Development of Safety Performance Functions for
Rural and Urban Arterials and Collectors for Network Screening

PREPARED FOR

PREPARED BY

UPDATED DECEMBER 2020

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Background

Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) are integral parts of the Highway Safety Manual (HSM) methods to support data-driven safety analysis. An SPF is a mathematical model that predicts the mean crash frequency for locations with similar characteristics. SPFs serve a number of functions, including the estimation of predicted crashes for a given site. Agencies can use these crash predictions alone or in combination with reported crash history (i.e., the Empirical Bayes method) to identify sites for further diagnosis. SPFs also support the economic analysis and safety evaluation steps in the roadway safety management process. While SPFs are available from a number of sources such as the HSM, CMF Clearinghouse, AASHTOWare Safety Analyst™, and state-specific reports, they are produced using data from specific locations and times. As such, the results may not be nationally applicable in their raw form. MassDOT calibrated the SPFs from the HSM to fit their local data, but the results suggested that state-specific SPFs may be more appropriate than calibrated national SPFs.

In 2017, MassDOT initiated a task to develop and integrate state-specific, planning-level SPFs in their roadway safety management process for network screening (i.e., selecting sites for further analysis from a larger group of sites). The primary data requirements to develop SPFs include quality crash, roadway, and traffic volume data for a large number of sites that represent the facility types of interest. Due to data limitations and data quality issues on interstates and local roads, MassDOT was not able to develop reliable SPFs for these facility types. Further, without an intersection inventory, MassDOT was not able to develop intersection SPFs. As such, this task focused on the development of planning-level segment SPFs for urban and rural arterials and collectors. This first SPF development effort resulted in the first version of "Development of Safety Performance Functions for Rural and Urban

Arterials and Collectors" in February 2018. In 2020, MassDOT initiated an effort to update the SPFs for rural and urban arterials and collectors. This report documents the development of these updated SPF and the results. The following sections are included in this report.

1. Data: description of data collected for this effort.
2. Methodology: brief description of the methodology used in SPF development and assessment process.
3. SPF Results: presentation of planning-level, segment-related SPFs for urban and rural arterials and collectors. This section presents the SPFs along with general summary statistics based on the underlying data.

The report also includes an appendix with the full model parameters and associated Cumulative Residual (CURE) Plots to provide interested readers with more detailed information.

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Data

VHB worked with MassDOT to obtain the data required for SPF development. The following sections describe the roadway, traffic, and crash data used for this assignment.

Roadway and Traffic Data

VHB obtained a roadway dataset based on the Q4 2019 version of the roadway network and segmentation. The data include key identifying variables such as route key, route system, route number, route direction, district, urban type, urban area, and functional classification. The data also include key geometric variables: segment length, number of lanes, number of opposing lanes, and median type. Traffic volumes were also included; however, a majority (about 60 percent) of segments in the dataset did not have a valid AADT value (i.e., value is either missing or entered as a default value).

The VHB team performed the following tasks to clean and process the data for SPF development:

1. Short segments: delete segments shorter than 0.05 miles.
2. Number of lanes: keep segments with 2 and 4 total lanes.
3. Median type: remove segments with missing median type, which is necessary to identify whether a segment is undivided or divided.
4. Classification: remove segments with functional class coded as Interstate, Principal Arterial - other freeways and expressways, and Local.
5. AADT: separate segments with and without AADTs. The "without AADT" category includes those segments with AADTs that are known to be default values. Table 1 summarizes the default AADT values by the "Urbanized Area" field within the road inventory.
6. Abnormal AADT values: a small number of segments appear to have abnormally high AADT values (e.g. 2-lane segments with 50,000 or 60,000 vehicles per day or 4-lane segments with over 100,000 vehicles per day). After screening the data, the team set the thresholds at 25,000 vehicles per day for 2-lane segments and 75,000 vehicles per day for 4-lane segments to remove a small number of AADT outliers.

Table 1 Summary of Default AADT Values

Urbanized Area	Description	Default AADT
05167	Barnstable Town, MA	1,069
09271	Boston, MA—NH—RI	1,154
49096	Leominster—Fitchburg, MA	1,069
61165	Nashua, NH—MA	1,069
61786	New Bedford, MA	1,069
69778	Pittsfield, MA	1,069
72505	Providence, RI—MA	1,184
83926	Springfield, MA—CT	898
97291	Worcester, MA—CT	682
99999	Rural	350
99998	Small Urban	1,000
99999	Rural Minor Collector	550

Crash Data

VHB obtained five years of crash data (2013 through 2017) for analysis. The data included crashes from all six districts as shown in Figure 1. The first step was to exclude all crashes coded as intersection-related using the "Roadway Junction Type" field in the crash data and retain only non-intersection crashes for analysis. Crashes with the following entries for that field were removed for this analysis:

- Five-point or more, Four-way intersection, Off-ramp, On-ramp, Railway grade crossing, T-intersection, Traffic circle, and Y-intersection.

The crashes were then merged to each segment based on location. After cleaning and processing the data, the VHB team further separated the data into smaller subsets, based specific facility and area types for analysis, including the following:

1. 2-lane, divided arterials and collectors by area type (urban, rural).
2. 2-lane, undivided, rural arterials and collectors by MassDOT district.
3. 2-lane, undivided, urban arterials and collectors by MassDOT district.
4. 4-lane, undivided, urban arterials and collectors by MassDOT district.
5. 4-lane, divided, urban arterials and collectors by MassDOT district.

In some cases, there were too few segments in each category to develop reliable SPFs and the team handled those as follows:

- If the number of segments for a category is too small, they were removed from the dataset. For example, there were only 3 segments for the rural, 2-lane, divided category, so the team removed these segments and developed SPFs for 2-lane divided urban segments.

- If the number of segments for a category is relatively small (e.g., 50 or 100 range), the team combined similar categories into one to increase the sample size for more reliable SPFs. For example, there are too few segments by District in the Urban 4 category to develop individual SPFs. As such, the team combined Districts 1, 2, and 3 in one dataset and Districts 4, 5, and 6 in another, with the consideration of geographical continuity.
- Table 2 summarizes the final SPFs and crash prediction equations developed for 2-lane arterials and collectors.
- Table 3 summarizes the final SPFs and crash prediction equations developed for 4-lane arterials and collectors.

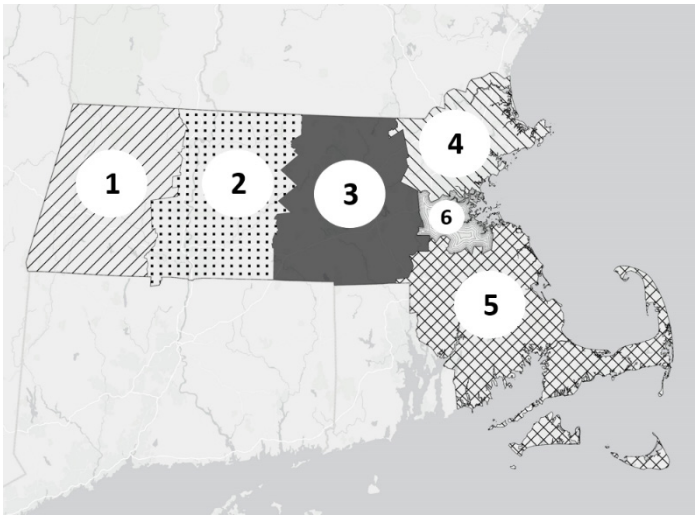

Figure 1 Overview of MassDOT Districts

Table 2 Summary of SPF Development for 2-lane Roadways

Facility type/District	With AADT	Without AADT (missing or default values)	Notes
Divided roadway	Yes	Yes	Only 3 segments in rural areas, eventually dropped and not used in the final SPF
Undivided roadway - Urban			
District 1	Yes	Yes	
District 2	Yes	Yes	
District 3	Yes	Yes	
District 4	Yes	Yes	
District 5	Yes	Yes	
District 6	Yes	Yes	
Undivided roadway – Rural			
District 1	Yes	Yes	
District 2	Yes	Yes	
Districts 3, 4, 5	Yes	Yes	Not enough data to develop satisfactory SPF for each district so these districts are combined
District 6	No	No	No data available for District 6 SPF development

Note: "Yes" indicates an SPF was developed and available for use; "No" indicates otherwise.

Table 3 Summary of SPF Development for 4-lane Roadways

Facility type/District	With AADT	Without AADT (missing or default values)	Notes
Divided roadway - Urban			
Districts 1, 2, 3	Yes	Yes	Not enough data to develop satisfactory SPF for each district so these districts are combined
Districts 4, 5, 6	Yes	Yes	Not enough data to develop satisfactory SPF for each district so these districts are combined
Undivided roadway – Urban			
District 1	No	No	No data available for District 1 SPF development
District 2, 3, 4	Yes	Yes	Not enough data to develop satisfactory SPF for each district so these districts are combined
District 5	Yes	Yes	
District 6	Yes	Yes	

Note: "Yes" indicates an SPF was developed and available for use; "No" indicates otherwise.

