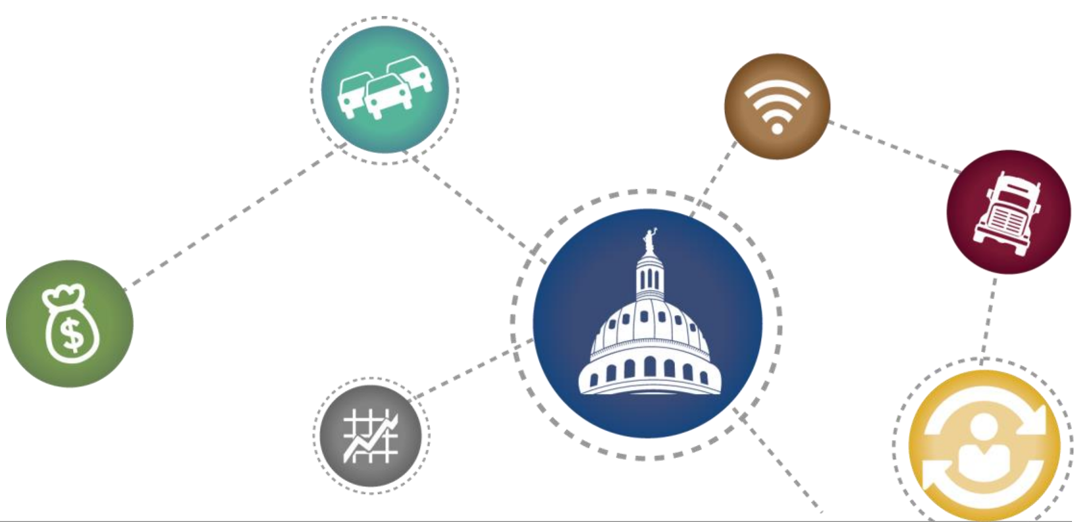
Texas A&M Transportation Institute

Methodologies Used to Estimate and Forecast Vehicle Miles Traveled (VMT)

Final Report

PRC 15-40 F



TRANSPORTATION
Policy Research CENTER

Methodologies Used to Estimate and Forecast Vehicle Miles Traveled (VMT)

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Executive Summary

Vehicle miles traveled (VMT) is a measure used in transportation planning for a variety of purposes. It measures the amount of travel for all vehicles in a geographic region over a given period of time, typically a one-year period. VMT is calculated by adding up all the miles driven by all the cars and trucks on all the roadways in a region. This metric plays an integral role in the transportation planning, policy-making, and revenue estimation processes due to its ability to indicate travel demand and behavior. These data are critical and required to be submitted to the Federal Highway Administration (FHWA) through the Highway Performance Monitoring System (HPMS) by state transportation agencies, and are posted on the Texas Department of Transportation's (TxDOT's) website (*1*).

In the United States, there was continuous growth in VMT in all 50 states until 2008 when growth leveled off due to the economic downturn. An upward growth trend had returned by 2014. Texas shared similar growth patterns with the rest of the nation. TxDOT's recent Texas Transportation Plan 2040 (*2*) notes that VMT in Texas is expected to increase by 62 percent from 2010 to 2040 (based on the Texas Statewide Analysis Model [SAM] [*3*]). Also, the plan states that population in Texas is expected to rise 61 percent over that same time period. This indicates that VMT, including both personal travel and commercial travel, is growing at the same rate as the Texas population. While there are ample data to find historic trends in VMT growth or decline, there are several challenges in forecasting VMT due to the many factors that affect growth rates. Demographics, roadway capacity, economic factors, and other factors contribute to the continued growth or decline, as well as the magnitude of change, of VMT.

There are various means of forecasting VMT available. The literature revealed three primary types of data-based methods for estimating and forecasting VMT:

- Traffic-count-based methods.
- Socioeconomic-data-based methods.
- Travel demand forecasting models.

The literature also revealed several quantitative and statistical techniques for estimating and forecasting VMT. These include trend/growth factor methods, time series analysis, and regression analysis.

The end users of VMT estimates and forecasts typically include state departments of transportation, state environmental agencies, transportation/environmental consultants, and regional planning organizations. These agencies use VMT primarily for transportation planning and emission analyses.

Research Objective

This document presents the results of research conducted to evaluate several key components of the VMT metric. This research had the following objectives:

- Identify recent trends, current forecasts, and growth factors of VMT in the United States and Texas.
- Summarize the existing methods of VMT estimation and forecasting through a literature review.
- Evaluate the current state of VMT estimation and forecasting specifically to Texas.
- Create a VMT Calculator scenario analysis tool.

State of the Practice

This report identifies methods currently used to measure and forecast VMT in Texas. VMT estimates in Texas are typically derived from reported traffic counts through the use of three main collection methods: manual counting, pneumatic tubes, and loop detectors (permanent counts). Other methods include radar, microwave, and laser detectors. The results of these traffic-counting methods are reported as annual average daily traffic (AADT) and average daily traffic (ADT). AADT reports traffic counts adjusted for day of the week and seasonal and axle variations, and denotes a representative average for an entire year, while ADT is the unadjusted average of the daily traffic counts taken during the data collection period.

Calculating VMT is a straightforward function of roadway centerline length and traffic count data. However, associating AADT with corresponding sections of the over 80,000 state-maintained centerline miles and additional roads not maintained by the state is more complex. This association is typically done for state-maintained miles by TxDOT specialists and is stored in the Road-Highway Inventory Network (RHiNO). The data within RHiNO bring together many data points for state roadways into a common network. These data points include traffic count data, daily traffic characteristics, roadway functional classification, and roadway geometry/design.

By using RHiNO and standard calculations, VMT estimates can be prepared for a variety of audiences and reports. The HPMS requires these estimates to be reported. The HPMS includes data on a series of metrics for the nation's highways. TxDOT reports annual VMT estimates into this system following the *HPMS Field Manual*. The annual HPMS VMT summaries are produced by roadway functional classification and rural/urban geography.

The Texas A&M Transportation Institute (TTI) uses its Transportation Revenue Estimator and Needs Determination System (TRENDS) model to forecast VMT. The TRENDS model is designed to provide transportation planners, policy makers, and the public with a tool to forecast transportation revenues and expenses based on a user-defined level of investment at both the state and local level. Two of the variables require VMT projections to produce future revenue streams: the motor fuel tax variable and the mileage fee variable. The TRENDS model analyzes gasoline and diesel fuel tax revenues and uses a regression analysis to project taxable gallons of gasoline through 2040. An estimated VMT is derived by multiplying these taxable gallons of gasoline by the average fleet-wide miles per gallon (MPG) for personal vehicles. The TRENDS model is available to the public online (*4*).

Many Texas agencies use travel demand models to forecast VMT. For the most part, the TxDOT Transportation Planning and Programming Division (TPP) maintains travel demand models in Texas. This group works in cooperation with metropolitan planning organizations (MPOs) spread across the 26 urban areas of the state. Houston and Dallas–Fort Worth perform travel forecasting and model development independently but in cooperation with TxDOT. These models can directly obtain VMT forecasts by using a routed demand across a geographic information system (GIS)–based network but with several inherent limitations. Lack of roadway coverage in urban areas, limited detail of existing statewide models, variability of seasonal patterns, limited scenario options, varying demographic estimates used as inputs, and uncertainty of mobility and capacity improvement projects included in the models affect VMT estimations.

Development of VMT Forecasting Model

As part of this report, researchers developed a tool to test a variety of VMT scenarios. This tool is programmed in an Excel worksheet and has its basis in the Texas SAM and Texas State Data Center (TSDC) population forecasts. The VMT Calculator model is based on the Texas SAM version 3 (SAM v3), population projections from TSDC, historical traffic count data from TxDOT's RHiNO, and user input.

This model enables the user to create VMT scenarios for each county's internal trips through the calculation of person trip rates (the number of trips per person) using the SAM v3 modeled trips and TSDC population projections. The model allows for adjustment of TSDC population scenarios to account for different levels of VMT that result from various population forecast scenarios.

The results of the model are presented through an interactive dashboard. In the dashboard, users are able to adjust variables such as trip rates, auto occupancies, and growth rate in trips both within and between Mexico and the U.S. to model different scenarios. This model allows planners and policy makers to test different scenarios on a local (county) and statewide level for use in the decision-making process.

Background on VMT Estimation and Forecasting

Introduction

VMT is a metric used extensively in transportation planning for a variety of purposes. It is a measure of the amount of vehicular travel in a geographic region over a given period of time. It refers to the number of miles traveled by one vehicle over a given period of time, and it is typically referred to on an annual basis. While typically *estimates* are made for current years and *forecasts* are performed for future years, the terms appear to be used interchangeably in the literature.

VMT data are used primarily by transportation agencies, environmental agencies, and consultants to perform a variety of functions such as "allocating resources, estimating vehicle emissions, computing energy consumption, and assessing traffic impacts" (*5*). VMT may also be used to evaluate conformity assumptions, adjust travel demand forecasts, and identify pavement maintenance needs (*6*, *7*). It is a key metric in transportation planning because it provides an indication of travel demand and behavior. Additionally, policy decisions and infrastructure investment planning incorporate VMT data. Understanding demand is critical to allocating resources, and VMT is an important measure to estimate and forecast.

