
# Developing Baseline Estimates to Support Safety Performance Management Targets: Virginia and North Carolina Experiences

## Session 5A: Data-Driven Approaches to Transportation Safety

Presented by
Scott Himes

December 12, 2019

# Acknowledgements


PennState

- Vikash Gayah

vhb

- Jeff Gooch

VDOT Virginia Department of Transportation

- Stephen Read
- Margie Ray
- Mark Cole

NORTH CAROLINA Department Of Transportation

- Chris Oliver
- Brian Mayhew
- Shawn Troy

# Agenda

- Background
- Predictive Model Considerations
- Data Collection
- Model Development
- Results
- Questions

# Background

- FHWA established Safety Performance Management Program (Safety PM) to support HSIP
- Safety PM established five performance measures
  - Number of fatalities
  - Rate of fatalities per 100 MVMT
  - Number of serious injuries
  - Rate of serious injuries per 100 MVMT
  - Number of non-motorized fatalities and serious injuries

# Background

- Baseline measures are calculated using a five-year rolling average

| Measure | 2013 | 2014 | 2015 | 2016 | 2017 | Baseline |
|---|---|---|---|---|---|---|
| Fatalities | 1,208 | 1,195 | 1,200 | 1,188 | 1,137 | 1,185.6 |
| Fatality Rate | 1.23 | 1.20 | 1.19 | 1.18 | 1.12 | 1.184 |

- Additionally, States are required to establish and report annual targets
  - Represent all roadways
  - Does not specify method for setting target

# Background

- Five-year trend commonly used
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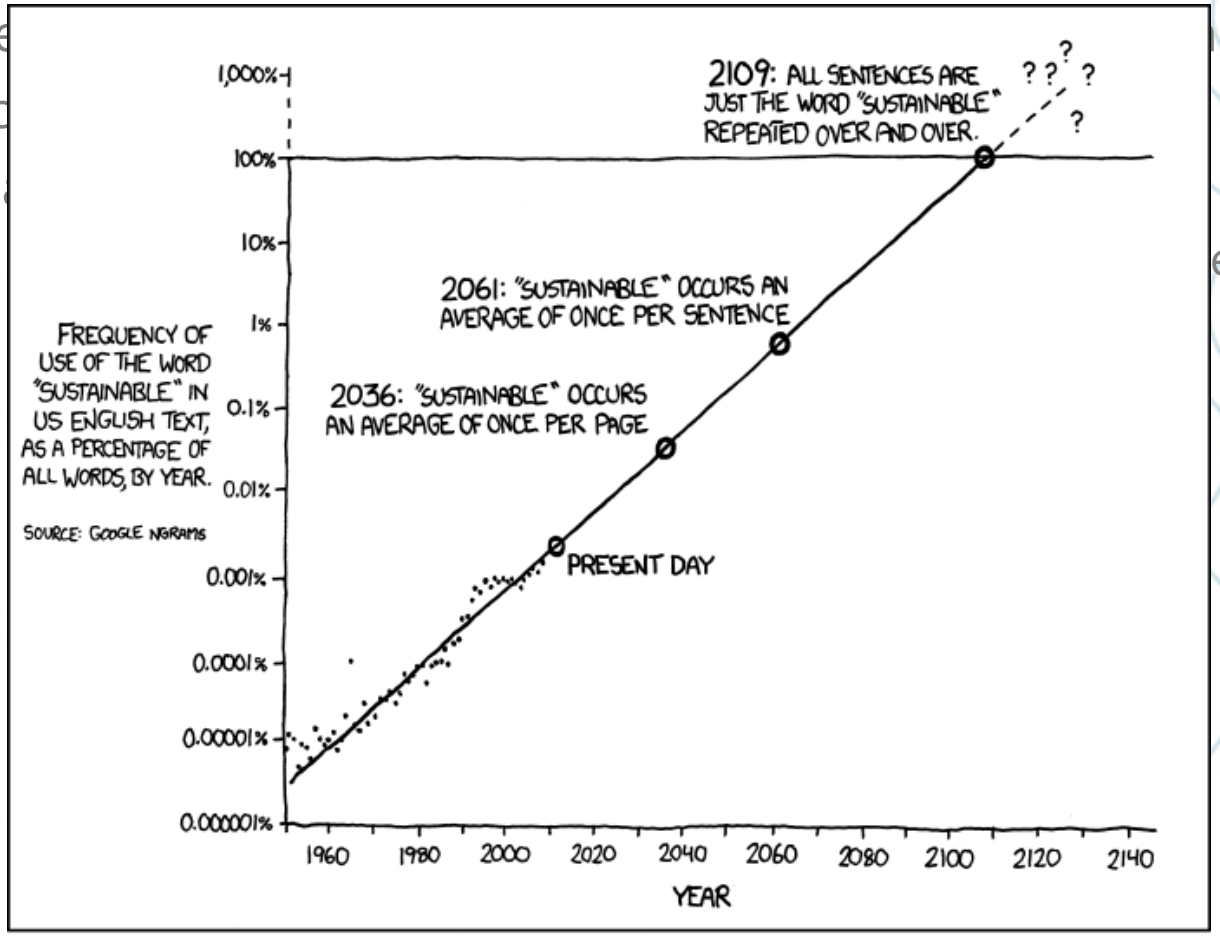
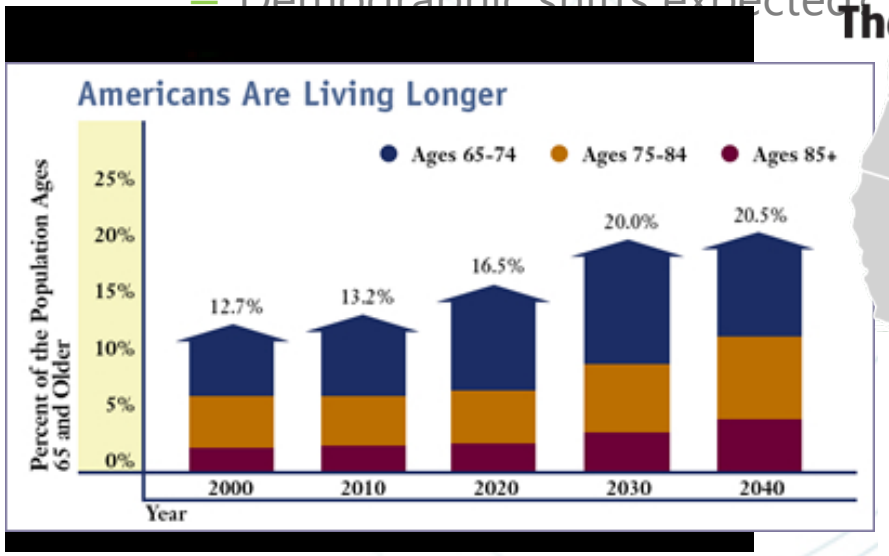


