

Vehicle Miles Traveled (VMT) Statewide Forecast Model

**Washington State Department of
Transportation – Economic Analysis**

Work Group Participants: Washington State Department of Transportation, Washington State Office of Financial Management, Washington Department of Licensing, Washington State Economic and Revenue Forecast Council, and House and Senate Legislative staff

April 2010

Table of Contents

Page

Acknowledgments.....	4
Executive Summary	5
Chapter 1. VMT Forecast Background.....	7
Chapter 2. Independent Variables and Functional Forms Considered.....	10
Chapter 3. New Statewide VMT Forecast Model	18
Chapter 4. Conclusions and Recommendations	26
Bibliography	27
Appendix I: Washington Preliminary Statewide VMT Forecast.....	29

Acknowledgements

In September 2009, the Washington State Department of Transportation formed a Technical Workgroup to develop a revised statewide vehicle miles traveled forecast. The Technical Workgroup met numerous times between September to April of 2010 to review the current vehicle miles traveled forecast and analyze methods for modifying the forecast. Presentations and group discussions examined data issues, forecast methodologies, critical assumptions, forecast drivers, forecast performance and local vehicle miles traveled issues. The following persons participated in the Technical Workgroup:

Department of Transportation	Doug Vaughn Lizbeth Martin-Mahar Thomas L. Smith Fanny N. Roberts Kasi Reeves Jeff Caldwell Brian Smith Elizabeth Robbins Judy Lorenzo Kathy Leotta Karin Landsberg Pat Morin George Xu Brian Calkins Shuming Yan
Department of Licensing:	Jean Du Alice Vogel
Office of Financial Management:	Lorrie Brown
Economic & Revenue Forecast Council:	Lance Cary
Senate Transportation Committee staff:	David Ward Amanda Cecil
House Transportation Committee staff:	Jerry Long Mark Matteson

Most of the analysis of the forecasts that appears in this study is the result of the eight months of research that this group devoted to evaluating the VMT forecast. Special thanks go to them for devoting their time to studying and improving the forecasting process for VMT.

Executive Summary

VEHICLE MILES TRAVELED DATA AND PAST FORECAST METHODOLOGY

- For more than 20 years WSDOT-Economic Analysis has been forecasting Washington VMT statewide
 - Past Methodology: The VMT forecast used the quarterly forecast of net fuel gallons and multiplied that number by a forecast of fleet miles per gallon to get vehicle miles traveled statewide.
 - Last Forecast (February 2008): This forecast projected Washington VMT to grow by 45% between FY 2008-2025 with total VMT reaching 75 billion miles by FY 2020
- WSDOT-Transportation Data Office (TDO) collects VMT at various levels: statewide, county and by type of vehicle
- Numerous uses of VMT forecasts:
 - future alternative revenue source for transportation
 - transportation planning purposes
 - green house gas emission statewide targets
 - Washington's Greenhouse Gas emission standards and vehicle miles traveled reduction targets were set in law with a baseline of 75 billion VMT for 2020.

FACTORS AFFECTING VEHICLE MILES TRAVELED

- There are many factors which determine the number of vehicles on the roadways, number of trips taken per driver and distance traveled per trip
- Numerous independent variables were tested in a econometric forecast model for VMT
 - Fuel consumption
 - Gas prices – as well as percentage change in prices and dummy variable for large price changes
 - Washington motor vehicle registrations
 - Washington employment
 - Washington unemployment rate
 - Washington personal income
 - Washington personal income per capita
 - Washington wages and salaries
 - Total and driver aged population
 - Labor force and population density
 - In-driver population
 - In-migration population
 - Total and interstate lane miles
- Various model functional forms and the necessity for lagging independent variables were also considered in a revised statewide VMT forecast model

NEW STATEWIDE VMT FORECAST METHODOLOGY

- The final statewide econometric VMT forecast model was determined after considering various forecast model specifications
- The final model is of log-log functional form which includes log of the following independent variables:
 - Washington employment
 - Washington motor vehicle registrations
 - Washington gas prices
- This new forecast model considers three separate types of impacts on VMT: economic activity, registration vehicles and gas prices
- This regression model was selected because it had the best overall fit, significant t-statistics and other critical statistics in the model
- Each of the independent variables have their own separate and distinct forecast which can be used to project VMT statewide

NEXT RELEASE OF VMT FORECAST

- The revised statewide VMT forecast model will be used to project VMT for the June 2010 transportation revenue forecast. This VMT forecast will be completed once a year typically in June, if new VMT data is available from the TDO in time for that forecast.

CONCLUSIONS

- In the last two years, revisions to the economic forecast drivers have a very significant impact on the VMT projections
- The further out the forecast is, the less reliable the forecast becomes
 - The past VMT forecasts have been fairly accurate, within 3%, in the near-term (up to 4 years out)
- This new regression model will improve the forecasting of statewide VMT by incorporating economic factors into a forecast model which will explain historical VMT trends
 - This new forecast produces lower VMT results than past forecasts under a different methodology
- This VMT forecast will be more transparent by separating out the VMT forecast into an alternative forecast in the June transportation forecast with an explanation of the econometric VMT forecast model, work group process and recent projections

Chapter 1: Vehicle Miles Traveled Forecast Background

Washington State Department of Transportation has been producing a statewide forecast of vehicle miles traveled (VMT) for more than 20 years. This VMT forecast had been a product of econometric fuel consumption forecasts that were completed each quarter. Essentially, the projected growth rate of gallons consumed of motor fuel was the driving indicator of VMT projections, not the actual VMTs in the state. This VMT forecast methodology had been the same for years and had not been reviewed by others for years. Even as recently as 2006, OFM reviewed the methodology for all the major transportation forecast models and the VMT forecast was not part of the bigger transportation forecast reviews.

Some of the reasons for the formation of this workgroup to review the Department's VMT forecast were due to the following:

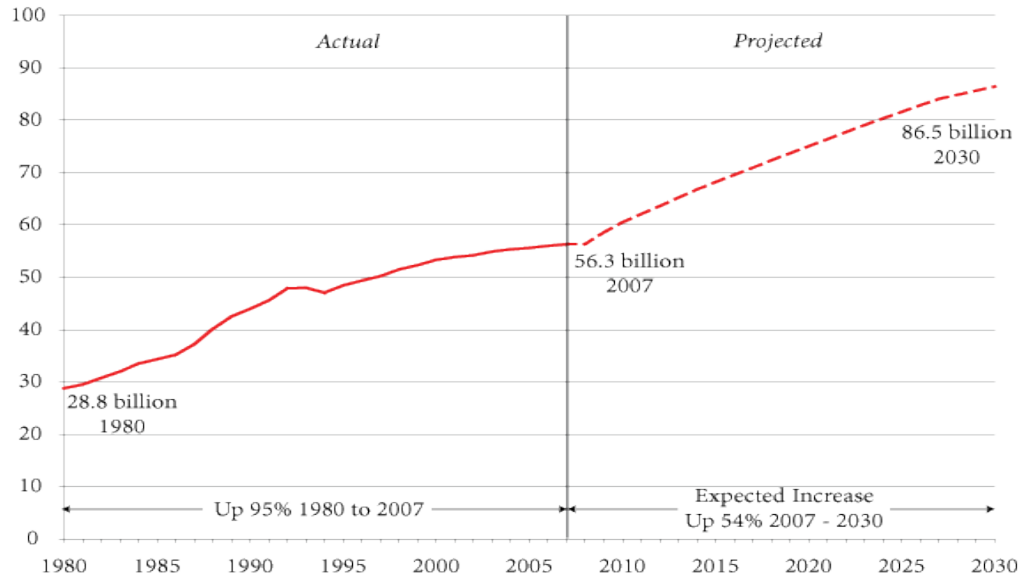
- an actual forecast model for Washington VMT had never been developed
- in light of the more recent trend of national and Washington VMT flattening, the accuracy of the past steep upward trending forecast was being questioned
- consultants and legislative staff have requested estimates for a VMT related tax as a new transportation revenue source
- capital planning purposes - to have an updated and accurate projection of VMT statewide
- enactment of Engrossed Second Substitute House Bill 2815 in 2008 established Washington statewide per capita VMT in order to reduce greenhouse gas emissions (RCW 47.01.440 2008 c. 14 § 8) where the baseline 2020 VMT was set at 75 billion VMT benchmark, consistent with the February 2008 VMT forecast for 2020.