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Methodology

This section describes the methodology used to develop the SPFs for use in segment-based network screening of arterials and collectors in Massachusetts. Negative Binomial regression modeling was applied, which is consistent with the state of research in developing SPFs. The focus crashes include SPFs for total crashes and fatal and injury crashes (KABC on the KABCO scale). The traffic volume (AADT), segment length, and number of years were initially considered in the model to account for exposure. Other factors were included to account for differences across roadway functional classes and among districts. Model coefficients were estimated using the Stata software package. In addition to the key measures of model fit such as the Modified R-squared and the standard errors of parameters, the team reviewed the correlation matrix and Cumulative Residual (CURE) Plots to guide the model development process.

VHB considered and tested several functional forms for developing the SPFs. Initial tests showed that specifying AADT directly in the model to account for exposure led to severe over-prediction, where the models consistently over predict the number of crashes in comparison to the observed crashes. After further research and testing, the team identified that specifying vehicle-miles, instead of number of vehicles (i.e., AADT) resulted in much more reliable crash prediction. In the end, the SPFs developed for this effort have the following general functional form:

$$Crashes/year = \ vehmiles^{\beta_1} * exp(C_1 * X_1 + \cdots + C_n * X_n)$$

Where:

- vehmiles is the measure of exposure calculated from the average daily traffic associated with the roadway segment and the segment length. (vehmiles=[AADT]*[SegLength]).
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- X_i is a vector of other independent variables (e.g., indicators for functional class and district).
- Constant, β_i and C_i are parameters estimated from data in the SPF development process.

As previously discussed, the MassDOT dataset has approximately 60 percent of segments with either missing or default AADT values (referred to as “without AADT” for the remainder of this memorandum).

VHB developed a method to predict crashes for segments without AADT based on a combination of the following:

1. The SPFs developed for segments with valid AADT (as discussed above).
2. Available variables and observed crash counts for segments without AADT.

This process included the following key steps:

1. Separate all segments without AADT into the same categories for the data with valid AADT (discussed in section I above and summarized in Table 1 and Table 2).
2. Select any AADT value (e.g., 100 or 500) for all segments without AADT and apply the SPFs developed for the same category (e.g., Urban, undivided 2-lane for district 1) to predict both total and fatal & injury crashes.
3. Search through the AADT range to find an AADT value that the SPFs produce the smallest differences between the observed crash counts and the predicted crash counts (for all segments without AADT). Microsoft Excel's Solver tool was used to find the AADT value.
4. Calculate adjustment factors (calibrate the predicted crashes to the observed crashes) using the AADT value found in step 3 to develop crash prediction equations for each category. These equations can be used to predict crashes for segments without AADT.

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SPF Results

This section presents the SPFs (when AADT is available) and crash prediction equations (when AADT is not available) by facility type and district. Below are the SPFs and crash prediction equations developed for each category presented in Table 2 and Table 3. Only the equations and key information readers would need to apply them are presented in this section. The full model parameters and CURE plots for model assessment are included in the Appendix for interested readers to find more detailed information.

2-lane Divided Roadways

Urban, Divided 2-lane

Data Summary

Table 4 presents the key statistics of the final dataset used for developing SPFs for urban, divided 2-lane roadway. Initially, the plan was to develop separate SPFs for urban and rural 2-lane divided roadways; however, only three rural roadway segments remained after data cleaning and the research team decided to remove them from the data set. Therefore, only urban roadway segments are in this final dataset.

Table 4 Summary of Urban, Divided 2-lane Roadway Segments (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	344	0.10	0.07	0.05	0.51
AADT (veh/day)	344	10,952	6,310	612	24,140
Total crashes (5 years)	344	5.08	7.05	0	35
Fatal & Injury crashes (5 years)	344	1.35	2.17	0	16

SPFs for Segments with AADT

The following SPFs predict crashes for urban, divided, 2-lane segments with AADTs.

$$Total = [vehmiles]^{0.186} * exp(1.034 * [aadt11to15k] + 0.765 * [aadt15kplus] - 1.745)$$

$$FI = [vehmiles]^{0.395} * exp(0.841 * [aadt11to15k] + 0.483 * [aadt15kplus] - 4.362)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt11to15k = indicator for AADT range (1 if 11000 ≤ AADT < 15000; 0 otherwise).
- aadt15kplus = indicator for AADT range (1 if AADT ≥ 15000; 0 otherwise).

Crash Prediction for Segments without AADT

The following table presents the value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- AADT: 10,000
- Adjustment Factor Total Crashes: 1.118
- Adjust Factor Fatal and Injury Crashes: 0.894

For urban 2-lane divided segments without AADT, the following equations predict total and fatal and injury crashes:

$$Total = 1.061 * [SegLength]^{0.186}$$

$$FI = 0.433 * [SegLength]^{0.395}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength = length of road segment (miles).

2-lane Undivided Roadways

Urban, Undivided 2-lane (District 1)

Data Summary

Table 5 presents the key statistics of the final data set used for developing SPFs for urban, undivided 2-lane roadway in District 1.

Table 5 Summary of Urban, Undivided 2-lane Roadway Segments in District 1 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	1,184	0.15	0.14	0.05	1.62
AADT (veh/day)	1,184	4,963	3,862	310	21,320
Total crashes (5 years)	1,184	2.85	4.72	0	33
Fatal & Injury crashes (5 years)	1,184	0.84	1.65	0	12

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 2-lane segments with AADTs in District 1:

$$Total = [vehmiles]^{0.289} * exp(0.285 * [aadt29to63] + 0.496 * [aadt63to14k] + 1.323 * [aadt14kplus] - 2.733)$$

$$FI = [vehmiles]^{0.258} * exp(0.420 * [aadt29to63] + 0.614 * [aadt63to14k] + 1.594 * [aadt14kplus] - 3.867)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt29to63 = indicator for AADT range (1 if 2900 ≤ AADT < 6300; 0 otherwise).
- aadt63to14k = indicator for AADT range (1 if 6300 ≤ AADT < 14000; 0 otherwise).
- aadt14kplus = indicator for AADT range (1 if AADT ≥ 14000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 1
- AADT: 260
- Adjustment Factor Total Crashes: 1.000
- Adjustment Factor Fatal and Injury Crashes: 0.745

For all urban 2-lane undivided segments without AADT in District 1, the following equations predict total and fatal and injury crashes:

$$Total = 0.324 * [SegLength]^{0.289}$$

$$FI = 0.065 * [SegLength]^{0.258}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 2-lane (District 2)

Data Summary

Table 6 presents the key statistics of the final data set used for developing SPFs for urban, undivided 2-lane roadway in District 2.

Table 6 Summary of Urban, Undivided 2-lane Roadway Segments in District 2 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	5,695	0.14	0.13	0.05	1.33
AADT (veh/day)	5,695	6,725	4,721	181	24,175
Total crashes (5 years)	5,695	4.51	6.25	0	39
Fatal & Injury crashes (5 years)	5,695	1.42	2.31	0	24

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 2-lane segments with AADTs in District 2:

$$Total = [vehmiles]^{0.254} * exp(0.181 * [aadt3to5k] + 0.526 * [aadt5to10k] + 0.638 * [aadt10to15k] + 0.902 * [aadt15kplus] - 2.207)$$

$$FI = [vehmiles]^{0.239} * exp(0.265 * [aadt3to5k] + 0.631 * [aadt5to10k] + 0.760 * [aadt10to15k] + 1.033 * [aadt15kplus] - 3.361)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt3to5k = indicator for AADT range (1 if 3000 ≤ AADT < 5000; 0 otherwise).
- aadt5to10k = indicator for AADT range (1 if 5000 ≤ AADT < 10000; 0 otherwise).
- aadt10to15k = indicator for AADT range (1 if 10000 ≤ AADT < 15000; 0 otherwise).
- aadt15kplus = indicator for AADT range (1 if AADT ≥ 15000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 2
- AADT: 100
- Adjustment Factor Total Crashes: 0.950
- Adjustment Factor Fatal and Injury Crashes: 0.956

For all urban 2-lane undivided segments without AADT in District 2, the following equations predict total and fatal and injury crashes:

$$Total = 0.337 * [SegLength]^{0.254}$$

$$FI = 0.100 * [SegLength]^{0.239}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 2-lane (District 3)

Data Summary

Table 7 presents the key statistics of the final data set used for developing SPFs for urban, undivided 2-lane roadway in District 3.

Table 7 Summary of Urban, Undivided 2-lane Roadway Segments in District 3 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	10,439	0.15	0.13	0.05	1.69
AADT (veh/day)	10,439	6,935	5,142	31	24,982
Total crashes (5 years)	10,439	4.28	6.04	0	41
Fatal & Injury crashes (5 years)	10,439	1.04	1.72	0	19

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 2-lane segments with AADTs in District 3:

$$Total = [vehmiles]^{0.350} * exp(0.207 * [aadt25to10k] + 0.559 * [aadt10to15k] + 0.713 * [aadt15to18k] + 0.922 * [aadt18kplus] - 2.832)$$

$$FI = [vehmiles]^{0.427} * exp(0.124 * [aadt25to10k] + 0.396 * [aadt10to15k] + 0.559 * [aadt15to18k] + 0.689 * [aadt18kplus] - 4.670)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt25to10k = indicator for AADT range (1 if 2500 ≤ AADT < 10000; 0 otherwise).