VMT is a critical data element in the United States, and state transportation agencies are required to report VMT annually to FHWA through the HPMS (*8*). The HPMS is a "federally mandated program used by FHWA to provide data to Congress on the nation's streets and highways. Congress uses the data for allocation of funds to states" (*9*). The VMT data are reported according to one of seven functional classes:

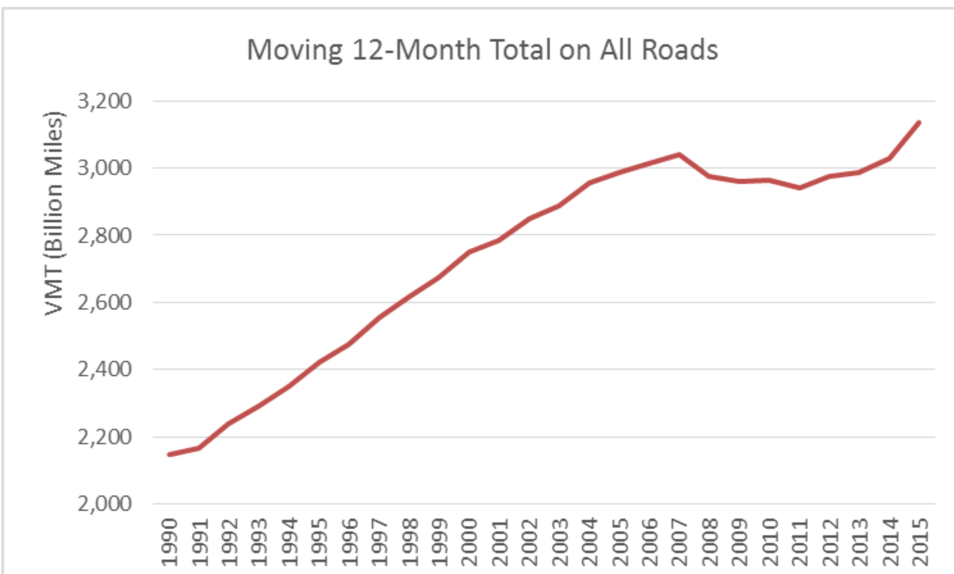
- Interstate freeway.
- Rural principal arterial—other freeways and expressways.
- Principal arterial—other.
- Minor arterial.
- Major collector.
- Minor collector.
- Local roads.

HPMS data for local roads, however, are not uniformly reported. States use their own methodologies and approaches for determining the VMT on local roads, which they subsequently report in the HPMS. Current practices vary widely and are not well documented (*8*).

FHWA maintains the HPMS, which is a national inventory of the public roadway system. According to Kumapley and Fricker (*5*), "The HPMS method of VMT estimation involved the use of adjusted 24-hour traffic counts, referred to as AADT, obtained on sample sections identified through a systematic stratified random sample." This estimation can be done using both continuous count stations and coverage count stations. Continuous count stations collect data day by day over a year. Cost prohibits this collection from being done on a larger scale or for all sections. Coverage count stations collect data on the remaining roadway sections. The data collected are for a short period of time usually measured in weeks. Estimates of the travel demand—in this case the AADT—are then derived or estimated from the count data using day-of-the-week and seasonal factors, among others. This traffic count method is the most common way to estimate VMT but is not the only method. Others are discussed in this section of the report.

Recent Trends in VMT

Figure 1 includes the most recent national, annualized VMT data reported by state agencies to FHWA. FHWA compiles these data using standardized input from all 50 states. Annual VMT growth leveled off in 2008 and returned to an upward trend in 2014.

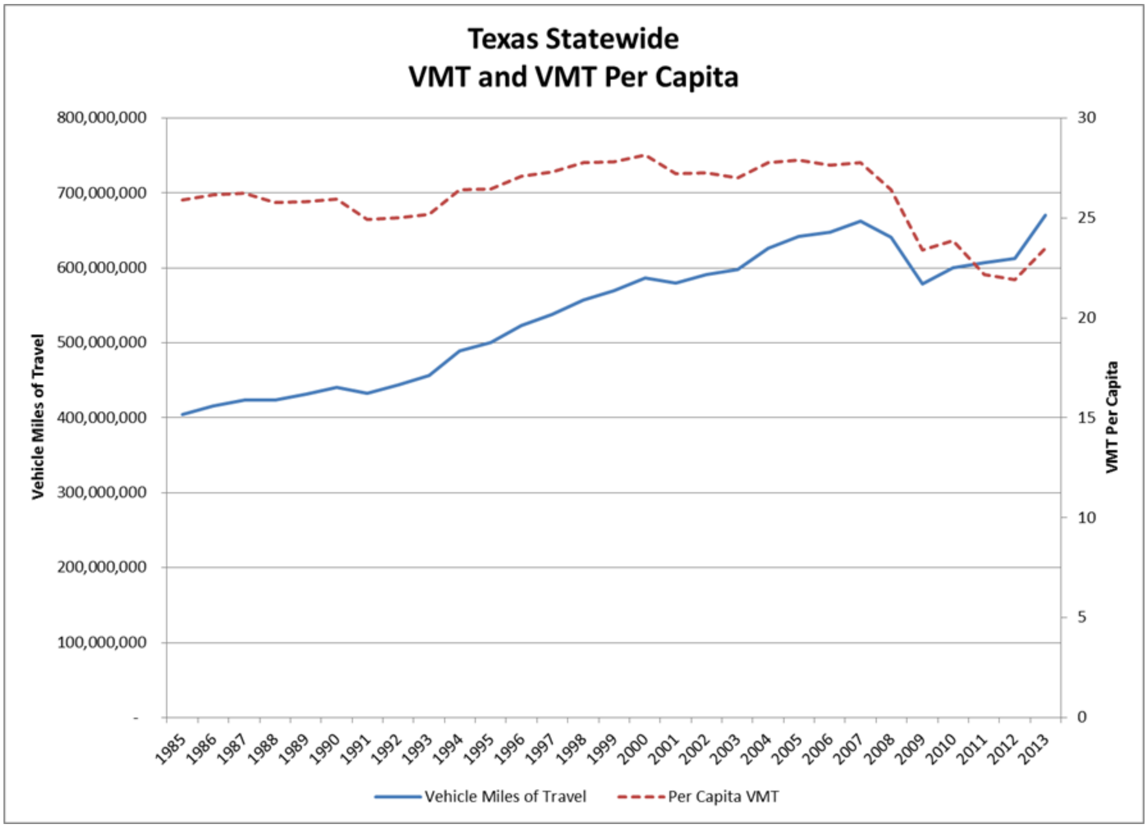


Source: (*10*)

Figure 1. 12-Month Moving Average Annual VMT as of August 2015 for the Entire United States.

Figure 2 shows the daily (not annualized) counted VMT in Texas from 1985 through 2013. The table shows that:

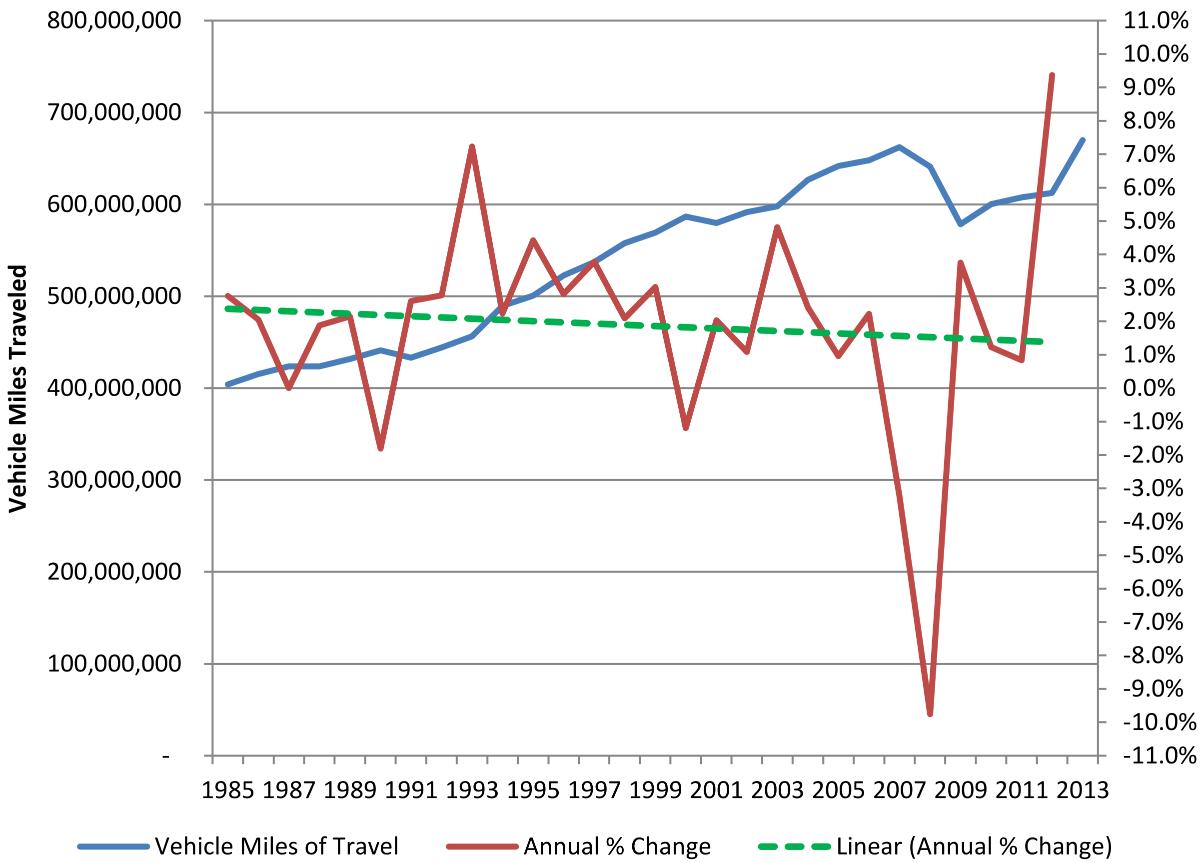
- Total VMT declined beginning in 2007 but returned to growth by 2009.
- Per-capita VMT has remained somewhat flat over time, declined significantly in 2007, and then returned to growth in 2013.



