Exploring the Relationship between Travel Demand and Economic Growth

Prepared by:
Liisa Ecola and Martin Wachs,
The RAND Corporation

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1. Introduction

There is growing concern about the negative externalities associated with transportation systems. The focus of transportation policy is increasingly on reducing greenhouse gas emissions, air pollution, traffic congestion, injuries and deaths from vehicle crashes. Reducing the volume of total travel, often measured as vehicle miles of travel (VMT), is one way to address these concerns, and many localities have adopted policies aimed at accomplishing their economic and social functions while reducing VMT and thus lessening the environmental footprint of the transportation system. These generally call for replacing motorized passenger vehicle trips by increasing walking, cycling, transit use, and telecommuting, and shifting goods movement to rail or marine modes in place of trucks. Reductions in VMT increasingly are sought through shifts of passenger travel from automobiles to public transit and walking and shifts of goods movement to trains and barges from trucks through transportation pricing, changes in the provision of infrastructure, and denser mixed-use urban development. It is important to assess whether these changes will spur economic growth, result in economic decline, or have no impact?

Given these changes underway in transportation policy, there are several reasons to consider the extent to which economic growth is associated with travel. Interest is particularly acute during a time of economic recession, when recovery is important to policymakers at every level of government and it is important to understand how strategies that affect travel might either limit or enhance economic growth. Many investments in transportation are justified or explained on the basis of contributions that they might make to economic growth through improved economic efficiency or job creation. Tracking the relationship between these key indicators is of inherent interest to economists and transportation policy makers interested in that association.

This paper presents results of an assessment of the state of research on “decoupling” the relationship between vehicle travel and economic growth. In the United States, the long-term trend has been for vehicle travel, as measured in total VMT, to increase at similar rates as economic growth, as measured in gross domestic product (GDP). The goal of this study was to identify policies that have been successful at decoupling the two. It is important to learn whether some countries, states, regions, or local governments have been able to discourage growth in—or even decrease—VMT while simultaneously encouraging economic growth.

Of course, reducing VMT is far from the only way to reduce negative externalities. Air pollution and greenhouse gas emissions can be addressed through fuel efficiency standards, changes in engine technology, and low-carbon fuels. Congestion can be addressed through techniques such as congestion pricing, which might or might not

reduce total VMT, but seeks to shift modes and times of travel. Safety can be addressed through technologies such as seat belts and enforcement of regulations that address risky behavior. All of these are important, and reducing VMT is only one policy option. Nevertheless, because of its recent prominence in the debate around reducing externalities, and the fact that VMT and GDP has historically seemed so tightly coupled, this paper focuses on that relationship. Ultimately, the relationship between VMT and GDT could be coincidental, but if it is causal policymakers wish to learn how they can reduce the externalities associated with transportation investments without doing damage to the economy.

For a number of reasons, this report does not resolve with certainty the nature of the relationship between travel and economic growth. First, research on the relationship between VMT and economic growth has not yet reached a definitive conclusion about causality. It may be that when done in some ways that decreasing VMT would have a negative effect on economic growth, or that it would not matter because they are not as tightly coupled as historical trend lines lead one to believe. Second, governments that have adopted goals to both encourage economic growth and discourage further growth in VMT have done so only recently, and not enough time has passed to evaluate their results. For example, while the introduction of congestion pricing and HOT Lanes is believed by some to both promote economic efficiency and growth while lessening VMT, it is too early to assess their collective impact on the economy nor to fully measure their impact on travel volumes. Finally, the authors were unable to identify concrete policies that explicitly seek these two goals simultaneously. Policies that seek to discourage vehicular travel in the name of “decoupling” often are the same ones that have been discussed for some years, usually without any reference to their potential economic impact.

We conducted this research largely through a review of academic literature and other reports and plans such as long-range transportation plans. The preliminary results were reviewed by several experts on transportation and the economy who offered comments on the draft report at a meeting held by the Federal Highway Administration, at which an open-ended discussion of the preliminary findings led to refinements and additions. Appendix B provides names of the expert reviewers and discussion attendees.

The remainder of this report is organized in six chapters and an appendix. Chapter 2 discusses why and how GDP and VMT are used as indicators and assesses their strengths and weaknesses as measures.. Chapter 3 looks at the research that assesses whether any causal link exists between VMT and economic growth. Chapter 4 explores policies that have been adopted to encourage decoupling, both in the United States and abroad. Chapter 5 examines some related areas of research, including relationships between economic growth and energy use, transportation investments, and productivity. Chapter 6

suggests areas for future research. Appendix A describes the techniques used to conduct the literature search.

2. Defining and Measuring VMT and Economic Growth

In many policy discussions, VMT is used almost automatically as the most basic or obvious indicator of aggregate travel and GDP is the most frequent measure by which aggregate economic activity is presented. Because they are so widely used, often without description or discussion, it is important for the purposes of this analysis to consider them a bit more carefully. While this paper reaches the same conclusion as many others about their usefulness, analysts using other measures might reach different conclusions about relationships between travel and economic growth.

VMT as a Measure of Transportation Use

VMT (or its metric equivalent, VKT) is widely used to measure the aggregate quantity of collective travel because it is easy to measure, widely available, and simple to understand. It can easily be measured using data from simple and ubiquitous devices like odometers. Where it cannot directly be measured, VMT can usually be estimated using simple arithmetic. Trips, another obvious and useful measure of the quantity of travel, differ from one another in terms of length, making VMT a more convenient measure by which to combine the travel consisting of multiple trips made by many people.

Because it is conceptually simple, VMT is easily used to compare travel across population groups, geographical areas, time periods, trip purposes, classes of vehicles, and in many other ways. And VMT, as a simple measure, can be easily combined with other measures associated with travel to provide useful insights—to construct rates and measure changes in quantities of interest to policymakers. Crash fatalities and injuries per VMT make traffic safety more understandable and comparable than they would be without including an indicator of the scale or extent of travel, while fuel consumed per VMT provides more insight into transportation energy efficiency than fuel consumption alone. VMT measures travel by vehicles, but vehicle occupancy is necessary to estimate passenger miles of travel in vehicles.

While simplicity, clarity, and interpretability make VMT a useful indicator of the quantity of travel, it is important to note that such simple measures also have obvious limits. Just as a yardstick can measure length without determining whether an object is too long or too short for a particular use, VMT does not, by itself, lead to useful conclusions. For example, VMT by itself is not an effective measure of congestion because the same quantity of travel can take place on a network having greater or smaller capacity. Similarly, if travel shifts to public transit, it is possible to increase passenger miles of travel while reducing VMT. Many important externalities are not directly related

to VMT—for example, carbon emissions are more closely related to energy consumption than VMT.

VMT is not in itself inherently good or bad. Useful policies can aim to increase VMT among isolated and immobile people or to reduce VMT in highly congested locations or to redistribute VMT across times or places.

When assessing transportation policies, a notable limitation of VMT is that it only captures vehicle trips. In the modern United States that is sufficient to capture most travel, since 94 percent of all U.S. travel is by car or truck (Santos et al., 2009). However, in many larger metropolitan areas in the US and in countries where other modes have larger shares, using VMT does not account for mobility in other forms. Thus, there are many settings in which increased mobility is not necessarily highly correlated with VMT. In some instances, passenger miles of travel (PMT) might be a much better indicator.