- aadt10to15k = indicator for AADT range (1 if 10000 ≤ AADT < 15000; 0 otherwise).
- aadt15to18k = indicator for AADT range (1 if 15000 ≤ AADT < 18000; 0 otherwise).
- aadt18kplus = indicator for AADT range (1 if AADT ≥ 18000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 3
- AADT: 200
- Adjustment Factor Total Crashes: 0.977
- Adjust Factor Fatal and Injury Crashes: 1.097

For all urban 2-lane undivided segments without AADT in District 3, the following equations predict total and fatal and injury crashes:

$$Total = 0.368 * [SegLength]^{0.350}$$

$$FI = 0.099 * [SegLength]^{0.427}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 2-lane (District 4)

Data Summary

Table 8 presents the key statistics of the final data set used for developing SPFs for urban, undivided 2-lane roadway in District 4.

Table 8 Summary of Urban, Undivided 2-lane Roadway Segments in District 4 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	10,112	0.12	0.09	0.05	1.22
AADT (veh/day)	10,112	8,509	5,990	54	24,983
Total crashes (5 years)	10,112	4.24	6.14	0	42
Fatal & Injury crashes (5 years)	10,112	1.16	1.89	0	16

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 2-lane segments with AADTs in District 4:

$$Total = [vehmiles]^{0.314} * exp(-0.162 * [aadt2kto2930] + 0.779 * [aadt2930to3k] + 0.181 * [aadt3kto8300] + 0.644 * [aadt8300to9050] + 0.336 * [aadt9050to13k] + 0.631 * [aadt13kplus] - 2.624)$$

$$FI = [vehmiles]^{0.306} * exp(0.875 * [aadt2930to3k] + 0.280 * [aadt3kto8300] + 0.872 * [aadt8300to9050] + 0.484 * [aadt9050to13k] + 0.738 * [aadt13kplus] - 3.987)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).

- SegLength = length of road segment (miles).
- aadt2kto2930 = indicator for AADT range (1 if 2000 ≤ AADT < 2930; 0 otherwise).
- aadt2930to3k = indicator for AADT range (1 if 2930 ≤ AADT < 3000; 0 otherwise).
- aadt3kto8300 = indicator for AADT range (1 if 3000 ≤ AADT < 8300; 0 otherwise).
- aadt8300to9050 = indicator for AADT range (1 if 8300 ≤ AADT < 9050; 0 otherwise).
- aadt9050to13k = indicator for AADT range (1 if 9050 ≤ AADT < 13000; 0 otherwise).
- aadt13kplus = indicator for AADT range (1 if AADT ≥ 13000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 4
- AADT: 150
- Adjustment Factor Total Crashes: 1.013
- Adjustment Factor Fatal and Injury Crashes: 0.995

For all urban 2-lane undivided segments without AADT in District 4, the following equations predict total and fatal and injury crashes:

$$Total = 0.354 * [SegLength]^{0.314}$$

$$FI = 0.086 * [SegLength]^{0.306}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 2-lane (District 5)

Data Summary

Table 9 presents the key statistics of the final data set used for developing SPFs for urban, undivided 2-lane roadway in District 5.

Table 9 Summary of Urban, Undivided 2-lane Roadway Segments in District 5 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	14,362	0.14	0.11	0.05	1.36
AADT (veh/day)	14,362	6,950	5,090	506	24,960
Total crashes (5 years)	14,362	3.73	5.82	0	52
Fatal & Injury crashes (5 years)	14,362	1.12	2.01	0	22

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 2-lane segments with AADTs in District 5:

$$Total = [vehmiles]^{0.413} * exp(0.115 * [aadt5kto75] + 0.249 * [aadt75to125] + 0.565 * [aadt125to16k] + 0.682 * [aadt16kto19k] + 0.907 * [aadt19kplus] - 3.273)$$

$$FI = [vehmiles]^{0.430} * exp(0.113 * [aadt5kto75] + 0.266 * [aadt75to125] + 0.587 * [aadt125to16k] + 0.733 * [aadt16kto19k] + 0.933 * [aadt19kplus] - 4.604)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).

- aadt5kto75 = indicator for AADT range (1 if 5000 ≤ AADT < 7500; 0 otherwise).
- aadt75to125 = indicator for AADT range (1 if 7500 ≤ AADT < 12500; 0 otherwise).
- aadt125to16k = indicator for AADT range (1 if 12500 ≤ AADT < 16000; 0 otherwise).
- aadt16kto19k = indicator for AADT range (1 if 16000 ≤ AADT < 19000; 0 otherwise).
- aadt19kplus = indicator for AADT range (1 if AADT ≥ 19000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 5
- AADT: 285
- Adjustment Factor Total Crashes: 1.002
- Adjustment Factor Fatal and Injury Crashes: 0.996

For all urban 2-lane undivided segments without AADT in District 5, the following equations predict total and fatal and injury crashes:

$$Total = 0.392 * [SegLength]^{0.413}$$

$$FI = 0.113 * [SegLength]^{0.430}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 2-lane (District 6)

Data Summary

Table 10 presents the key statistics of the final data set used for developing SPFs for urban, undivided 2-lane roadway in District 6.

Table 10 Summary of Urban, Undivided 2-lane Roadway Segments in District 6 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	4,767	0.10	0.06	0.05	1.04
AADT (veh/day)	4,767	9,123	6,249	554	24,945
Total crashes (5 years)	4,767	3.47	5.04	0	33
Fatal & Injury crashes (5 years)	4,767	1.07	1.79	0	17

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 2-lane segments with AADTs in District 6:

$$Total = [vehmiles]^{0.372} * exp(1.60 * [func3] + 1.307 * [func5] + 1.193 * [func6] + 0.188 * [aadt33to36] - 1.329 * [aadt40to42] + 0.140 * [aadt8kto10k] - 0.497 * [aadt10kto12k] + 0.158 * [aadt18kto22k] - 4.128)$$

$$FI = [vehmiles]^{0.360} * exp(1.633 * [func3] + 1.366 * [func5] + 1.077 * [func6] + 0.142 * [aadt33to36] - 0.889 * [aadt40to42] - 0.376 * [aadt10kto12k] - 0.142 * [aadt12kto16k] - 5.162)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].

- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- func3 = indicator for functional class of roadway segment (1 if functional class =3 Principal Arterial – other; 0 otherwise).
- func5 = indicator for functional class of roadway segment (1 if functional class =5 Major Collector; 0 otherwise).
- func6 = indicator for functional class of roadway segment (1 if functional class =6 Minor Collector; 0 otherwise).
- aadt33kto36 = indicator for AADT range (1 if 3300 ≤ AADT < 3600; 0 otherwise).
- Aadt40to42 = indicator for AADT range (1 if 4000 ≤ AADT < 4200; 0 otherwise).
- Aadt10kto12k = indicator for AADT range (1 if 10000 ≤ AADT < 12000; 0 otherwise).
- aadt12kto16k = indicator for AADT range (1 if 12000 ≤ AADT < 16000; 0 otherwise).
- aadt18kto22k = indicator for AADT range (1 if 18000 ≤ AADT < 22000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 6
- AADT: 4,200
- Adjustment Factor Total Crashes: 0.996
- Adjustment Factor Fatal and Injury Crashes: 0.815

For all urban 2-lane undivided segments without AADT in District 6, the following equations predict total and fatal and injury crashes:

$$Total = 0.358 * [SegLength]^{0.372} * \exp(1.60 * func3 + 1.307 * func5 + 1.193 * func6)$$

$$FI = 0.094 * [SegLength]^{0.360} * \exp(1.633 * func3 + 1.366 * func5 + 1.077 * func6)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).
- func3 = indicator for functional class of roadway segment (1 if functional class = 3 Principal Arterial – other; 0 otherwise).
- func5 = indicator for functional class of roadway segment (1 if functional class = 5 Major Collector; 0 otherwise).
- func6 = indicator for functional class of roadway segment (1 if functional class = 6 Minor Collector; 0 otherwise).

Rural, Undivided 2-lane (District 1)

Data Summary

Table 11 presents the key statistics of the final data set used for developing SPFs for rural, undivided 2-lane roadway in District 1.

Table 11 Summary of Rural, Undivided 2-lane Roadway Segments in District 1 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	2,066	0.32	0.31	0.05	3.14
AADT (veh/day)	2,066	1,929	1,842	46	15,897
Total crashes (5 years)	2,066	0.67	1.30	0	12
Fatal & Injury crashes (5 years)	2,066	0.21	0.54	0	5

SPFs for Segments with AADT

The following SPFs predict crashes for rural, undivided 2-lane segments with AADTs in District 1:

$$Total = [vehmiles]^{0.717} * exp(-0.466 * [aadt4kto7k] - 6.282)$$

$$FI = [vehmiles]^{0.662} * exp(-0.829 * [aadt4kto7k] - 7.090)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).

- SegLength = length of road segment (miles).
- aadt4kto7k = indicator for AADT range (1 if 4000 ≤ AADT < 7000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 1
- AADT: 320
- Adjustment Factor Total Crashes: 1.005
- Adjustment Factor Fatal and Injury Crashes: 0.780

For all rural 2-lane undivided segments without AADT in District 1, the following equations predict total and fatal and injury crashes:

$$Total = 0.117 * [SegLength]^{0.717}$$

$$FI = 0.030 * [SegLength]^{0.662}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Rural, Undivided 2-lane (District 2)

Data Summary

Table 12 presents the key statistics of the final data set used for developing SPFs for rural, undivided 2-lane roadway in District 2.