Trends in Washington's VMT Forecast Model

Figure 1 is Washington's actual and forecasted VMT since 1980, with forecasts for years 2008 and beyond based on the February 2008 projections. Even though the average historical growth rate from 1980 to 2007 was 3.5%, some observers have commented that the VMT forecast through 2030 was too aggressive given the recent flattening of the VMT trend in the period 2000 to 2008.

Others have noticed this trend change in national VMT data. Polzin, (2006), Polzin et al. (2004a), Polzin et al. (2004b), and the East-West Gateway Council of Governments (2008) are among those who have noticed the flattening of national and regional VMT growth and have speculated why that growth has moderated. For many years VMT, both nationally and in Washington State, experienced robust growth. Between 1984 and 2000, national VMT grew at an average rate of 3.1% (FHWA, 2009) while Washington's VMT growth was 3.0% for the same period. In recent years, VMT growth has slowed. From 2000 to 2008, the national average growth rate was 1.2%, while Washington's was 0.7% for 2000 to 2008. For the last year, national VMT growth was negative, at -0.8% for 2008. Washington had a -0.9% growth rate for 2008 (Transportation Data Office, 2009).

FIGURE 1. TOTAL VEHICLE MILES TRAVELED 1980 - 2030 (FEBRUARY 2008 FORECAST)
(Miles in billions)



Components of OLD VMT Forecast Model

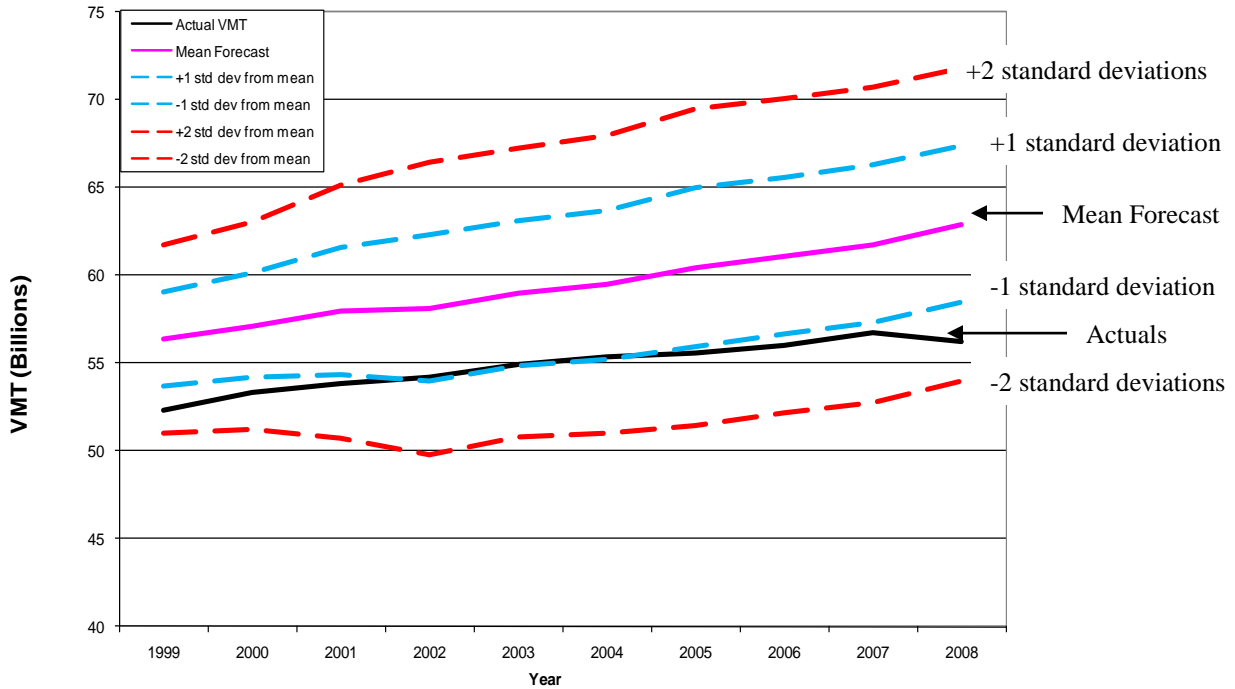
WSDOT’s old methodology for forecasting VMT was essentially a by-product of its fuel revenue forecasts. The VMT forecast uses the quarterly forecast of net fuel gallons and multiplies that number by a forecast of fleet miles per gallon. The net fuel gallons forecast was based on two separate consumption models: one for gasoline fuel and another for diesel fuel consumption. Washington’s forecast of gasoline consumption per capita in gallons uses a log-log regression model with past consumption of gasoline, annual moving average of fuel prices, fuel efficiency and dummy variable for oil supply disturbances as the independent variables in the model. Washington’s forecast of diesel consumption in gallons uses a log-log regression model with past consumption of diesel and personal income.

Forecast Accuracy – Old Methodology

In the beginning of this VMT forecast technical workgroup, WSDOT-Economic Analysis section analyzed the accuracy of the forecast methodology prior to February 2008. In order to determine the accuracy of the past VMT forecasts, WSDOT-Economic Analysis compared VMT forecasts published by the Transportation Revenue Forecast Council (TRFC) from 1991 to 2008 with the actual VMT as reported by the WSDOT- Transportation Data Office. This study compared the February (in even years) or March (in odd years) forecast for each year to test accuracy. The results from 177 forecasts revealed that forty-eight forecasts had percentage errors less than 3%, 27 between 3 and 6%, and 101 exceeded 6%. For the period 1991 to 2008, the forecast proved to be accurate between plus or minus 3 per cent, 27% of the time. The majority of the time, the VMT forecasts had an error of 6% or greater. The results revealed that the forecasts were consistently overestimating vehicle miles traveled as seen in Figure 2 as the actual VMT for

years 1999-2008 was consistently below the mean forecast every year. If the absolute mean percent error is examined by the number of periods in the future the forecast is made, the results reveal that in the near term, like up to 4 years, the forecast has been very accurate, within 3%. The further out the forecast, the less reliable the projection becomes. For further information on the analysis of the old VMT forecast methodology, see the report titled DOT's Vehicle Miles Travelled (VMT) Forecast Accuracy Prior to 2009 (WSDOT 2009).

Figure 2. Mean Forecast (Years 1999-2008) Compared to Actual VMT (billions of miles)



Chapter 2: Independent Variables and Functional Forms Considered

The key factors that determine the total vehicle miles in the state can be broken down into the number of vehicles on the roads, the number of trips people take each year and the miles traveled on each trip. Identifying key factors that can be used in an econometric model can be complex. Some of these factors are hard to predict (e.g., socio-demographics, cultural shifts, gas prices, road capacity); some factors are random (e.g., weather conditions). Typically, economists only have a limited number of economic variables which can be used to predict relationships in regression models. The following independent variables were tested in an econometric forecast model for statewide VMT.

- Fuel consumption
- Gas prices; percentage change in fuel prices; “dummy” variable for large fuel price changes
- Washington motor vehicle registrations
- Washington employment
- Washington unemployment rate
- Washington personal income
- Washington personal income per capita
- Washington wages and salaries
- Total and driver aged population
- Labor force and population density
- In-driver population
- In-migration population
- Total and interstate lane miles

FUNCTIONAL FORMS FOR ECONOMETRIC FORECAST MODEL

The workgroup was presented with various functional forms for the VMT regression model. A linear VMT forecast model was the starting point and other forms like log-log, logistic, cubic were tested to see if they fit the historical VMT data better. Figures 3-6 are graphs of the historical VMT data, in billions, compared to a forecast with trends of different functional forms. The * depict the actual historical VMT and the blue line of ++++ depict the forecasted trend line. The linear trend model overestimates VMT in recent years, since 2003, as the amount of vehicle miles traveled has leveled off. The log trend model underestimates VMT since 1990. The logistic model is similar in form to the log model and it fits the historical VMT better than the log functional form. The forecast with the logistic trend is more optimistic than the forecast with the log trend form. The cubic functional form fits the historic VMT the best but given the trend of a cubic function, the forecast for VMT with the cubic trend is downward sloping. That may not be realistic to assume VMT will fall in the future consistent with a cubic trend curve. These different functional form trends are interesting to consider how the historical VMT fits these curves and their prediction of future VMT. Considering different types of trends is important for improving the overall fit of a forecast model and the fit of independent variables in the model.

