NATIONAL CAPITAL REGION
TRANSPORTATION PLANNING BOARD

MEMORANDUM

To: **TPB Technical Committee**

From: **Yu Gao**
JC Park
Elena Constantine

Date: **September 5, 2014**

Re: **An Update to the Vehicle Population Projection Methodology – Used for regional Air Quality Conformity Analysis**

An integral part of performing the regional air quality conformity analysis of the CLRP and TIP is the estimation of the various criteria pollutants from the mobile source for a pre-defined set of existing and future years. The technical procedures include the use of the MWCOG's regional travel demand forecasting model together with the US EPA's emissions estimates model (MOVES). Included among the transportation and environmental inputs used in the analysis is the forecasts of the regional vehicle population for future years.

The methodology of deriving future vehicle population projections was updated as part of the regional Air Quality Conformity determination for the 2014 Constrained Long Range Plan (CLRP) and FY2015-2020 Transportation Improvement Program (TIP). This technical memorandum lists the reasons for the update, summarizes the previous method, and describes the update to the methodology. The memorandum also includes the results of a sensitivity test comparing the previous and the updated processes, both on the change in vehicle population and the regional emissions estimates.

As will be seen, an update to the methodology was merited, and the update adopted is consistent with the overall approach previously used and with standard technical procedures used in developing forecasts based on empirical data.

REASONS FOR CHANGE:

1. **New approach to vehicle start emissions:** One part of the total motor vehicle emissions calculated by the US EPA's emissions estimation model is associated with the start phase of each vehicular trip. The newly released US EPA emissions model, MOVES 2010a, used in the regional air quality conformity analysis for the 2014 CLRP and FY 2015-2020 TIP uses a different approach to calculate the vehicle start emissions than the previous model, MOBILE 6.2. Start emissions estimates based on the MOBILE model (which was the previous emissions estimating model used in conformity determination) were more dependent on vehicle trips projections – which traditionally are derived using a travel demand model or other travel activity forecasting methods. Start emissions estimates in the MOVES model are dependent on the vehicle population estimates for each analysis year. Therefore, there is a greater emphasis on the vehicle population projections. Due to the above, the previous methodology used to derive future year vehicle population projections was reviewed and a need to update the methodology being used identified.

2. **Expanded empirical data set:** The previous methodology had been developed in 1992 and it has been using vehicle population data (by jurisdiction) for the period 1975 through 1989 without taking advantage of more recent data that was gathered over time and covered the period 1999 through 2011. By consolidating the more recent data with appropriate data sets from the 1975-1989 period, TPB would be able to create an enlarged set of empirical data and a more robust sample to develop future forecasts of vehicle population.

3. **Improved data consistency:** The data used to develop the previous methodology was obtained before a systematic and coordinated effort by the agencies in the region to collect vehicle population data on a regular basis. As such, the data used in developing the previous methodology had relied on data from a variety of sources. By re-examining the sources of the data from the 1975-1989 period it was possible to identify one consistent source. This, together with the consistent source of data for the 1999-2011 time period, improves the data quality and provides an increased sense of comfort in the forecasts.

THE PREVIOUS PROCESS:

To date the basis for developing future year vehicle population projections has been annual vehicle population growth rates – by jurisdiction. The growth rates were originally developed in 1992[1] based on analysis of vehicle population data for the period 1975 through 1989. The growth rates were applied to the most recent year of vehicle population data available at the time – year 2002 -- for use in the analysis.

It is worth noting that the growth rates, first developed in 1992, were based on a statistical analysis of

[1] *Source: Harinath Gouru memorandum to M. Clifford with subject matter: "Forecasts of Total Vehicles and Diurnal Emissions in the Washington Metropolitan Region (December 1992)*

past trends and forecasts trends. Past vehicle population trends were examined using data published by The Washington Post (for years 1975, 1980, 1987, 1988 and 1989), and the Highway Statistics published by the FHWA for the period 1975 to 1990. In order to develop future year vehicle population projections three alternative regression models were developed: first model (Post 1) used The Washington Post data for the 1975-1989 period; second model (Post 2) used the Post data for 1987-1989 period and third was a MWCOG auto ownership model that had been previously developed. Using the vehicle registration data for 1987 provided by the transportation agencies of Maryland, Virginia and the District of Columbia, as the base forecasts by the three modes for years 1990, 1996, 1999 and 2000 were developed. For each jurisdiction the trends in these forecasts were compared to the past trends and the model that provided forecasts with the best fit was selected for that jurisdiction. Using the forecasts from the selected model, a growth rate by jurisdiction was established and is listed in the Table 1 below.

TABLE 1 – VEHICLE POPULATION GROWTH RATES (PREVIOUS PROCESS)

Jurisdiction	Annual Growth Rates
District of Columbia	0.44%
Calvert County	3.93%
Charles County	2.71%
Frederick County	2.63%
Montgomery County	2.10%
Prince George's County	1.59%
City of Alexandria	0.44%
Arlington County	0.44%
Fairfax County	1.76%
Loudoun County	2.98%
Prince William County	2.44%

It must be noted that the previous process produced vehicle population forecasts that were primarily used to calculate (through an offline process) diurnal and resting emissions (VOC) from gasoline powered vehicles. Vehicle population forecasts were not used within the MOBILE model to calculate vehicle start emissions. Start emissions estimates in the MOBILE model were more dependent on vehicle trips projections traditionally derived using a travel demand model or other travel activity forecasting methods.

One significant change in the EPA's MOVES model, now being used for regional emissions estimation analysis, is the calculation of vehicle start emissions based on vehicle population as opposed to estimates of vehicle trips forecasted by the travel demand model. With this emphasis and use of vehicle population in emissions estimation a thorough re-examination of the vehicle population forecast process used in the regional air quality conformity analysis was undertaken.

The examination identified the following areas in which the previous forecasting process needed to be updated:

1. Sample size of the data used to establish a trend could be doubled. The previous process derived growth rates using data from a rather small sample size (mostly from the 1980s) whereas the region now has five additional and more recent data sets (years 1999, 2002, 2005, 2008 and 2011).

2. Forecasts could be based on a statistical (regression) equation representative of each jurisdiction rather than on a fixed growth rate that was calculated using data from a limited period from the past. "Fixed" annual growth rates representative of a certain time period, are likely to become stale over time if they are not systematically monitored for relevance, and ultimately refreshed periodically.

3. A forecast model could be set up to account for trendline changes resulting from new data points gathered over time. The region currently has a system in place of collecting vehicle population data every three years and has been doing so since 2005. With the infusion of new vehicle registration data every three years the databases are automatically replenished and expanded, the resulting trendlines are automatically adjusted, which is reflected in the future year vehicle population projections.

THE UPDATED PROCESS:

The updated process is still based on linear regression analysis, using older vehicle population data (i.e., the 1975 – 1989 period), later years data (i.e., 1999 and 2002), and data from "new sources" reflecting years 2005, 2008, and 2011 to develop future year projections. As a result, it is based on a much larger – and more recent -- pool of data points than the previous process.