Table 12 Summary of Rural, Undivided 2-lane Roadway Segments in District 2 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	1,827	0.31	0.27	0.05	2.03
AADT (veh/day)	1,827	2,520	2,437	99	15,289
Total crashes (5 years)	1,827	1.16	2.20	0	23
Fatal & Injury crashes (5 years)	1,827	0.35	0.84	0	6

SPFs for Segments with AADT

The following SPFs predict crashes for rural, undivided 2-lane segments with AADTs in District 2:

$$Total = [vehmiles]^{0.641} * exp(-0.498 * [aadt18less] - 0.642 * [aadt18to3k] - 1.011 * [aadt4kto45] - 0.304 * [aadt45to75] - 0.293 * [aadt75plus] - 5.071)$$

$$FI = [vehmiles]^{0.617} * exp(-0.334 * [aadt18less] - 0.397 * [aadt18to3k] - 0.650 * [aadt4kto45] - 6.326)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt18less = indicator for AADT range (1 if AADT < 1800; 0 otherwise).
- aadt18to3k = indicator for AADT range (1 if 1800 ≤ AADT < 3000; 0 otherwise).
- aadt4kto45 = indicator for AADT range (1 if 4000 ≤ AADT < 4500; 0 otherwise).
- aadt45to75 = indicator for AADT range (1 if 4500 ≤ AADT < 7500; 0 otherwise).
- aadt75plus = indicator for AADT range (1 if 7500 ≤ AADT; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 2
- AADT: 520
- Adjustment Factor Total Crashes: 0.995
- Adjustment Factor Fatal and Injury Crashes: 1.010

For all rural 2-lane undivided segments without AADT in District 2, the following equations predict total and fatal and injury crashes:

$$Total = 0.334 * [SegLength]^{0.641}$$

$$FI = 0.086 * [SegLength]^{0.617}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Rural, Undivided 2-lane (Districts 3, 4, 5)

Data Summary

Table 13 presents the key statistics of the final data set used for developing SPFs for rural, undivided 2-lane roadway in Districts 3, 4, and 5.

Table 13 Summary of Rural, Undivided 2-lane Roadway Segments in Districts 3, 4, and 5 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	1,409	0.25	0.22	0.05	1.75
AADT (veh/day)	1,409	3,224	2,920	350	22,384
Total crashes (5 years)	1,409	1.80	2.93	0	27
Fatal & Injury crashes (5 years)	1,409	0.51	1.05	0	14

SPFs for Segments with AADT

The following SPFs predict crashes for rural, undivided 2-lane segments with AADTs in Districts 3, 4, 5:

$$Total = [vehmiles]^{0.616} * exp(0.574 * [dist3] + 0.189 * [aadt45less] - 0.556 * [aadt45to5k] - 5.524)$$

$$FI = [vehmiles]^{0.599} * exp(0.473 * [dist3] + 0.285 * [aadt45less] - 6.673)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- dist3 = indicator for MassDOT district (1 if roadway segment in District 3; 0 otherwise).
- aadt45less = indicator for AADT range (1 if AADT < 4500; 0 otherwise).
- aadt45to5k = indicator for AADT range (1 if 4500 ≤ AADT < 5000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for

information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 3, 4, 5
- AADT: 400
- Adjustment Factor Total Crashes: 1.018
- Adjustment Factor Fatal and Injury Crashes: 0.929

For all rural 2-lane undivided segments without AADT in Districts 3, 4, and 5, the following equations predict total and fatal and injury crashes:

$$Total = 0.197 * [SegLength]^{0.616} * exp(0.574 * [dist3])$$

$$FI = 0.044 * [SegLength]^{0.599} * exp(0.473 * [dist3])$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).
- dist3 = indicator for MassDOT district (1 if roadway segment in District 3; 0 otherwise).

4-lane Divided Roadways

Urban, Divided 4-lane (Districts 1, 2, 3)

Data Summary

Table 14 presents the key statistics of the final data set used for developing SPFs for urban, divided 4-lane roadway in Districts 1, 2, and 3.

Table 14 Summary of Urban, Divided 4-lane Roadway Segments in Districts 1,2, and 3 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	378	0.13	0.10	0.05	0.78
AADT (veh/day)	378	17,786	7,742	2,503	41,088
Total crashes (5 years)	378	10.68	13.99	0	79
Fatal & Injury crashes (5 years)	378	3.18	4.88	0	29

SPFs for Segments with AADT

The following SPFs predict crashes for urban, divided 4-lane segments with AADTs in Districts 1, 2, 3:

$$Total = [vehmiles]^{0.374} * exp(-0.344 * [dist3] + 0.278 * [aadt12kto17k] - 1.942)$$

$$FI = [vehmiles]^{0.308} * exp(-0.746 * [dist3] + 0.406 * [aadt12kto15k] - 2.496)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- dist3 = indicator for MassDOT district (1 if roadway segment in District 3; 0 otherwise).
- aadt12kto17k = indicator for AADT range (1 if 12000 ≤ AADT < 17000; 0 otherwise).
- aadt12kto15k = indicator for AADT range (1 if 12000 ≤ AADT < 15000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 1, 2, 3
- AADT: 13,500
- Adjustment Factor Total Crashes: 1.007
- Adjustment Factor Fatal and Injury Crashes: 0.960

For all urban 4-lane divided segments without AADT in Districts 1, 2, and 3, the following equations predict total and fatal and injury crashes:

$$Total = 6.685 * [SegLength]^{0.374} * exp(-0.344 * [dist3])$$

$$FI = 2.222 * [SegLength]^{0.308} * exp(-0.746 * [dist3])$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).
- dist3 = indicator for MassDOT district (1 if roadway segment in District 3; 0 otherwise).

Urban, Divided 4-lane (Districts 4, 5, 6)

Data Summary

Table 15 presents the key statistics of the final data set used for developing SPFs for urban, divided 4-lane roadway in Districts 4, 5, and 6.

Table 15 Summary of Urban, Divided 4-lane Roadway Segments in Districts 4,5, and 6 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	1,201	0.12	0.08	0.05	0.87
AADT (veh/day)	1,201	24,332	12,646	2,487	68,099
Total crashes (5 years)	1,201	7.06	10.64	0	73
Fatal & Injury crashes (5 years)	1,201	2.14	3.31	0	26

SPFs for Segments with AADT

The following SPFs predict crashes for urban, divided 4-lane segments with AADTs in Districts 4, 5, and 6:

$$Total = [vehmiles]^{0.216} * exp(0.630 * [aadt14kto16k] + 0.793 * [dist4] + 0.774 * [dist5] - 1.916)$$

$$FI = [vehmiles]^{0.195} * exp(0.571 * [aadt14kto16k] - 0.201 * [aadt16kto20k] + 0.351 * [aadt20kto22k] + 0.417 * [dist4] + 0.453 * [dist5] - 2.694)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt14kto16k = indicator for AADT range (1 if 14000 ≤ AADT < 16000; 0 otherwise).
- aadt16kto20k = indicator for AADT range (1 if 16000 ≤ AADT < 20000; 0 otherwise).
- aadt20kto22k = indicator for AADT range (1 if 20000 ≤ AADT < 22000; 0 otherwise).

- dist4 = indicator for MassDOT district (1 if roadway segment in District 4; 0 otherwise).
- dist5 = indicator for MassDOT district (1 if roadway segment in District 5; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 4, 5, 6
- AADT: 15,900
- Adjustment Factor Total Crashes: 1.321
- Adjustment Factor Fatal and Injury Crashes: 1.280

For all urban 4-lane divided segments without AADT in Districts 4, 5, and 6, the following equations predict total and fatal and injury crashes:

$$Total = 2.950 * [SegLength]^{0.216} * exp(0.793 * [dist4] + 0.774 * [dist5])$$

$$FI = 1.011 * [SegLength]^{0.195} * exp(0.417 * [dist4] + 0.453 * [dist5])$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).
- dist4 = indicator for MassDOT district (1 if roadway segment in District 4; 0 otherwise).
- dist5 = indicator for MassDOT district (1 if roadway segment in District 5; 0 otherwise).

4-lane Undivided Roadways

Urban, Undivided 4-lane (Districts 2, 3, 4)

Data Summary

Table 16 presents the key statistics of the final data set used for developing SPFs for urban, undivided 4-lane roadway in Districts 2, 3, and 4.

Table 16 Summary of Urban, Undivided 4-lane Roadway Segments in Districts 2, 3, and 4 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	601	0.11	0.08	0.05	0.72
AADT (veh/day)	601	20,369	8,794	2,608	52,164
Total crashes (5 years)	601	16.07	15.61	0	78
Fatal & Injury crashes (5 years)	601	4.97	5.12	0	29

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 4-lane segments with AADTs in Districts 2, 3, 4:

$$Total = [vehmiles]^{0.318} * exp(-0.563 * [aadt7kto10k] - 1.214)$$

$$FI = [vehmiles]^{0.375} * exp(0.349 * [aadt10kto17k] - 2.932)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt7kto10k = indicator for AADT range (1 if 7000 ≤ AADT < 10000; 0 otherwise).
- aadt10kto17k = indicator for AADT range (1 if 10000 ≤ AADT < 17000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 2, 3, 4
- AADT: 6,300
- Adjustment Factor Total Crashes: 1.000
- Adjustment Factor Fatal and Injury Crashes: 0.922

For all urban 4-lane undivided segments without AADT in Districts 2, 3, and 4, the following equations predict total and fatal and injury crashes:

$$Total = 4.797 * [SegLength]^{0.318}$$

$$FI = 1.306 * [SegLength]^{0.375}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 4-lane (District 5)

Data Summary

Table 17 presents the key statistics of the final data set used for developing SPFs for urban, undivided 4-lane roadway in District 5.