# Background

- Process used for data driven methodology
  - Develop prediction model for baselines
    - Number of fatalities
    - Number of serious injuries
    - Number of non-motorizes fatalities and serious injuries
  - Withhold most recent year for validation
  - Forecast inputs to develop predicted baseline for target year
  - Evaluate programmed projects and behavioral program for potential impact to baseline (VDOT)

# Predictive Model Considerations

- Regression models use historic trend information
- If no significant changes anticipated, should not deviate greatly from trend line
- Models flexibly consider breaks in trends
  - Gas prices expected to drop?
  - Significant change in demand
  - Demographic shifts expected?

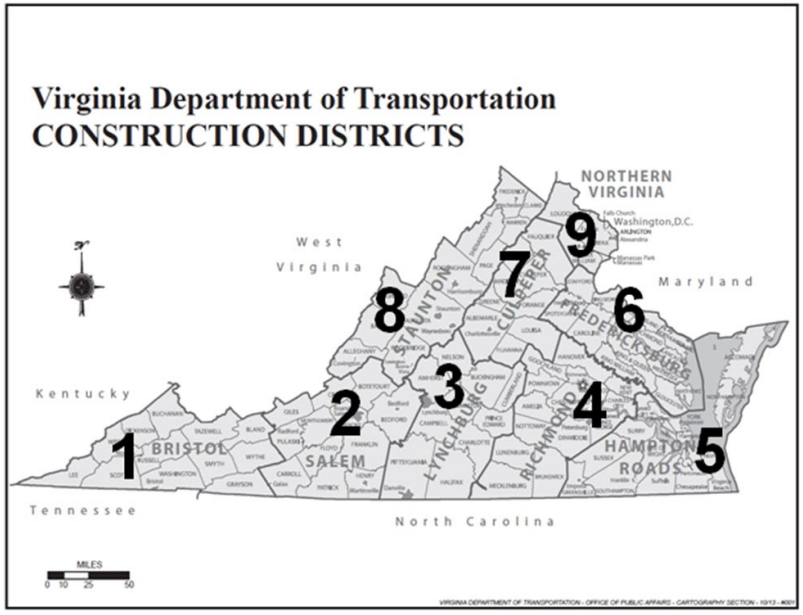


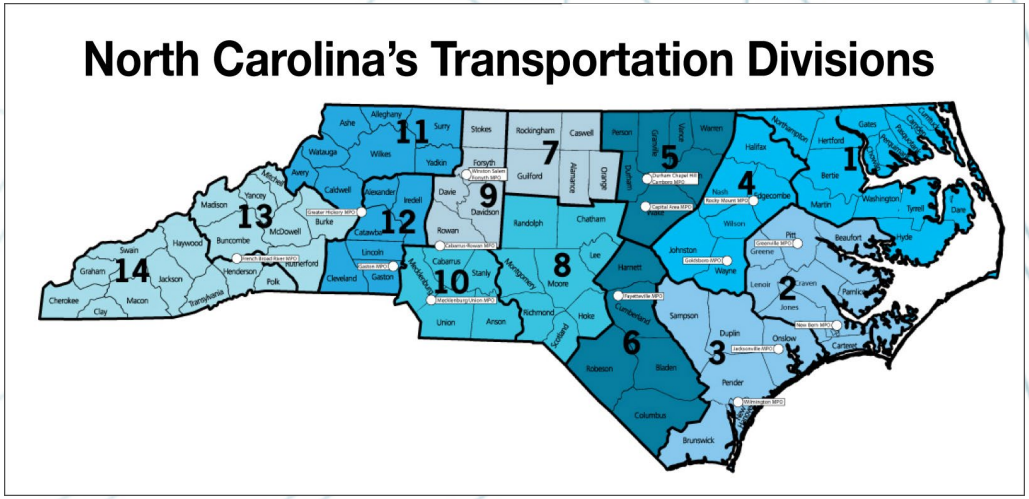

*Flood of Oil Is Coming, Complicating Efforts to Fight Global Warming*


HOUSTON — A surge of oil production is coming, whether the world needs it or not.