Source: TTI analysis of data obtained from TxDOT and U.S. Census Bureau

Figure 2. Texas Daily VMT and Per-Capita VMT Estimates.

Figure 3 shows the growth trends for daily VMT in Texas. Growth in total daily VMT estimates varies, as can be seen in the "Annual % Change" line. While total daily VMT has grown, the annual percent change is trending downward. According to the linear approximation, annual VMT growth was near 3 percent in 1985, fell to 2 percent in 2000, and is nearing 1 percent today.



Source: TxDOT and TTI analysis

Figure 3. Texas Daily VMT and VMT Growth Trend.

VMT Growth

The recent Texas Transportation Plan 2040 (*2*) notes that VMT is expected to increase by 62 percent from 2010 to 2040 (based on the Texas SAM). Also, the plan states that population is expected to rise 61 percent. These numbers indicate that VMT, including both personal travel and commercial travel, is growing at the same rate as total Texas population. If the VMT-per-capita growth rate is declining, indicating a slowing in personal VMT growth, then commercial vehicles (trucks) need to be growing faster than personal travel in order to even out the growth rates as reported.

It is imperative that planners and policy makers recognize that a trend of past VMT values is but one of many scenarios that could result in the future. While trend analysis remains a useful tool, it is important to take many factors into account when analyzing growth in overall travel, as measured by VMT, in Texas.

FHWA has built a forecasting methodology that takes many variables into account in forecasts of VMT. Table 1 lists the variables tested. Table 2 shows the results of the 20- and 30-year forecasts of national VMT by FHWA, listed in compound annualized growth rate (CAGR) (*11*).

Table 1. List of Variables Tested in FHWA VMT Projection Model.

Variable Type	Variable	Source
Dependent variable	Total annual VMT*†	
Demographic characteristics	Total population Percent of population aged 20–65 years Number of households Average persons per household Percent of households that are families Percent of families with children < 18 years Percent of population in urban areas Regional population variables	State Data Center
Economic activity/income measures	Total gross domestic product (GDP)*† Disposable personal income*† Median household income Consumer confidence index Real value of durable nondurable goods Real retail sales Real retail sales (percentage of GDP) Electronic and mail-order sales (as percentage of retail sales) Real value of service sector (percentage of GDP) Real consumer spending Real private fixed residential investment Value of durable plus nondurable goods Value of durable plus nondurable goods (percentage of GDP) Imports plus exports of goods (percentage of GDP) U.S. industrial production Diesel price per gallon	Bureau of Economic Analysis and U.S. Energy Information Administration
Cost of driving	Gasoline price per gallon Gasoline fuel cost per mile driven Gasoline fuel economy (MPG) Diesel price per gallon Diesel fuel cost per mile driven Diesel single-unit truck MPG Diesel combination truck MPG Driver wages	U.S. Energy Information Administration and TTI's TRENDS
Vehicle price	New vehicle price index Used vehicle price index Vehicle parts and price index New vehicle price index/consumer price index New vehicle real sales price Producer price index (transportation equipment)	Bureau of Labor Statistics
Road supply	Total highway miles Total highway miles per all vehicles Highway miles in urban areas Percent of population in urban areas Total public road miles Total road miles*† Road miles per vehicle	FHWA Highway Stats
Employment	Total employment Labor force participation rate (percent) Employed persons per household	Bureau of Labor Statistics

Variable Type	Variable	Source
Transit service	Vehicle miles of bus and rail transit service* Vehicle miles of rail transit service* Number of cities with rail transit service	FHWA Highway Stats

* Examined in per-capita terms.
† Examined in per-household terms.
Source: (*12*)

Table 2. Baseline FHWA National VMT Forecast.

Vehicle Class	Compound Annual Growth Rates 2013–2033 (20 Year)	Compound Annual Growth Rates 2013–2043 (30 Year)
Light-duty vehicles	0.92%	0.60%
Single-unit trucks	2.15%	1.93%
Combination trucks	2.12%	2.04%
Total	1.04%	0.76%

Source: TTI analysis of data (*10*)

The Texas Transportation Plan 2040 lists VMT growth between 2010 and 2040 at an overall increase of 62 percent. This rate of increase translates to a CAGR of 1.62 percent, a rate of growth more than double that of the FHWA national CAGR.

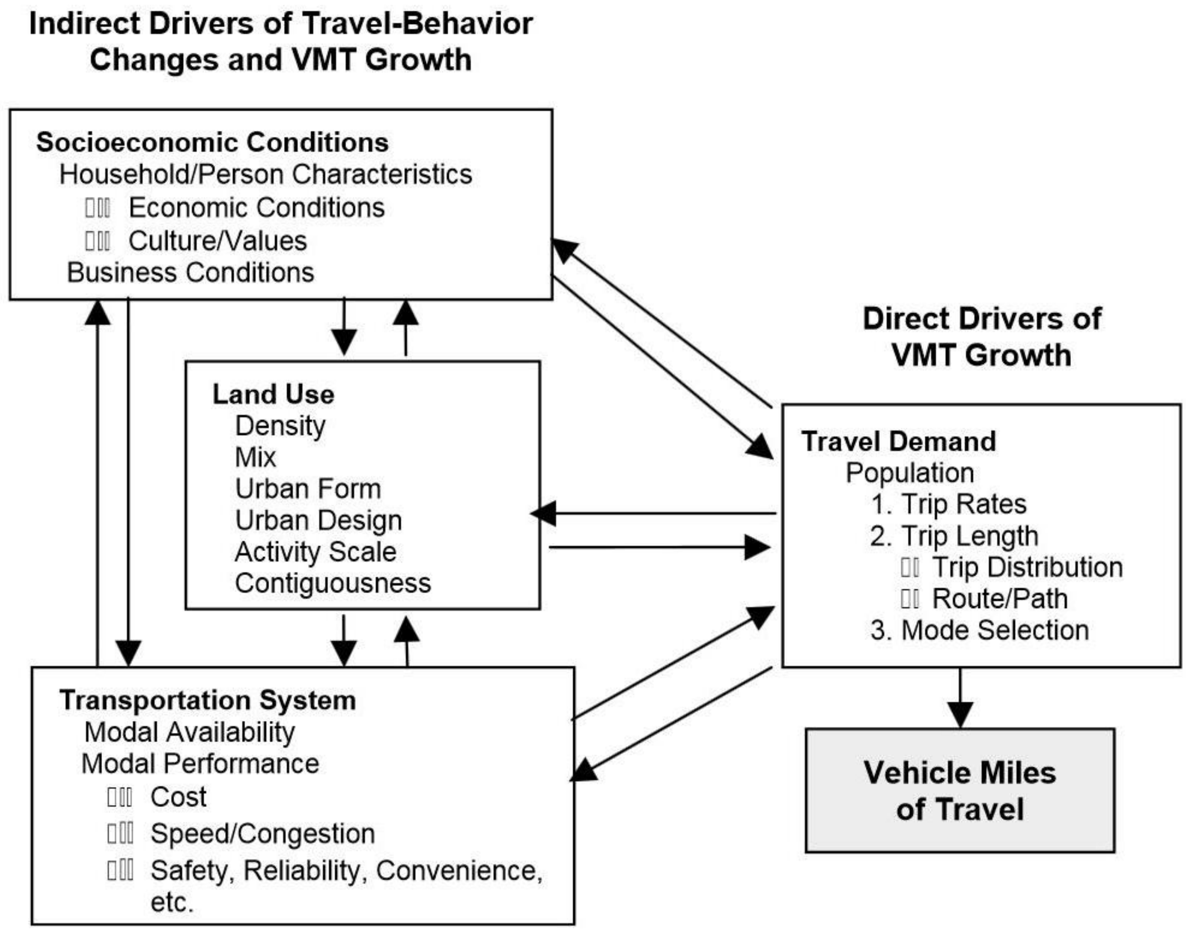
Is Texas going to grow at double the rate of the rest of the nation? What factors could change that rate of growth? These and other issues are discussed in this report.

Factors Influencing VMT Estimates and Forecasts

Many factors influence travel demand. Since VMT is a measure of travel demand, understanding the many influencing factors provides a greater comprehension of VMT and the issues that affect VMT estimates and forecasts.

VMT forecasting can be a difficult and often inaccurate process (*6*). The influencing factors are wide ranging, and their level of influence varies. Factors affecting VMT forecasts include "socio-economic and demographic growth, changes in the cost of travel, urban sprawl, technological innovation, social change, and legislative factors" (*6*). Polzin et al. (*13*) also note that some trends emerged from their work showing that VMT growth may be moderating. This was seen in increasing trip lengths and increasing travel time budgets. Many of these factors are typically incorporated into the different stages of the travel demand forecasting process and the various statistical models that are developed to estimate and forecast VMT. Polzin et al. articulated this conceptual relationship, as shown in Figure 4.

A large number of factors and variables influence and can affect VMT. These are discussed in more detail later in this report. Being aware of these primary factors can help create a better understanding of the relationship and dynamics between the current transportation system and the demands on it, particularly the daily or annual VMT. Table 1 lists several variables that were tested as part of the national VMT growth model built by FHWA.



Source: (*13*)

Figure 4. Conceptual Model of VMT Growth Drivers.

Existing/Traditional VMT Forecasting Methods

The literature describes a number of methods used to estimate and forecast VMT. The count method, mentioned previously, is the most common and is the method recommended by the Environmental Protection Agency for estimating VMT for environmental analyses. However, there are others that use a variety of data types and procedures. VMT estimating and forecasting methodologies can essentially be placed into one of two categories:

- Those based on data.
- Those based on a particular forecasting technique.