The updated process utilizes data from the following sources: (1) a single source data for the 1975 – 1989 period based on the Washington Post; (2) year 1999 data obtained directly from the MD and VA departments of motor vehicles, and from an online FHWA source[2] for DC; (3) year 2002 data obtained directly from the MD, DC, and VA departments of motor vehicles; and (4) year 2005, 2008 and 2011 from detailed databases based on DMV vehicle population (based on VIN) and created by the TPB staff through a collaboration with the state air agencies facilitated by the MWCOG Department of Environmental Programs (DEP). Thanks to an existing agreement among the above participants, the supply of new data to replenish and augment the databases is expected to continue on a triennial cycle.

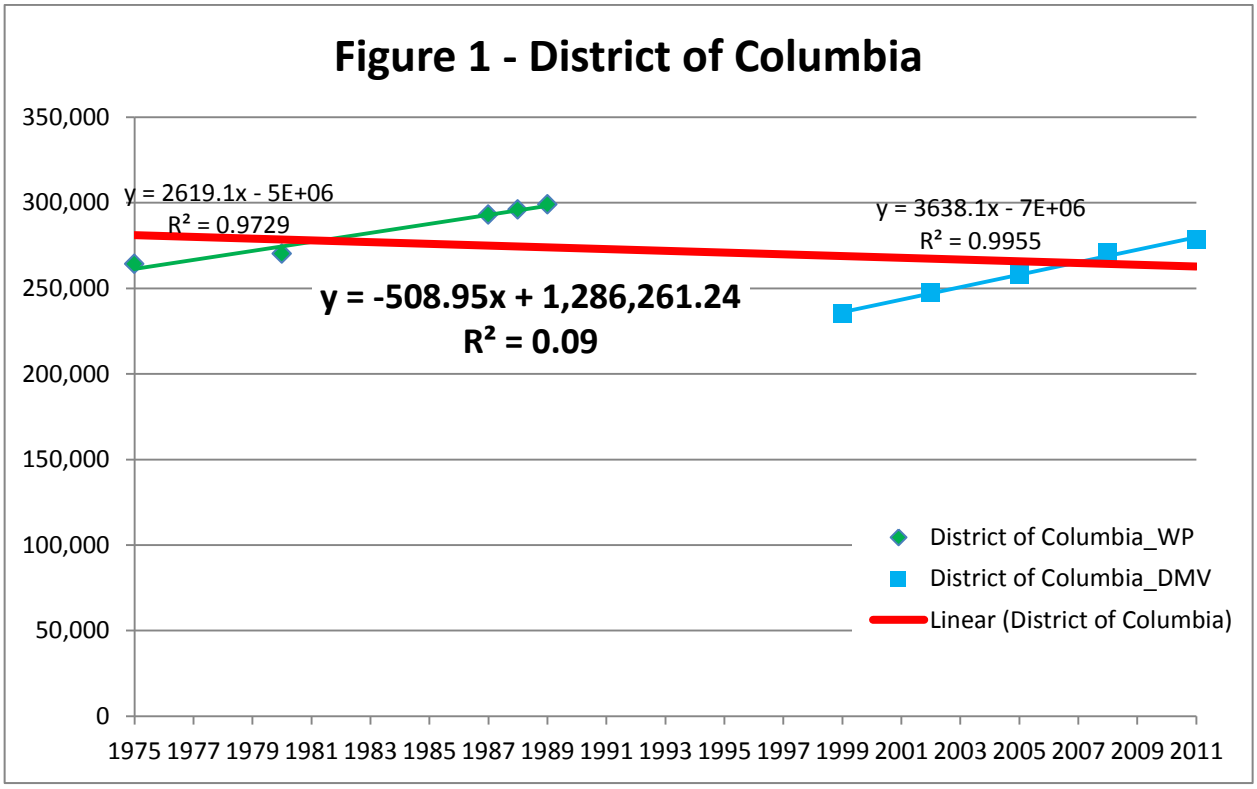
The second major difference of the update is that it no longer yields annual growth rate representative of certain fixed time period of vehicle population by jurisdiction. Instead, the future year vehicle population projections are calculated directly from the resulting "best-fit" linear regression equation for each jurisdiction.

Technical note: It must be noted that while data is currently available for an extended period (1975 through 2011; a 39 year period), there is a data gap for the period 1990-1998. This data gap provides an

[2] *Source: http://www.fhwa.dot.gov/ohim/hs99/tables/mv1.pdf*

option for the regression analysis to either use all data points in spite the data gap period (1990-1998) or to develop two trendline per jurisdiction and use the more robust regression to forecast future population. Both options were tested: (1) a trendline was drawn encompassing all the available data (called the Linear Trendline in Figures 1-11 shown in red) for each jurisdiction despite the eight-year data gap; and (2) separate trendlines by jurisdiction drawn for the pre-1990 period (called WP Trendline in Figures 1-11 referring to the Washington Post as the single source origin of the data shown in green), and for the post-1998 period (called the DMV Trendline in Figures 1-11 referring to the state DMV origin of the data shown in blue).

It was concluded that by including all available data points the "fit" is better as evidenced by the higher R^2 coefficients. In general, the resulting R^2 were above 0.90, which is an indication of a strong "fit" between the trendline and the scattered data points. As such, the trendline across the entire data set (1975-2011) was used to develop future year vehicle population projections by jurisdiction. The only exception was the case of the District of Columbia. As may be seen in Figure 1, the pre-1990 and post-1998 data sets, while similar in trend, were no longer along a single slope. Instead, they appeared disjoined. In this case, the post-1998 data set resulted in a substantially higher R^2 value than the R^2 value for the trendline using all of the data points. Consequently the post-1998 trendline was used to derive future annual vehicle population projections for the District of Columbia. Figures 2 through 11 display the three trendlines for the jurisdictions in the Metropolitan Washington DC, (DC-MD-VA) non-attainment area, and they also display the adopted trendline for each jurisdiction for the purpose of developing vehicle population projections.