# Predictive Model Considerations

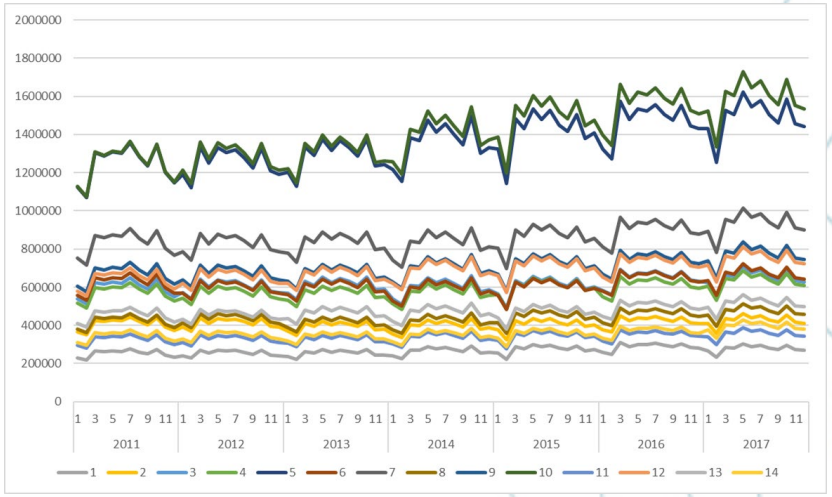
- Sample size
  - Spatial aggregation
  - Temporal aggregation
- Spatial and temporal correlation
- Macro-level models for independent (somewhat) rare events



# Data Collection

- VMT
  - County level
  - Division level




- VMT Type
  - Proportion
  - Area type
  - Functional class

| Division | Prop Rural | Prop Local | Prop Collector | Prop Interstate |
|---|---|---|---|---|
| 1 | 0.82 | 0.14 | 0.32 | 0.05 |
| 2 | 0.53 | 0.15 | 0.34 | 0.03 |
| 3 | 0.53 | 0.23 | 0.22 | 0.09 |
| 4 | 0.62 | 0.13 | 0.27 | 0.30 |
| 5 | 0.13 | 0.22 | 0.20 | 0.24 |
| 6 | 0.54 | 0.17 | 0.28 | 0.20 |
| 7 | 0.25 | 0.17 | 0.21 | 0.32 |
| 8 | 0.60 | 0.15 | 0.24 | 0.14 |
| 9 | 0.22 | 0.24 | 0.16 | 0.23 |
| 10 | 0.12 | 0.28 | 0.17 | 0.27 |
| 11 | 0.71 | 0.25 | 0.22 | 0.15 |
| 12 | 0.36 | 0.18 | 0.22 | 0.28 |
| 13 | 0.32 | 0.19 | 0.19 | 0.32 |
| 14 | 0.58 | 0.20 | 0.17 | 0.22 |

# Other Data Items

- Proportion of licensed drivers by age category
  - Younger:
    - 15 – 19 years
    - 15 – 24 years
    - 15 – 29 years
  - Older:
    - 55 plus years
    - 65 plus years
    - 75 plus years
    - 85 plus years
  - Statewide/division
  - Annual-level

# Other Data Items

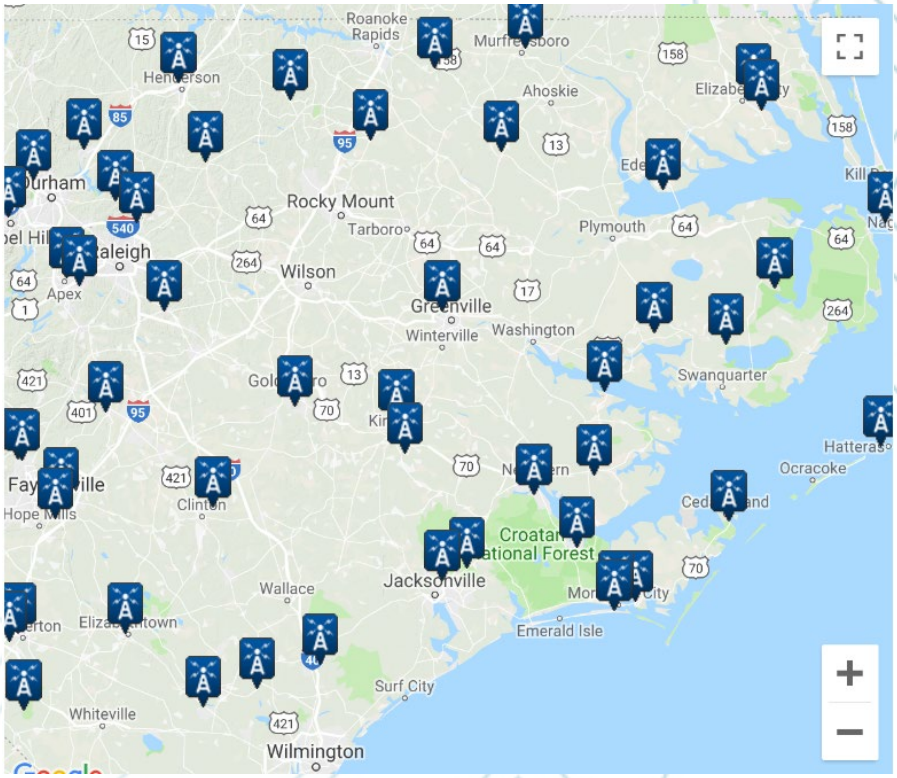
- Population proportion by age category
  - Younger:
    - 15 – 19 years
    - 15 – 24 years
    - 15 – 29 years
  - Older:
    - 55 plus years
    - 65 plus years
    - 75 plus years
    - 85 plus years
  - County/Division-level
  - Annual-level

# Other Data Items

- Unemployment proportion by age category
  - Total proportion unemployed
  - Younger:
    - 16 – 19 years
    - 16 – 24 years
  - Older:
    - 55 plus years
    - 65 plus years
    - 75 plus years
  - County/Division-level
  - Annual-level