Data-Based Methods

The literature revealed three primary types of data-based methods for estimating and forecasting VMT:

- Traffic-count-based methods.

- Socioeconomic-data-based methods.
- Travel demand forecasting models.

Traffic-Count-Based Methods

Traffic-count-based VMT forecasting methods are the most commonly used to forecast VMT growth (*14*). As Liu et al. note, these methods are fairly simple, are easy to implement, and use count data that are routinely updated. Traffic count methods use both continuous count data and coverage count data that count traffic on a particular roadway section for a short period of time. Both of these types of count data are converted to annual counts using various expansion factors that include seasonal factors and time-of-day factors that may vary by functional class. These methods are typically designed for statewide use, meaning that they may not be statistically valid for smaller units of analysis such as counties or regions (*14*).

Count-based methods assume that VMT growth will be similar to that of the past. Liu et al. point out that "count-based methods rely heavily on the assumption that growth will behave in the same or a similar manner as in the past, regardless of demographic, land use, and other factors" (*14*). Essentially, the methods do not take into consideration any changes that might occur in land use patterns or any changes in socioeconomic data.

Socioeconomic-Data-Based Methods

Socioeconomic-data-based methods do not rely on any characteristics of the roadway but rather on those factors that affect travel behavior. According to Liu et al. (*14*), "These methods attempt to estimate and forecast VMT growth at a more fundamental level than the growth factor method by using variables that can be projected into the future."

Examples of these types of approaches include the use of travel surveys to estimate VMT based on household travel characteristics and licensed driver data, a fuel-sales-based approach used to estimate and forecast VMT, and an approach that relies on odometer readings.

Travel Survey Data. The approach used by the Indiana Department of Transportation is an example of a method that relies on travel survey data, specifically licensed driver and household information. The model developed in Indiana "predicts the total vehicle miles driven by all licensed drivers for all vehicle types, using demographic predictions of the population of licensed drivers, age, and gender" (*5*). One potential problem with this approach is the inaccuracies associated with travel surveys from the respondents not providing accurate information.

Fuel Sales. Fuel sales have also been used to estimate and predict VMT. The Oregon Department of Transportation uses this approach in an effort to forecast state tax revenues. According to Liu et al. (*14*), "Oregon DOT uses monthly fuel consumption data, fuel refund claims, and national miles per gallon estimates to calculate VMT." This is done for light and medium-heavy vehicles. For heavy vehicles, the state uses actual mileage data from weight-mile records along with an adjustment factor. Texas has employed a similar fuel-sales-based method in forecasting revenues.

Odometer Readings. Odometer readings are mentioned in the literature, but as a practical matter, this method is largely discounted because of its number of potential problems and shortcomings. Kumapley and Fricker (*5*) note that this method is considered resource intensive, which may explain why it is not widely used. The authors mention several potential sources of error, including odometer calibration errors, reporting errors, odometer rollovers, and odometer tampering. In addition, travel occurring outside of the area could be considered to have taken place inside the area, thus overestimating the VMT.

Travel Demand Forecasting Models

The use of travel demand models to forecast VMT combines both traffic count data and socioeconomic data. This approach takes into account travel behavior and other factors that affect VMT growth. These models are "often limited in the number of links that can be built onto the network to represent the real world situation" (*5*). Thus, what is created is a network biased toward larger roads, which often limits the number of smaller or local roads in the region. However, calibrating these models can improve the accuracy of the VMT estimates. Usually, a post-processing method to account for non-modeled roadway VMT is added for more localized travel.

This method is suitable for forecasting VMT by functional class, area type, and different jurisdictions such as different counties and regions (*14*). This method may also "provide greater sensitivity to changes in transportation investments or policies compared to many manual calculation procedures" (*6*). However, it is not without concerns. Travel models are not typically statewide in their scope, nor do they account for local travel since local roads are not accounted for on the travel network. The lack of local roads and travel accounted for in these models makes them suspect for statewide VMT forecasting with biases toward larger roadways and a tendency to overestimate travel demand (*5*, *14*). In addition, a high number of external trips in smaller regions and the lack of robust demographic and land use components can contribute to inaccuracies with this approach (*6*).

One of the major limiting factors of using travel models to forecast VMT is the time and effort needed to produce the forecast. These can be significant and often limit the responsiveness needed to produce VMT forecasts, particularly when comparing scenarios or other alternatives that may require several model runs.

However, travel models offer a method that includes the network geographic component—roadway miles—that is fundamental to VMT estimation and forecasting.

Forecasting Techniques/Methods

The literature revealed several types of quantitative or statistical techniques and methods for estimating and forecasting VMT. These include:

- Trend/growth factor method.
- Time series method.

- Regression method.

Trend/Growth Factor Method

Liu et al. (*14*) note that the growth factor method is the most-used technique for forecasting VMT. Using historical traffic count data, a growth rate is determined and used to project future growth. This can be done for different functional classes and vehicle types.

Time Series Method

The time series method is not as widely used and is sensitive to the quality of the data used in the analysis (*14*). Since this type of analysis relies heavily on the past trend, if the data are from a rapidly growing area, the VMT growth may be overestimated. This method is best when used in a smaller area experiencing steady growth.

Regression Method

Regression models are used to describe a relationship between a dependent variable and any explanatory variables or independent variables. The literature shows that regression analysis has been used to forecast travel on various roadways in New York, Indiana, and West Virginia (*14*). In these studies, a variety of independent variables have been tested "including major demographic, economic, land use, highway supply, and accessibility variables" (*14*). These methods have not been identified as being used in practice for estimating or forecasting VMT statewide. Figure 5 provides a summary comparison of the different techniques developed for use by the Pennsylvania Department of Transportation.

	PENNDOT Needs for a VMT Growth Forecasting System					
	Forecasting Level of Detail			Forecasting Variables and Data		
Candidate Method	Four Area/ Functional Groups[a]	County-Level (all counties)	Passenger vs. Truck Travel	Socioeconomic Variables	Traffic Information Variables	Land Use
Method based on the type of data used						
Traffic count–based forecasting	X	X	X		X	
Socioeconomic data–based methods		X	X	X		
Travel demand forecasting models	X		X	X	X	X
Method based on forecasting techniques						
Growth factors	X	X	X		X	
Time series models	X	X	X			
Econometric modeling (regressions)	X	X	X	X	X	X

[a]Urban Interstate, urban non-Interstate, rural Interstate, and rural non-Interstate.

Source: (*14*)

Figure 5. Comparison of Different Forecasting Methods.

Innovative/Specialized VMT Forecasting Methods

Several methods and techniques are available for estimating and forecasting VMT. They all have their own advantages and disadvantages and their own limitations. These limitations have led some to attempt to improve upon methods by addressing the shortcomings and inaccuracies associated with certain components and processes. All of this is an effort to increase the accuracy of the overall VMT estimates and projections.

The literature highlights two of these areas—local road VMT and commercial vehicle VMT. In addition, the literature also refers to the use of intelligent transportation system (ITS) and global positioning system (GPS) data to improve VMT estimation and forecasting.

Local Road VMT

Local road VMT refers to VMT that occurs as a result of localized travel that is not typically accounted for in forecasting models or as a part of traffic-counting programs. Usually, this includes residential streets and commercial parking areas.

Methods for determining local road VMT are inconsistent among states and can often be left out or underestimated with current methods of estimating and forecasting VMT. The current approaches used by the states to estimate local road VMT are not well documented and vary widely. Zhang and He state that the existing methods used for local road VMT cannot be validated with the current data available and examine the feasibility and advantages of using GPS data to estimate local road VMT (*8*). Zhang and He's case study examined the benefits of using GPS data collected as part of a travel survey. GPS-based travel surveys can be more time consuming and costly than traditional travel surveys, which can be a disadvantage. The authors also note that some trade-offs can be made between sample size and costs. Their results did show the ability to estimate local road VMT using GPS data within 5 percent error at the 95 percent confidence level with 670 samples and a 15-day survey. According to Zhang and He (*8*), "The increased accuracy has some giving more consideration to this method. Recognizing the potential benefits of more accurate trip recording and collection of more travel information by GPS, governments and research agencies are becoming more and more willing to conduct GPS-based travel surveys, despite the higher cost per household."

Commercial Vehicle VMT

Brown et al. (*15*) describe a method for adjusting VMT for commercial vehicles. This was done to better estimate commercial-vehicle-related crash rates at the state level. This approach uses FHWA's *Annual Highway Statistics* and applies a series of calculations to better estimate commercial vehicle exposure, which is defined as the truck and bus VMT. These data are not available at the state level, and this approach develops state-level estimates of commercial vehicle VMT. This VMT, along with existing crash data, is then used to calculate crash rates for commercial vehicles. This type of VMT estimation analysis is used for different purposes than typically seen—that being crash analysis. According to Brown et al. (*15*), "The adjusted state VMT for commercial vehicles supports measurement of program effectiveness and development of countermeasures to promote motor carrier safety." It essentially has a safety purpose that enables state and federal agencies to better focus their safety and enforcement resources.

ITS Data

The HPMS consists of data that are largely count based and emanate from coverage counts or continuous counts. Teng and Wang (*7*) state that one source of error involves the application of various factors in the process, including seasonal factors and day-of-the-week factors. Teng and Wang propose the use of ITS data to enhance the VMT estimates. The data are called ITS data because they are collected for daily traffic operations purposes, which are a function of ITS. They often include the use of traffic management centers to monitor traffic operations and collect data.