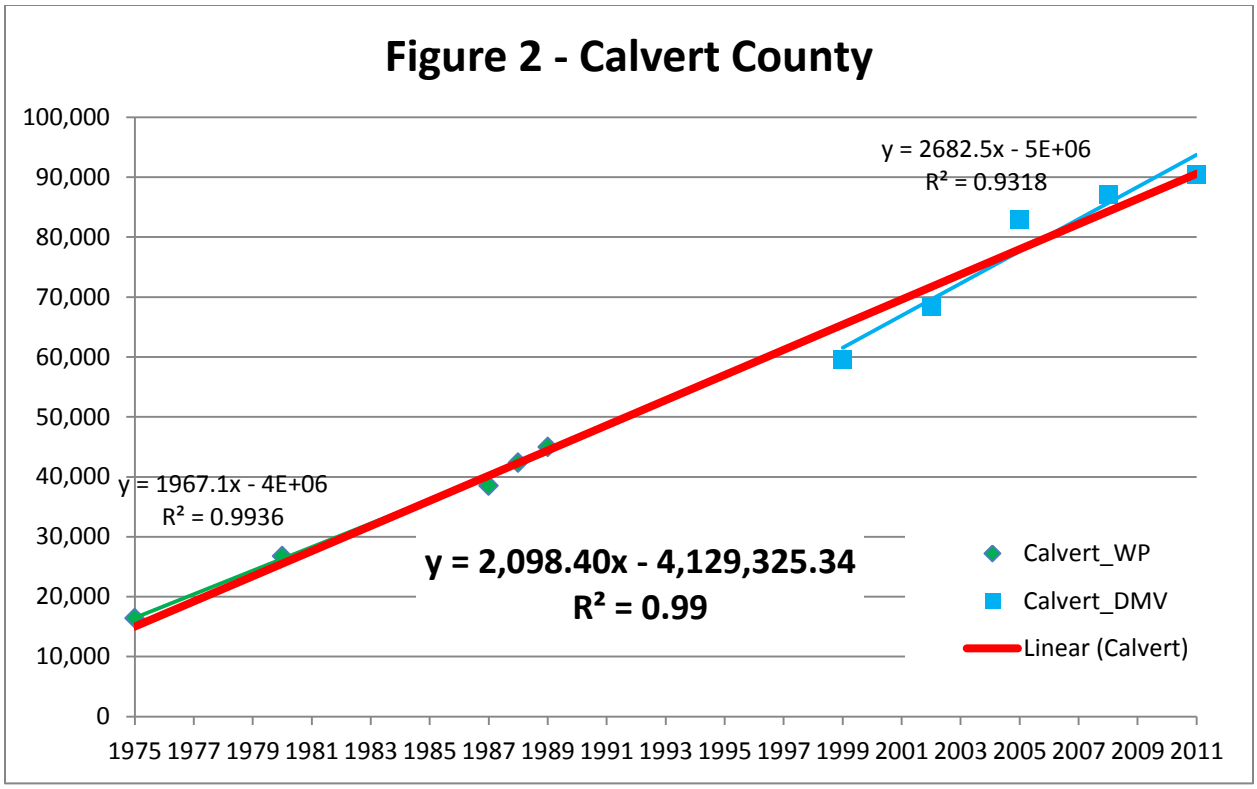


Figure 2 - Calvert County
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 2682.5x - 5E+06
R² = 0.9318
y = 1967.1x - 4E+06
R² = 0.9936
y = 2,098.40x - 4,129,325.34
R² = 0.99
Calvert_WP
Calvert_DMV
Linear (Calvert)

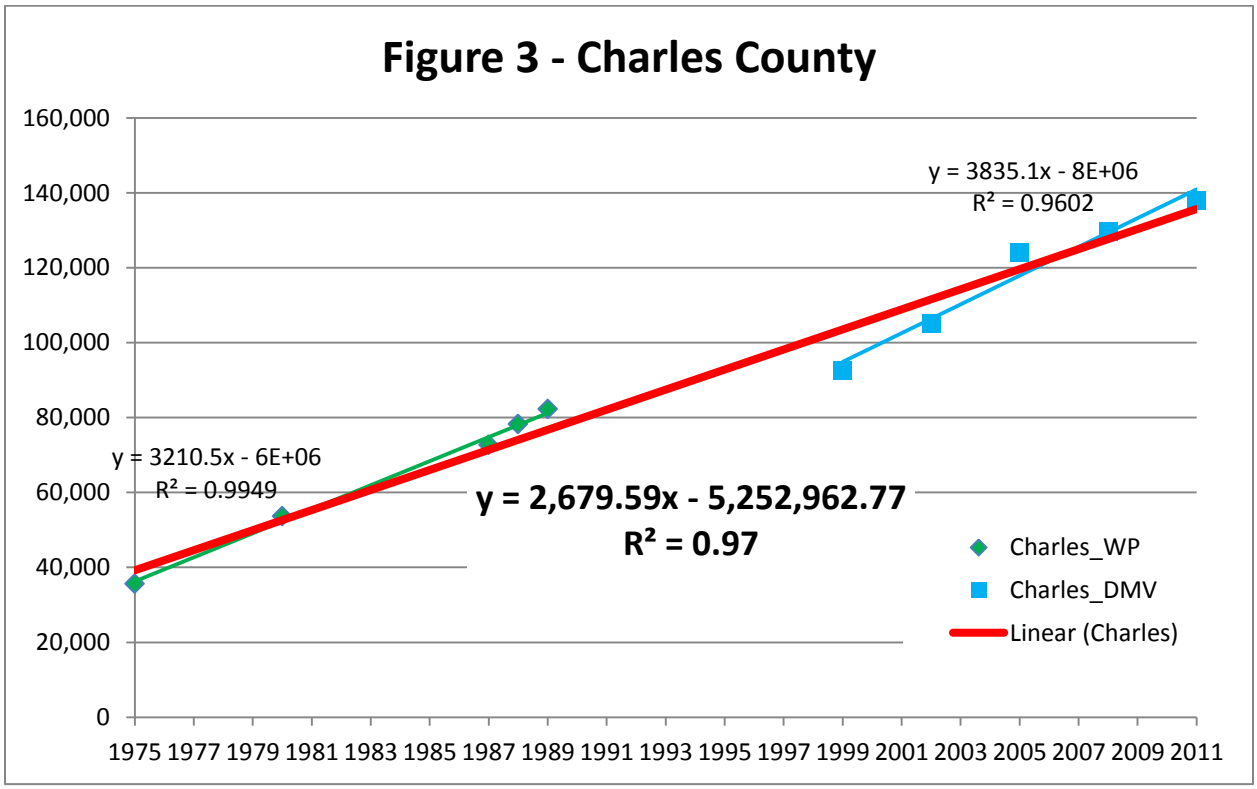


Figure 3 - Charles County
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 3835.1x - 8E+06
R² = 0.9602
y = 3210.5x - 6E+06
R² = 0.9949
y = 2,679.59x - 5,252,962.77
R² = 0.97
Charles_WP
Charles_DMV
Linear (Charles)