# Data Items – Precipitation

- Inches of precipitation
- Inches of snowfall
  - Both monthly totals
  - Average for the division
  - NOAA data



# Data Items – VDOT Specific

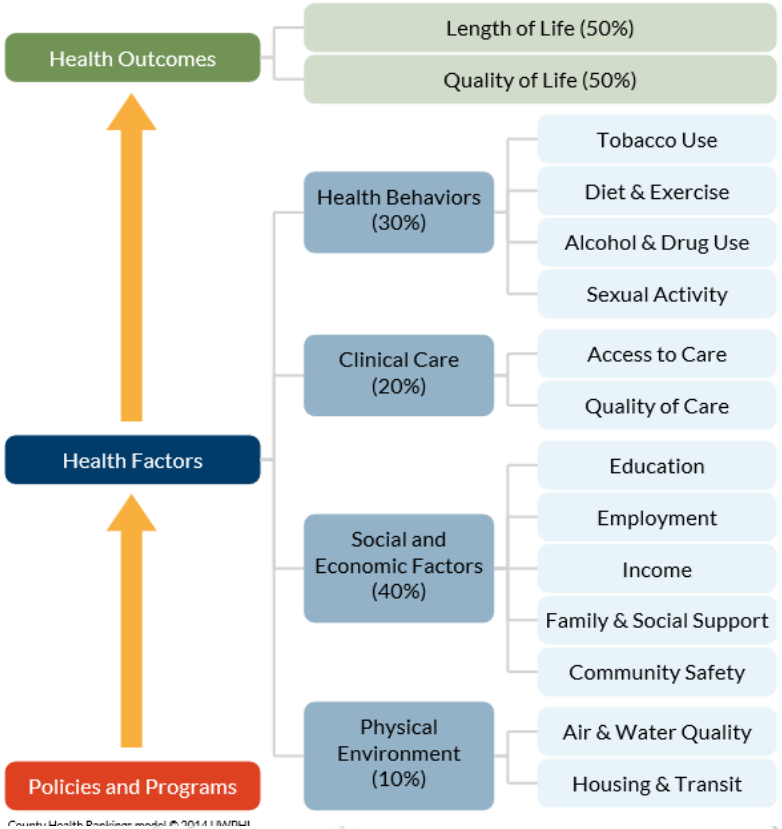
- ABC sales
- ABC number of liquor licenses
- Construction-related spending
- Maintenance-related spending
- Behavioral-related spending


| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bristol | Traffic and Safety | Guardrail and Traffic Barriers | Guardrail and Traffic Barriers | 28,104 | 18,219 | 20,562 | 4,986 | 49,162 | 3,689 | 53,343 | 35,678 | 34,088 | 5,890 | 118,766 | 1,997 |
| Bristol | Traffic and Safety | | TAMS | 63,031 | 63,031 | 63,031 | 63,031 | 63,031 | 63,031 | - | 126,063 | 69,334 | 63,031 | 63,031 | 63,031 |
| Bristol | Traffic and Safety | | UPC-Guardrail and Traffic Barriers | 41,910 | 89,293 | 19,793 | 60,862 | 26,075 | 31,833 | 20,148 | (0) | 55,898 | 22,414 | ######## | 23,161 |
| Bristol | Traffic and Safety | | UPC-Guardrail Hits | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | | UPC-MASH | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | Lights | Lights | 2,970 | 1,519 | 2,347 | 2,755 | 3,164 | 485 | 5,472 | 5,933 | 635 | 17,096 | 7,229 | 11,423 |
| Bristol | Traffic and Safety | Markings, Markers and Messag | Pavement Markers | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | | Pavement Markings | 89,878 | 146,810 | 81,324 | 72,165 | 46,688 | 46,739 | 102,915 | 45,554 | 33,428 | 51,075 | 81,278 | 111,213 |
| Bristol | Traffic and Safety | | TAMS | 6,303 | 6,303 | 6,303 | 6,303 | 6,303 | 6,303 | - | 12,606 | - | 6,303 | 6,303 | 6,303 |
| Bristol | Traffic and Safety | | UPC-Markings, Markers and Message | 177,780 | 223,769 | 502,991 | 30,073 | 9,746 | - | 232 | 594 | 1,961 | 54 | 122 | 7,873 |
| Bristol | Traffic and Safety | Miscellaneous Traffic and Safe | Payments to Railroads | - | - | - | - | 19,883 | - | - | 22,822 | 11,659 | 29,109 | 155 | 117,889 |
| Bristol | Traffic and Safety | | Traffic and Operations Structure Insp | - | - | - | - | - | - | - | - | - | - | - | 11,514 |
| Bristol | Traffic and Safety | | Traffic Counts Program | - | - | - | - | 1,631 | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | | Traffic Engineering Studies | 23,013 | 27,234 | 17,055 | 63,332 | 42,380 | 16,419 | 12,973 | 22,600 | 16,478 | 26,716 | 27,676 | 16,455 |
| Bristol | Traffic and Safety | | UPC-Traffic Engineering Studies | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | Signals | Signals | 232,910 | 55,653 | 64,002 | 168,625 | 50,651 | 108,347 | 109,373 | 175,091 | 87,326 | 142,894 | 58,824 | 184,631 |
| Bristol | Traffic and Safety | | Traffic Signal Optimization | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | | Traffic Signal Sys Pln & Eng | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | | UPC-Signal Studies | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | | UPC-Signals | - | - | - | - | - | - | - | - | - | - | - | - |
| Bristol | Traffic and Safety | Signs | Integrated Directional Signing | - | 54 | - | - | - | - | - | - | 503 | - | - | - |
| Bristol | Traffic and Safety | | Signs | 175,246 | 138,883 | 148,228 | 122,405 | 140,469 | 61,350 | 90,798 | 107,802 | 142,975 | 151,268 | 168,724 | 292,845 |
| Bristol | Traffic and Safety | | TAMS | 31,516 | 31,516 | 31,516 | 31,516 | 31,516 | 31,516 | - | 63,031 | 31,516 | 31,516 | 31,516 | 31,516 |
| Bristol | Traffic and Safety | | UPC-Signs | - | 65,266 | 4,256 | - | 177,018 | - | 313,887 | 103,483 | - | - | 488,238 | 106,569 |
| | | | | 872,661 | 867,549 | 961,409 | 626,052 | 667,718 | 369,712 | 709,141 | 721,256 | 485,801 | 547,367 | 934,699 | 986,418 |