Table 17 Summary of Urban, Undivided 4-lane Roadway Segments in District 5 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	374	0.13	0.09	0.05	0.67
AADT (veh/day)	374	18,948	8,362	3,153	42,930
Total crashes (5 years)	374	13.53	14.37	0	77
Fatal & Injury crashes (5 years)	374	4.12	4.90	0	27

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 4-lane segments with AADTs in District 5:

$$Total = [vehmiles]^{0.500} * exp(-0.440 * [aadt8kless] - 2.802)$$

$$FI = [vehmiles]^{0.520} * exp(-0.668 * [aadt8kless] - 4.134)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt8kless = indicator for AADT range (1 if AADT < 8000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 5
- AADT: 33,500
- Adjustment Factor Total Crashes: 1.002

- Adjustment Factor Fatal and Injury Crashes: 0.893

For all urban 4-lane undivided segments without AADT in District 5, the following equations predict total and fatal and injury crashes:

$$Total = 11.126 * [SegLength]^{0.50}$$

$$FI = 3.225 * [SegLength]^{0.52}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

Urban, Undivided 4-lane (District 6)

Data Summary

Table 18 presents the key statistics of the final data set used for developing SPFs for urban, undivided 4-lane roadway in District 6.

Table 18 Summary of Urban, Undivided 4-lane Roadway Segments in District 6 (with AADT)

Description	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Segment length (miles)	391	0.10	0.06	0.05	0.55
AADT (veh/day)	391	24,080	11,670	5,076	69,980
Total crashes (5 years)	391	8.42	10.42	0	53
Fatal & Injury crashes (5 years)	391	2.72	3.19	0	18

SPFs for Segments with AADT

The following SPFs predict crashes for urban, undivided 4-lane segments with AADTs in District 6:

$$Total = [vehmiles]^{0.550} * exp(0.764 * [aadt9kto10k] - 0.507 * [aadt10kto18k] - 3.703)$$

$$FI = [vehmiles]^{0.559} * exp(0.669 * [aadt9kto10k] - 0.443 * [aadt10kto16k] - 4.917)$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.

- vehmiles = vehicle-miles travelled for the segment (vehmiles=[AADT]*[SegLength].
- AADT = annual average daily traffic (vehicles per day).
- SegLength = length of road segment (miles).
- aadt9kto10k = indicator for AADT range (1 if 9000 ≤ AADT < 10000; 0 otherwise).
- aadt10kto18k = indicator for AADT range (1 if 10000 ≤ AADT < 18000; 0 otherwise).
- aadt10kto16k = indicator for AADT range (1 if 10000 ≤ AADT < 16000; 0 otherwise).

Crash Prediction for Segments without AADT

The value of AADT found to provide the lowest difference between predicted and observed crashes, as well as the adjustment factors for total and fatal and injury crashes are presented in the following table. The AADT and adjustment factors in this table are included here for information purpose only. They have been incorporated in the crash prediction equations, so no further application of these adjustment factors to the equations is needed.

- District: 6
- AADT: 8,500
- Adjustment Factor Total Crashes: 0.993
- Adjustment Factor Fatal and Injury Crashes: 1.101

For all urban 4-lane undivided segments without AADT in District 6, the following equations predict total and fatal and injury crashes:

$$Total = 3.546 * [SegLength]^{0.55}$$

$$FI = 1.268 * [SegLength]^{0.559}$$

Where:

- Total = predicted number of total crashes per year.
- FI = predicted number of fatal and injury crashes per year.
- SegLength=length of road segment (miles).

5

Network Screening Results

Network screening will follow the sliding window Empirical Bayes procedure laid out in MassDOT's Network Screening Guide. Predicted crashes total and FI crashes will be calculated for each collector and arterial segment. Under sliding window network screening, these totals will be summed for each 0.3-mile window, slid along the network in 0.1-mile increments. Empirical Bayes will then be used to calculate expected crash frequency – the statistically weighted average between the observed and predicted crashes on the segment. Excess total and FI crashes will then be calculated as the difference between expected and predicted crashes within the window. The segments are then ranked based on excess crashes. These results are used to generate Statewide rankings as well as individual MPO rankings. For Statewide rankings, all segments in the State are sorted by excess crashes, then the Top 5 percent and the Next 10 percent of segments are identified. This process is repeated at the MPO level, where the Top 5 percent and Next 10 percent of segments by excess crashes are identified for each MPO. The minimum length for a segment to be included in network screening is 0.05 miles.

Appendix

Model parameters and CURE Plots

Urban, Divided 2-lane

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =        344
                                                LR chi2(3)        =      55.48
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -878.90573                     Pseudo R2         =     0.0306
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.1860164	.0925425	2.01	0.044	.0046364	.3673963
aadt11_15k	1.033934	.2116347	4.89	0.000	.6191379	1.448731
aadt_15kplus	.7650227	.2160854	3.54	0.000	.3415031	1.188542
_cons	-1.745244	.567093	-3.08	0.002	-2.856726	-.6337621
ln(num_ye~s)	1	(exposure)				
/lnalpha	.4549429	.0981942			.2624858	.6473999
alpha	1.576083	.1547622			1.300158	1.910567

LR test of alpha=0: chibar2(01) = 1296.20 Prob >= chibar2 = 0.000

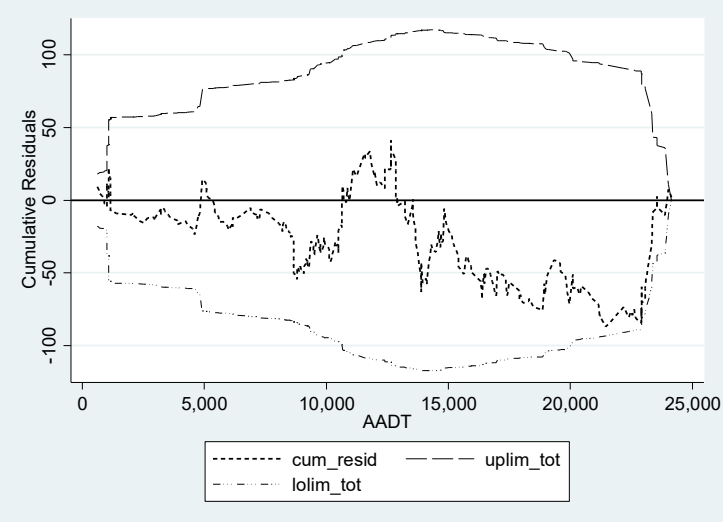

Figure 2 CURE Plot by AADT for Total Crashes on Urban, Divided 2-lane Segments

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =        344
                                                LR chi2(3)        =      51.06
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -514.07126                     Pseudo R2         =     0.0473
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3951812	.1201017	3.29	0.001	.1597862	.6305762
aadt11_15k	.8409866	.233166	3.61	0.000	.3839897	1.297983
aadt_15kplus	.4829034	.2418866	2.00	0.046	.0088144	.9569924
_cons	-4.361701	.750273	-5.81	0.002	-5.83221	-2.891193
ln(num_ye~s)	1	(exposure)				
/lnalpha	.3101071	.1552284			.0058649	.6143492
alpha	1.363571	.211665			1.005882	1.848453

LR test of alpha=0: chibar2(01) = 200.57 Prob >= chibar2 = 0.000

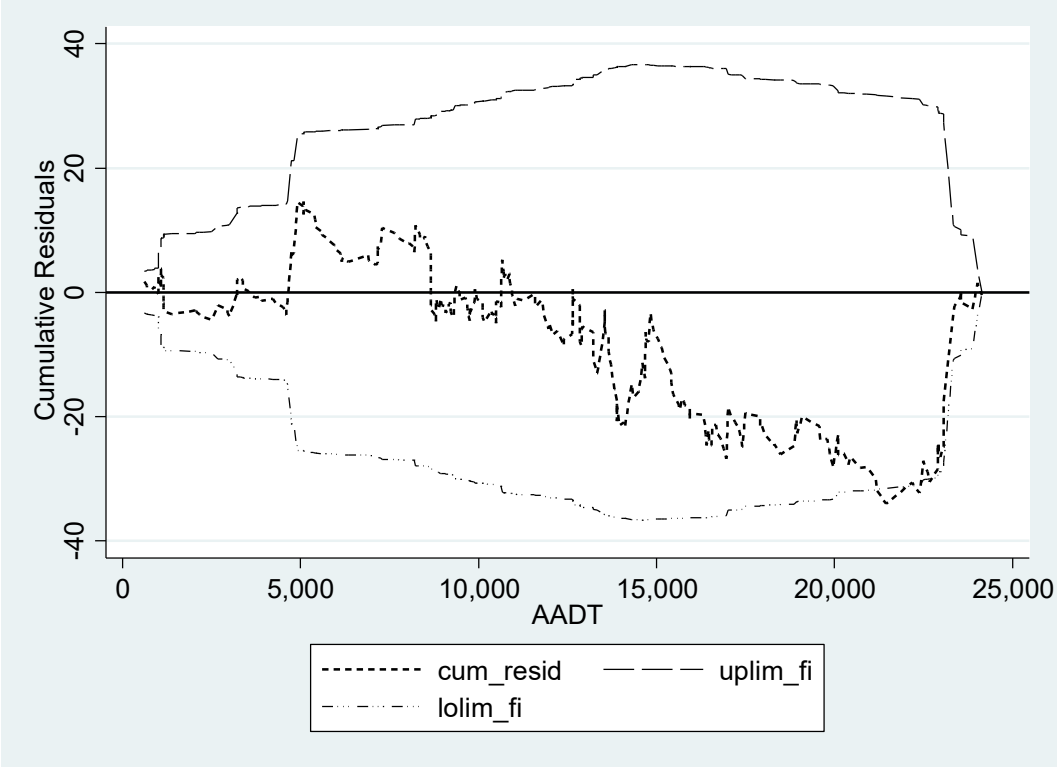

Figure 3 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Divided 2-lane Segments

