highways, but Wisconsin spent 91%. Neither state had approved a gas tax increase since 2008, but both have had major metropolitan areas pass ballot measures to increase transportation funding (32). When metropolitan areas increase transportation funding they use this money for improving their transportation systems. Michigan’s gas tax was $0.38, in 2011, and Wisconsin’s was $0.33.

Wisconsin had higher VMT per capita than Michigan (10,251 to 9,594), and a higher percentage of vehicles that are pickups, vans and SUVs (48 percent versus 45 percent for Michigan). Michigan had lower Lane Miles per 1000 people, 4.5 versus 6.0 for Wisconsin. Michigan had better indicators for all three travel characteristics in this analysis.

Wisconsin emitted more CO_2 emissions per capita than Michigan, 5.0 MT versus 4.8 MT per capita, as shown in Table 5. The CAP indicators are mixed for this group. The CO, VOCs and PM were higher for Michigan. NO_2 was slightly higher for Wisconsin and SO_2 was the same for both states.

From the comparison of the two Medium Density Suburban states, we see that Michigan and Wisconsin had different transportation spending policies, which leads to different environmental outcomes. Michigan spends more on transit than Wisconsin, and had lower VMT than Wisconsin. These differences result in lower CO_2 emissions for Michigan. This suggests that Wisconsin policy makers could improve environmental outcomes by spending more on transit and working to increase the density of cities and suburbs.

4.4.4 High Density Suburban-Urban

In the High Density Suburban-Urban group we compare Indiana's and Illinois' land development characteristics from Table 1. Illinois had 35 percent of its population living in central cities versus 30 percent in Indiana. The density of Illinois' central cities is 5,874 versus 2,338 for Indiana. Illinois had a large portion of its population living in dense suburbs, 48 percent versus 36 percent in Indiana. The suburb density in Illinois is 389 people per square mile, almost double that of Indiana, at 199 people per square mile. Illinois had a small percentage of its population living in small towns and rural areas, 8 and 9 percent respectively. Indiana had 21 percent of its

population living in rural areas, and 12 percent live in small towns. From this population and density comparison, we see that Illinois is more urbanized than Indiana.

Table 5 shows that Illinois spent more per capita on highway spending than Indiana, $556 versus $416 respectively. Illinois also spent more on CMAQ funding than Indiana did in 2011, at $3.98 per capita versus $2.67 per capita. The significant policy difference is that Illinois spent 68 percent of its surface transportation budget on highways and the remainder on transit. Indiana spent 95 percent of its budget on highways and the remainder on transit. In 2011, Illinois' gas tax was $0.43 and Indiana's was $0.37. Despite a higher gas tax, VMT per capita in Illinois is lower than in Indiana. Neither state had approved a gas tax increase since 2008.

Illinois' VMT per capita was 8,022, much less than Indiana's VMT per capita of 11,736. In Indiana 47 percent of passenger vehicles were pickup trucks, vans and SUVs, while in Illinois 42 percent of passenger vehicles were of these types. Indiana spent 5.3 percent of state GDP on fuel, yet Illinois spent 3.4 percent. Compared with Indiana, Illinois performed better for each travel characteristic and consequently has more favorable environmental outcomes.

Illinois' CO_2 emissions from on-road gasoline and diesel fuel were 4.3 MT per capita versus 5.9 MT per capita for Indiana. Illinois had 3.7 lane miles per 1000 people whereas Indiana had 4.2 lane miles per 1000 people. The CO emissions per 1000 people for Illinois were 166 versus 283 for Indiana. The NO_2 emissions for Illinois were 24 tons per 1000 people versus 35 for Indiana. SO_2 emissions were 0.7 in Illinois versus 1.4 in Indiana. VOC emissions were 13 for Illinois and 23 for Indiana. PM10 and PM 2.5 were 0.09 and 0.06 respectively for Illinois, whereas they were 1.26 and 0.93 tons per 1000 people for Indiana.

Every indicator shows that Illinois' policy decisions and development patterns generate better surface transportation outcomes than Indiana's. Indiana is a high density suburban-urban state that should enact policy decisions to spend more on transit. At all levels of government, transit oriented development needs to take place. Transit serves high density suburbs better than low density ones. Town zoning policies in Indiana may want to consider the benefits of higher density suburbs and how transit will be more effective at reducing automobile travel and the negative environmental impacts that come with high levels of automobile travel.

5.0 CONCLUSION

The key finding of this research is that the Percent of Transportation Spending on Highways per Capita is a strong policy indicator of VMT and therefore of environmental impacts of VMT. The other three policy indicators that we investigated are not highly correlated with VMT per capita or with the environmental indicators.

Based on the analysis in this study, increasing the portion of spending on transit should reduce the environmental impacts of transportation within the United States. This suggests that if there were modal shift from cars to transit, automobile travel would fall and reductions of environmental emissions would ensue. High density suburban and urban development appears to reduce vehicle travel and reduce CO_2 pollution in states where compact development was the prevalent pattern. States with these patterns also tend to spend more on transit.

States that spend a higher percent of their budget on highway transportation have worse environmental impacts than those with lower percentages of highway spending. Transportation funding and planning are largely organized at the state level while land use planning occurs

mostly at the local level. The current method of planning that segregates land use and transportation planning does not allow for states to attain the most sustainable transportation systems. State DOT's should spend transportation funds on housing near transit and work with urban planning agencies to promote smart growth communities that are transit and bicycle friendly. This will help reduce unnecessary automobile travel and the negative environmental impacts that it generates.

High polluting states should consider the potential benefits of having high percentages of the population living in dense suburbs and central cities, as New Hampshire, Arizona, Michigan and Illinois demonstrate. These characteristics enable them to outperform their peer states with fewer carbon emissions per capita per year as well as lower CAP emissions (in most cases). People also drive less in these states and consequently spend less of the state's GDP on gasoline. The more urbanized development patterns lead to travel behavior that translates into fewer CO_2 emissions and lower emissions of other CAPs. Urban states also use less land for roadways per capita. In general, these patterns appear to reduce the environmental impacts of automobile transportation.

One policy change that the US DOT could make is to set target percentages of funding that states have to spend on transit versus highways. They could set 10 percent for low density rural-suburb states, 20 percent for low density mixed states, 30 percent for medium density suburb states and 40 percent for high density suburb urban states. This would encourage urbanization and development of better transit networks, which would help lower VMT, congestion and emissions, and would increase the health and social benefits of the population.

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