Figure 3. VMT and linear trend model

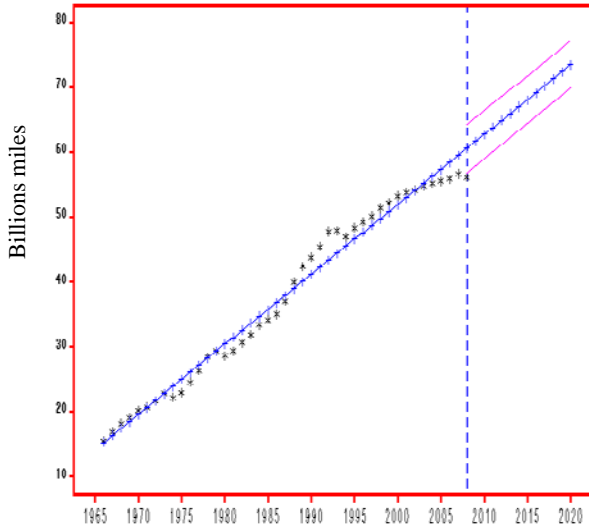


Figure 4. VMT and log trend model

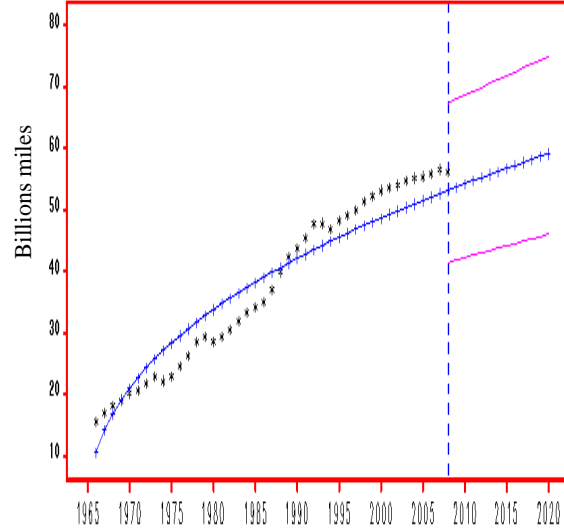


Figure 5. VMT and logistic trend model

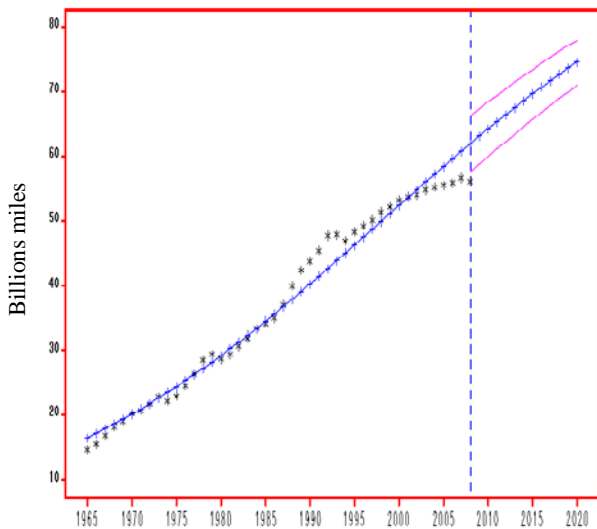
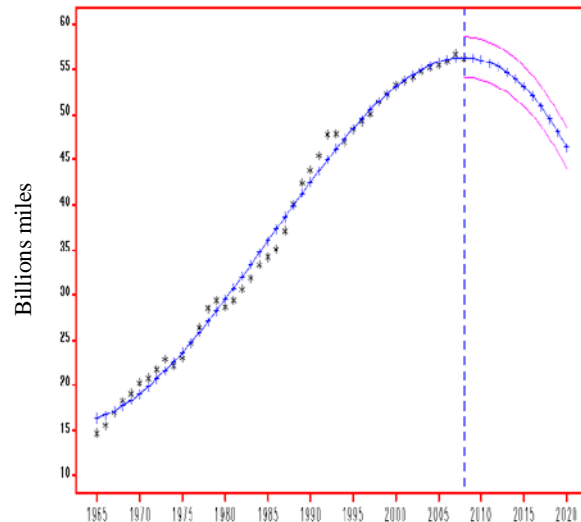


Figure 6. VMT and cubic trend model



The independent variables considered by the workgroup in the VMT forecast model fell into one of five broad categories: economic activity, population, motor vehicle registrations, fuel consumption & prices and lane miles. The majority of these potential independent variables were very closely correlated with VMT as reflected in high correlation coefficients.

Economic Activity Independent Variables

Various measures of economic activity in the state were considered as independent variables in the VMT forecast model. We anticipated needing an economic activity variable to predict when people’s driving behavior may change due to the economy. The tested variables included: Washington employment, Washington unemployment rate, Washington personal income and personal income per capita. From an economic perspective, one would predict that as

Chapter 2: Independent Variables Considered

Washington employment, personal income or personal income per capita rises, so would vehicle miles traveled. As people have employment or additional income then they will likely make more vehicle trips to work or other extracurricular activities. More families will take vacations further away from home as incomes rise. As employment and state income rises, so should business activities on the highways as businesses fulfill orders and provide services which would increase vehicle miles traveled in the state. In contrast to the positive relationship between VMT and income and employment, there should be a negative relationship between VMT and the unemployment rate. As the unemployment rate rises, employment falls so there are less people traveling to work daily so VMT is anticipated to fall.

Model results, as summarized in Figure 7, revealed the following:

- Washington employment, personal income and personal income per capita all had a positive correlation with VMT
- When used in separate models with an autoregressive term of lag 1, Washington employment, personal income and personal income per capita each had significant t-statistics in their respective models
- Due to the correlation between the economic activity variables, only one of these variables can be used in a regression model
- Log-log forecast models did the best at producing the highest regression statistics for the economic activity variables
- The unemployment rate as an independent variable did the poorest of the four economic activity independent variables as it was not statistically significant
- Wages and salaries, a component of personal income, was tested in the VMT regression model as a substitute for personal income but the correlation between wages and salaries and VMT was not as strong as personal income and VMT
- Both log employment and log personal income performed well in the VMT regression models

Figure 7. Regression Results from Economic Activity Independent Variables

Independent Variables	Estimate	T-statistic	R² / RMSE
Log real personal income + ARMA(1)	0.630	5.63	0.994 / 0.85
Log real personal income per capita + ARMA(1)	0.892	4.80	0.994 / 1.09
Log employment + AR(1)	0.839	6.27	0.994 / 1.01
Log unemployment rate + ARMA(1)	-0.0014	-0.34	0.996 / 0.78

Population Independent Variables

There were several population statistics that were considered in the regression model;

- total population
- driver age population (16 years and older)
- driver age population less elderly population over age 75 years
- labor force
- population density
- in-migration population
- in-driver population

Chapter 2: Independent Variables Considered

From an economic perspective, one would predict that as Washington population (total, driver age, in-migration and in-driver) as well as labor force increases so would vehicle miles traveled. More people in the state means more people on the road traveling so total vehicle miles traveled is likely to increase. One could hypothesize that using a broad measure of population may be helpful at capturing all the different factors that determine how many trips people take each year. Certainly, the “pre-driving age” or “elderly” population has an influence on the number of trips and the distance traveled by car that each household makes annually.