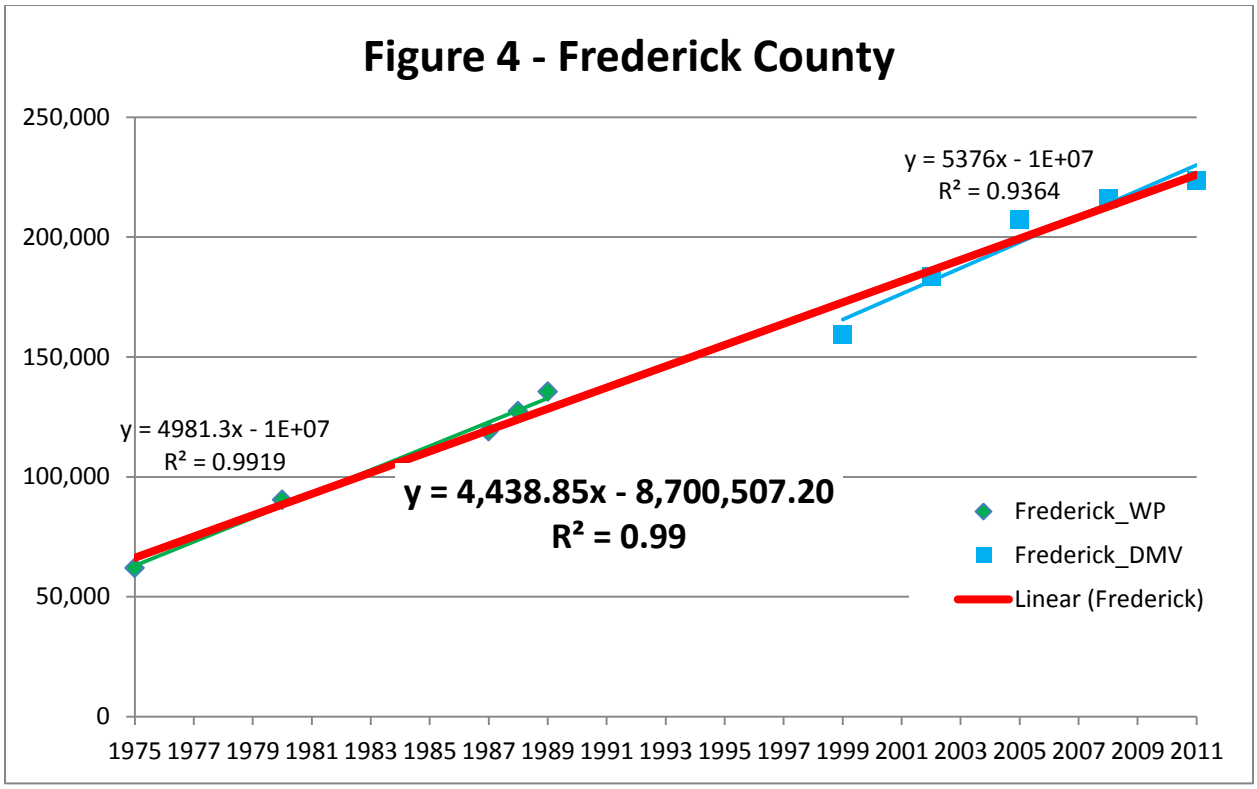


Figure 4 - Frederick County
250,000
200,000
150,000
100,000
50,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 5376x - 1E+07
R² = 0.9364
y = 4981.3x - 1E+07
R² = 0.9919
y = 4,438.85x - 8,700,507.20
R² = 0.99
Frederick_WP
Frederick_DMV
Linear (Frederick)

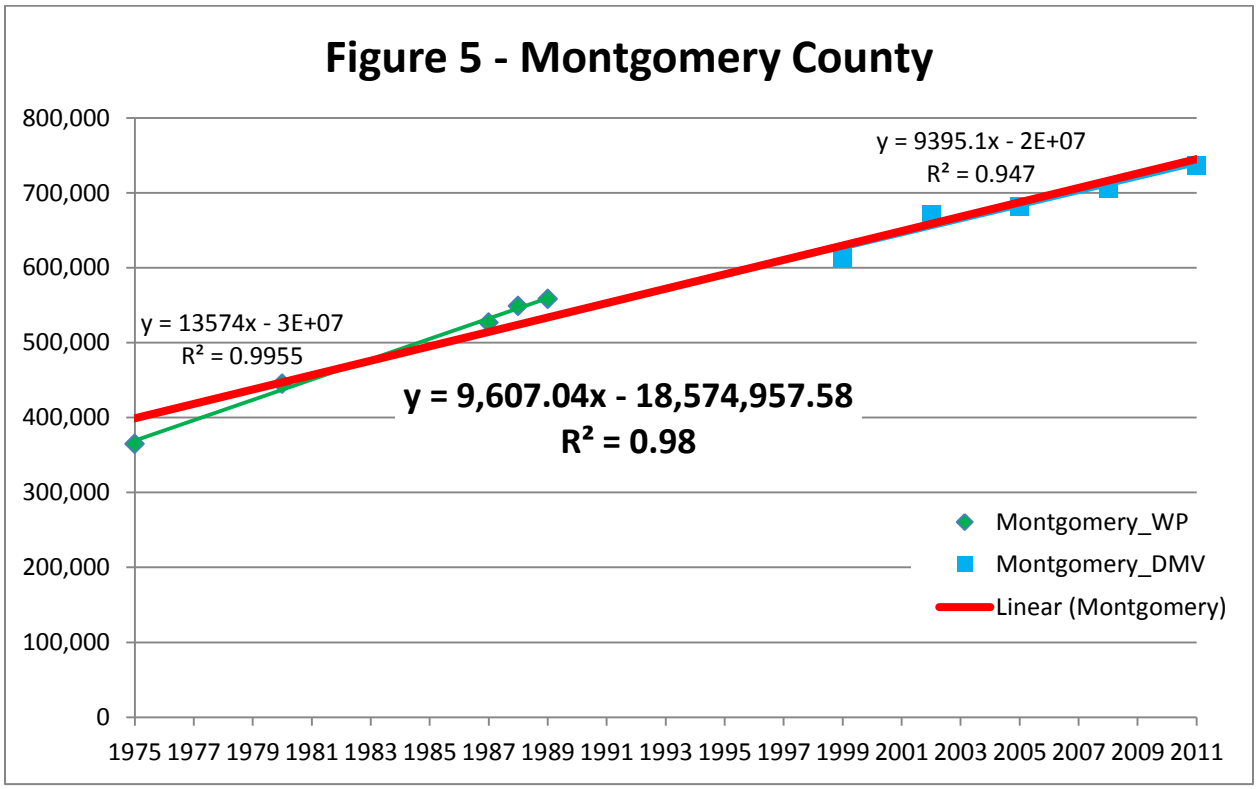


Figure 5 - Montgomery County
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 9395.1x - 2E+07
R² = 0.947
y = 13574x - 3E+07
R² = 0.9955
y = 9,607.04x - 18,574,957.58
R² = 0.98
Montgomery_WP
Montgomery_DMV
Linear (Montgomery)