ITS data can essentially replace continuous data counts because they are essentially the same thing—counts of traffic operations on a particular roadway for 24 hours a day, seven days a week. These data, "with appropriate data quality screening, can be used to replace the coverage counts to derive AADT directly in the corresponding (roadway) sections" (*7*). This eliminates the need to develop and apply any factors to the data and makes reasonable the assertion that the data are more reliable. The approach further involves the application of statistical methods (Monte Carlo simulation) to account for missing data, but the result is a more accurate VMT estimate with potentially great implications when used for pavement management, resource allocation, and air quality analysis.

End Users of VMT Data

VMT data are used by a variety of transportation professionals and government officials for a variety of reasons.

Users

The users of VMT data are:

- State departments of transportation.
- State environmental agencies.
- Transportation/environmental consultants.
- Regional planning organizations.

Purpose

These users use the VMT data for the following purposes:

- Transportation planning:
  - Statewide implementation plans.
  - Maintenance plans.
  - Rate-of-progress plans.
  - Safety analyses.
  - Enforcement resources.
  - Infrastructure investment planning.
  - Financial decision making/resource allocation.
  - Policy decision making.
  - Alternative revenue analysis.
  - Travel demand forecasting.
- Emissions analyses:
  - Emissions inventories.
  - Conformity analysis.

State of the Practice in Texas

This section describes the methods currently used in Texas to estimate and forecast VMT. Included is a description of the approach TTI uses to forecast VMT for the purpose of forecasting revenue using the TRENDS model.

Texas VMT Data, Estimates, and HPMS Reporting

FHWA defines VMT as "the number of miles traveled nationally by vehicles for a period of 1 year" (*16*). VMT is usually estimated for geographies including states, counties, cities, and combinations thereof or for arbitrary geographies (e.g., an area bounded by any number of roads). Estimates of VMT are typically derived from traffic counts and roadway GIS. These estimates are reported by and to various agencies including state departments of transportation, MPOs, and FHWA. Forecasts of VMT are also developed in addition to current and past VMT estimates as projections of future demand.

Texas Traffic Counting

Traffic count data are the most commonly used basis for producing past-year (historical) VMT estimates. TxDOT collects more than 83,000 traffic counts every year (*17*). Data collection methods include:

- **Manual counting:** based on in-person observations or review of video footage.
- **Pneumatic tubes:** laid across the road bed and count the number of axles that cross the tubes.
- **Loop detectors (also known as permanent counts):** embedded in the roadbed and collect data based on changes in the magnetic field.
- **Various other technologies:** including radar, electromagnetic field, and laser detectors.

Traffic counts from these methods, with the exception of permanent counts, are collected for any number of weekdays but typically for a 24-hour period on Tuesday, Wednesday, Thursday, or all three days. Permanent count locations collect data 24 hours a day, every day for a year. These counts are usually reported in 15-minute intervals.

Most of the traffic counts collected by TxDOT only report the number of vehicles using a singular section of roadway and do not differentiate the vehicle classification between personal vehicles (e.g., cars, pickup trucks, and motorcycles) and larger vehicles (tractor-trailers, box trucks, and buses). A smaller subsample of locations is used to identify vehicle classification using automated techniques.

Traffic count data are reported in two ways:

- **AADT:** reports traffic counts adjusted for the day of the week, seasonal variations, and axle variations. AADT gives a representative average for an entire year.
- **ADT:** reports the unadjusted average of the daily traffic counts taken during the data collection period.

Texas VMT Estimates

Calculating VMT is straightforward, being a function of the roadway centerline length and traffic count data, represented as:

$$\text{AADT} \times \text{Roadway Length} = \text{Daily VMT}$$

However, associating various sections of roadway with their respective representative AADT is a bit more complex because traffic count data must be conflated from a singular (point) count location to a linear line. This task is performed every year by TxDOT specialists who look at where every count is taken and associate the counts with linear geospatial roadbed data based on the counted location relative to other counted locations, intersecting roadways, on-off ramps, and other features. Primarily, this is done for the 80,268 centerline miles of state-maintained roadway (*18*). TxDOT also develops estimates from other public roadways not maintained by the state—these include county roads, toll roads, city streets, and local streets (e.g., neighborhood streets). Traffic count data for these streets are often sparse, so data for these roads are usually an estimate based on similar roads and/or previous sampling efforts.

The results of this effort are stored in TxDOT's RHiNO geospatial database (http://www.txdot.gov/inside-txdot/division/transportation-planning/roadway-inventory.html). The data within RHiNO bring together many data points for state roadways into a common network. These data points include traffic count data, daily traffic characteristics, roadway functional classification, and roadway geometry/design. By using RHiNO and the calculation presented here, VMT estimates can be prepared for a variety of audiences and reports including:

- Statewide planning efforts (Texas Transportation Plan 2040).
- Yearly reporting from TxDOT's Finance Division via *District and County Statistics (DISCOS)*.
- TxDOT's annual *Pocket Facts* publication.
- FHWA's HPMS.

RHiNO can also be used to calculate VMT by county and other geographic boundaries along with separate estimates for passenger and truck VMT.

HPMS Reporting in Texas

All 50 U.S. states annually report highway data for inclusion in the HPMS. VMT is one of the items reported. States also report data on pavement and bridge conditions and safety/crashes, among other data items. According to FHWA (*19*):

> The HPMS is a national level highway information system that includes data on the extent, condition, performance, use and operating characteristics of the nation's highways. The HPMS contains administrative and extent of system information on all public roads, while information on other characteristics is represented in HPMS as a mix of universe and sample data for arterial and collector functional systems.

TxDOT follows the *HPMS Field Manual* to report annual VMT estimates to FHWA. Annual VMT is calculated using the following formula (*20*):

$$\text{Daily VMT} \times \text{Annualization Factor } [365.25] = \text{Annual VMT}$$

The annual HPMS VMT summaries are produced by roadway functional classification and rural/urban geography. Functional classification is a hierarchical classification of roadways based on its relative role for accessibility versus mobility in the overall transportation network. Simply put:

Local Streets flow to → Collectors flow to → Arterials flow to →
Principal Arterials (e.g., a Major Freeway)

For more information on how functional classification is designated, see *Highway Functional Classification Concepts, Criteria and Procedures, 2013 Edition* (*21*). Table 3 provides HPMS VMT estimates for five years.

Table 3. HPMS Annual VMT (Millions) in Texas.

Functional Class		Year 2007	2008	2009	2010	2011
Rural	Interstate	18,398	15,397	14,869	15,480	15,549
	Other freeways and expressways	NA	NA	NA	NA	NA
	Other principal arterial	22,005	20,448	19,938	20,388	20,513
	Minor arterial	15,519	12,012	11,548	11,888	12,081
	Major collector	22,841	17,173	15,527	15,807	16,430
	Local	7,203	5,516	5,630	5,462	5,515
	Total	85,966	70,546	67,512	69,024	70,087
Urban	Interstate	37,132	39,492	39,269	39,732	40,185
	Other freeways and expressways	26,976	32,328	29,960	31,134	32,294
	Other principal arterial	39,235	37,503	36,954	37,109	37,100
	Minor arterial	27,874	28,410	29,028	29,161	28,883
	Collector	17,028	17,769	17,655	18,359	19,245
	Local	9,232	9,334	9,605	9,496	9,646
	Total	157,477	164,836	162,472	164,992	167,353
Total	Interstate	55,530	54,889	54,138	55,212	55,734
	Other freeways and expressways	26,976	32,328	29,960	31,134	32,294
	Other principal arterial	61,240	57,951	56,892	57,497	57,613
	Minor arterial	43,393	40,422	40,576	41,049	40,964
	Collector	39,869	34,942	33,182	34,166	35,675
	Local	16,435	14,850	15,235	14,958	15,161
	Total	243,443	235,382	229,984	234,016	237,440

How the TRENDS Model Forecasts VMT

The TRENDS model is designed to provide transportation planners, policy makers, and the public with a tool to forecast transportation revenues and expenses based on a user-defined level of investment at both the state and local level. Two of the variables require VMT projections to produce future revenue streams: the motor fuel tax variable and the VMT fee variable.

The TRENDS model forecasts VMT using gasoline and diesel fuel tax revenue data as follows.

Determining Gasoline and Diesel Fuel Tax Revenue

The model uses the following procedure to determine the gasoline fuel tax revenue:

1. Take the dollar amount of state fuel tax received from gasoline sales each year.
2. Divide this dollar amount by the fuel tax rate of 20 cents per gallon to determine the number of taxable gallons sold.
3. Use regression analysis to establish the relationship between the historic gallons of taxable gasoline and state population.
4. Use the resulting regression equation to project taxable gallons of gasoline through 2040.
5. Derive the VMT by multiplying the taxable gallons of gasoline by the average fleet-wide MPG for personal vehicles.

6. Split the derived VMT into commercial VMT and personal VMT based on default fuel consumption variables. The default percent of gasoline consumed by personal vehicles is 98 percent, leaving 2 percent of gasoline to be consumed by commercial vehicles. The user can adjust these percentages, and the VMT is split accordingly.
7. Divide the personal VMT by the average fleet-wide MPG for personal vehicles, and divide the commercial VMT by the average fleet-wide MPG for commercial vehicles.
8. Add these values together to produce fuel-efficiency-adjusted gallons of gasoline.
9. Multiply these adjusted gallons of gasoline by the fuel tax rate to generate the future fuel tax revenue.

The model uses the same methodology to determine the diesel fuel tax revenue.