Urban, Undivided 2-lane (District 1)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =      1,184
                                                LR chi2(4)        =     158.93
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -2450.8702                     Pseudo R2         =     0.0314
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.2891764	.0548359	5.27	0.00	.1817	.3966528
aadt_29_63	.2846936	.110793	2.57	0.010	.0675434	.5018438
aadt_63_14k	.4964795	.1306068	3.80	0.000	.2404948	.7524642
aadt_14kplus	1.323733	.2248927	5.89	0.000	.882951	1.764514
_cons	-2,733191	.3064294	-8.92	0.002	-3.333782	-2.1326
ln(num_ye~s)	1	(exposure)				
/lnalpha	.4846639	.0587818			.3694536	.5998741
alpha	1.623629	.0954398			1.446944	1.821889

LR test of alpha=0: chibar2(01) = 2648.94 Prob >= chibar2 = 0.000

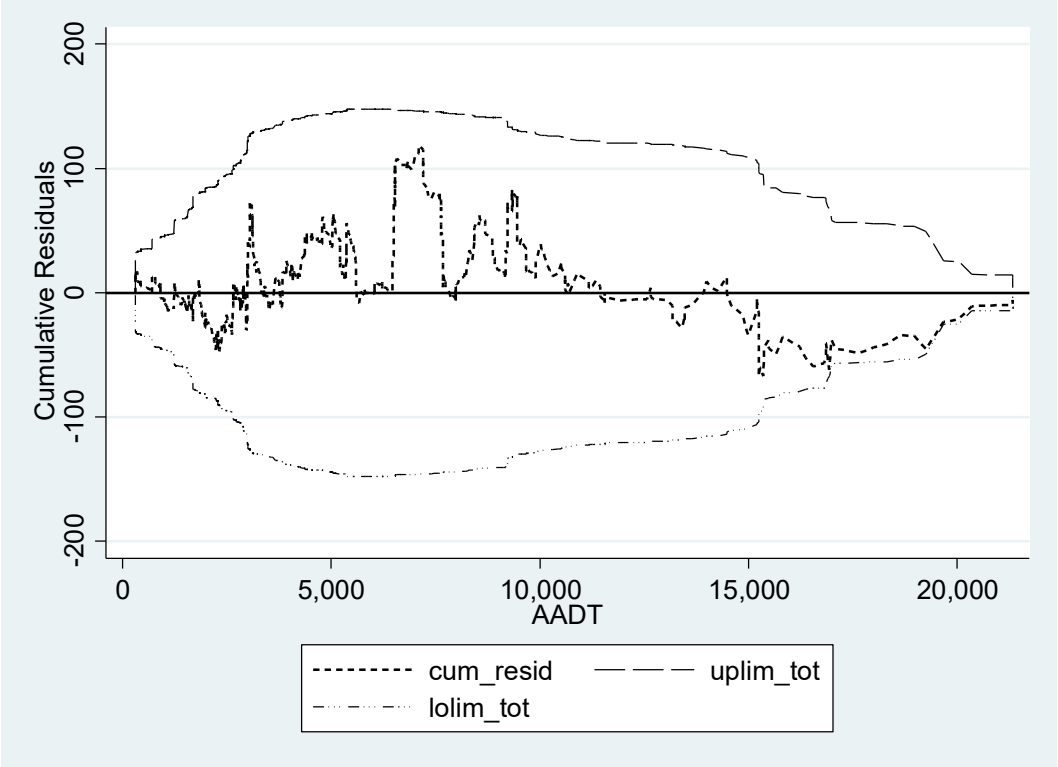

Figure 4 CURE Plot by AADT for Total Crashes on Urban, Undivided 2-lane Segments (District 1)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      1,184
                                                LR chi2(4)        =     121.00
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1395.5324                     Pseudo R2         =     0.0416
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.2579153	.0699405	3.69	0.000	.1208344	.3949962
aadt_29_63	.4196069	.143499	2.92	0.003	.138354	.7008598
aadt_63_14k	.6143668	.1645526	3.73	0.000	.2918497	.9368839
aadt_14kplus	1.593985	.2615489	6.09	0.000	1.081358	2.106611
_cons	-3.86752	.3949742	-9.79	0.000	-4.641655	-3.093385
ln(num_ye~s)	1	(exposure)				
/lnalpha	.5951407	.0961029			.4067825	.783499
alpha	1.813286	.1742621			1.501977	2.189119

LR test of alpha=0: chibar2(01) = 513.29 Prob >= chibar2 = 0.000

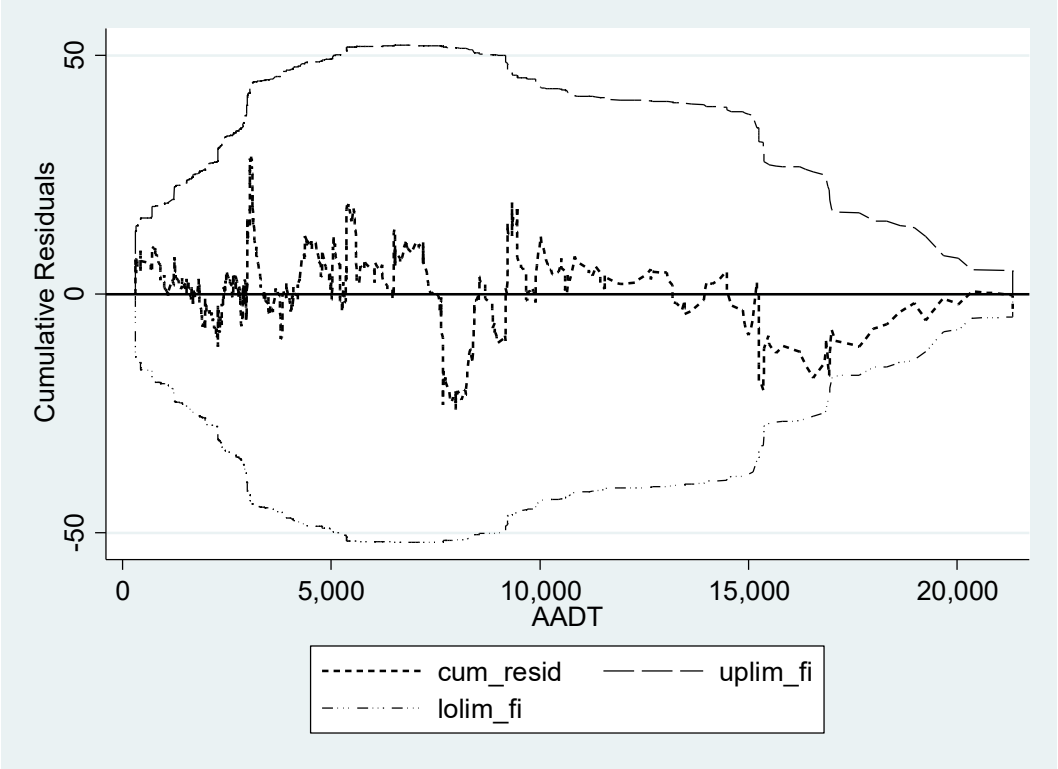

Figure 5 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 2-lane Segments (District 1)

Urban, Undivided 2-lane (District 2)

Model parameters for Total crashes

Negative binomial regression — Number of obs = 5,695
LR chi2(5) = 760.34
Dispersion = mean — Prob > chi2 = 0.0000
Log likelihood = -14312.393 — Pseudo R2 = 0.0259

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.2538405	.0234885	10.81	0.000	.2078039	.2998771
aadt_3_5k	.1806433	.0544567	3.32	0.001	.0739101	.2873765
aadt_5_10k	.5256555	.0586013	8.97	0.000	.410799	.6405119
aadt_10_15k	.6378327	.0719289	8.87	0.000	.4968545	.7788108
aadt_15kplus	.9016963	.0867052	10.40	0.000	.7317572	1.071635
_cons	-2.206801	.1328011	-16.62	0.000	-2.467086	-1.946516
ln(num_ye~s)	1	(exposure)				
/lnalpha	.2400949	.0239734			.1931079	.287082
alpha	1.27137	.0304791			1.213014	1.332533