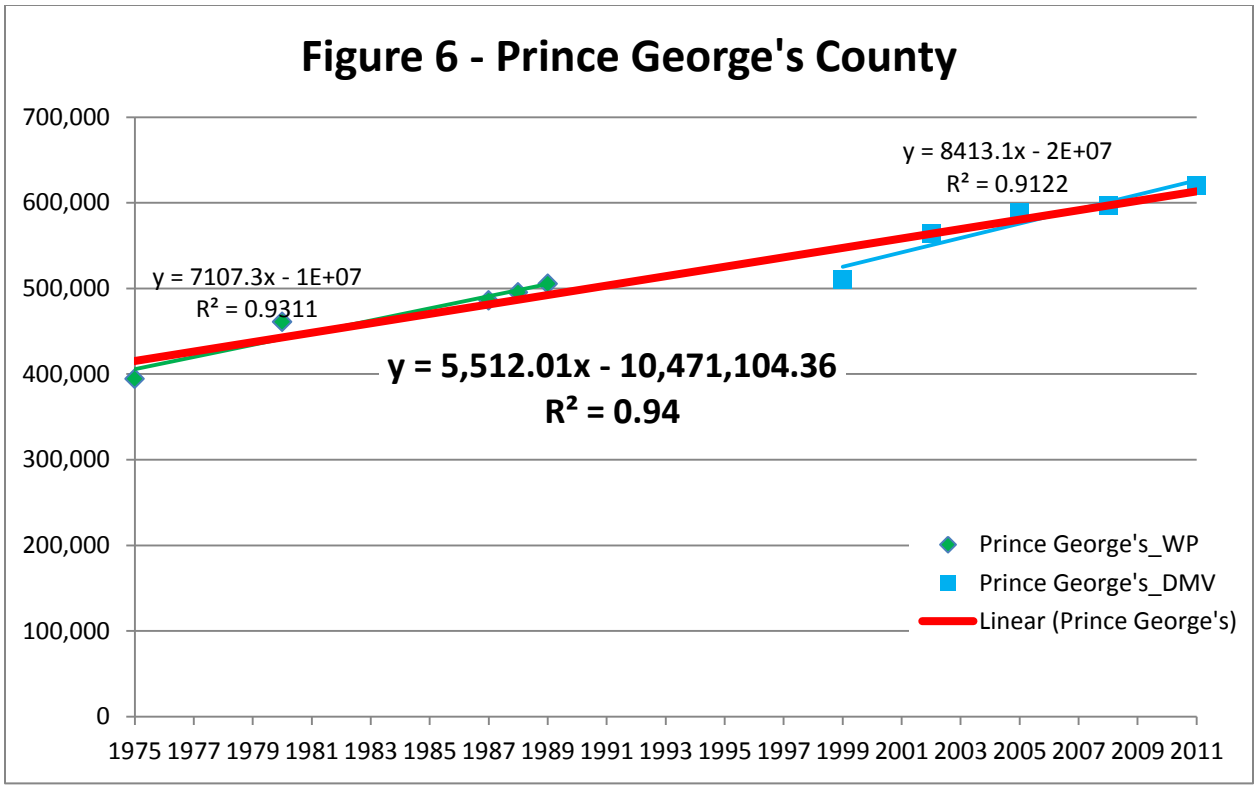


Figure 6 - Prince George's County
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 8413.1x - 2E+07
R² = 0.9122
y = 7107.3x - 1E+07
R² = 0.9311
y = 5,512.01x - 10,471,104.36
R² = 0.94
Prince George's_WP
Prince George's_DMV
Linear (Prince George's)

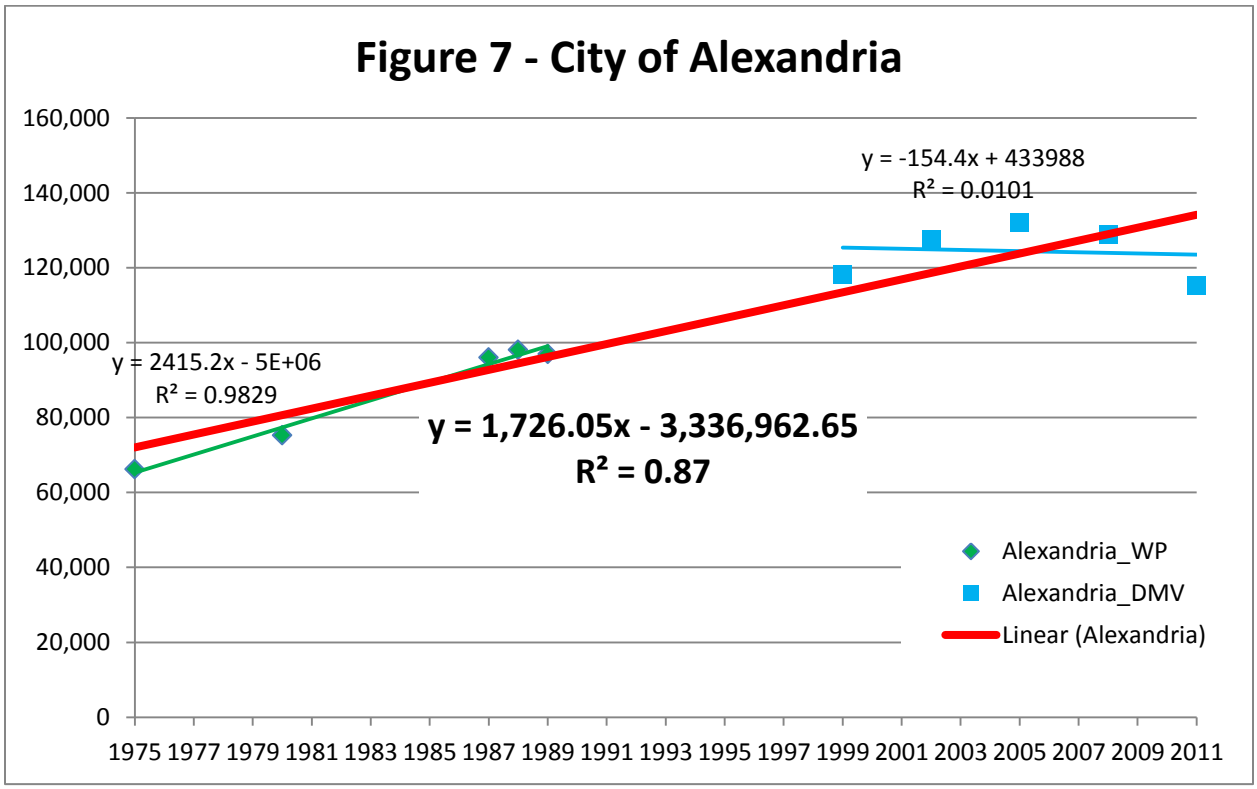


Figure 7 - City of Alexandria
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = -154.4x + 433988
R² = 0.0101
y = 2415.2x - 5E+06
R² = 0.9829
y = 1,726.05x - 3,336,962.65
R² = 0.87
Alexandria_WP
Alexandria_DMV
Linear (Alexandria)