GDP as a Measure of Economic Growth

Like VMT, gross domestic product (GDP) is a useful indicator of economic activity because it is simple to measure, readily available, and relatively easy to comprehend. GDP is an estimate of the market value of all final goods and services produced within a geographic location over some specified period of time—typically a quarter or a year. It can be applied to metropolitan areas, states, or nations, and can be used to compare regions or to measure growth and change over time. Its usefulness has resulted in GDP becoming the most widely used measure of the scale of an economy. It is a quick and easy way of adding up the dollar values of different types of economic activity: retail sales, the output of farms, the production outputs of factories, the construction of new homes, and operations performed by surgeons.

However, the GDP measure has several weaknesses. People engage in many activities that are economically productive but not included in the GDP. Many household activities, like cooking and cleaning and spending time driving children to school are examples. When we pay others to do them, they count as economic activity and included in GDP, but they are omitted when carried out by household members because there are no market transactions or prices to contribute to the economic valuation of the activities.

Increasing globalization of economic activity also causes concern about the validity of GDP as a measure of economic activity. Workers from other countries who send money home, rent paid to foreign owners of domestic real estate, interest and dividends arising from domestic production but paid to individuals located outside the country, all complicate the usefulness of GDP as a measure of domestic economic performance. Though they change GDP in the United States by only a few percent today, these elements of the economy are increasing in importance over time and have larger effects

in some other countries (Seskin and Smith, 2011). Alternative indicators, like Gross National Income (GNI) are available but are more rarely employed. GNI is defined as GDP less net taxes on production and imports, less compensation of employees and property income payable to the rest of the world plus the corresponding items receivable from the rest of the world (Commission on the Measurement of Economic Performance and Social Progress, 2009).

Also like VMT, it can be risky to associate GDP with the achievement of social objectives. As useful as GDP can be for simple aggregate comparisons of economic scale, it is the source of increasing controversy among economists and social critics. At the core of these objections is the notion that the scale of economic activity as measured by GDP is ultimately a poor indicator of economic wellbeing. When people spend money on medical care because the transport system is unsafe, or spend more money on fuel because their vehicles are inefficient or because petroleum prices rise, they are contributing to growth in GDP without necessarily improving wellbeing.

As a result of this fundamental shortcoming, there is an active movement in the United States and Europe to replace GDP by a better measure of economic wellbeing. In this country, a system of measurement, called “State of the USA,” has been introduced to overcome what are perceived to be limitations stemming from the limited range and scope of GDP by broadening the range of dimensions considered in the measurement of social conditions and “wellbeing.”[1] State of the USA, which began as a study at the Government Accountability Office and is now an independent organization, is a collection of hundreds of indicators available online that will ultimately become a Key National Indicator System that can supplement GDP.

Research and development of alternative measures that might succeed GDP faces many challenges and it is not at all clear that alternatives will soon come into widespread use. The development of alternative measures is not based on concerns specific to the assessment of transportation policy, and it is clearly possible that many of the proposed alternatives may not be usable in that realm while others may be.

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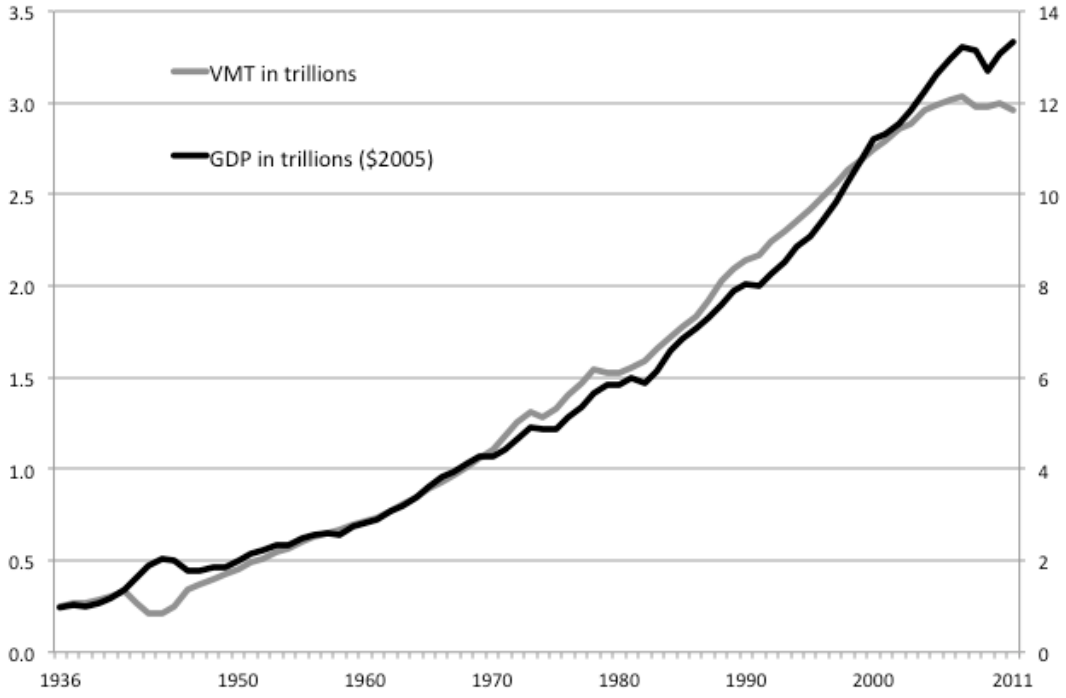
[1] For a popular account of the controversy over GDP see Gertner, 2010.

3. Relationship Between VMT and Economic Growth

It has long been observed that VMT and economic growth appear in the aggregate to be "correlated." Figure 1 shows how the two measures have grown largely in parallel since 1936, the earliest year for which Federal Highway Administration figures on VMT are readily available. Except for the World War II period, when many national resources were devoted to the war effort, the two indicators have largely followed the same path until the past decade. Beginning around 2003, the two trajectories began diverging.

Figure 1. Total Auto and Truck VMT (trillions) and GDP (trillions of $2005), 1936-2011



Note: VMT axis on left; GDP on right

Sources: VMT: FHWA,1995 (Table VM-201); FHWA, 2012; BTS, 2012 (Table 1-35); GDP: BEA, 2012 (Current-dollar and "real" GDP file as of February 29, 2012)

Growth over time in the scale of the economy is apparently related to growth in travel by automobiles and trucks. It is easier to observe that changes in economic growth and VMT at the national or state level are related than it is to understand why they are or to explain what the connection means for society. Causality is important but difficult to prove. Assertions that improved mobility cause growth in the economy or that declines in travel result from declines in economic growth are common but they are usually based upon changes in coarse and highly aggregated indicators. To the extent possible, this study explores research that clarifies the relationships and policy actions that attempt to achieve economic growth without increasing VMT.

As shown in Figure 1, VMT and economic growth have increased at similar rates, beginning in the 1930s. From a theoretical perspective, four relationships are possible:

1) Changes in VMT "cause" changes in economic growth, meaning that travel is an essential component of and helps produce economic growth;
2) Changes in economic growth "cause" changes in VMT, meaning that growth in the demand for travel depends on economic growth;
3) The causality is "bi-directional," meaning that each has an effect on the other; and
4) There is no relationship, meaning that the fact that they have grown in tandem does not imply that one produces the other; this would also suggest that there is no reason they have to continue growing in tandem.

The search of the literature located only three documents that directly and empirically addressed the nature of this relationship in the United States. Liddle (2009) addressed the relationship and generally found that several factors affect each other. Pozdena (2009) found that generally changes in VMT cause changes in GDP. Eckstein (2011) found different types of relationships between VMT and GDP—or in some cases, no relationship—depending on the historic period, whether the analysis is national or regional, and whether the business cycle was taken into account. These papers will be fully presented and reviewed below.