Model results, summarized in Figure 8, with population independent variables revealed the following:

- Washington total population, driver age population, driver aged population less elderly population and labor force all had a positive correlation with VMT when used separately in regression models
- There was only a minimal difference in the forecast model results from using total population versus driver age population; or driver age population less elderly population; or adding the teenage population to the driver age population
- Washington in-migration and in-driver populations were positively correlated with VMT but they were not very effective at predicting past or future VMT
 - these independent variables produced fairly volatile VMT forecasts due to the irregular nature of the change in these variables themselves
- When used in separate models with an autoregressive and moving average term of lag 1, Washington total population, driver age population, population density and labor force each had significant t-statistics in their respective models (See Figure 8)
- Due to the correlation between the different population variables, only one of these variables can be used in a forecast model
- Log-log forecast models did the best at producing the highest regression statistics for the population variables
- Both log employment and log personal income performed well in the VMT regression models

Figure 8. Regression Results from Population Related Independent Variables

Independent Variables	Estimate	T-statistic	R ² / RMSE
Log total population + ARMA(1)	0.0003	2.38	0.994 / 1.00
Log driver age population + ARMA(1)	0.0003	3.35	0.994 / 0.95
Log population density + ARMA(1)	0.0193	5.69	0.995 / 0.85
Log labor force + ARMA(1)	1.1572	19.76	0.995 / 0.87

Motor Vehicle Registrations Independent Variable

Washington private motorized vehicle registrations were tested in the VMT forecast model. The motor vehicle registrations included all vehicles paying the \$30 basic fee, all combined license fee vehicles, restored antique vehicles and mopeds. One would expect that the number of motorized vehicles in the state to be closely tied to vehicle miles traveled in the state. As motor vehicle registrations increase statewide so should vehicle miles traveled. This reasoning can be flawed if we see that Washington families are getting more vehicles per household but still taking the same number of trips and driving the same distance only using more vehicles to

perform the same amount of travel over Washington roads. The correlation between motor vehicle registrations and VMT is bound to be strong but it could overstate VMT growth in the future if families are not driving more miles, just driving more vehicles. On the business side, we should see a close correlation between truck registrations and truck VMT. As the economy improves and truck registrations increase, then we should see an increase in VMT from added truck traffic on the roadways.

Model results with motor vehicle registration variable, as shown in Figure 9, revealed the following:

- Washington total car and truck registrations had a strong positive correlation with VMT
- Both a linear and log VMT model were tested with Washington motorized vehicle registrations and the log-log model produced the best overall regression statistics with higher adjusted R squared and lower root mean square error

Figure 9. Regression Results from Motor Vehicle Registrations Independent Variables

Independent Variables	Estimate	T-statistic	R² / RMSE
Motor Vehicle Registrations	0.0100	47.56	0.981 / 1.86
Log Motor Vehicle Registrations + ARMA(1)	27.697	8.83	0.995 / 0.89

Fuel Consumption and Prices Independent Variables

Washington motor fuel consumption was tested in the VMT forecast model. One would expect that as fuel consumption grows so should vehicle miles traveled. It is logical that since fuel consumption is necessary in order to have vehicle miles traveled statewide so the trend of this variable would be a good predictor of VMT. In the past, the fuel consumption (gasoline and diesel) model projections were the primary driving forces in the old VMT forecasts.

Regression model results with fuel consumption variable, summarized in Figure 10, revealed the following:

- Washington motor fuel consumption had a strong positive correlation with VMT
- Both a linear and log VMT model were tested with Washington vehicle registrations and the log-log model with an autoregressive term lagged 1 quarter produced the best overall regression statistics with higher adjusted R squared and lower root mean square error

Figure 10. Regression Results from Fuel Consumption Independent Variables

Independent Variables	Estimate	T-statistic	R² / RMSE
Motor Fuel Consumption	0.0197	40.73	0.975 / 2.16
Log Motor Fuel Consumption + AR(1)	0.6526	5.84	0.994 / 0.98

Washington fuel prices are currently forecasted by WSDOT-Economic Analysis section and could be used as a factor in predicting statewide VMT. One would expect that as fuel prices get high enough, some people may choose other transportation options besides driving a car and decrease their number of trips which would reduce VMT statewide. In order to attempt to capture this change in household behavior, Washington gasoline prices, percentage change in gasoline prices as well as a “dummy” variable for times of large swings in gasoline prices were tested in

the VMT forecast model. The same is true for businesses as they may find ways to reduce the number of vehicles they drive as fuel prices increase and thus reduce truck VMT statewide.

Model results with gasoline prices, summarized in Figure 11, revealed the following:

- Washington gasoline prices had a negative correlation with VMT in the tested models
- Washington gasoline prices or the change in gasoline prices were most closely correlated with VMT as opposed to the “dummy” variable for times of large swings in gasoline prices
- As revealed in Figure 11 below, the log-log VMT models had significant t-statistics for the gas prices and percentage change in gas prices as independent variables but the “dummy” variable for large changes in gas prices was not significant at 95% confidence level
- The log-log VMT model with Washington gas prices and an autoregressive and moving average term lagged 1 year produced the best overall regression statistics with higher adjusted R squared and lower root mean square error

Figure 11. Regression Results from Gasoline Price Independent Variables

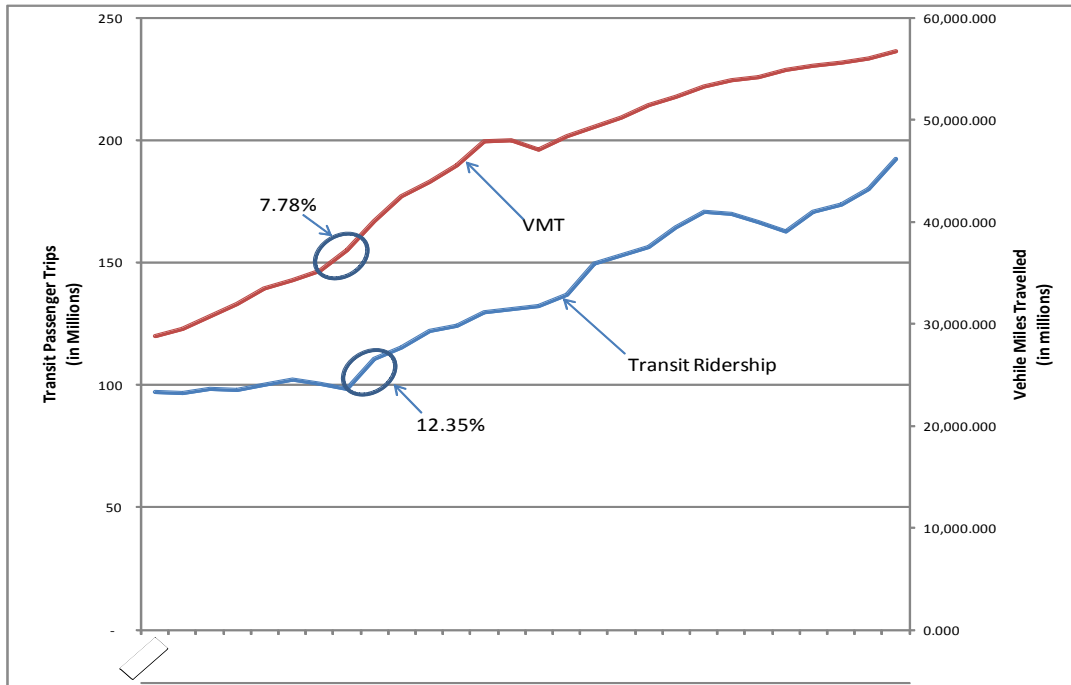
Independent Variables	Estimate	T-statistic	R² / RMSE
Log Gas Prices + ARIMA(1)	-2.119	-2.72	0.997 / 0.63
Log % Change Gas Prices + ARIMA(1)	-1.011	-2.48	0.997 / 0.66
Log “Dummy” Variable (High % Chg Gas Prices) + ARIMA(1)	-0.247	-1.21	0.997 / 0.68