| All Behaviors | | Funding | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| District | District Name | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| 1 | Bristol | $1,391,218 | $1,622,523 | $1,634,712 | $1,367,801 | $1,341,852 | $1,040,392 | $1,122,191 | $1,180,753 | $1,239,315 | $1,308,237 | $1,145,986 |
| 2 | Salem | $2,044,830 | $2,703,600 | $2,567,668 | $2,205,627 | $1,980,563 | $1,679,872 | $1,737,760 | $2,136,973 | $2,536,187 | $2,664,604 | $2,674,803 |
| 3 | Lynchburg | $1,173,011 | $1,464,547 | $1,366,058 | $1,178,723 | $1,147,287 | $966,185 | $1,003,324 | $1,057,060 | $1,110,796 | $1,278,232 | $1,187,965 |
| 4 | Richmond | $3,882,529 | $5,029,948 | $4,957,310 | $3,966,065 | $3,504,154 | $3,196,174 | $3,128,726 | $3,383,518 | $3,638,310 | $4,122,769 | $3,996,112 |
| 5 | Hampton Roads | $4,611,565 | $5,624,145 | $5,349,894 | $4,598,367 | $3,811,336 | $4,014,374 | $4,076,873 | $4,295,437 | $4,514,000 | $4,817,321 | $4,746,610 |
| 6 | Fredericksburg | $1,372,821 | $1,482,645 | $1,385,570 | $1,248,555 | $1,075,139 | $1,110,784 | $1,215,393 | $1,282,916 | $1,350,440 | $1,595,005 | $1,544,346 |
| 7 | Culpeper | $1,069,397 | $1,288,082 | $1,282,093 | $997,366 | $852,439 | $795,887 | $873,967 | $948,183 | $1,022,399 | $1,140,920 | $1,061,996 |
| 8 | Staunton | $1,500,278 | $1,766,686 | $1,824,490 | $1,486,436 | $1,229,361 | $1,184,743 | $1,239,532 | $1,326,138 | $1,412,743 | $1,579,854 | $1,525,062 |
| 9 | Northern Virginia | $4,687,195 | $5,890,563 | $5,439,569 | $4,803,971 | $4,309,395 | $4,844,287 | $4,623,944 | $5,516,616 | $6,409,287 | $8,310,682 | $8,487,467 |

# Data Items – County Health Rankings

- Provides a snapshot of how health is influenced by where we live
- Identifies challenges and opportunities to improve outcomes
- In our case, may help identify underlying or surrogate relationships (e.g., risk-taking)
- Data available from University of Wisconsin Public Health Institute



# Model Development

- Purpose of Input Variables
  - Identify macro-trends influencing performance measures
  - Account for confounding factors
  - Develop trend factors for unobserved influences
- Model Type and Considerations
  - Count regression model (negative binomial)
  - Correlations among predictors considered
  - One-way relations (e.g., variable only ever increases in study period)
  - Fixed and random effects considered for spatial and temporal correlation
- Validation
  - Most recent data excluded to verify model predictions

# Findings – Fatality Models

- Associated with increased fatalities
  - VMT
  - Proportion of licensed drivers 15 to 19 (or population 15 to 24)
  - Proportion of population 75 or older
  - Proportion VMT on local roads
  - Physical environment score (longer commute, more driving alone)

- Associated with decreased fatalities
  - Inches of snowfall
  - Increase in gas price (lagged 1 month)
  - Increase in percentage of high school graduates
  - Proportion of 16- to 24-year-olds unemployed
  - Annual highway maintenance spending
  - Emergency incident management spending (excluding snow removal)
  - Total behavioral-related spending