Other work (such as Johnston, 2008, and Lucas and Jones, 2009) explored trends in VMT and economic growth without analyzing causality or more precisely describing the relationship between the two. These pieces have tended to find evidence of natural decoupling over time—meaning that trends in VMT and economic growth are beginning to differ without any particular policy encouraging it—but these were descriptive analyses not backed up by rigorous statistical methodology.

These studies reached different conclusions about the relationship between VMT and economic growth. There does seem to be consensus that the relationship is not necessarily constant over long periods of time, and that both are affected by other factors, such as gains in population, productivity, fuel prices, and employment levels.

U.S. Studies of VMT and Economic Growth

Liddle (2009) studied the relationship between VMT, income as measured by GDP per capita, fuel consumption, and fuel prices over the period 1946 to 2006. He used "cointegration" (a statistical test for whether variables have a long-run equilibrium relationship), and concluded that, "(i)n the U.S. mobility demand has a long-run systemic, mutually causal relationship with gasoline price, income, and vehicle ownership." (pg. 81).

Pozdena (2009), conducting the first empirical study of potential causality, looked at the relationship between VMT, fuel efficiency, fuel price, and economic growth from 1949 to 2007. He noted that there are two ways for transportation to be linked to the economy: through production and consumption functions. Production means that transportation is an input to production, as when raw materials are transported to a factory. Consumption means that individuals drive to fulfill personal needs. One key problem with this categorization is that all household travel is considered consumption, but some of this travel is commuting to workplaces, which could be considered a production input.

Using an econometric model, Pozdena found that VMT is a major driver of GDP, although more strongly in the short run than the long run. A one percent change in VMT per capita results in a 0.9 percent change in GDP per capita within two years, and a 0.46 percent change in 20 years.

In terms of policies that might help decouple VMT from GDP, he suggested that congestion pricing should be the first choice, because it generates economic benefits based on the value of drivers' time. A revenue-neutral carbon tax was considered a distant second, because such a tax would be expected to produce only modest results. He concluded that policymakers should be conservative about decoupling strategies: "The intimacy of the relationship between vehicle activity and the economy is such that we should approach direct intervention solutions with great caution." (pg. 12)

Eckstein (2011) used time series techniques to test the relationship between VMT and GDP. He incorporated a larger number of variables, broke data into different time periods, compared economic activity against the business cycle, and looked at regional as well as national economic trends. National data included VMT, GDP, and personal income (both total as well as per capita) from 1929 to 2009. Metropolitan regional data, with similar measures, was analyzed from 1982 to 2009 (VMT data were not available for the earlier period).

At the national level, between 1929 and 2009, changes in economic growth "caused" changes in VMT. A separate national analysis looked at data from 1949 to 2007 (to make his time period consistent with Pozdena's 2009 study), and incorporated a "structural break" in 1982. Eckstein found a change in the relationship between VMT and GDP at

the national level in 1982. From 1949 to 1981, there was a strong bi-directional causality between the two, most likely linked to the construction of the interstate system. After 1982, there was no causal relationship in either direction.

The relationship between VMT and GDP can also vary depending on the stage of the business cycle. The years between 1929 and 2009 were each categorized as upturns or downturns, depending on peaks and troughs of economic activity. Eckstein found that in times of growth GDP caused growth in VMT, but in downturns, changes in VMT either caused changes in GDP or the relationships were bi-directional.

Finally, the analysis considered how VMT and GDP interact in urban areas. Eckstein analyzed data for 98 urban areas, divided into four size categories, and found that in the three largest categories, there was no relationship in either direction. For the fourth group, comprised of the smallest urban areas (under 500,000 people), changes in VMT drove those in GDP. Looking at individual cities, in nine cities changes in VMT caused changes in GDP, in another nine the reverse was true, in two there was bi-directional causality, and there was no relationship in the other 68 cities. Eckstein did not offer an explanation regarding what these groups of cities had in common that might explain these results.

Eckstein concluded on a rather optimistic note about the potential for decoupling:

> This study does not imply that VMT reductions can universally be introduced into a transportation system without reducing mobility or economic activity, but suggests that [under] normal circumstances in well-developed urban areas, it is reasonable that GHG related VMT reduction policies would not result in significant drops in economic activity (pg. 48).

These three studies led to different and sometimes ambiguous conclusions, so interpreting these studies does not enable us to specify with certainty the direction(s) of causality between GDP and VMT. This is not surprising because the studies used different model formulations in which relationships between variables had different specifications. They also used different time periods. It is quite possible that the underlying relationships are complex, non-linear, and that they differ over time. The mathematical models that were used can be very sensitive to changes in specification and the inclusion or deletion of an independent variable A shift in the representation of a variable within the model can change the value of model coefficients and sometimes even the sign of a resulting relationship. There may also be problems with these models due to the fact that some element of GDP is produced directly by the transportation sector, such as manufacturing cars and car parts. It is important to compare results with these sensitivities in mind, and to look beyond these few studies for insight into the fundamental relationships between travel and the performance of the economy.

Other Studies of VMT and Economic Growth

While the term "decoupling" is used more often in Europe than in the United States, the work in this area is generally concerned with decoupling emissions, usually carbon, from economic growth. However, some of their conclusions are applicable to VMT. None of the papers identified did any type of causality analysis. Instead they dealt with the more theoretical underpinnings of why these two measures would move in tandem and what factors might cause them to decouple.

Crozet (2009) looked at inter-city travel, and used macroeconomic theory and data from major world regions to demonstrate that there is an "iron law" linking mobility (which he defined as travel volume) to GDP. As he put it, "(A) given percentage of growth in GDP per capita is matched by an identical percentage of growth in the distance travelled over a year." (pg. 4) Increases in mobility are driven by technologies that make it possible to travel longer distances in shorter amounts of time, as well as decreases in the relative costs of travel, which makes it more affordable to a larger number of people.

While the desire for enhanced mobility will likely continue into the future, Crozet argued that at some point there must be a limit to the amount of travel most people are willing to undertake. He termed this "saturation of mobility," and it occurs in part because time budgets are limited, and in part because the infrastructure to support higher-speed travel is expensive and imposes a societal cost. Decoupling mobility from economic growth might occur because of large increases in the cost of energy that could result from approaching exhaustion of world supplies, possible changes in preferences and tastes, and saturation of mobility. He presented descriptive evidence that at least in Europe, GDP has been growing faster than passenger car mobility since the early 2000s. But long-distance travel demand has not fallen off in a similar fashion.

The New Zealand Ministry of Transport and Statistics (2009) reported that between 1992 and 2000, VKT and GDP increased at a similar rate. In contrast, between 2001 and 2007, VKT increased about 12 percent, while GDP increased 22.5 percent. They noted this as potential evidence of decoupling, but were very tentative in explaining the trend. They also noted that these figures were only for road traffic and that some of the "missing" VKT could have represented shifts to other modes, such as rail and air transport.

Finally, Lehtonen (2006) noted that it has long been assumed that freight traffic is a driver of economic growth. However, in recent years there appears to have been a "weak decoupling" of freight movement from GDP, based on data showing that GDP growth exceeds road freight volume growth. In his review of freight literature, he noted that any movement toward decoupling is not necessarily one-way; that is, various studies have found that freight movement and GDP can decouple but later recouple, for a variety of reasons.

Attempting to deconstruct these trends, he looked at data from several countries, including England. He found that these figures may well be misleading in that they fail to take into account the increasing proportion of foreign haulers who are operating in England, and there are several indications that the presence of foreign haulers is indeed increasing with time.