Transit Ridership Independent Variable

This technical workgroup also considered the impact of transit ridership on statewide VMT. An independent variable for transit ridership was added to the VMT regression model. We believed that as transit ridership increased, VMT would likely fall due to fewer people driving their own vehicle on the roadways so we anticipated a negative relationship between these variables. The data revealed that in recent years VMT has been growing at a slower pace than the growth in transit ridership. Figure 12 graphically shows the growth, of both VMT and transit ridership, from 1980 to 2007. While both data series trended upwards throughout the period, their growth rates were very different. Therefore, as forecast models with transit ridership as an independent variable were developed, it was found that there was a strong positive not negative correlation between transit ridership and VMT. In most circumstances VMT and transit ridership increased at the same time and in the same direction. One might conclude that the underlying economic factors that cause increases in VMT also affect transit ridership in the same manner. In periods of economic growth, people make choices about getting to work and doing business. Some chose to travel in passenger vehicles, while others choose public transit. Second, there is a close connection between gas prices and transit ridership. There is a strong body of work that demonstrates this connection (Boyle 1982; Chang and Sinha 1981; Currie and Phung 2007; Transit Cooperative Research Program 2005; Mattson 2008; Haire and Machemehl 2007) and transit agencies are very aware how gas price increases affect transit ridership. In times of steep and sustained gas price increases, we can see transit ridership increase and VMTs decrease, however, in the forecast of VMT, this impact can be modeled by including gas prices, which have external forecasts available. We do not have reliable statewide forecasts for transit

ridership. As a result, transit ridership is not recommended to be included in the VMT forecast model but gas prices would be a better proxy for capturing the change in household behavior regarding transit ridership. For further information on this topic see the WSDOT report titled Transit Ridership and Vehicle Miles Traveled (WSDOT 2009).

Figure 12. Transit Passenger Trips (in millions) Compared to VMT (in millions)



Lane Miles Independent Variables

The technical workgroup had several discussions about the limiting factors on vehicle miles traveled and wanting to test those factors in the VMT forecast model. Some of these limiting factors on VMT that were brainstormed at meetings were congestion, lane miles and travel time. Unfortunately, we had trouble finding a history for one single measure for congestion and travel time that would be important for statewide estimates of VMT. In addition, we needed the independent variable to have a forecast or be “easily” forecasted. We did test total and interstate lane miles since 1980 as a predictor of VMT. Note that vehicle miles traveled in the state of Washington is a direct function of the number of center lane miles we have statewide. Including either total or interstate lane miles in a VMT forecast model was anticipated to be positively correlated because the independent variable was an indirect component of the calculation of the dependent variable VMT.

One question that arose during the workgroup’s discussions on lane miles and VMT was which one caused the other. Does VMT growth cause more lane miles to be built or does roadway expansion increase VMT? On one side, people say that Transportation Departments build new roads and lanes where the traffic and congestion already exists so the VMT comes first. Others say that once a highway is expanded, more people are able to use it so VMTs increase for that segment of the highway. The traffic may not be “new” VMT to the state but drivers choosing now this expanded highway for their trips. Contradictory research suggests

Chapter 2: Independent Variables Considered

either causality relationship could be true (Cervero 2002) (Cervero and Hansen 2002) (Fulton et al, 2000) (Noland and Lem 2002) (Noland and Coward 2000) (Pozdena 2009).

The following four independent variables related to lane miles were tested to determine their relationship with VMT:

- Total and interstate lane miles
- Total and interstate land miles per driver

Model results with lane miles variables revealed the following, as summarized in Figure 13:

- Washington interstate lane miles had a positive correlation with VMT provided the model was the log-log model but total lane miles logged had an insignificant negative correlation with VMT
 - One reason for this difference in the relationship between total lane miles and VMT and interstate lane miles and VMT is because the data for total lane miles is less reliable and could change irregularly given changes to local lane miles
- Washington interstate lane miles per driver was negatively correlated with VMT but total lane miles per driver was not correlated well with VMT
 - A reason for total lane miles per driver to not be correlated with VMT is because total lane miles has a shorter history than interstate lane miles and it has not been growing at the same pace as drivers. Therefore, the ratio of total lane miles to drivers has actually been falling or was fairly flat during this same period as VMT was increasing therefore little correlation existed between the two variables.
- As indicated in Figure 13 below, the log interstate lane miles per driver model and the log interstate lane miles model both had significant t-statistics for interstate lane miles per driver and interstate lane miles
 - Interstate lane miles per driver had a better overall fit as reflected in a higher R squared and lower root mean square error (RMSE)

These results revealed a negative correlation between interstate lane miles per driver and VMT. This indicates that interstate lane miles increased faster than the growth in drivers resulting in interstate lane miles per driver to increase over time at the same time as VMT was growing but at a slower pace. This result is counter intuitive to what one might have expected. Even though the log interstate lane miles per driver appeared to produce good overall regression statistics with an adjusted R squared of 0.982 and root mean square error of 1.69, other indicators revealed that the model was not stationary and a possible unit root could be present in the data. These indicators made it difficult to select this model as a reasonable VMT statewide forecast model.

Figure 13. Regression Results from Lane Miles Independent Variables

Independent Variables	Estimate	T-statistic	R² / RMSE
Log Interstate Lane Miles per driver	-0.238	-47.79	0.982 / 1.69
Log Interstate Lane Miles	0.000438	16.69	0.880 / 3.10
Log Total Lane Miles	-5.54E-7	-0.049	-0.164/ 7.62

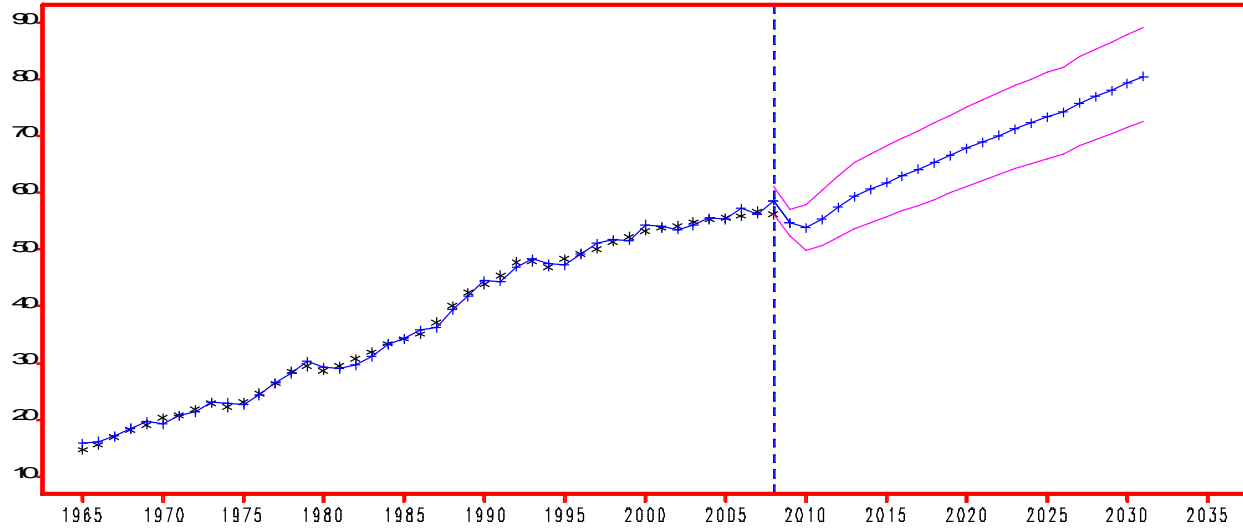
Chapter 3: New Statewide VMT Forecast Model

The next step after examining numerous independent variables separately in a VMT forecast model was to determine if there were combinations of variables which would improve any single regression forecast model for VMT. The forecast workgroup reviewed various combinations of independent variables in the statewide forecast model. The review examined data issues, forecast methodologies, model specifications, critical assumptions, and forecast performance. In this case, the workgroup examined the correlation between independent variables closely to verify that severe multicollinearity did not exist between independent variables in the regression model. The workgroup's review of the statewide VMT forecast arrived at the following econometric VMT forecast model specification and as outlined below.