# Findings – Serious Injury Models

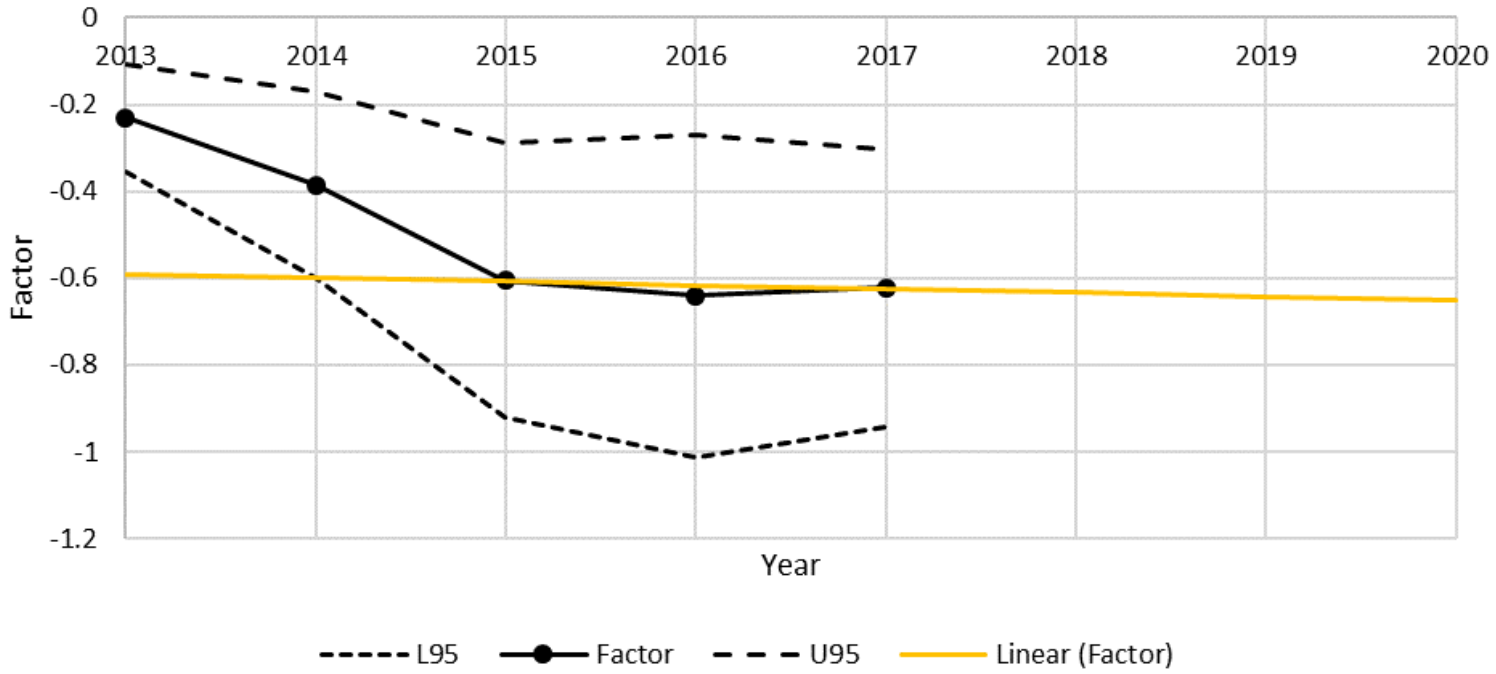
- Associated with increased serious injuries
  - VMT
  - Percentage of drivers who drive alone
  - Proportion of licensed drivers 15 to 19
  - Proportion of VMT on local roads
  - Proportion of population 75 or more years old
  - Change in serious injury description
- Associated with decreased serious injuries
  - Inches of snowfall
  - Increase in percentage of high school graduates
  - Proportion of 55-plus unemployed
  - Annual roadway maintenance spending (excluding bridges)

# Findings – Non-motorized KA Models

- Associated with increased NM-KAs
  - VMT
  - Proportion of population 15 to 19 years old
  - Proportion of population 75 years or older
  - Health behavioral score
  - Change in serious injury description
  - Proportion of VMT on local roads
  - Proportion of population 15 to 24 years old
  - Total number of liquor licenses
- Associated with decreased NM-KAs
  - Inches of snowfall
  - Increase in gas price (lagged 1 month)
  - Increase in percentage of high school graduates
  - Proportion of 65-plus unemployed
  - Proportion of VMT on rural roads
  - Total pedestrian and bicycle behavioral spending

# Annual Unobserved Trends

- Accounts for uncollected data elements
- Plotted over time to determine trend
- Can be difficult to forecast