4. Attempts to Reduce VMT and Promote Economic Growth

This study considered documents from both U.S. metropolitan planning organizations[2] and other countries to determine whether any had explicitly adopted policies to reduce VMT while promoting economic growth, and if so, what were the stated goals and the specific policies to achieve them. Of those located (given resource constraints, this work did not include a survey or an exhaustive search) most were prospective, not policies that had been undertaken in the past and whose success could be measured. So it is impossible to reach a conclusion, even anecdotally, about whether any such policies have been effective.

In the MPO cases reviewed, the government agency adopting the policy—generally within some type of long-range plan—simply stated both goals: reducing VMT and maintaining or increasing economic growth. They did not discuss any attempts to link them, adopt specific policies to achieve both in tandem, or provide a theoretical basis on which to show that decoupling was in fact possible. As a result, most actual policies adopted to reduce VMT were the same as those that have been discussed for the past several decades: transportation demand management, better coordination of transportation with-land use planning, and greater use of non-motorized modes.

MPO Examples

Using online searches and contacts with the Association of Metropolitan Planning Organizations, seven MPOs with goals related to both reducing VMT and maintaining or increasing economic growth were identified. Five have specific percentage targets for VMT reduction. All were adopted very recently, so it is too early to evaluate their effectiveness. A summary of the adopted goals and policies to achieve them is provided in Table 1.

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[2] States and cities also have adopted or are considering greenhouse gas reduction targets as part of environmental policies, but Metropolitan Planning Organizations appear to be the most common level of government involved in such efforts in the US. In most cases states have required planning for these purposes to be done at the MPO level, and MPOs have placed requirements on the cities and counties within their jurisdiction. This is the case, for example, in California under the state greenhouse gas reduction policy enumerated under SB 375.

Table 1: Selected MPO VMT and Economic Goals

Capital Area Metropolitan Planning Organization (Austin, TX)	
Plan Name	2035 Regional Transportation Plan
VMT Goal/ Target Reduction	"Use transportation investments to support continued reduction of per capita vehicle miles traveled." (No specific target)
Economic Goal	Maximize the economic competitiveness of the region
Specific Policies to Achieve Goals	None provided.

Denver Regional Council of Governments	
Plan Name	Metro Vision 2035 Plan
VMT Goal/ Target Reduction	10 percent reduction in VMT per capita by 2035 (a decrease from 26.3 to 23.7 VMT per capita)
Economic Goal	These types of [regional and transportation] initiatives not only serve to protect and enhance the quality of life in our region, but also support a strong and vibrant regional economy.
Specific Policies to Achieve Goals	Implement multimodal facilities and system management when constructing new or retrofitting existing travel corridors. Develop opportunities for congestion pricing and other tolling techniques on existing freeways and new lane projects, where feasible. Support legislation that would implement VMT-based fees, pay-as-you-drive insurance, and other pricing strategies that more directly and immediately reflect the cost of vehicle travel to the user.

Sacramento Area Council of Governments	
Plan Name	Sacramento Metropolitan Transportation Plan (MTP) for 2035
VMT Goal/ Target Reduction	"The overall philosophy followed in this MTP seeks to:…provide a system that reduces vehicle miles traveled (VMT) per household, holds growth in congestion even with a huge growth in population, and increases transit mode share significantly…" Specific goal: 10 percent reduction.
Economic Goal	"economic vitality: [the ability to] efficiently connect people to jobs and

	get goods to market."
Specific Policies to Achieve Goals	Continue and increase the region's previous commitment to TDM program as strategy for education and promotion of alternative travel modes for all types of trips toward reducing vehicle miles traveled (VMT) per household by 10 percent.

Metropolitan Transportation Commission (San Francisco Bay Area)	
Plan Name	Change in Motion, the Transportation 2035 Plan
VMT Goal/ Target Reduction	"Reduce daily per-capita vehicle miles traveled (VMT) by 10 percent from today by 2035."
Economic Goal	One principle: "a prosperous and globally competitive economy".
Specific Policies to Achieve Goals	Double funding for MTC's Transportation for Livable Communities (TLC) program Leverage TLC investments to support compact, transit-oriented development in established urban districts identified as Priority Development Areas Seek to protect industrial land in the region's urban core that serves critical goods movement facilities such as the Port of Oakland and the Bay Area's major commercial airports.

Metro (Portland, OR)	
Plan Name	2035 Regional Transportation Plan
VMT Goal/ Target Reduction	"By 2035, reduce vehicle miles traveled per person by 10 percent compared to 2005."
Economic Goal	"Economic Prosperity – Current and future residents benefit from the region's sustained economic competitiveness and prosperity."
Specific Policies to Achieve Goals	"1. Use advanced technologies, pricing strategies and other tools to actively manage the transportation system 2. Provide comprehensive real-time traveler information to people and businesses 3. Improve incident detection and clearance times on the region's transit, arterial and throughway networks 4. Implement incentives and programs to increase awareness of travel options and incent change"

Puget Sound Regional Council (Seattle)	
Plan Name	Transportation 2040
VMT Goal/ Target Reduction	Goals established in state legislation: "RCW 47.01.440 establishes statewide annual per capita reduction benchmarks for vehicle miles traveled. The legislation established the forecast baseline of statewide vehicle miles traveled of 75 billion by the year 2020, exempting trucks over 10,000 pounds. – By 2020, decrease by 18 percent – By 2035, decrease by 30 percent – By 2050, decrease by 50 percent"
Economic Goal	"The region's economy prospers by supporting businesses and job creation." Sub-goals discussed economic development, business climate, industry clusters, and Seattle's position as an international gateway.
Specific Policies to Achieve Goals	*"Land Use:* Build upon the VISION 2040 Regional Growth Strategy to further the goal of providing an improved jobs-housing balance, and pursue additional refinements through strategies such as transit-oriented development. *User Fees:* Recognize the critical role of price in reducing vehicle miles traveled and emissions, transition the region over time to a user fee/roadway pricing system. *Choices:* Provide travelers options to single-occupant vehicles, and continue to research the costs and benefits of various strategies. *Technology:* Recognize that improvements to vehicles and fuels will play a crucial role in reducing emissions. PSRC has undertaken research with the Department of Ecology on the potential technological advances that may be likely in our region by the year 2040."

Tri-County Regional Planning Commission (Lansing, MI)	
Plan Name	Regional 2035 Transportation Plan
VMT Goal/ Target Reduction	As part of the Climate Change and Energy Sustainability goal: "Implement the regional land use vision to reduce greenhouse gas emissions and the rate of growth of vehicle miles of travel." And "Encourage mixed use and other development designs which reduce vehicle miles of travel, greenhouse gas emissions and energy consumption, including examples such as Leadership in Energy and

	Environmental Design (LEED) standards." No specific target.
Economic Goal	"Develop a multi-modal transportation system that fosters integrated regional economic development to minimize competition and results in reduced costs and better opportunities consistent with the Regional Growth plan."

Other MPOs had similar goals of reducing transportation use, but without specific reference to VMT. For example, the North Jersey Transportation Planning Authority in its *Plan 2035, The Regional Transportation Plan for Northern New Jersey,* stated that, "Transportation investments should encourage economic growth while protecting the environment and minimizing sprawl in accordance with the state's Smart Growth Plan, Energy Master Plan, and Greenhouse Gas Plan."

International Examples

In Europe, and to a lesser extent in Asia, there has been a lively debate on the issue of decoupling, but this review finds that there is much more written advocating future decoupling than evidence of past decoupling. Like their American counterparts, some communities in Europe have adopted plans to lower greenhouse gas emissions by reducing vehicular travel, but these in almost every case used standard tools to achieve VMT reductions and did not put forth new policies that are meant to achieve decoupling.