LR test of alpha=0: chibar2(01) = 1.8e+04 — Prob >= chibar2 = 0.000

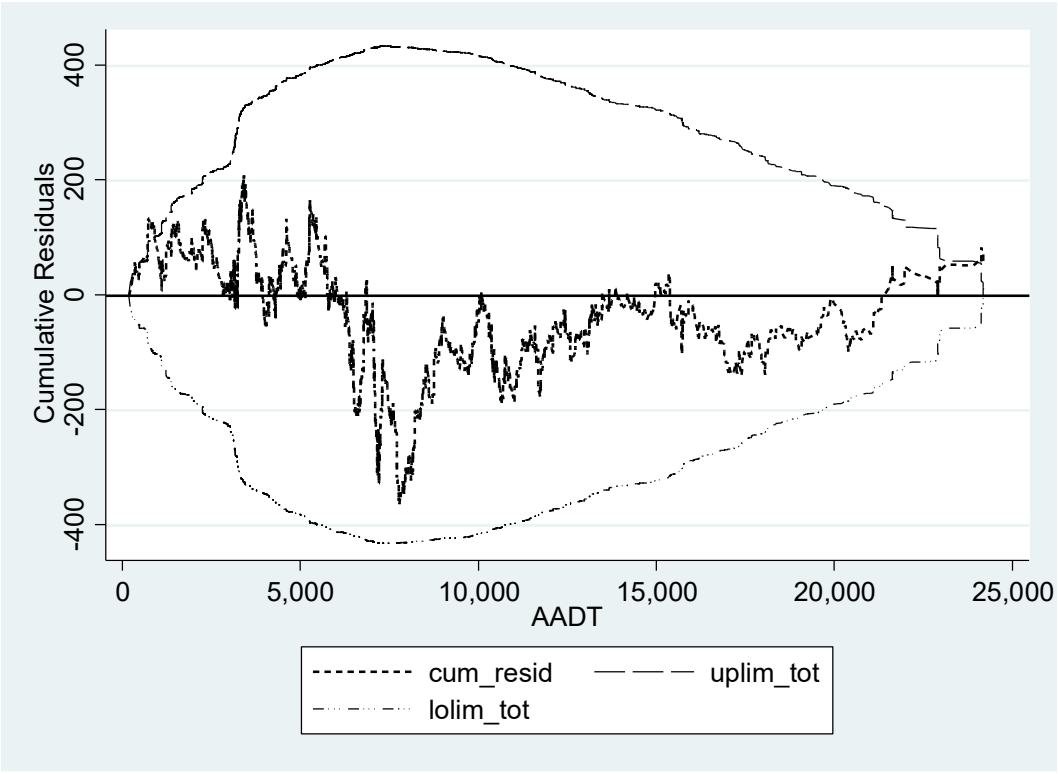

Figure 6 CURE Plot by AADT for Total Crashes on Urban, Undivided 2-lane Segments (District 2)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      5,695
                                                LR chi2(5)        =     554.68
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -8926.6031                     Pseudo R2         =     0.0301
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.2394022	.0286078	8.37	0.000	.1833319	.2954724
aadt_3_5k	.2651167	.0699709	3.79	0.000	.1279762	.4022572
aadt_5_10k	.6307552	.0733442	8.60	0.000	.4870032	.7745073
aadt_10_15k	.759734	.0876999	8.66	0.000	.5878455	.9316226
aadt_15kplus	1.032976	.1034787	9.98	0.000	.8301613	1.23579
_cons	-3.361281	.1648978	-20.38	0.000	-3.684475	-3.038087
ln(num_ye~s)	1	(exposure)				
/lnalpha	.3695471	.0353533			.3002559	.4388383
alpha	1.447079	.051159			1.350204	1.550905

LR test of alpha=0: chibar2(01) = 4135.30 Prob >= chibar2 = 0.000

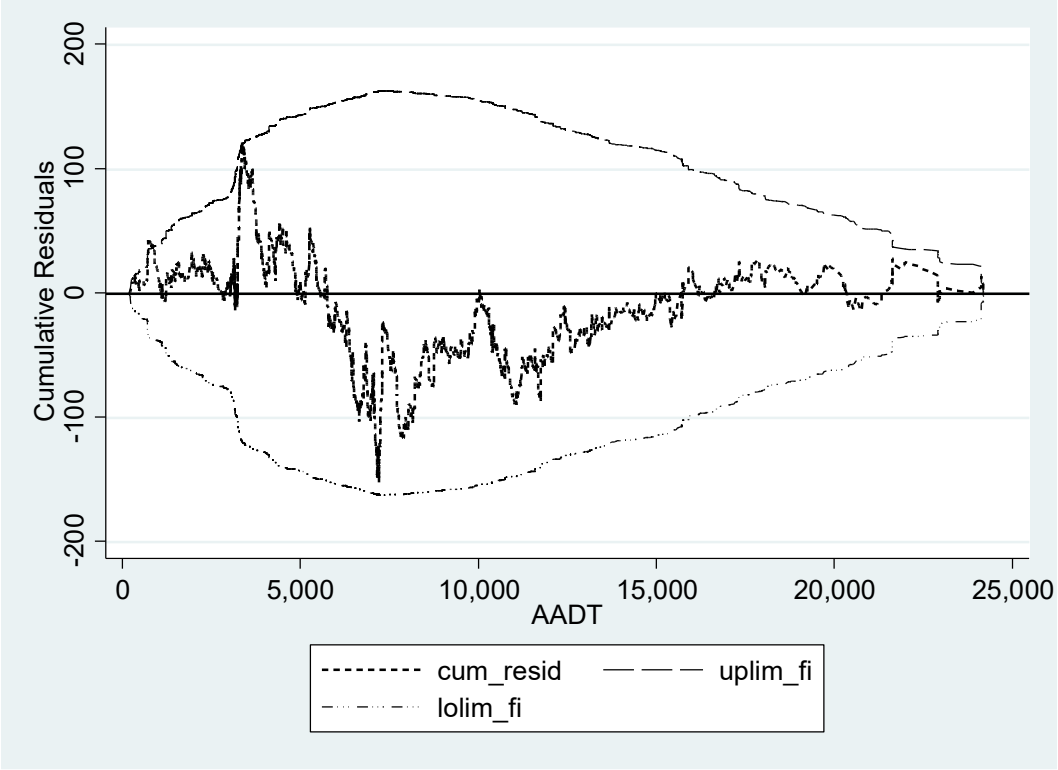

Figure 7 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 2-lane Segments (District 2)

Urban, Undivided 2-lane (District 3)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =     10,439
                                                LR chi2(5)        =   1873.90
Dispersion     = mean                           Prob > chi2       =    0.0000
Log likelihood = -25508.316                     Pseudo R2         =    0.0354
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3496893	.0160261	21.82	0.000	.3182787	.3811
aadt_25_10k	.2066322	.0383727	5.38	0.000	.1314232	.2818413
aadt_10_15k	.5588497	.0514856	10.85	0.000	.4579398	.6597595
aadt_15_18k	.7128069	.0689419	10.34	0.000	.5776833	.8479305
aadt_18kplus	.9221539	.0731851	12.60	0.000	.7787137	1.065594
_cons	-2.831699	.0915489	-30.93	0.000	-3.011132	-2.652267
ln(num_ye~s)	1	(exposure)				
/lnalpha	.1680701	.0183603			.1320845	.2040556
alpha	1.183019	.0217206			1.141205	1.226366