Forecasting VMT

The TRENDS model forecasts VMT by using the following procedure:

1. For the gasoline fuel tax revenue, assume that 98 percent of gasoline is consumed by personal vehicles and 2 percent by commercial vehicles. Split the revenues accordingly and divide by the average fleet-wide MPG for either personal or commercial vehicles. For the diesel fuel tax revenue, assume that 97 percent of diesel is consumed by commercial vehicles and 3 percent by personal vehicles. Again, split the revenues accordingly and divide by the average fleet-wide MPG for either personal or commercial vehicles.
2. Combine the personal and commercial VMT from gasoline and diesel to generate a total annual VMT number.

The TRENDS model allows the user to set a separate VMT fee for personal and commercial vehicles. This fee is multiplied by the personal and/or commercial VMT to produce a possible revenue stream. Figure 6 shows a snapshot of the model.

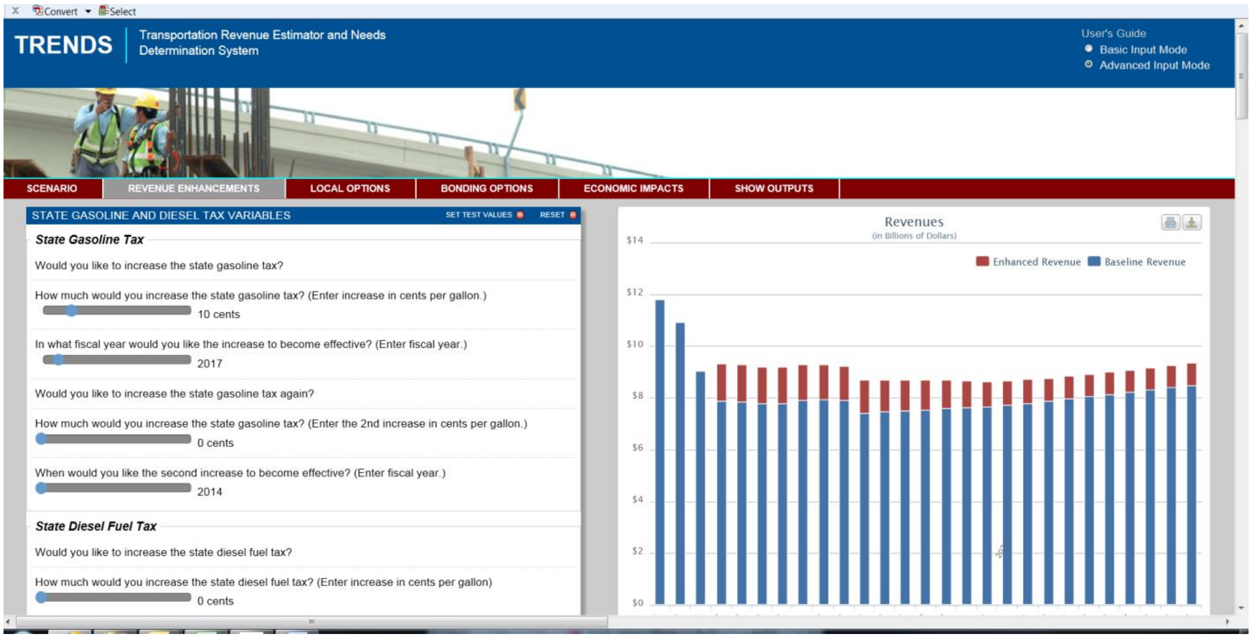


Figure 6. TRENDS Model.

Review of Demand Models for VMT Forecasting

Many agencies in Texas are involved in models for the purpose of travel forecasting. Statewide, TxDOT TPP is responsible for most of the production of travel models across the 26 urban areas of the state. Houston and Dallas–Fort Worth perform travel forecasting and model development independently but in cooperation with TxDOT. TxDOT TPP works in cooperation with regional MPOs to produce input population, employment, and transportation network data, giving the models direct control over local inputs. TxDOT also contracts with private firms for collection of traffic counts, which are used extensively in the model development process. TxDOT also maintains a large program of travel surveying—updating household and workplace surveys approximately every 10 years in each urban area.

All of the demand forecasting models can be used directly to obtain VMT forecasts, simply by using a routed demand across the GIS-based network. There are inherent limitations to using these types of planning models to forecast VMT:

- The models are limited to larger roadways.
- There is variability across days of the week and months or seasons.
- The models usually include a limited number of scenarios.
- The projects and plans included in forecast model networks influence the resulting forecasted VMT.

Limited to Larger Roadways

The roadways that are included in models in urban areas are limited to larger roadways—usually all roadways except for local residential streets and parking areas. Urban models, by definition, cover only urban areas. These models are usually designed to account for travel that occurs within an urban area travel shed, based on the most recent Census responses about home and work location. Urban models are usually confined to county boundaries to ease the accumulation of data.

The SAM is a demand model that covers the entire state. Because of computing limitations and the purpose of the SAM, the level of detail within urban areas is limited. The SAM includes all state-maintained roadways outside of urban area model coverage. The SAM has even fewer smaller, more local roadways than do the urban area models. The SAM also estimates demand for commercial vehicles on a statewide basis.

Variability across Days of the Week and Months or Seasons

Demand models are designed to represent a typical 24-hour day. The parameters that are used to calibrate trip rates are derived from household and workplace travel surveys, supplemented by external station counts. These surveys are typically performed in the fall or spring to include school-related travel. Validation of demand models is done by routing the demand across a GIS-based network and comparing the results with traffic counts, usually represented in annual averages, such as AADT. Inherent in any forecast of travel is the issue of variability across days of the week and months or seasons. Accumulation of daily travel from demand models to annual forecasts then becomes problematic. The average day is not precisely represented by demand models, and annualization factors are assumed to account for weekend travel, non-resident travel that is seasonal, and non-school periods of the year.

Limited Number of Scenarios

Another limitation to using the planning-level network forecasting models for VMT forecasting is the limited number of scenarios that are typically included in these systems. For the purposes of planning, the most relevant forecast scenario over time has been one where travel behavior, technology, and other social influences on trip making remained constant between a past base year and the forecast year. Planning models typically hold the trip rates constant over time, and other parameters are calibrated to match a measured travel behavior, usually from area-wide household and workplace surveys. These models are not easily adaptable to other forecast scenarios that include changing travel behavior or technological advances that may influence travel choices.

Typically, several population and employment forecasts are available for a region. TSDC produces several forecast scenarios based on variations in county-level migration rates. One of these scenarios is chosen for use in the long-range forecasting done with the Texas SAM. While the SAM is a very useful tool, it requires a significant effort to adjust the modeling system for a different population and employment forecast.

Influence of Projects and Plans

The projects and plans represented in the modeled networks influence the forecast VMT obtained from planning models. Capacity additions to the models, either in roadways or transit systems, are included in the models based on the adopted long-range plans for urban areas produced by MPOs in cooperation with TxDOT. Statewide, intercity projects are included in the SAM. The timing of these capacity additions is subject to available funding and decision making, and is not included in the modeling systems—usually only one or a limited number of forecast years are represented in the models.

Texas VMT Calculator: A Scenario Analysis Tool

This study developed a VMT scenario tool programmed in an Excel worksheet. Named the VMT Calculator model, the tool has its basis in the Texas SAM and TSDC population forecasts. It is based on the SAM v3, population projections from TSDC, historical traffic count data from TxDOT's RHiNO, and user input.

VMT Calculator Methodology

The VMT Calculator produces daily forecasts. Annualization must be done by using a reasonable annualization factor.

Base-year daily VMT from the SAM v3 is factored by county to estimates from the RHiNO, which is a GIS system that uses traffic counts to estimate VMT, and is the basis for the HPMS VMT estimates produced annually by TxDOT and FHWA.

Person trip rates (the number of trips per person) are calculated using the SAM v3 modeled trips and the TSDC population projections for each county's internal-to-internal trips. This feature enables the VMT Calculator to be adjusted according to various population projection scenarios produced by TSDC.

Trip making is divided into two modes, passenger and truck. Trips are then categorized as being:

- **Internal to internal:** The trip begins and ends in the same county.
- **Internal to external/external to internal:** The trip begins in one county and ends in another and vice versa.
- **External to external:** The trip passes through the county and does not stop.

Passenger trips are further divided into home-based work (HBW) trips and other trips. Other trips represent shopping, school, and other non-work activities. Table 4 lists all trip types included in the VMT Calculator. An estimate of trip length for each county's trips is calculated by dividing each county's VMT by trip type by its total estimated trips for each of the trip types, yielding VMT per trip for each of the different trip types.

Internal-county trips are further segregated into trip types by drive-alone or shared-ride modes, using an average auto occupancy factor for each county. Trips are further categorized by direction: internal to internal, internal to external/external to internal, and external to external (Figure 7).

Table 4. Texas VMT Calculator Trip Types.