Of the two examples described below, Lund has adopted aggressive measures to reduce VMT per person even while attracting new residents and businesses in an effort to achieve economic growth. However, these measures are similar to those taken by American MPOs: they sought to reduce vehicle traffic without any explicit reference to the economy. In Singapore, the linkage was more explicit, although the transportation goal was reducing congestion in the central business district to attract new businesses to locate there. Both locations have been successful to date in achieving these goals, although Lund's program is fairly recent while Singapore's dates back several decades.

Lund, Sweden

Lund, a city of about 80,000, first adopted a sustainable transportation plan popularly called LundaMaTs (a short form of the Swedish name, Lund's Sustainable Transport System) in 1996. LundaMaTs sought to reduce vehicle travel while increasing use of other modes. A recent report about its successor, LundaMaTs II, noted two specific goals in this regard:

- "Reduce motor vehicle traffic per inhabitant on the state and municipal road network [no percentage goal].

- Reduce motor vehicle traffic per inhabitant on the municipal road network by 2% by the year 2013 and 5% by the year 2030." (City of Lund, 2009)

The initial plan focused on eight "reforms," or areas in which policies would be adopted:

- **Town and country planning:** TDM, transportation and land use planning, and better infrastructure for non-motorized modes;
- **"Bicycle friendly town"**: High priority to bicycle traffic and safety through improved bicycle infrastructure;
- **Extended public transportation**: Two light rail systems, better intermodal connections, a high-priority bus system, and better inter-city transit;
- **Environmentally friendly car traffic:** Eco-driving, technical improvements in vehicles, and a new parking management strategy;
- **Commercial and industrial transportation**: Coordinated distribution to make transportation of goods more effective, employer-based TDM, and home delivery of goods;
- **IT**: IT centers in small communities to facilitate telework, internet support for various projects, and route guidance information systems in order to minimize distances travelled;
- **Trips outside Lund**: An information campaign about alternative transportation and an online calculator about the environmental burden of a trip; and
- **Information, consultation and marketing**: Outreach programs such as education in eco-driving and programs of traffic education for children and adolescents.

From these eight categories, about 70 percent of the 1 billion Swedish crowns (US$150 million at the current exchange rate, not adjusted for inflation) were to be spent on public transit, and another 10 percent each on bicycle improvements and environmentally friendly car traffic (City of Lund, no date). In 2010, average VKT per capita was 2 percent lower than the preceding year, achieving the stated goal (ICLEI, 2011). While this report did not contain details of how this reduction was achieved, 43 percent of all trips were made on bicycle, a high percentage even by European standards.

Singapore

Singapore, an island city-state of about 5 million, began planning for traffic growth and economic growth to be decoupled decades ago, although these policies were designed to decrease congestion, not VMT.[3] This distinction is important, because while the two are related, reducing congestion does not necessarily reduce VMT. In the case of Singapore, congestion was successfully reduced and more importantly has remained low over the past several decades. However, it is not clear if these policies would be effective in areas that are different from Singapore.

Beginning in the late 1950s, the colonial government and later the national government adopted plans that called for reducing congestion in the central business district as part of a strategy to produce economic growth through attracting foreign firms to establish offices in Singapore. At the time, this was the country's main economic development strategy; Singapore was a poor country with few natural resources and thus sought to grow its economy by becoming an Asian business hub for multinational companies. Low congestion levels were thought to be one attractive element for companies looking to open offices in Asia.

As a key element of this strategy, Singapore instituted a number of policies designed to reduce congestion, in large part by making driving less affordable. Ironically, although the country's per capita income was not very high, rates of vehicle ownership were higher than other countries at similar levels of development. This was due in part to the ongoing construction of new housing at further distances from the city center, and the lack of good transit service. These policies to reduce congestion were introduced over several decades, and most remain in effect, having been adjusted over the years to improve their performance. They include:

- The Additional Registration Fee, import duties, and a Road Tax all imposed substantial costs on car owners. The Fee started at 15 percent of the vehicle's value in the late 1950s, and through gradual increases reached 150 percent in 1980. The import duty was 30 percent when implemented in 1968, and raised to 45 percent in 1972. The Road Tax, an annual fee based on the engine size, dates to this period as well, and has been raised a number of times.

- The Area License Scheme (ALS) began in 1975. All vehicles, except those with 4 or more occupants, had to pay a fee of S$3 per day (about US$2.40 at the current

[3] Unless otherwise noted, the discussion of Singapore's efforts to decouple vehicle use and economic development is based on Willoughby (2000).

exchange rate, not adjusted for inflation) or S$60 per month to enter the central business district during the morning peak hour. In 1989 the ALS was extended to afternoon peak, and exemptions for carpools, freight, and motorcycles were eliminated. In 1994 the ALS was enforced all day on weekdays.

- Electronic Road Pricing (ERP) was introduced on a number of highways and arterials in 1998. Drivers pay a fixed price when they drive through the ERP gantries; the prices are set based on average target vehicle speeds and adjusted quarterly, and they are generally highest during peak hours in peak directions. The ALS entry points were folded into the ERP system.

- Parking charges in the CBD were also raised to S$70/month when the ALS began; these charges were levied on both public and private spaces. The pricing structure for hourly parking was also changed to discourage long-term parking.

- The "Certificate of Entitlement," essentially a permit required to purchase a vehicle, was implemented in 1990. The government issued as many COEs as it felt were warranted based on current levels of vehicle ownership, and they were sold to persons wishing to buy a car. Prices were allowed to adjust to demand. Since 1999, COEs have been available for two classes of vehicles, medium cars/taxis, and big cars. By 1994, a COE cost S$40,000 for a medium car and $65,000 for a big car.

These policies have been very successful. Congestion in the CBD decreased when the ALS was implemented and remains low. As Willoughby notes in an understated way, "Growth of the economy has not visibly suffered from the high price of transport by motor car." (pg. 17) Indeed, Singapore currently ranks as one the world's wealthiest countries on a GDP/capita basis.

There does not appear to be a readily available and reliable set of long-term VMT figures that would shed light on the question of whether VMT was also reduced from the 1950s through the present. However, several recent data points suggest decoupling is occurring. From 1995 to 2005, per capita GDP increased by nearly 40 percent, while VKT per capita increased by about 13 percent. Similarly, per capita GDP increased by 54 percent from 2002 to 2010, while VKT per *vehicle* fell by 6 percent.[4]

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[4] Data used for these calculations: GDP per capita in current dollars (Singapore Department of Statistics, 2011), VKT per capita (Newman, undated, slide 69), and VKT per vehicle (LTA, various years)

5. Other Findings on Transportation, Energy Use, and Economic Growth

In contrast to studies that have directly addressed in quantitative terms the connection between economic growth and VMT, there is a large relevant literature on the relationship between transportation, energy use, and economic activity. This literature is similar in purpose and related to studies that specifically address decoupling economic growth from VMT. That is, some studies and policy documents may not specifically address decoupling, but they advocate policies or develop plans to grow the economy and also to reduce VMT. Sometimes they even argue that reducing travel will have positive economic development implications. The sections following address these threads in the literature.

Energy Use and Economic Growth

Transportation is a major sector in terms of energy use, and a number of studies that have assessed the link between energy use and economic growth address transportation as one component. For example, Azar et al. (2002) looked at the decoupling of environmental impacts from GDP in a number of developed countries (United States, European Union, and Japan), as well as China, India, and Brazil. They found that while energy use was increasingly decoupled from economic growth over the past 40 years in developed countries, some of this was offset by increases in travel volume. They also found that among the developed countries, only the United States reduced the energy intensity of its economy, including the transportation sector, from 1970 to 1990, and remained relatively stable from 1990 to 2000. Energy intensity is the amount of energy consumed in a sector divided by GDP contributed by that sector.