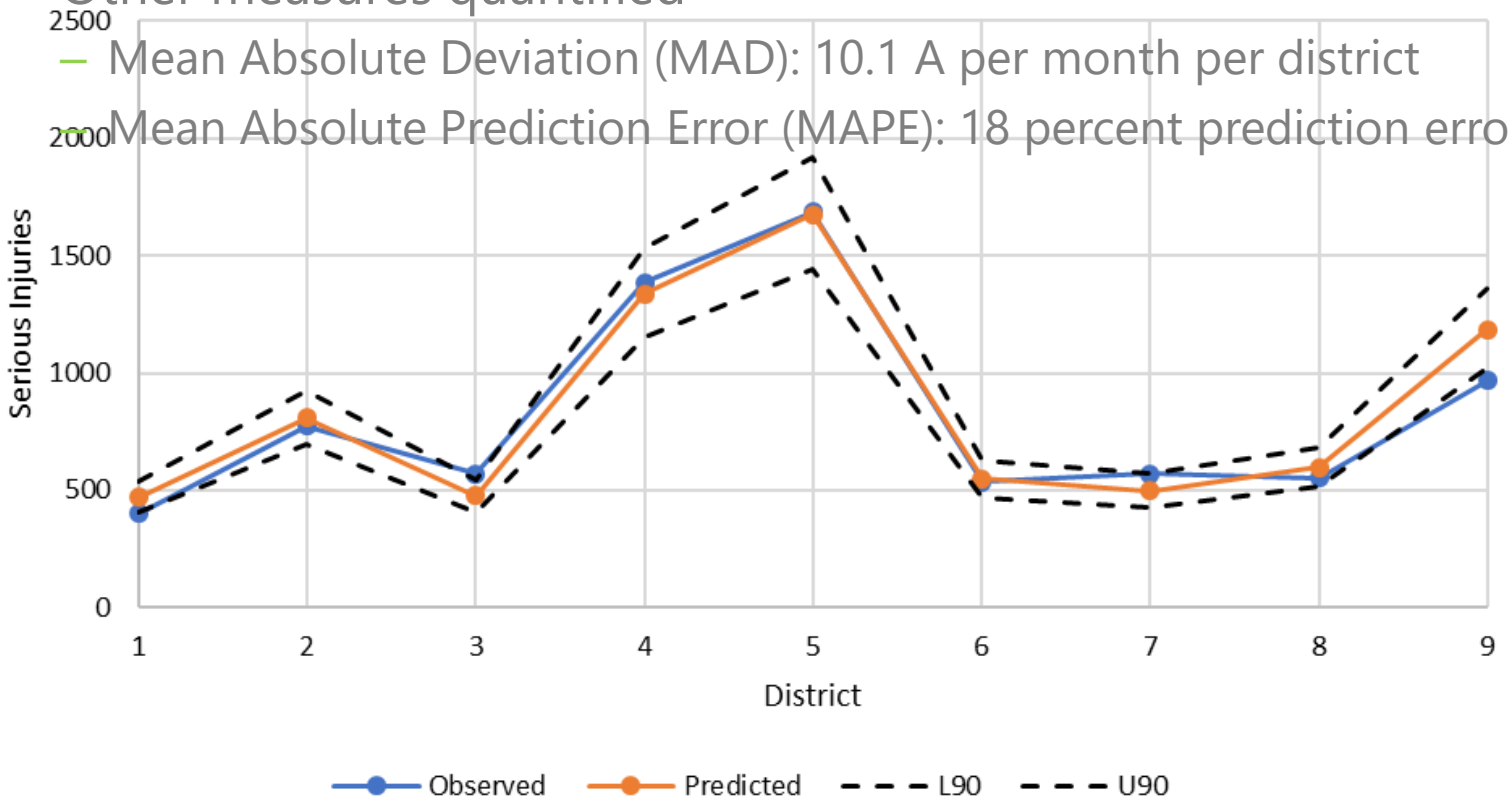
# Forecasting Based on Input Trends

- Forecasting includes making assumptions on future trends
- How will input variables look in the future?
- Trendline reasonable approach unless anticipating a change
- Example: VMT (Note 2018 was held constant from 2017)

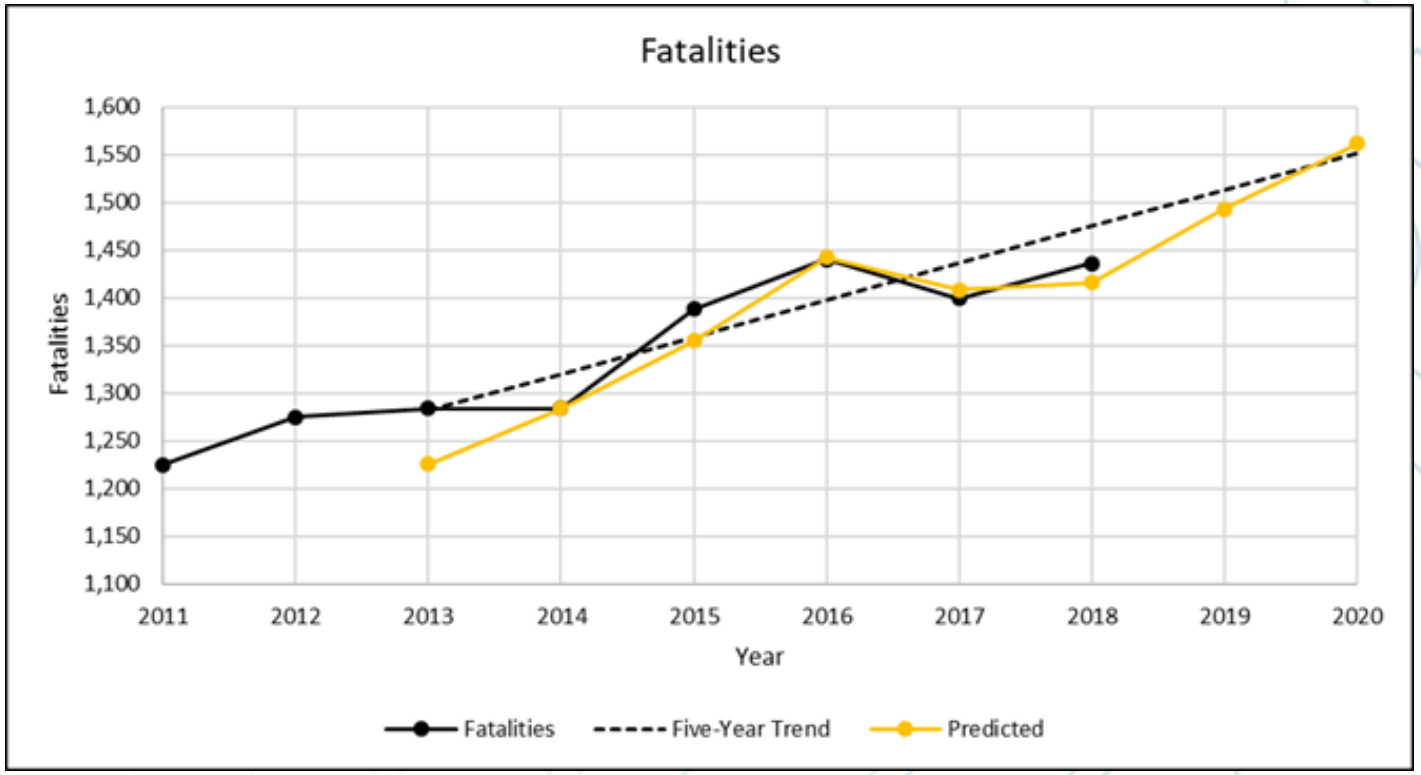
| District | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| 1 | 143.7 | 143.7 | 145.9 | 147.2 | 147.9 | 147.9 | 149.5 | 150.5 |
| 2 | 230.2 | 232.8 | 237.4 | 239.2 | 241.6 | 241.6 | 245.7 | 248.1 |
| 3 | 126.6 | 128.4 | 130.5 | 133.3 | 134.2 | 134.2 | 137.0 | 138.7 |
| 4 | 462.2 | 474.5 | 496.9 | 495.7 | 502.1 | 502.1 | 517.0 | 525.0 |
| 5 | 511.5 | 509.4 | 518.4 | 525.9 | 533.3 | 533.3 | 540.8 | 546.1 |
| 6 | 190.1 | 193.1 | 196.7 | 195.6 | 204.4 | 204.4 | 207.8 | 210.8 |
| 7 | 153.2 | 155.4 | 160.3 | 165.4 | 168.0 | 168.0 | 173.4 | 176.7 |
| 8 | 221.9 | 226.1 | 232.4 | 238.1 | 241.2 | 241.2 | 248.3 | 252.5 |
| 9 | 609.0 | 612.4 | 618.3 | 624.3 | 638.5 | 638.5 | 646.7 | 653.3 |
| Total | 2,648.4 | 2,675.8 | 2,736.9 | 2,764.6 | 2,811.2 | 2,811.2 | 2,866.2 | 2,901.8 |