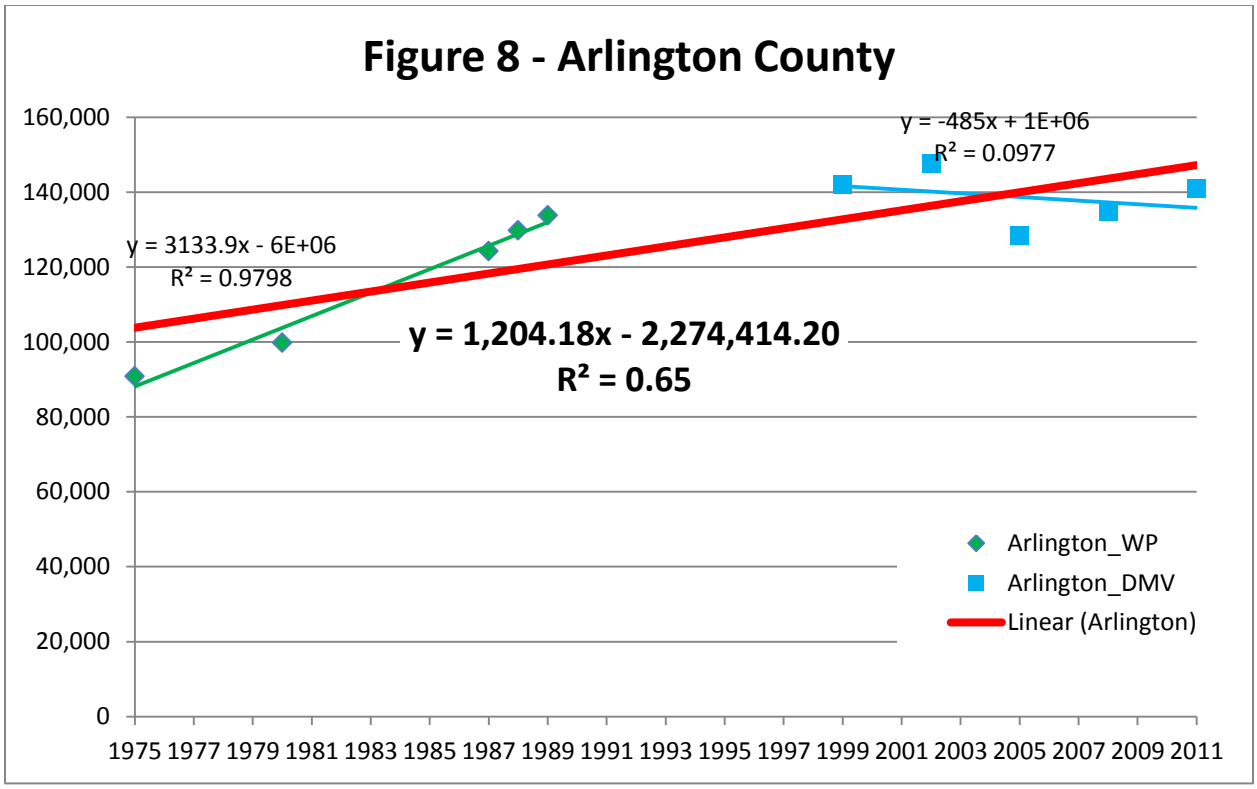


Figure 8 - Arlington County
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
y = -485x + 1E+06
R² = 0.0977
y = 3133.9x - 6E+06
R² = 0.9798
y = 1,204.18x - 2,274,414.20
R² = 0.65
Arlington_WP
Arlington_DMV
Linear (Arlington)
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011

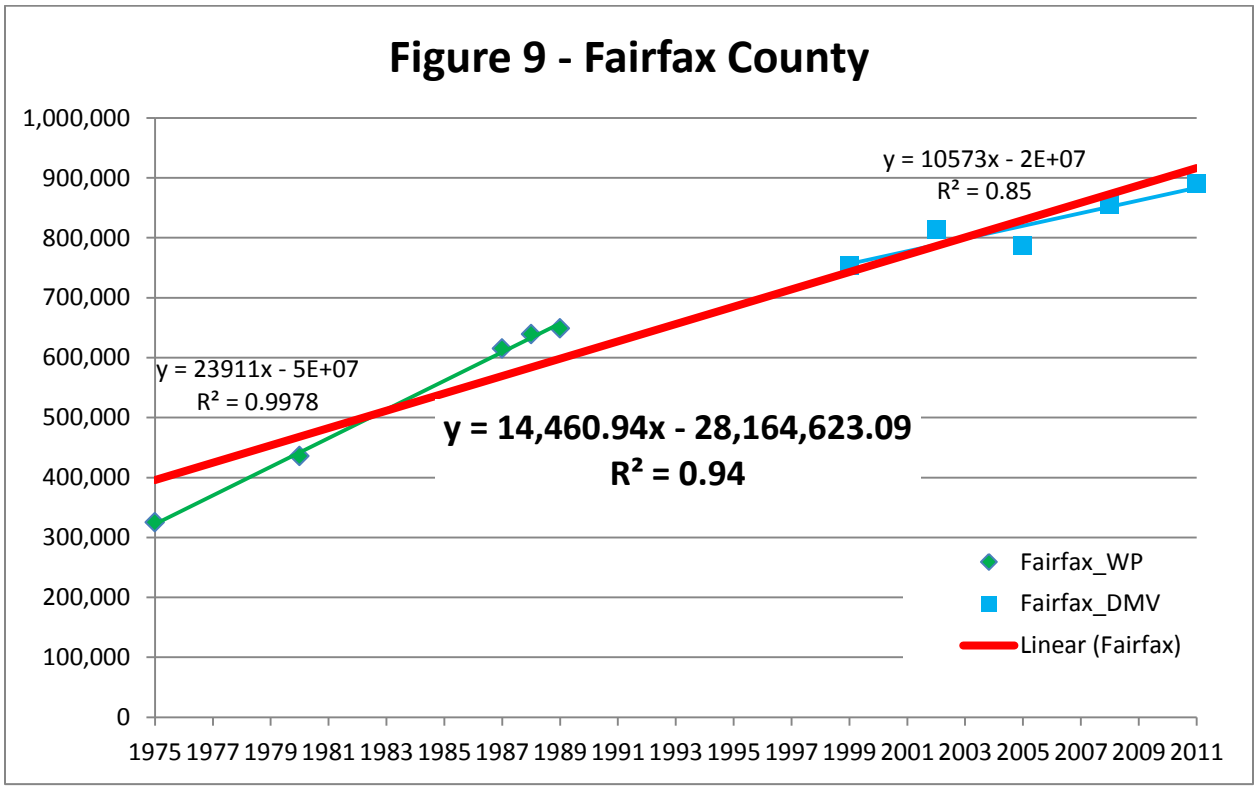


Figure 9 - Fairfax County
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
y = 10573x - 2E+07
R² = 0.85
y = 23911x - 5E+07
R² = 0.9978
y = 14,460.94x - 28,164,623.09
R² = 0.94
Fairfax_WP
Fairfax_DMV
Linear (Fairfax)
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011