Azar et al. (2002) also explored prospects for the possibility of decoupling globally. Their analysis included all industries and was not specific to transportation—they addressed a wide variety of energy uses and materials consumed in economic activity—but they reached conclusions applicable to transportation. They argued, for example, that higher levels of economic growth and higher standards of living lead to social preferences for environmental conservation and that this brings acceptance of pricing and regulation that can shift demand from higher to lower carbon sources of energy and to more energy efficient forms of production (or transportation). They also noted that it is easier to decouple environmental issues from the economy as a whole than from personal income.

Researchers at Oak National Laboratory (David Greene and others) and at the University of California Davis (Daniel Sperling and others) and Berkeley campuses (Susan Shaheen, Tim Lipman, and others) have addressed reductions in transportation energy use. While

they have considered possible implications of such strategies on economic growth, their findings are not definitive.

A wider review of the literature did not find consensus on the relationship between energy use and economic growth. Pozdena (2009) categorized 32 studies and found that 7 showed no causality; 9 showed bi-directional causality; 8 showed changes in energy use causes changes in GDP; and 8 showed the opposite: changes in GDP caused changes in energy use. Liddle (2007) noted: "the literature on temporal causality between energy consumption and economic growth has offered neither robust results nor convincing rationale."

Policies to Reduce VMT

Many studies and reports—some academic, some advocating particular policies—have assessed policies to reduce VMT as a possible mitigation for climate change and other negative environmental externalities. Conclusions of many writers are strongly influenced by ideological commitments and prior positions taken by the authors. Moore, Staley, and Poole (2010) argued that VMT reduction is too costly and inefficient to serve as a useful mitigation measure, while Winkelman, Bishins, and Kooshian (2010) claimed that even with improvements in fuel efficiency, VMT reduction is still needed to reduce GHG emissions because travel can increase over time by enough to erase the energy-savings resulting from greater fuel efficiency.

Discussions of VMT reduction strategies often turn to land use patterns as a principal strategy for achieving such reductions in the medium to longer term. A thorough review of the ties between VMT reduction and land use can be found in Transportation Research Board Special Report 288, entitled *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions* (Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption, 2009). The relationship between economic growth and land use, however, has not been investigated to any significant degree in such studies.

Transportation Investments, Productivity, Efficiency, and Economic Growth

A number of studies have looked at the relationship between investments in transportation infrastructure and whether they produce economic growth, but they leave some questions unanswered as to how economic growth affects the relationship between GDP and VMT.

One of the most important criteria by which transportation investments are judged is their contribution to economic efficiency, which is measured by changes in economic productivity per unit of investment. Sound transportation investments should lower the costs of moving people and goods. These cost reductions increase economic productivity, which can be roughly measured as the output of goods and services per dollar of private and public investment. Improved productivity leads to a higher standard of living, more demand for goods and services, and more efficient utilization of natural resources. Because productivity is a central component of economic growth, it should be of major concern when assessing the value of transportation expenditures. It is important to focus on improving economic productivity even when policymakers strive to serve other important long-term transportation policy objectives, such as safety improvements, energy independence, and environmental sustainability. High-productivity transportation investments increase connectivity and reduce congestion; by doing so they improve economic well-being (Holtz-Eakin and Wachs, 2011; Shatz et al., 2011).

Because of the coarseness of the measures widely used to quantify comparisons, it is not clear whether high-productivity transportation investments reduce or increase either economic growth or aggregate VMT. Sound investments lead to reductions in expenditures on moving people and goods per unit of economic output, so in the short term they might reduce both economic growth and VMT by making travel less circuitous while increasing economic efficiency. But the economy responds to short-term reductions in expenditures on transportation by making new investments that would create growth and these often increase economic growth in the longer term.

6. Directions for Future Research

This survey of the literature suggests three major conclusions. First, there is not yet sufficient understanding of the relationship between VMT and economic growth to develop sophisticated policies aimed at decoupling the two. Empirically there is evidence that a statistical association exists between them, while causal relationships are more difficult to specify. Increased economic activity could be associated ultimately with increased shipment of goods and more travel by workers and customers. The critical issue for policy is *not* the level of economic activity as measured by economic growth, nor the amount of VMT, but the efficiency embodied in the relationship between them. That has rarely been considered in the literature. Efficiency is also relevant when linking economic and environmental sustainability to economic growth. The transportation system can be made more energy efficient and less polluting by both reducing VMT and by reducing energy consumption and emissions per VMT. Policy objectives increasingly emphasize the reduction of pollution and GHG emissions while enhancing economic productivity.

Second, where decoupling initiatives have been undertaken, too little time has passed for them to have been thoroughly evaluated. It is not yet clear whether policies designed to reduce VMT can achieve their aim without producing unwanted economic outcomes, yet there also is no definitive indication that policies seeking to reduce VMT because of negative externalities will slow or reduce economic growth. Third, the policy objectives of improving productivity, efficiency, and sustainability may be poorly articulated when complex relationships among them are expressed in terms of relatively coarse measures like GDP and VMT.

Based upon such conclusions, in the final section of this paper some directions are suggested for future research that could be sponsored by the Federal Highway Administration, the National Cooperative Highway Research Program, and others. These include expanding research that uses existing data series to further explore associations between economic growth and VMT. Future research also is suggested below that might focus on whether some of the current efforts by MPOs, states, and others to achieve greater economic growth while reducing VMT prove successful over the coming decade.[5] More promising and undoubtedly longer-term and more costly studies could be aimed at

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[5] As noted in Section 2, the research conducted for this paper looked for policies implemented at the national or regional level, not state or local. Therefore it is possible, although given these findings perhaps unlikely, that successful policies have been developed and implemented at the state or local level.

refining the measures that are used in order to clarify underlying relationships that are inadequately captured by existing data and reports.

Cross Sectional Research

Earlier sections of this paper summarized a modest number of analyses of statistical associations between GDP and VMT. These were almost exclusively time series analyses, in which changes in VMT from year to year were compared with changes in GDP over the same years.

Results from other countries were reported where identified in the literature review, but no "cross sectional" studies in which patterns across jurisdictions or across sectors of the economy were compared at one point or over multiple points in time were identified. It might be useful to compare experience across states or across nations. While results for the United States, Europe, and New Zealand were reported, for example, they were not systematically compared with one another, and the forms in which data were presented made it difficult to make comparisons without more extensive analysis. Greater understanding of relationships between travel and economic activity could be gained by conducting comparative studies for similar time periods across nations.

Countries are at different stages of economic and social development and are constantly changing, though at different rates. It is possible that relationships between VMT and economic growth in Europe, Asia, and North America display similar trends over time, which would indicate that global influences such as economic cycles (e.g., recessions) may be important determinants of the relationships. Longitudinal cross-national comparisons could explore the impacts of changes in economic conditions, including GDP, on VMT.

Similar patterns in different countries that differ by time periods might indicate that the relationships of interest are a function of the stage of development that characterizes a country at a particular time period. For example, if patterns in China were to be similar to those experienced in Japan forty years earlier and in Germany even earlier, it might be possible to explain the relationships in part on the basis of stages in economic development and possibly to begin to build models that predict such relationships over time in still other countries.