# Validation Using 2018 Data

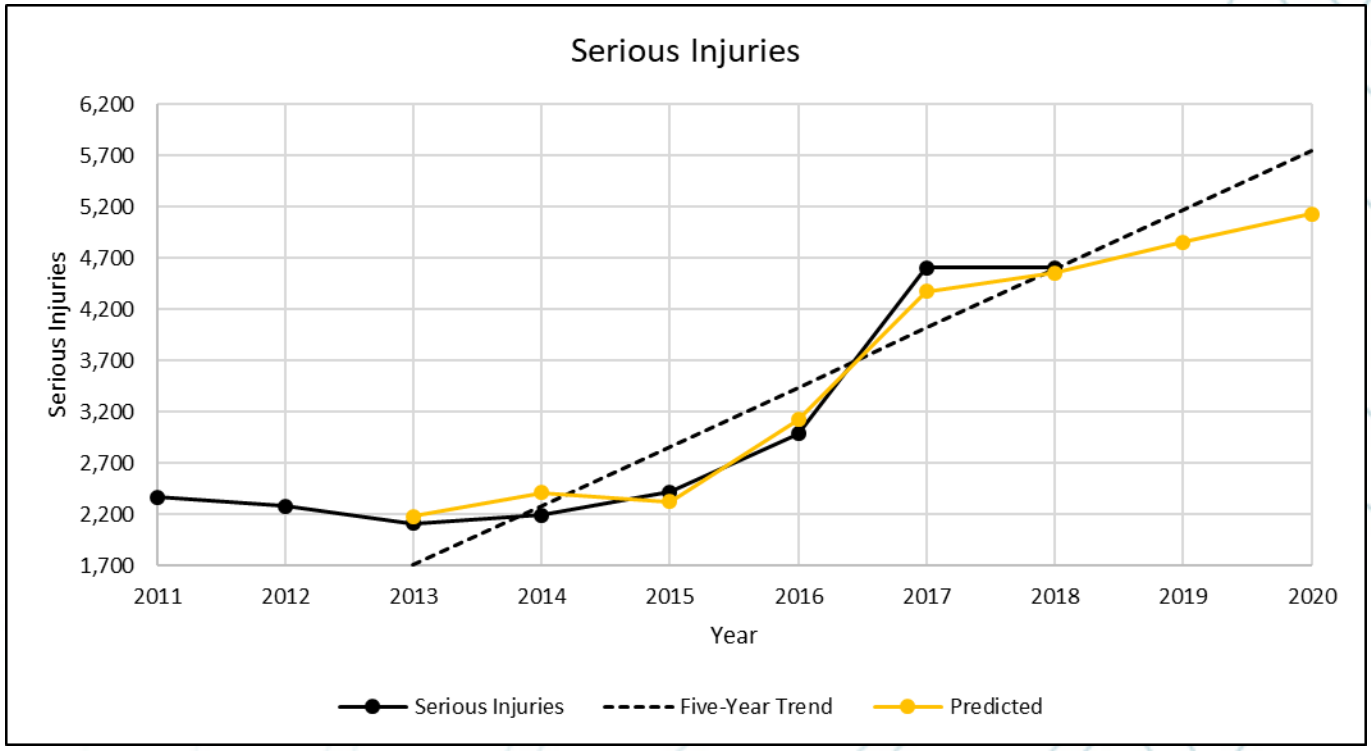
- Most recent data held back from models for validation
- Plots informative
- Other measures quantified
  - Mean Absolute Deviation (MAD): 10.1 A per month per district
  - Mean Absolute Prediction Error (MAPE): 18 percent prediction error



# Sample Forecast - Fatalities



# Sample Forecast – Serious Injuries



# Final Step

- Models provide baselines for measures assuming no changes
- Output can be adjusted for increased projects targeting measures
  - VDOT focusing on deep dive of planned projects
  - Deep dive highlights increased need for focus on systemic approach
- Caution should be used when scenario testing
  - Doubling safety-related spending
  - Shifting spending categories
- NC considering merits of model-based approach at this time

# Conclusions

- Data driven models more informative than rolling average
- Require more data and forecast assumptions
- Flexibility built in for scenario planning (with caution)
- Models should be updated annually
  - Increase sample size for models
  - Add variables as data become available or reliable
  - Identify shifts in trends as they occur

# Questions?


22 offices throughout the east coast
www.vhb.com

Scott Himes| shimes@vhb.com | 919.334.5608