Mode	Trip Type	Trip Purpose
Passenger	Internal county	HBW
	Internal county	Other
	Internal county to Texas	HBW
	Internal county to Texas	Other
	Through county—Texas to Texas	All
	Internal county to Mexico	HBW
	Internal county to Mexico	Other
	Through county—Texas to Mexico	HBW
	Through county—Texas to Mexico	Other
	Internal county to rest of U.S.	HBW
	Internal county to rest of U.S.	Other
	Through county—Texas to U.S.	HBW
	Through county—Texas to U.S.	Other
Truck	Internal county	NA
	Internal county to Texas	NA
	Through county—Texas to Texas	NA
	Internal county to Mexico	NA
	Through county—Texas to Mexico	NA
	Internal county to U.S.	NA
	Through county—Texas to U.S.	NA
	Through county—Mexico to U.S.	NA
	Through county—U.S. to U.S.	NA

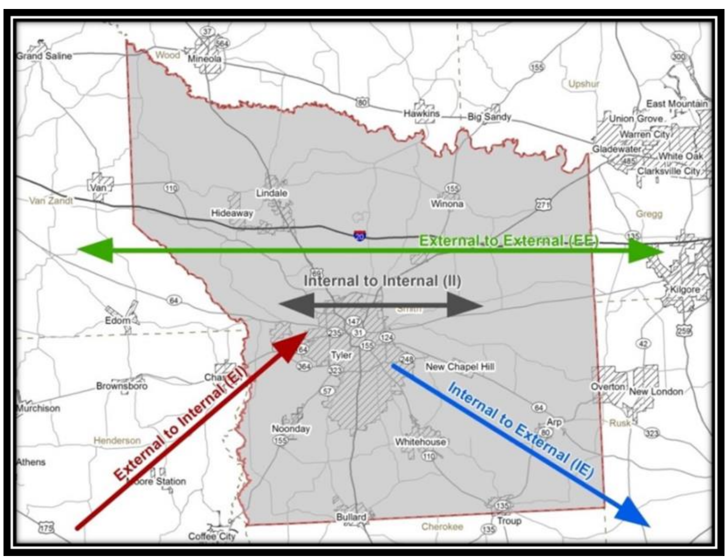


Figure 7. Representation of Internal and External Trips.

For out-of-state travel that either begins, ends, or passes through Texas, trips are categorized as Mexico to United States (through Texas), Mexico to Texas, United States to United States (through Texas), and United States to Texas, and vice versa. Growth rates are then assumed for Mexico- and U.S.-oriented trips since no population projections for Mexico or other U.S. states are included in the model.

The model allows for adjustment of the TSDC population scenario to account for different levels of VMT that would result from various population forecast scenarios. Users can increase or decrease trip rates, auto occupancies, and growth rate in Mexico- and U.S.-oriented trips and their resulting VMT.

Urban form scenarios can be tested by modifying the percent of surrounding county share of jobs. A greater percent share of surrounding jobs by a central county leads to more cross-county commuting, thereby increasing HBW VMT.

VMT Calculator Dashboard

The following sections are included on the dashboard shown in Figure 8:

1. **VMT bar graph:** The bar graph shows the comparison of two counties from Section 3.
2. **TSDC population scenario selector:** Users can choose from the 0.0, 0.5, and 1.0 population projection scenarios. Information on what these scenarios represent is available at the TSDC website, linked from this worksheet.
3. **County-to-county comparison table:** Users can select any two counties and any two forecasts. The two forecasts include the following choices:
    - 2013 through 2050.
    - Total VMT, passenger VMT, or truck VMT.
4. **Statewide and regional total VMT pivot table:** Users can adjust the year of the forecast and the variables in the pivot table by right-clicking and selecting “Show Field List.”
5. **Pivot table selector:** Regional summaries are enabled with this pivot table selector. It controls the VMT summaries in Section 4. Clicking on the upper right “no filter” symbol results in the total statewide summary. A selection of “rural” calculates all non-urban VMT outside these regions.
6. **Adjustment sliders:** Growth scenarios can be tested from these adjustment sliders.

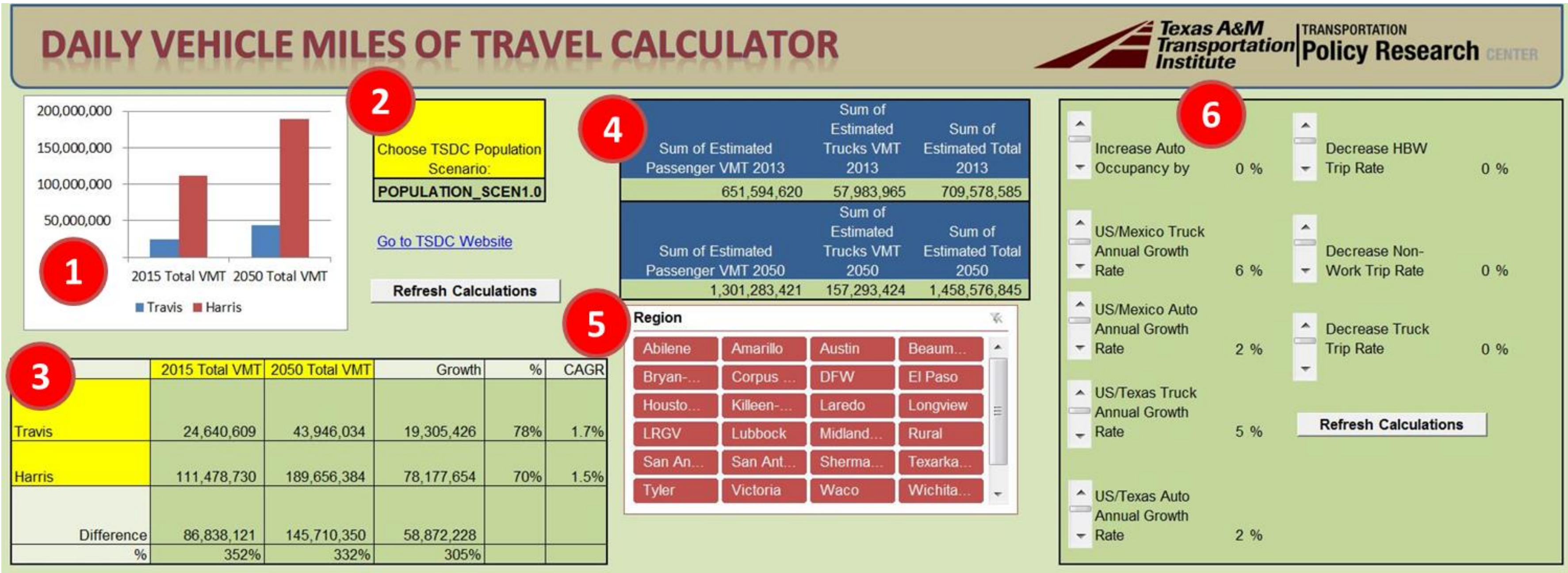


Figure 8. Dashboard for the Texas Daily VMT Calculator.

Jobs-to-Housing Balance Scenarios

The VMT Calculator also includes the ability to build forecast jobs-to-housing balance scenarios. First, surrounding adjacent counties for each county in Texas are tabulated. Using 2010 population and employment data, the percent of regional jobs that are located in each county is calculated. This percentage, representing the jobs-to-housing scenario for each county, can then be adjusted.

For instance, Figure 9 shows that the "Basis % of Surrounding Jobs" in 2010 for Bexar County is 87 percent. This shows that San Antonio, located within Bexar County, is the major employer in this region. The user can lower this percentage to represent more sprawl development in the forecast or raise this percentage to show greater densification of regional employment. Flow between regional counties and resulting daily VMT are forecast based on user input.

	A	B	C	D	E	F	G	H	I	J	K
1	County	FIPS	Cnty_Type	Cnty_Group	MX_Border_Cnty	US_Border_Cnty	Base Population - 2013	Base Jobs - 2013	Basis % of Surrouding Jobs	User Adjust % of Surrounding Jobs	Balanced Adjusted % of Surrounding Jobs
2	Anderson	1	2	2	-	-	59,220	11,848	25%	0%	25%
3	Andrews	3	6	2	-	1	15,466	5,388	4%	0%	4%
4	Angelina	5	2	2	-	-	88,956	30,445	36%	0%	36%
5	Aransas	7	4	4	-	-	23,080	4,091	3%	0%	3%
6	Archer	9	4	4	-	-	9,031	1,642	3%	0%	3%
7	Armstrong	11	4	4	-	-	1,912	223	0%	0%	0%
8	Atascosa	13	3	3	-	-	46,214	10,392	1%	0%	1%
9	Austin	15	4	4	-	-	28,887	8,114	4%	0%	4%
10	Bailey	17	6	6	-	1	7,448	1,530	10%	0%	10%
11	Bandera	19	4	4	-	-	20,291	2,942	0%	0%	0%
12	Bastrop	21	3	3	-	-	75,509	12,107	2%	0%	2%
13	Baylor	23	4	4	-	-	3,689	909	2%	0%	2%
14	Bee	25	4	4	-	-	32,540	5,505	17%	0%	17%
15	Bell	27	2	2	-	-	327,455	85,507	24%	0%	24%
16	Bexar	29	1	1	-	-	1,780,534	676,165	87%	0%	87%
17	Blanco	31	4	4	-	-	10,469	1,793	0%	0%	0%
18	Borden	33	4	4	-	-	650	-	0%	0%	0%
19	Bosque	35	4	4	-	-	18,144	2,525	1%	0%	1%
20	Bowie	37	6	6	-	1	93,854	31,596	75%	0%	75%
21	Brazoria	39	3	3	-	-	323,792	80,192	3%	0%	3%
22	Brazos	41	2	2	-	-	201,377	57,295	65%	0%	65%
23	Brewster	43	6	6	1	-	9,451	2,436	29%	0%	29%
24	Briscoe	45	4	4	-	-	1,674	129	4%	0%	4%
25	Brooks	47	4	4	-	-	7,488	1,571	1%	0%	1%
26	Brown	49	4	4	-	-	38,513	12,964	47%	0%	47%
27	Burleson	51	4	4	-	-	17,268	3,199	4%	0%	4%
28	Burnet	53	4	4	-	-	42,978	10,414	1%	0%	1%
29	Caldwell	55	4	4	-	-	38,903	6,080	1%	0%	1%
30	Calhoun	57	4	4	-	-	21,872	8,029	13%	0%	13%
31	Callahan	59	4	4	-	-	13,578	1,414	2%	0%	2%
32	Cameron	61	6	6	1	-	428,608	99,190	35%	0%	35%

DASHBOARD | How it Works | Maps | MODEL_INPUT | MODEL_OUTPUT

Figure 9. Regional Jobs-to-Housing Balance Adjustment Worksheet.