It might or might not be possible to explore cross sectional relationships between Gross State Products and VMT among the fifty states. This report has not assessed the availability of data nor the extent to which economic activity in some states is more strongly related to travel in other states than to travel within its own borders. For example, economic activity at a manufacturing center might be associated with the shipment of raw materials across other states and business in a tourist center could be

strongly associated with long distance person travel outside its borders. If such analysis is feasible, causality in relationships between gross measures of economic activity and travel may be more revealing if disaggregated to state levels than when conducted at the level of national aggregates. Economic activity studied in relation to the physical form of states might add rich variety to the study of such relationships. The feasibility of conducting comparisons among different geographies should be explored further.

Research Using Refined Measurement Tools

The studies found in the literature explored correlations between gross measures of national GDP and VMT. Without abandoning the concept of measuring associations between them, it might be possible to sharpen those comparisons using adjustments to the measures that are employed.

For example, earlier reference was made to the fact that Gross National Income (GNI) is defined as GNP less taxes on production and imports, less compensation of employees and rent and dividends and interest paid to entities and individuals outside the country, and less other "transfers." Research might be fruitful which employs such alternative measures of association between the economy and travel. For more than thirty years, some economists have proposed further adjustments to the economic measures used for such comparisons. One of these would be to use Net Domestic Income (NDI) which removes from GNI the consumption of fixed capital, which some consider to represent a kind of double counting of economic activity, leading those measures to overstate the economic wellbeing of the country for which it is reported (Weitzman, 1976; Boarini, Johansson, and Mir d'Ecole, 2006; Diewart, 2005). It is not likely that official government statistical reports will be changed, but since these indicators already exist, it is possible to conduct research into the implications of such alternative measures of economic activity when examining the strength of relationships between the economy and VMT.

The foregoing may be considered modest adjustments to the process of statistical measurement of decoupling, but more extensive adjustments may also be considered. For example, some critics have asserted that measures including GDP, GNI and NDI are all fatally flawed since the "real" intent of measuring the strength of association with GDP is to assess human wellbeing. To do so, alternative measures such as family, household, or personal income could be investigated as potential indicators whose correlation with VMT could be tested in place of GDP. Because government initiatives like the American Recovery and Reinvestment Act (ARRA) are based upon the premise that investments in transportation infrastructure create employment opportunities, it would be informative to conduct research that explores the relationship between travel (VMT or PMT) and either levels of employment or unemployment rates.

In addition to testing alternatives to GDP as representations of economic activity, it would also be possible to explore the contributions that could be made by alternatives to VMT as measures of travel. Relationships, for example, might be stronger using truck and passenger vehicle miles separately and by testing the power of passenger miles as a measure of personal travel in place of vehicle miles. Such alternatives can be evaluated on the basis of their conceptual strengths in representing the phenomena under study as well as the obvious statistical goodness of fit.

More Disaggregate Research

It seems likely that if relationships exist between travel and the economy, stronger quantitative evidence of those relationships could be found through applying models using disaggregated data. Three such disaggregations seem to be fruitful paths of inquiry, and others are possible as well. First, it is likely that the strength and nature of relationships between the economy and travel are stronger for travel related to goods movement than to passenger movement. Thus, looking separately at ton-miles of freight movement and passenger miles of person travel might be a useful refinement in future quantitative comparisons of the economic impacts of travel. A great deal of data is available on freight flows at spatially aggregate levels, while less is available for smaller geographic units of analysis.

Second, where relationships between the economy and travel reflect the contribution of travel to employment, it would be useful to examine VMT disaggregated by the traveler's age, since travel by children and retired people is logically less likely to be related to commuting and employment. A strongly related topic, discussed by paper reviewers, is the notion of accessibility measures.

Third, relationships between travel and economic activity may well be stronger when examined at the state, city or metropolitan area level than when considered in the aggregate at the national level. This point is especially important because most of the domestic initiatives that were reviewed earlier in this paper were carried out by MPOs rather than through national policies. There have been few assessments of the effectiveness of these policies. Though it is in some cases too soon to see impacts, it is also the case that there are few longitudinal data bases at the local, regional, and state levels that would allow such assessments to be conducted as doing so becomes more timely. In addition, indicators such as retail sales, office rents, and household income, may be more important in developing an assessment of regional economic health than a "regional" GDP figure.

It seems likely that the focus has been on aggregate analysis because the more detailed data to conduct the studies suggested above do not exist, or at least not in complete data

sets (for example, data on travel and economic indicators for the country's 350 metropolitan areas would need to be assembled from a multitude of sources). Developing these data sources would be a key priority for conducting future research in these areas, and these comparisons would be valid only if different areas collect the same type of data. Data might also be available from emerging private-sector sources, such as firms that aggregate and analyze traffic data to provide real-time traffic information.

Refocusing the Goals of Further Research

VMT and GDP are aggregate indicators widely used for numerous purposes. Most uses of both of these indicators do not require explorations of statistical correlations or structural relationships between them. The review of the literature revealed that in most policy debates in which they are linked to one another, both measures are most often surrogates for broader concepts. Those who promote investments in transportation systems often do so in pursuit of enhanced economic wellbeing and improved economic productivity with lower societal costs, especially through the reduction of the negative impacts of the externalities associated with travel. GDP happens to be a convenient, widely used, and conventional measure but as an indicator it also it has many shortcomings.

Citizens who promote environmental sustainability seek reductions in transportation energy consumption and greenhouse gas emissions, and often invoke VMT as a readily available measure that is highly symbolic of their intended objectives. VMT has traditionally been correlated with the negative externalities of travel by many observers and increased VMT symbolizes for them increasing emissions and energy consumption. The discussion by the reviewers touched on five particular externalities: safety, air pollution, greenhouse gas emissions, congestion, and noise. They noted that the first three are becoming decoupled from VMT, even without any particular policies enacted, but congestion and noise pollution remain tightly linked with changes in VMT.

While additional research is clearly needed, the single most important policy implication of this study is that no basis was found in the literature to conclude that efforts to increase environmental sustainability in transportation in the short run either require or depend upon reductions in VMT. Similarly, no strong evidence was found to argue that policies by states or MPOs to reduce VMT will necessarily have negative impacts on economic growth.

Even in the absence of convincing statistical evidence of causal relationships between VMT and GDP, clearly many MPOs wish to enhance the economic vitality of their regions while simultaneously improving environmental quality and enhancing energy efficiency. The literature review demonstrated that this is also true of national

governments around the world. No indication was found in the literature that they cannot achieve both objectives at the same time. To the extent that their statements about "decoupling" symbolize such goals, it may be unnecessary to articulate national or state objectives for decoupling per se. In fact, if decoupling is actually occurring as a result of either adopted policies or as a result of the natural evolution of societal trends, treating these goals as separable but complementary becomes increasingly logical—decoupling is most logical only where coupling is proven and strong and this research has not clearly demonstrated that this strong bond exists. Given that GDP and VMT are imperfect measures that are used to encapsulate the purposes of policies intended to promote sustainable economic growth, it may be appropriate to design public policy that address those objectives more directly rather than to promote further investigations of decoupling as an end in itself.

Appendix A. Literature Search Techniques

The search for literature on decoupling of VMT and economic growth was limited to surface transportation as opposed to other areas (e.g., electricity generation and air or ocean based transport) so as to focus the scope of the review on the policies that may be most useful to the transportation sector. Additionally, decoupling of VMT from economic growth may be occurring "naturally", as a result of macroeconomic changes such as the U.S. shift from an economy based on manufacturing and agriculture to service specific industries; however, this review was focused on policies to explicitly change transportation behavior.