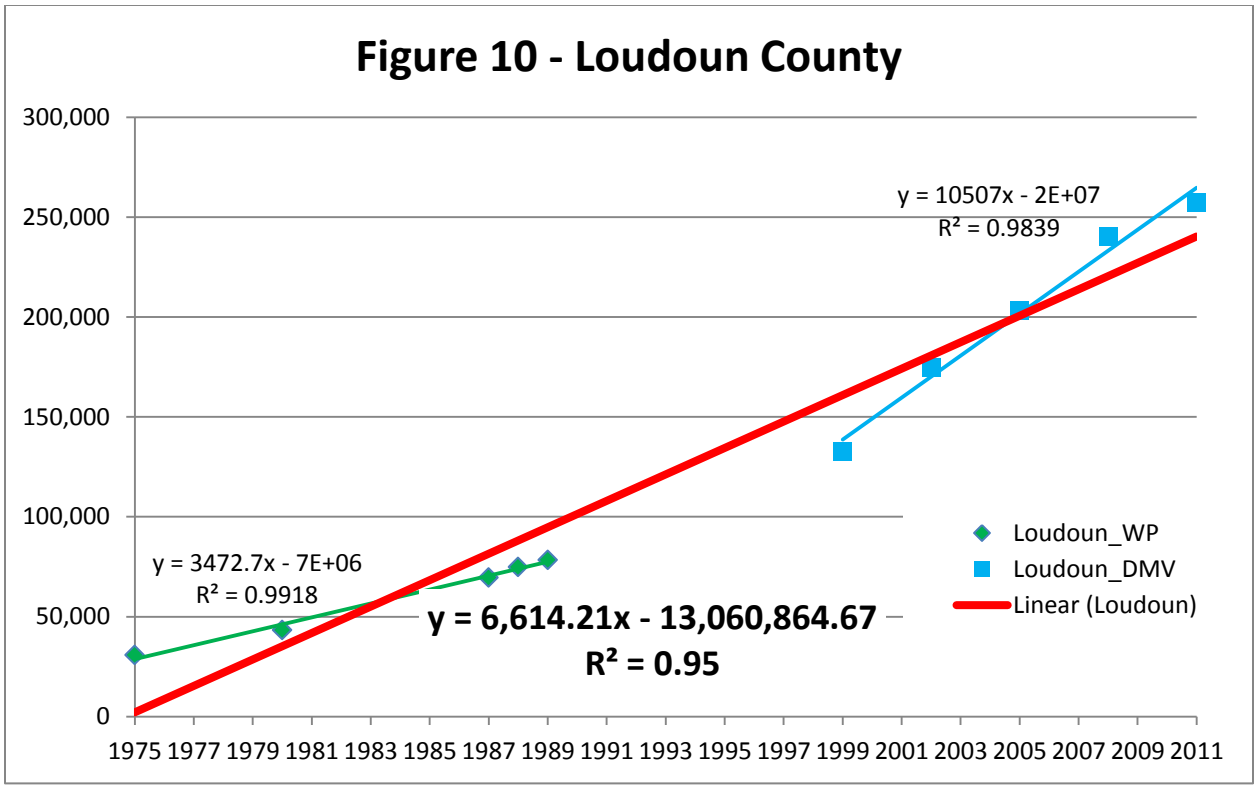


Figure 10 - Loudoun County
300,000
250,000
200,000
150,000
100,000
50,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 10507x - 2E+07
R² = 0.9839
y = 3472.7x - 7E+06
R² = 0.9918
y = 6,614.21x - 13,060,864.67
R² = 0.95
Loudoun_WP
Loudoun_DMV
Linear (Loudoun)

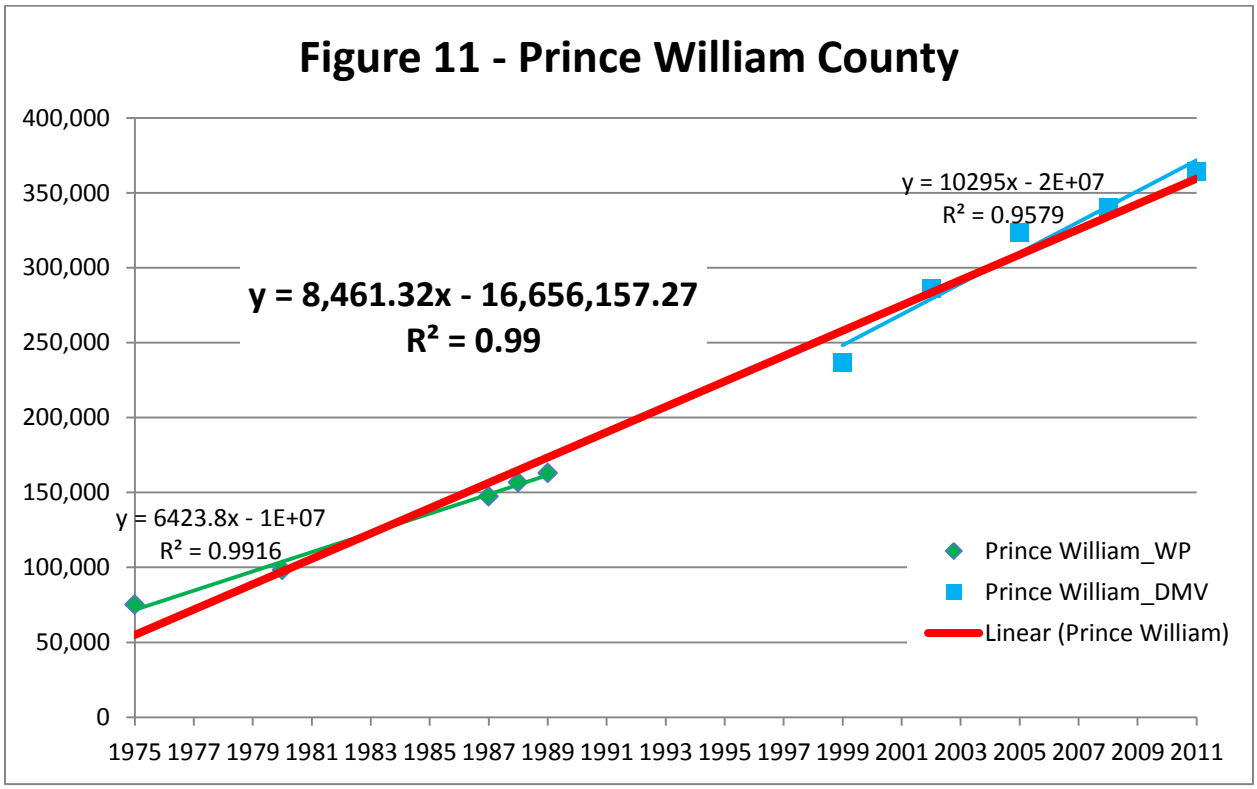


Figure 11 - Prince William County
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
y = 10295x - 2E+07
R² = 0.9579
y = 8,461.32x - 16,656,157.27
R² = 0.99
y = 6423.8x - 1E+07
R² = 0.9916
Prince William_WP
Prince William_DMV
Linear (Prince William)

COMPARATIVE ANALYSIS OF THE TWO PROCESSES

In order to assess the potential impacts of the updated process, a comparative analysis of the two processes was undertaken. Differences resulting by applying the two processes on mobile emissions and vehicle population projections for the analysis years of the 2014 CLRP and FY2015-2020 TIP air quality conformity assessment were evaluated They are documented below.