Examples of VMT Forecasting Using the Texas VMT Calculator

Daily VMT by Population Scenario

Population and total VMT were forecast using the TSDC population scenario (Figure 10):

- The 1.0 scenario projects the total Texas population in 2050 to be 59.6 million (Texas population in 2010 was 25.2 million). VMT under the 1.0 scenario is forecast to be 1.343 billion miles traveled per day.
- The 0.0 scenario projects the total Texas population in 2050 to be 31.3 million. VMT under the 0.0 scenario is forecast to be 821 million miles traveled per day.

The 1.0 scenario 2050 VMT forecast is:

- 91 percent higher in population than the 0.0 scenario.
- 64 percent higher in VMT than the 0.0 scenario.

Total growth in daily VMT from 2010 to 2050 is:

- 37 percent under the 0.0 scenario.
- 72 percent under the 0.5 scenario.
- 124 percent under the 1.0 scenario.

This analysis shows that by 2050, there could be a wide range of resulting total statewide VMT, depending on the growth in total state population.

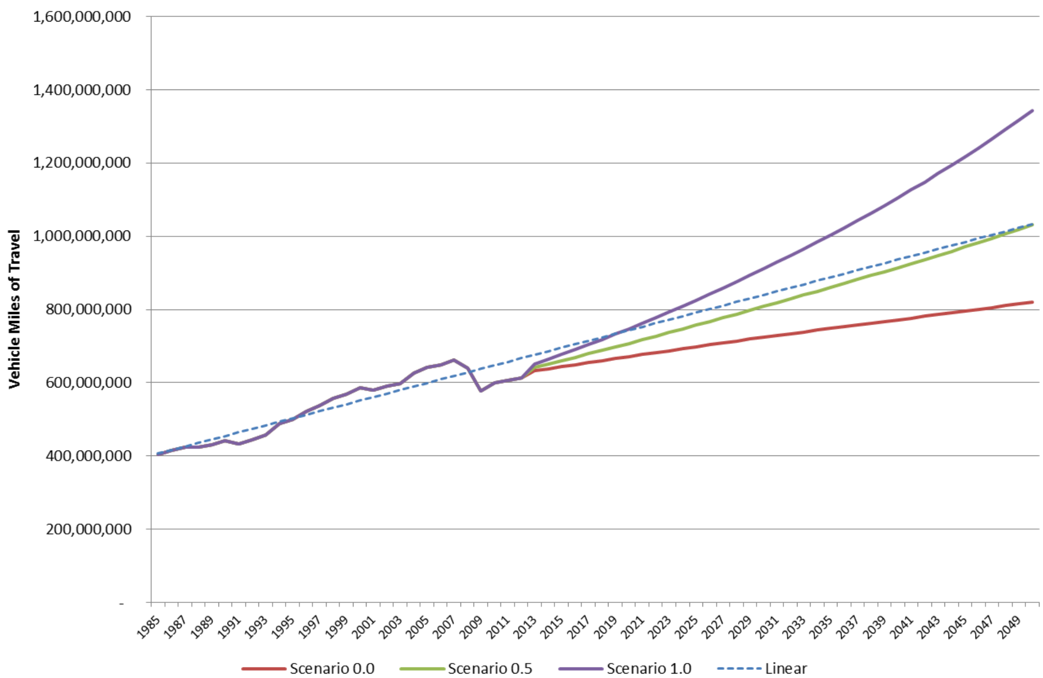


Figure 10. Daily VMT Forecast by Three TSDC Population Scenarios.

VMT Impact: Urban versus Rural

VMT is summarized in Table 5 for urban counties (see Figure 11 for a map) and rural counties for 2013 and 2050 using the 0.5 population forecast scenario. In 2013, 76 percent of the total statewide daily average VMT was in urban counties, and 60 percent of truck VMT was in urban counties. In 2050, the rate of growth in truck VMT is much higher than the rate of growth in passenger VMT in both rural and urban areas. In 2050, 84 percent of passenger VMT growth is forecast to go to urban counties, while 44 percent of truck VMT growth is forecast to go to rural counties.

Table 5. 2013 and 2050 Rural and Urban VMT in the 0.5 Scenario.

Scenario	Passenger VMT	Truck VMT	Total VMT
2013			
0.5 urban	453,031,715	34,337,176	487,368,891
0.5 rural	131,753,341	22,807,739	154,561,080
2050			
0.5 urban	721,120,557	74,374,946	795,495,503
0.5 rural	180,963,892	54,731,438	235,695,330
Total Growth			
0.5 urban	268,088,842	40,037,770	308,126,612
0.5 rural	49,210,551	31,923,699	81,134,250
Percent Growth			
0.5 urban	59%	117%	63%
0.5 rural	37%	140%	52%
Annual Growth Rate			
0.5 urban	1.26%	2.11%	1.33%
0.5 rural	0.86%	2.39%	1.15%
Percent of Total Growth			
0.5 urban	84%	56%	79%
0.5 rural	16%	44%	21%

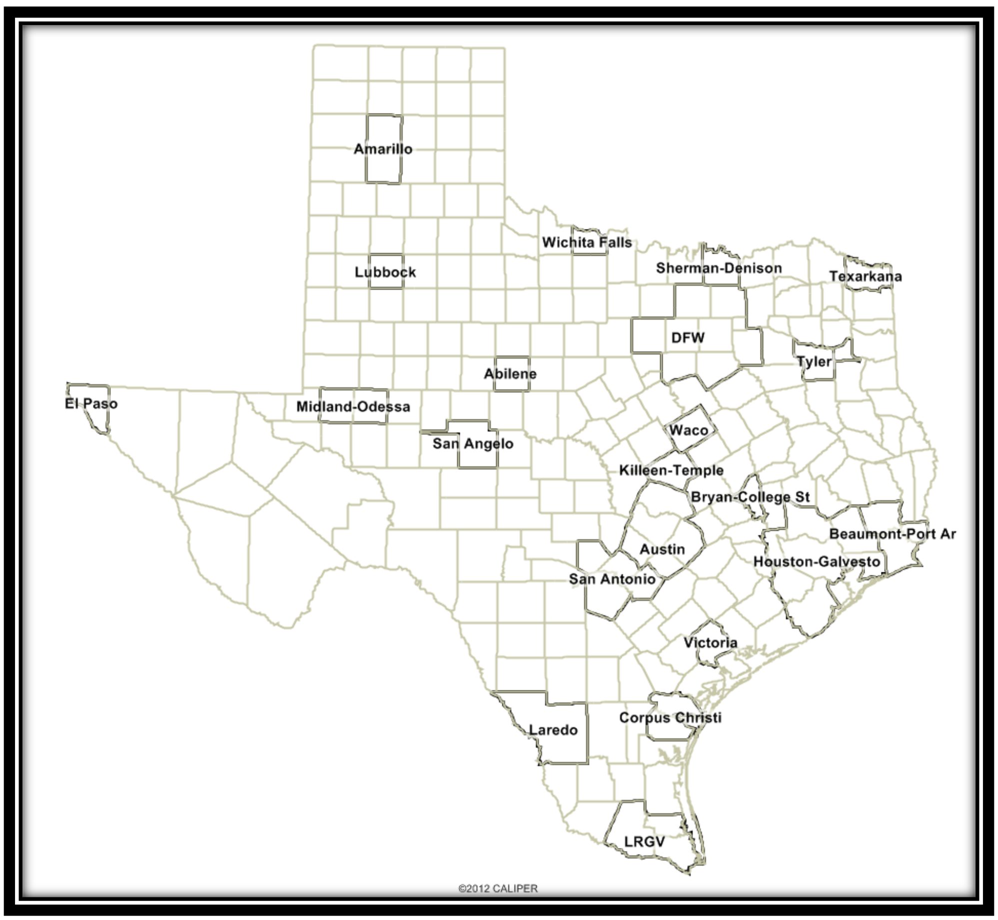


Figure 11. Texas Urban Regions in VMT Calculator.

Selected Scenario Results

The following are some statements about forecast VMT in Texas under various scenario adjustments to the VMT Calculator. All of these forecasts were done using the 0.5 TSDC population projections.

1. El Paso and Hidalgo Counties have similar VMT totals, with about 20 million VMT per day in 2015, and both will grow to about 35 million VMT by 2050.
2. Harris County has the highest VMT in Texas in 2015 with 109 million VMT, followed by Dallas County with 57 million VMT per day.
3. Harris County is forecast to add an additional 50 million VMT by 2050, which is about 87 percent of Dallas County's 2015 VMT total (57 million).
4. Chambers, Collin, Crocket, Denton, Fort Bend, Hays, Hemphill, Kaufman, Montgomery, Sutton, Wheeler, and Williamson Counties all have forecast annual growth rates greater than 2.0 per year. Hays County is the highest at 2.41 percent per year. Collin, Denton, Fort Bend, Hays, Montgomery, and Williamson Counties are all suburban counties close to Austin, Houston, or Dallas.
5. Increasing the statewide average auto occupancy 10 percent (from 1.28 to 1.41 persons per vehicle) lowers 2030 statewide VMT by −8.0 percent and 2050 VMT by −7.8 percent. This represents a decrease of 70 million VMT in 2030 (87 million in 2050). This decrease is greater than the total 2015 VMT in Dallas County.
6. Increasing the total U.S.-Mexico and Mexico-U.S. truck trip growth rate from 6 percent per year to 12 percent per year adds a little more than 1 million VMT in 2030 and 1.4 million VMT by 2050 to Texas roadways. This represents a 0.1 percent and a 1.3 percent change in total statewide VMT over the 6 percent growth rate scenario.

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