Given the enormity of the literature and a limited budget, RAND employed an innovative approach to the literature review intended to increase efficiency and lower cost. To begin the review, several important seed articles were identified. These articles were rated as being more or less relevant to the search on a three tier scale: "High," "medium," and "low." These articles were familiar to the research team or were suggested by FHWA staff. The rankings were assigned to each article after a careful review of the findings and methodologies depicted by the study and also by each article's relative contribution to the search for evidence and policies that promote decoupling VMT and economic growth. Although these seed articles are identified in the references section, Table 2 depicts the document titles by their assigned ranking.

Table 2. Seed Search Articles Arrayed by High-Low Ranking

High	*Medium*	*Low*
Center for Clean Air Policy (2010)	Congressional Budget Office (2008)	Goodin, Baker & Pourteau (2009)
Crafts & Leunig (2005)	Johnston (2008)	Harrington & McConnell (2003)
Litman (2010)	LeVine, Polak & Jones (2009)	Hirota & Poot (2005)
Regmi & Hanaoka (2010)	McCurdy & Clay (2010)	Hu & Reuscher (2004)
	Millard-Ball & Schipper (2010)	Parry, Walls & Harrington (2007)
	Polzin (2010)	Petersen, et al. (2009)
	Puentes & Tomer (2009)	Santos, McGuckin, Nakamoto, Gray & Liss (2011)
		Schettkat (2009)
		Whitelegg (2003)

Each seed article was analyzed with the aid of a text analytics computing system called "Evidence Lens," developed by RAND. Evidence Lens allows an expert user to more easily view the important connections between a series of related documents, which may be less visible otherwise. Unlike a query based approach to uncovering information, Evidence Lens takes as input raw documents and helps a user to discover important terms, phrases and paragraphs. In this case Evidence Lens was used to identify co-located word pairs, which are high frequency two- and three-word combinations (e.g., economic growth, vehicle miles traveled) used to create several article database queries to find relevant research. Although Evidence Lens identified many co-located word pairs from within the reviewed documents, the term "economic growth" was found to be the most frequent within the text in the medium and high ranked seed articles.

To find new studies, in addition to the identified seed articles, the terms and phrases found through the Evidence Lens system were structured into several queries to be used with major article databases. The online article databases included Google Scholar as well as several journals including Transportation Business Journal, Transportation Research Record, and the Journal of Planning Education and Research. Table 3 summarizes the number of articles returned, considered and finally downloaded for further review by each article database and for each query. As depicted in Table 3, a single query might produce many thousands of results; however, the most relevant articles to the query will be presented early in the result list. After testing several queries with the article databases it was decided that at most the abstracts of the first 150 returned articles would be read and considered for inclusion. In total, 757 journal article abstracts were reviewed by a researcher. All of the searches were performed during September 2011.

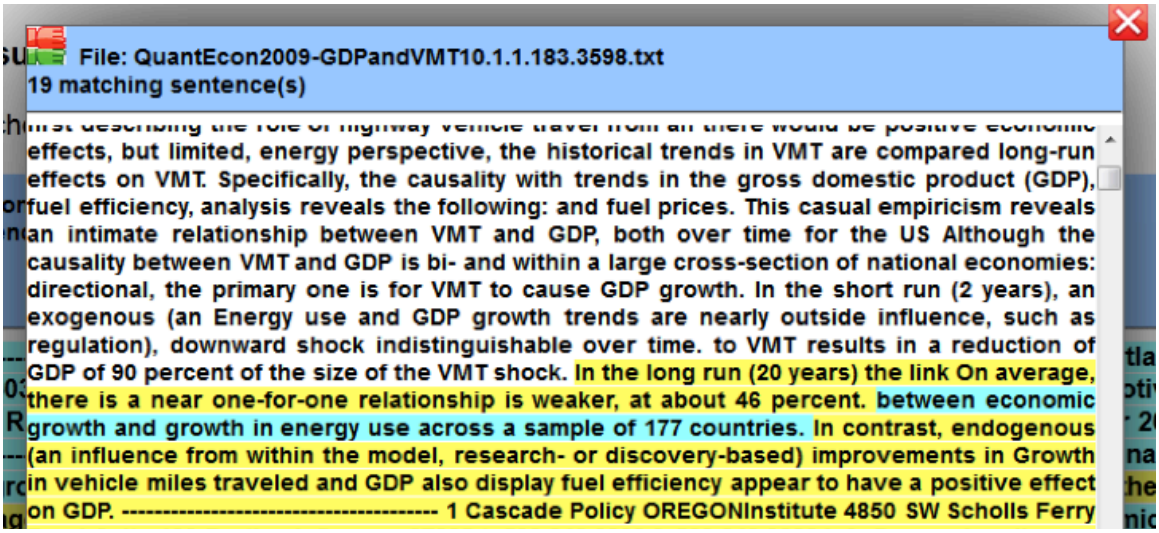
Table 3. Articles Returned from Database Queries

Query	*Database*	*Returned*	*Considered*	*Downloaded*
“Economic Growth” + “Vehicle Miles Traveled”	Google Scholar	12,600	140	33
Inline Citations from "Seed" Articles (High + Medium)	Google Scholar	15,000	110	25
"Economic Growth"	Transportation Business Journal	29	29	6
"Economic Growth"	Transportation Research Journal	8	8	3
"Economic Growth"	Transportation Research Part A	449	150	20
"Economic Growth"	Transportation Research Part B	256	150	20
"Economic Growth"	Transportation Research Part D	172	150	5
"Economic Growth VMT"	Journal of Planning Education and Research	7	7	0
"Economic Growth VMT"	Journal of Transport Economics and Policy	8	8	0
"Economic Growth VMT"	Journal of Urban Economics	5	5	0
	Total	28,534	757	112

After completing an initial pass through the article databases, the 112 downloaded articles were searched through Evidence Lens to determine relevance. Secondary searches were made to extract more specific information from the literature, such as the long term planning documents of several metropolitan planning offices and international work in this area.

Figure 2 is a screenshot from Evidence Lens that depicts how the search results are presented. Sentences containing a set of query terms are highlighted in blue; the sentence below and above are highlighted yellow to draw the reviewer’s attention to a paragraph rather than a single instance of the terms. Other features of Evidence Lens use these sentences to generate different frequencies as well as statistical summarization of the texts. These tools available through Evidence Lens were used to look for key passages in these 112 documents to determine their relevance to the research question and ultimately winnowed the list to roughly 45-50 that were directly relevant.

Figure 2. Evidence Lens Nominal Results Screenshot



Appendix B. FHWA Workshop

The research team presented interim findings at a workshop held at the U.S. Department of Transportation headquarters building on September 11, 2012. The participants' names, affiliations, and roles are listed below.

Name	Affiliation	Role
Martin Wachs	RAND	Facilitator
Liisa Ecola	RAND	Presenter
Johanna Zmud	RAND	Participant
Roger Mingo	RDM Associates	Prime Contractor
Rabinder Bains	FHWA	Project Manager
Wayne Berman	FHWA	Co-project Manager
Karen White	FHWA	Former Project Manager
Alan Pisarski	Independent consultant	Expert Reviewer
Robert Puentes	Brookings Institution	Expert Reviewer
Dennis Leach	Arlington County, Virginia	Expert Reviewer
Don Pickrell	Volpe	Expert Reviewer
MaryLynn Tischer	FHWA	Participant
Jack Wells	FHWA	Participant
Tianjia Tang	FHWA	Participant
David Winter	FHWA	Participant
Cheryl Richter	FHWA	Participant
Keith Gates	FTA	Participant
Lauren Donnelly	FRA (Detail to FHWA)	Participant

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