FINAL STATEWIDE VMT FORECASTING MODEL

The technical workgroup determined that an econometric VMT forecast with three different independent variables would be best at predicting statewide vehicle miles traveled. This new forecast model has an economic activity, motor vehicle registrations and gas price independent variables. The economic activity variable is Washington non-farm employment which was chosen because it helps captured those periods of recessions when there may be less truck and business traffic and fewer trips made by households because more are unemployed. Washington motor vehicle registrations was also chosen as an independent variable in the model because knowing the number of passenger cars and trucks that potentially are on the roadways will go a long way in estimating vehicle miles traveled. It was felt that motor vehicle registrations would be a closer nexus to vehicle miles traveled than just population. In addition, the long-term forecast for vehicle registrations is based on the growth rates of Washington population. Essentially, the vehicle registrations capture both economic indicators. Finally, Washington gasoline prices were added as a driver in the model because it explains a different trend not yet captured by the other two variables. The gas price variable explains that in certain period of rising gasoline prices, vehicle miles traveled will fall due to people finding new ways to minimize their trips, change their mode of transportation or shift trucks used on the roadways to lower their fuel costs. The final model was a log-log functional form model solved using ordinary least squares.

Figure 14. Historical VMT Since 1965 and New VMT Forecast Model Estimates



* denote actual VMT
 + denote forecast model estimate
 Solid pink lines denote 95% confidence interval

MODEL EVALUATION

The new VMT forecast methodology and model for gasoline consumption was accepted by the technical workgroup. The estimated model statistics (e.g., coefficients, t-statistics, R-squared, White noise tests, unit root tests) were examined. The individual regression coefficients are significant and have reasonable values. Overall, the independent variables are able to explain most of the variation in gasoline consumption. The model fits the historical VMT data well.

Forecasting Methodology and Model

- Equation – The equation for vehicle miles traveled in Washington is defined as

$$\ln(\text{VMT}) = \alpha + \phi \ln(\text{WA_Emp}) + \delta \ln(\text{WA_reg}) + \varphi(\text{WA_GasP}) + \varepsilon$$

Where

VMT = Annual statewide vehicle miles traveled from WSDOT-TDO,
 WA_Emp = Annual Washington non-farm employment,
 WA_reg = Annual Washington motorized vehicle registrations,
 WA_GasP = Annual Washington gas prices.

And

ε = Stochastic disturbance on vehicle miles traveled.

The model also has first-order autoregressive and moving average terms to correct for serial correlation.

The model has an Adjusted R-squared value of 0.996 and a root mean square error of .75068. The t-statistics for the variables include 4.76 for the Washington employment,

Chapter 3: New Statewide VMT Forecast Model

3.59 for Washington motor vehicle registrations, and -2.85 for the Washington gas prices. The model statistics are presented in the following table.

Figure 15. Washington Statewide VMT Forecast Model Statistics

Dependent Variable: LOG(VMT)				
Method: Least Squares				
Sample: 1965- 2008				
Included observations: 44				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-5.49495	0.6147	-8.9396	0
LOG(WA_Emp)	0.69795	0.1463	4.7696	0
LOG(WA_Reg)	0.46757	0.1304	3.5854	0.001
LOG(WA_GasP)	-0.07244	0.0252	-2.8786	0.0068
MA(1)	-0.73222	0.1730	-4.2336	0.0002
AR(1)	0.71161	0.1478	4.8143	0
R-squared	0.997	Model variance	0.00046	
Adjusted R-squared	0.996	Amemiya's Adjusted R-squared	0.995	
Mean Square Error	0.5635	Akaike info criterion	-11.5154	
Root Mean Square Error	0.75068	Schwarz criterion	-1.2339	

- Forecast drivers** – Washington employment has the strongest explanatory power in the forecast model of all three independent variables. It is positively correlation to vehicle miles traveled. The model’s coefficient value for the Washington employment is 0.70 which in a log model is also the employment elasticity for VMT. Washington motorized registrations also have a strong positive correlation to VMT but it is less important than employment in the model as the coefficient is 0.47. Gas prices are not as important in the forecast model as the other two drivers but it is still negatively correlated with VMT and statistically significant.

Figure 16. VMT Forecast Model: Autocorrelations

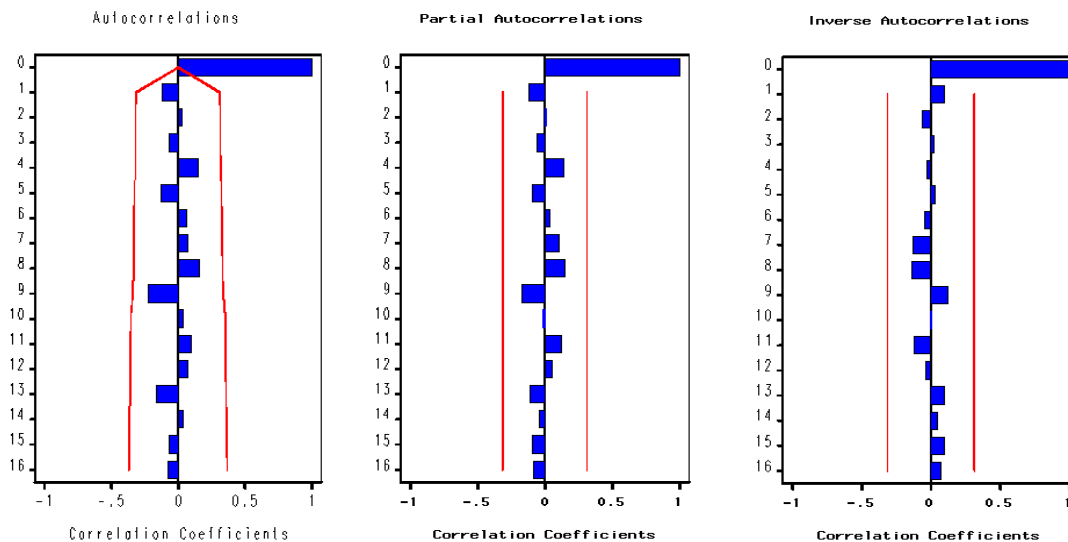
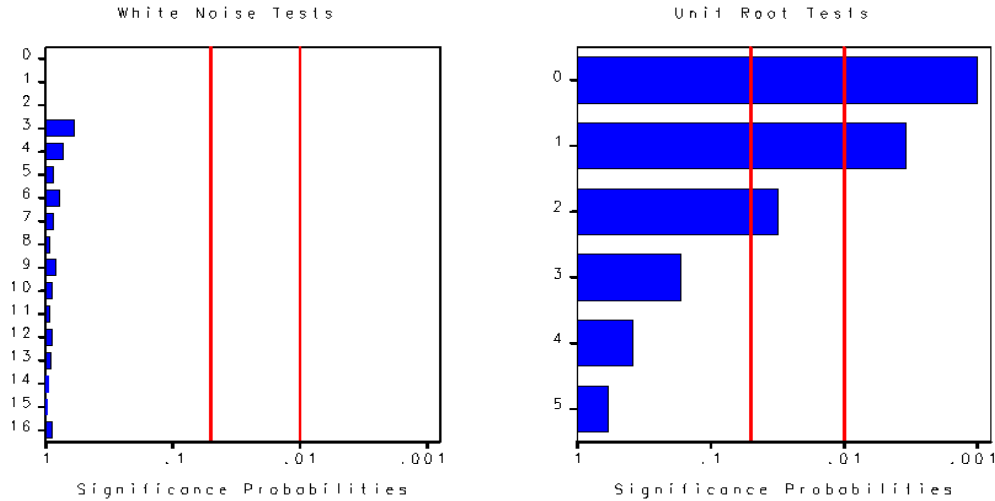


Figure 17. VMT Forecast Model: White Noise and Unit Root Tests



Other Statistical Tests

- Autocorrelations
 - Autocorrelation function plots show the degree of correlation with past values of the series as a function of the number of periods in the past (that is, the lag) at which the correlation is computed.
 - As Figure 16 reveals, in the current period (lag 0), all three of the autocorrelations have high correlation (nearly 1) which is a sign of a strong relationship between the dependent and independent variables in the model
 - By examining the plots in Figure 16, you can judge whether the series is stationary or nonstationary. In this case, a visual inspection of the autocorrelation function plot indicates that the VMT series is stationary, since the autocorrelation function decays quickly. In subsequent periods, the autocorrelations decrease significantly and stay within the red lines depicting the confidence band.
 - The sample inverse autocorrelation function (SIACF) can be useful for detecting over-differencing. If the data come from a nonstationary or nearly nonstationary model, the SIACF has the characteristics of a noninvertible moving-average. Likewise, if the data come from a model with a noninvertible moving average, then the SIACF has nonstationary characteristics and therefore decays slowly. In this case, the SIACF decays quickly revealing a stationary series.
 - All three autocorrelation graphs reflect a stationary series