1. Impacts on Mobile Emissions Projections

The impacts of the updated process on mobile emissions are marginal on a regional scale. The emissions estimates obtained using the updated process for developing future year vehicle population projections are close, and statistically no different, to the estimates obtained using the vehicle population forecasts produced by the previous process. Both the Ozone precursors (VOC and NO_x), and the $PM_{2.5}$ precursors ($PM_{2.5}$ and NO_x) estimates are lower by less than 1% in 2015 and 2017. The same holds true for 2040 with the exception that Ozone Day VOC is about 3.7% lower. A similar trend can be observed with Wintertime Carbon Monoxide (CO) in 2017 and 2040 with the exception of 2015 where a 0.2% increase is observed. The results of the analysis are shown in Table 2.

TABLE 2 - COMPARATIVE ANALYSIS OF THE TWO PROCESSES

Impacts on Mobile Emissions Projections

Pollutant	Updated	Previous	Difference	Updated/Previous
2015				
Ozone Day NO_X (t/d)	131.9	132.04	-0.13	99.9%
Ozone Day VOC (t/d)	58.52	58.79	-0.27	99.5%
Annual Precursor NO_X (t/y)	46,115.39	46,155.39	-40.00	99.9%
Annual $PM_{2.5}$ (t/y)	1,926.40	1,927.52	-1.12	99.9%
Winter CO (t/d)	494.12	493.14	0.98	100.2%
2017				
Ozone Day NO_X (t/d)	103.13	103.34	-0.21	99.8%
Ozone Day VOC (t/d)	49.84	50.29	-0.45	99.1%
Annual Precursor NO_X (t/y)	36,095.40	36,165.67	-70.27	99.8%
Annual $PM_{2.5}$ (t/y)	1,695.51	1,697.60	-2.09	99.9%
Winter CO (t/d)	411.22	411.59	-0.37	99.9%
2040				
Ozone Day NO_X (t/d)	61.09	61.61	-0.52	99.2%
Ozone Day VOC (t/d)	39.88	41.42	-1.54	96.3%
Annual Precursor NO_X (t/y)	21,943.98	22,170.86	-226.88	99.0%
Annual $PM_{2.5}$ (t/y)	1,298.51	1,308.88	-10.37	99.2%
Winter CO (t/d)	381.26	391.04	-9.78	97.5%
Annual GHG (t/y)	26,722,145	26,785,300	-63,155	99.8%

2. Impacts on Vehicle Population Projections

The forecasts of the updated methodology are slightly lower than the previous method of forecasting vehicle population on a regional scale. The results of the analysis are shown in Table 3.

TABLE 3 - COMPARATIVE ANALYSIS OF THE TWO PROCESSES

Impacts on Vehicle Population Projections

Jurisdiction	2015		2017		2025		2030		2040	
	Updated	Previous	Updated	Previous	Updated	Previous	Updated	Previous	Updated	Previous
District of Columbia	294,342	283,338	301,618	285,814	330,723	295,720	348,914	301,912	385,295	314,294
Calvert Co.	98,950	104,560	103,147	111,660	119,934	140,061	130,426	157,812	151,410	193,314
Charles Co.	146,405	152,794	151,765	160,257	173,201	190,109	186,599	208,766	213,395	246,081
Frederick Co.	243,781	247,138	252,659	258,907	288,170	305,986	310,364	335,411	354,753	394,260
Montgomery Co.	783,222	798,923	802,436	829,896	879,293	953,787	927,328	1031218	1,023,398	1,186,082
Prince George's Co.	635,586	659,763	646,610	679,469	690,706	758,292	718,266	807557	773,386	906,086
City of Alexandria	141,034	117,262	144,486	118,284	158,295	122,376	166,925	124933	184,186	130,047
Arlington Co.	152,012	143,437	154,420	144,685	164,054	149,676	170,075	152,795	182,116	159,034
Fairfax Co.	974,175	953,012	1003096	984,298	1118784	1109444	1191089	1187660	1335698	1344093
Loudoun Co.	266,765	288,146	279,994	303,479	332,907	364,811	365,979	403,144	432,121	479,809
Prince William Co.	393,396	399,774	410,318	417,534	478,009	488,578	520,316	532,980	604,929	621,784
REGIONAL TOTAL	4129669	4148147	4250550	4294283	4734076	4878840	5036280	5244188	5640687	5974884
Updated/ Previous	99.5%		98.9%		97.0%		96.0%		94.4%	

Overall, the range of differences is between 0.5% and 5.6% on a regional scale. The same trend is observed in most jurisdictions in the region and for all analysis years. In general, the quality and reliability of the recent data in conjunction with well-known local demographic trends and changes in the regional economy and lifestyles, support the observed trend that yields marginally lower vehicle population projections for years 2015, 2017, 2025, 2030 and 2040 than previously forecasted.

An exception to this trend may be noticed in the District of Columbia, City of Alexandria, and Arlington County where the vehicle population projections using the updated process are higher than those of the previous process.

In case of the District of Columbia both sets of data (1975-1988; and 1999-2011) have an upward slope with the most recent data having a slightly steeper slope. As has been noted previously, the trendline

being used to develop future year vehicle population projections for the District of Columbia is based only on the most recent data set (i.e., 1999-2011).

In the cases of the City of Alexandria and Arlington County (Figures 7 and 8) there is a marked difference in the slope of the two sets of data: 1975-1988 and 1999 and 2011. The earlier data set indicates a steep slope of vehicle population while the more recent data set indicates a flatter trend. But in both cases the R^2 value of the latest data set is very low while the data set with a higher R^2 value is quite old. Combing both sets of data provides an acceptable R^2 value. Additionally the City of Alexandria and Arlington County data include vehicles at the National Airport which are not as closely correlated with the population and land use trends within the City.

CONCLUSIONS

1. The updated process at a regional level is based on a larger empirical data set, and uses a statistical method to provide future year vehicle population forecasts. This, in addition to the inherent higher degree of confidence in the forecasts, supports using the forecasts from the updated methodology.

    - ✓ This finding notwithstanding it is recognized that the differences in the old and new data sets in the City of Alexandria and Arlington County together with the low R^2 value would need to be further examined. This examination will continue as part of an existing inter-agency consultation process between the transportation and air agencies as well as the MWCOG Departments of Transportation and Environmental Planning.

2. The long-term advantages of the updated process are:

    - ✓ There are no “fixed” annual growth rates representative of a certain time period, which may become stale over time if they are not systematically monitored for relevance, and ultimately refreshed periodically

    - ✓ With the infusion of new vehicle registration data into the vehicle population database every three years, this updated database can be used to refresh the fit of the vehicle population trend line for each jurisdiction, thus resulting in updated future year vehicle population projections.