- White Noise Tests
 - Tests were performed for model “white noise” or randomness implying that the sum of the squares of a group of consecutive autocorrelations should all sum to 0 for all periods

Chapter 3: New Statewide VMT Forecast Model

- Ljung-Box Chi-square statistic – joint test for autocorrelations of residuals; this considers several autocorrelations together to calculate a statistic that has chi-square distribution
 - Figure 17 “White noise” tests reveals the significance possibilities of the Ljung-Box Chi-square statistics for 16 periods
 - Each bar shows the probability computed on autocorrelations up to the given lag with longer bars favoring rejection of the Null hypothesis that the prediction errors represent “White Noise” or randomness
 - In this case, the graph in Figure 17 reveals a low level of significance meaning we can assume randomness in this VMT model
- Unit Root Tests
 - Tests were performed to see if the time series was stationary and if unit roots appeared; if a series has a unit root, the series is nonstationary and then the ordinary least squares estimator is not normally distributed
 - The Augmented Dickey-Fuller single mean test was completed to test the hypothesis that the variables in the model have a unit root
 - Figure 17 unit root test reveals the results of the unit root tests by showing the significant probabilities of the Augmented Dickey-Fuller test for unit roots;
 - When the horizontal bars on the graph are longer and beyond the first vertical line, then you can reject the Null hypothesis that the series is non-stationary, meaning the series is stationary.
 - The model results indicate that the series is stationary because the significance probability is above the threshold for the current and prior two periods.

Source of Independent Forecasted Variables

- Washington employment – The forecast for Washington employment was taken from the Economic and Revenue Forecast Council February 2010 forecast in the near-term and from OFM’s 2009 long-term non-farm employment projections for Washington.
- Washington motorized vehicle registrations – The forecast for Washington motorized vehicle registrations was forecasted by WSDOT-Economic Analysis section for the Transportation Revenue Council and included the February 2010 forecast
- Washington gasoline prices – The forecast for Washington gasoline prices was taken from the WSDOT forecast for the Transportation Revenue Council for February 2010 forecast

Other Multivariate Forecast Model Specifications Considered

- The technical workgroup discussed other model specification before deciding on this final VMT forecast model (see Figure 19). One alternative VMT forecast model that was considered was the final model without the gas price variable included. Some workgroup members expressed concerns with including gas prices in the model given the difficulty that is inherent in the gas price forecast. Figure 18 reveals the difference between a VMT forecast model with and without gas prices. The graph indicates that a VMT forecast model without gas prices produces slightly higher VMT forecasts than a model with gas prices included. The difference between the two models in the near-term is insignificant. In the long-term, the higher future gas prices do have a dampening effect on the VMT forecasts. When you compare the Akaike's Information Criterion (AIC) for those two models, the regression model without gas prices had a slightly smaller AIC than the model with gas prices included indicating that the regression model without gas prices would be slightly better. Given our uses of this regression model and the fact that we receive questions on the impact of fuel prices on VMT we wanted to keep the fuel price variable in the model so we could answer those types of questions.
- Another top VMT forecast model considered included personal income per capita plus motor vehicle registrations and that model was not selected as the best model because of the broad nature of personal income and the fact that an increase in personal income may not translate into increased vehicle miles traveled.
- Another top VMT forecast model considered was combining population with fuel consumption. The reason why this model was not selected was because motor vehicle registrations have a closer nexus to vehicle miles traveled than just population. Fuel consumption has been the primary driver in the past for VMT forecasts and has a close nexus with VMT when it is combined with MV registration, the data results in non-stationary and randomness problems. Having these two variables together in a single regression model for VMT is problematic.
- Another VMT model specification option considered was combining lane miles per driver with fuel consumption. The drawbacks to this model are that it lacks any economic activity independent variables and there is not a readily available forecast for lane miles. In the future as additional alternative fuel based vehicles become more common, there could be reductions in fuel consumption without corresponding reductions in VMT.
- During the course of the forecast review, model results were also run on truncated VMT annual data beginning in 1990. The reason why some workgroup members asked for a truncated model is because the trend in VMT in recent years has been flatter than the longer history. The truncated model produced flatter forecasts of VMT in the future. Currently the truncated model has only 18 observations which is less than is advisable for forecasting models. If the flat VMT trend continues in the future, this issue may be revisited.

Critical Forecast Assumptions

- Forecast Procedure – The calculation of the new VMT forecast each year will consist of running the econometric forecast model with new VMT actual and economic variables. The new forecast will be based on the model regression coefficients for each independent variable along with the last actual for statewide VMT and the new forecast for each independent variable. By using these components, the new VMT forecast will be calculated from the last actual VMT. This procedure helps reset the new forecast to the last known actual VMT while applying the same model growth rates.
- Critical assumptions – VMT forecast assumptions will be presented in a Transportation Revenue Forecast Council assumptions meeting before the forecast and at the forecast adoption meeting each year. An alternative forecast for the VMT projections will be completed along with a description of the forecast model. The most current statewide vehicle miles traveled from WSDOT-TDO and Washington motor vehicle registrations and gas price forecasts from WSDOT are incorporated into the VMT forecast.

Figure 18. VMT Forecast Model: With and Without Gas Prices

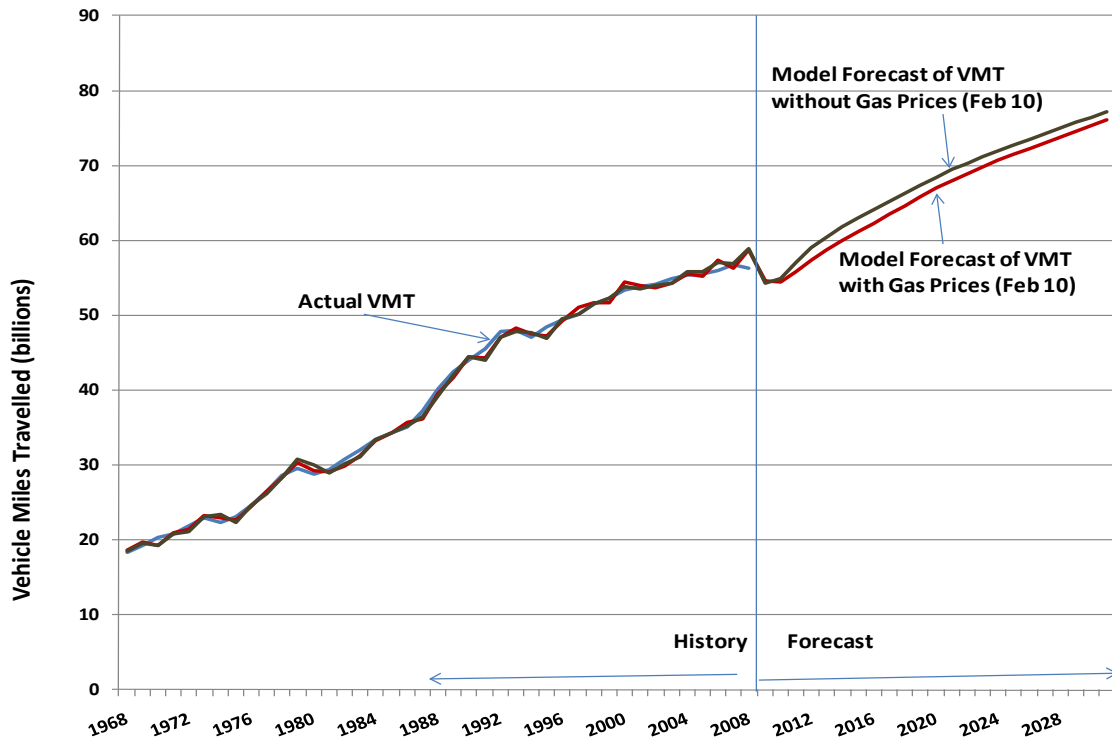


Figure 19. Top VMT Forecast Models Considered

Model description	RMSE	Adj. R squared	Akaike Info Criterion (AIC)
Log WaEmp + Log Mv-Reg + Log GasP + ARMA(1,1)	0.75	0.996	-11.5154
Log WaEmp + Log Mv-Reg + ARMA(1,1)	0.78	0.996	-12.5435
Log Personal Income/pop + Log Mv-Reg + ARMA(1,1)	0.80	0.996	-8.1802
Log Pop + Log Fuel Consumption + ARMA(1,1)	0.79	0.996	-9.3378
Lane Miles per Driver + Log Fuel Consumption + ARMA(1,1)	0.87	0.995	-0.9979

The yellow highlighted model represents the final VMT forecast regression model

Chapter 4: Conclusions and Recommendations

Vehicle miles traveled has flattened in recent years and the revised VMT forecast model has reflected a slower growth for future VMT. This change in the VMT forecast has been the result of revised economic indicators and a new forecast modeling specification. In the past, the VMT forecast was fairly accurate, within 6% on average, in a 4-year near-term horizon. This new VMT forecast model has revised the February 2008 forecast projections downward 13% by FY 2020 and 15% by FY 2025. On average this new VMT forecast has a growth rate of 1.3% between FY 2009 and 2027. It was found that this new model growth rate was comparable and even a little more conservative than national VMT forecasts from EIA¹.

The technical workgroup concluded that there were advantages to having an econometric VMT forecast model to project VMT based on the relationship of historical VMT to the historical data of other economic indicators. The new forecast model incorporated economic activity, motor vehicle registrations and fuel price independent variables. There were discussions by the workgroup about leaving off the gas price variable due to the difficulty in forecasting fuel prices. The model results indicated that removing the gas price variable from the model does not change the VMT forecast much at all. A detailed review of Washington's VMT forecast model revealed that other variables beside fuel consumption like motor vehicle registrations and employment are equally important in projecting VMT.

One problem with the old statewide VMT forecast was that it was not very transparent and the VMT forecast methodology was not documented. This new annual VMT forecast will be presented as a separate alternative forecast document each June in the Transportation Revenue Forecast Council quarterly forecast. In this alternative forecast, a description of the VMT forecast model and summary of the model projections will be provided.

Recommendation for further research includes the following:

The Technical Workgroup should review this forecast model again in a few years to see if truncating the data would produce better forecasts than using the longer term history of VMT. In addition, periodically the group should monitor and coordinate consistency between the various transportation related forecasts.

¹ EIA 2009 VMT forecasts

Bibliography

- Boyle, Daniel K. "Transit Use and Energy Crises: Experience and Possibilities." *Transportation Research Record* 870, 1982: 16-21.
- Cervero, R. (2002) "Induced demand: An urban and metropolitan perspective," Working Together to Address Induced Demand, ENO Transport Foundation, Washington DC
- Cervero, R. and M. Hansen (2002). "Induced travel demand and induced road investment," *Journal of Transport Economics and Policy*, 36 (3) 469-490
- Chang, Chia-Juch, and Kumares C. Sinha. "A Methodology to Forecast Transit Demand Under Restricted Fuel Availability." *Compendium of Technical Papers, 51st Annual Meeting*. Washington, D. C.: Institute of Transportation Engineers, 1981. 68-75.
- Currie, Graham, and Justin Phung. "Transit Ridership, Auto Gas Prices, and World Events: New Drivers of Change?" *Transportation Research Record* 1992, 2007: 3-10.
- East-West Gateway Council of Governments. 2008, February. *Trends in Regional Traffic Volumes: Signs of Change?* Saint Louis. Available: <http://www.ewgateway.org/pdffiles/library/trans/trafficvolumes/vmtrpt.pdf>
- FHWA. 2009 May. Traffic Volume Trends. Available: <http://www.fhwa.dot.gov/ohim/tvtw/09maytvt/09maytvt.xls>
- Fulton, L.D. Meszler, R. Noland and J. Thomas (2000). "A statistical analysis of induced travel effects in the U.S. Mid-Atlantic region," *Journal of Transportation and Statistics*, 3 (1) 1-14
- Haire, Ashley R., and Randy B. Machemehl. "Impact of Rising Fuel Prices on U.S. Transit Ridership." *Transportation Research Record* 1992, 2007: 11-19.
- Mattson, Jeremy. "The Effects of Rising Gas Prices on Transit Ridership." *Community Transportation*, Spring 2008: 38-41.
- Noland, R. and L. Lem (2002). "A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK," *Transportation Research D*, 7 (1) 1-26
- Noland, R. and W. Cowart (2000). "Analysis of metropolitan highway capacity and the growth in vehicle miles of travel," presented at the 79th Annual Meeting of the Transportation Research Board, Washington DC
- Polzin, Steven E.; Chu, Xuehao; and Toole-Holt, Lavenia. Forecasts of Future Vehicle Miles of Travel in the United States. 2004a. *Transportation Research Record* 1895, pp. 147-155.
- Polzin, Steven E.; Chu, Xuehao; and Toole-Holt, Lavenia. 2004b, November 3. *The Case for More Moderate Growth in VMT: A Critical Juncture in U. S. Travel Behavior Trends*. Powerpoint Presentation. Tampa: Center for Urban Transportation Research, University of South Florida.

Bibliography

- Polzin, Steven E. 2006, April. *The Case for More Moderate Growth in VMT: A Critical Juncture in U. S. Travel Behavior Trends*. Tampa: Center for Urban Transportation Research, University of South Florida. Available:
<http://www.cutr.usf.edu/pdf/The%20Case%20for%20Moderate%20Growth%20in%20VMT-%202006%20Final.pdf>
- Pozdena, R. (2009). "Driving the economy: Automotive travel, economic growth, and the risks of global warming regulations." Cascade Policy Institute, Portland Oregon
- Revised Code of Washington Title 47 (RCW 47.01.440 2008 c. 14 § 8). Adoption of statewide goals to reduce annual per capita vehicle miles traveled by 2050.
- Transit Cooperative Research Program. "Evaluation of Recent Ridership Increases." *Research Digest 69*. Washington, D. C.: Transportation Research Board, April 2005.
- Washington State Department of Transportation. 2009, DOT's Vehicle Miles Travelled (VMT) Forecast Accuracy Prior to 2009.
- Washington State Department of Transportation. 2009, Transit Ridership and Vehicle Miles Travelled (VMT).
- Washington State Department of Transportation. 2008, February. Vehicle Miles Traveled. Available:
<http://www.wsdot.wa.gov/planning/wtp/datalibrary/Modes/VehicleMilesTraveled.htm>
- Transportation Data Office. 2009, June 16. Annual Travel and Mileage Information. Washington State Department of Transportation. Available:
<http://www.wsdot.wa.gov/mapsdata/tdo/annualmileage.htm>

Appendix I: Washington Preliminary Statewide VMT Forecast

The following table provides the new preliminary forecast for VMT with the best available forecast data from February 2010 forecasts. This forecast will be revised for the June 2010 VMT forecast with another VMT actual for 2009 and revised economic forecasts for Washington employment, motor vehicle registrations and gas prices.

Fiscal Year	VMT (billion miles)	% change
2009	55.58	-1.17%
2010	53.89	-3.03%
2011	54.79	1.67%
2012	56.30	2.75%
2013	57.71	2.51%
2014	58.62	1.57%
2015	59.53	1.56%
2016	60.45	1.54%
2017	61.41	1.59%
2018	62.41	1.64%
2019	63.49	1.72%
2020	64.62	1.78%
2021	65.65	1.59%
2022	66.67	1.56%
2023	67.71	1.55%
2024	68.67	1.43%
2025	69.62	1.38%
2026	70.43	1.16%
2027	71.88	2.06%