LR test of alpha=0: chibar2(01) = 2.8e+04 Prob >= chibar2 = 0.000

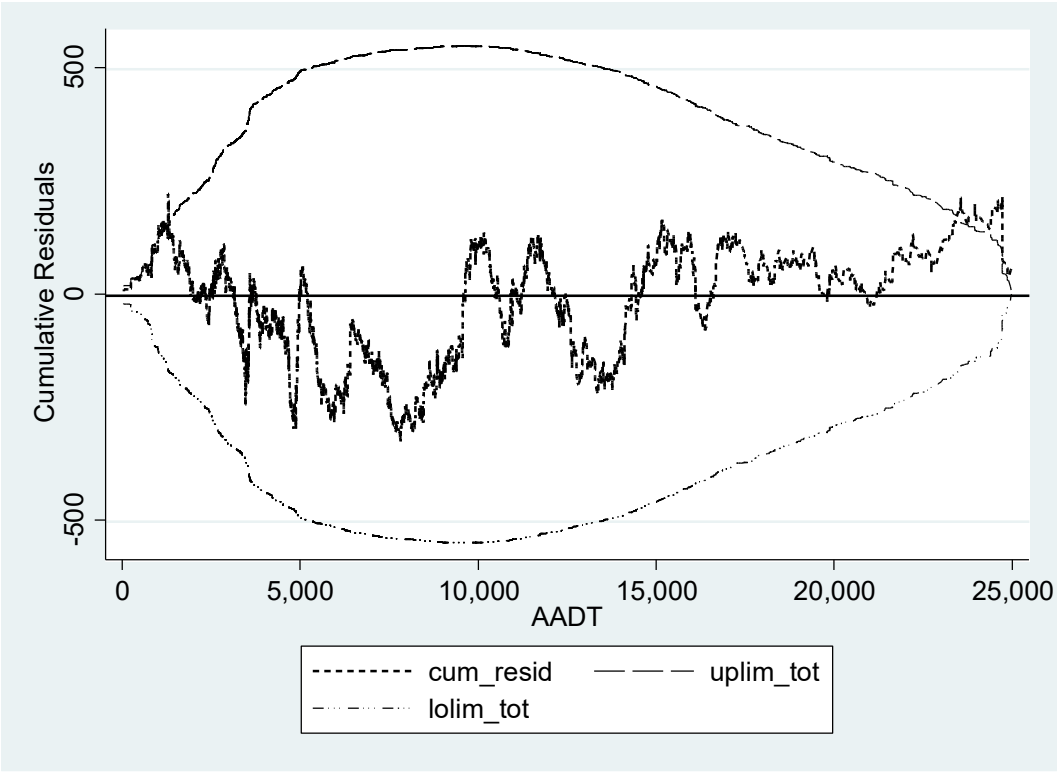

Figure 8 CURE Plot by AADT for Total Crashes on Urban, Undivided 2-lane Segments (District 3)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =     10,439
                                                LR chi2(5)        =   1310.69
Dispersion     = mean                           Prob > chi2       =    0.0000
Log likelihood = -13926.206                     Pseudo R2         =    0.0449
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.4272895	.0202875	21.06	0.000	.3875268	.4670521
aadt_25_10k	.1241047	.0516606	2.40	0.016	.0228519	.2253576
aadt_10_15k	.3960009	.0656695	6.03	0.000	.2672911	.5247107
aadt_15_18k	.558823	.0835693	6.69	0.000	.3950303	.7226158
aadt_18kplus	.6890174	.0876897	7.86	0.000	.5171488	.860886
_cons	-4.670323	.1193398	-39.13	0.000	-4.904225	-4.436422
ln(num_ye~s)	1	(exposure)				
/lnalpha	.1760909	.0326304			.1121365	.2400454
alpha	1.192547	.0389133			1.118666	1.271307

LR test of alpha=0: chibar2(01) = 3602.12 Prob >= chibar2 = 0.000

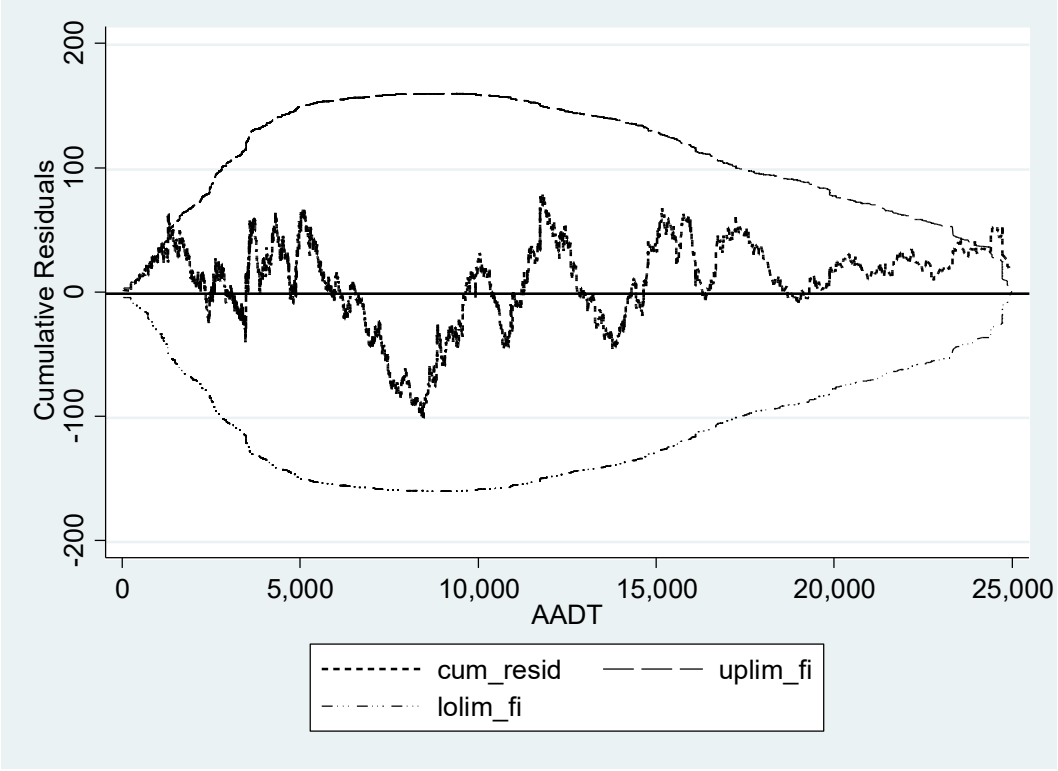

Figure 9 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 2-lane Segments (District 3)

Urban, Undivided 2-lane (District 4)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =     10,112
                                                LR chi2(7)        =    1310.57
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -24790.689                     Pseudo R2         =     0.0258
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3138871	.0209913	14.95	0.000	.2727449	.3550294
aadt_2_2930	-.1620951	.0783942	-2.07	0.039	-.3157449	-.0084454
aadt_2930_3k	.778899	.0919653	8.47	0.000	.5986504	.9591477
aadt_3_83	.1808351	.0636143	2.84	0.004	.0561534	.3055169
aadt_83_9050	.6437584	.0859834	7.49	0.000	.475234	.8122827
aadt_9050_13k	.3362727	.0761729	4.41	0.000	.1869766	.4855688
aadt_13kplus	.6308287	.0792982	7.96	0.000	.4754072	.7862503
_cons	-2.623987	.1180368	-22.23	0.000	-2.855334	-2.392639
ln(num_ye~s)	1	(exposure)				
/lnalpha	.2965334	.0181275			.2610041	.3320627
alpha	1.345188	.0243849			1.298233	1.39384

LR test of alpha=0: chibar2(01) = 3.2e+04 Prob >= chibar2 = 0.000

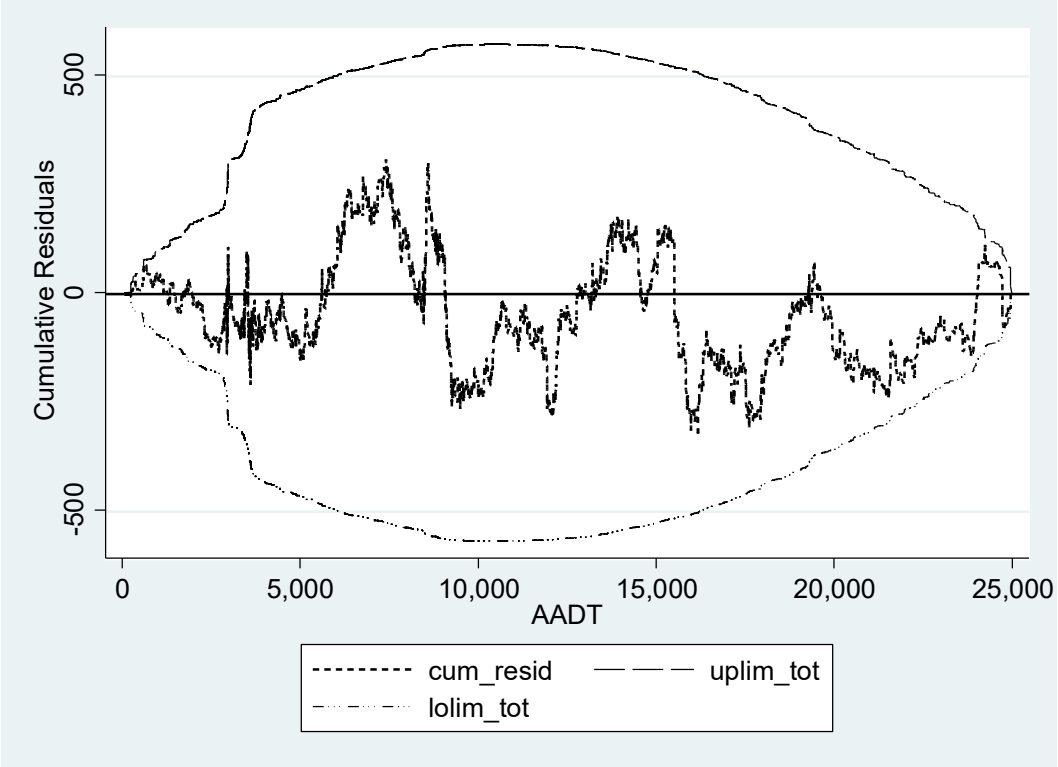

Figure 10 CURE Plot by AADT for Total Crashes on Urban, Undivided 2-lane Segments (District 4)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =     10,112
                                                LR chi2(6)        =     944.99
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -14431.132                     Pseudo R2         =     0.0317
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.306436	.0244837	12.52	0.000	.2584489	.3544231
aadt_2930_3k	.8749421	.1003563	8.72	0.000	.6782473	1.071637
aadt_3_83	.2802714	.0604772	4.63	0.000	.1617382	.3988045
aadt_83_9050	.8719994	.0869635	10.03	0.000	.701554	1.042445
aadt_9050_13k	.4837399	.0743876	6.50	0.000	.337943	.6295369
aadt_13kplus	.7376431	.0768936	9.59	0.000	.5869344	.8883518
_cons	-3.98715	.1427186	-27.94	0.000	-4.266874	-3.707427
ln(num_ye~s)	1	(exposure)				
/lnalpha	.3078742	.0295013			.2500527	.3656958
alpha	1.36053	.0401374			1.284093	1.441517

LR test of alpha=0: chibar2(01) = 5022.47 Prob >= chibar2 = 0.000

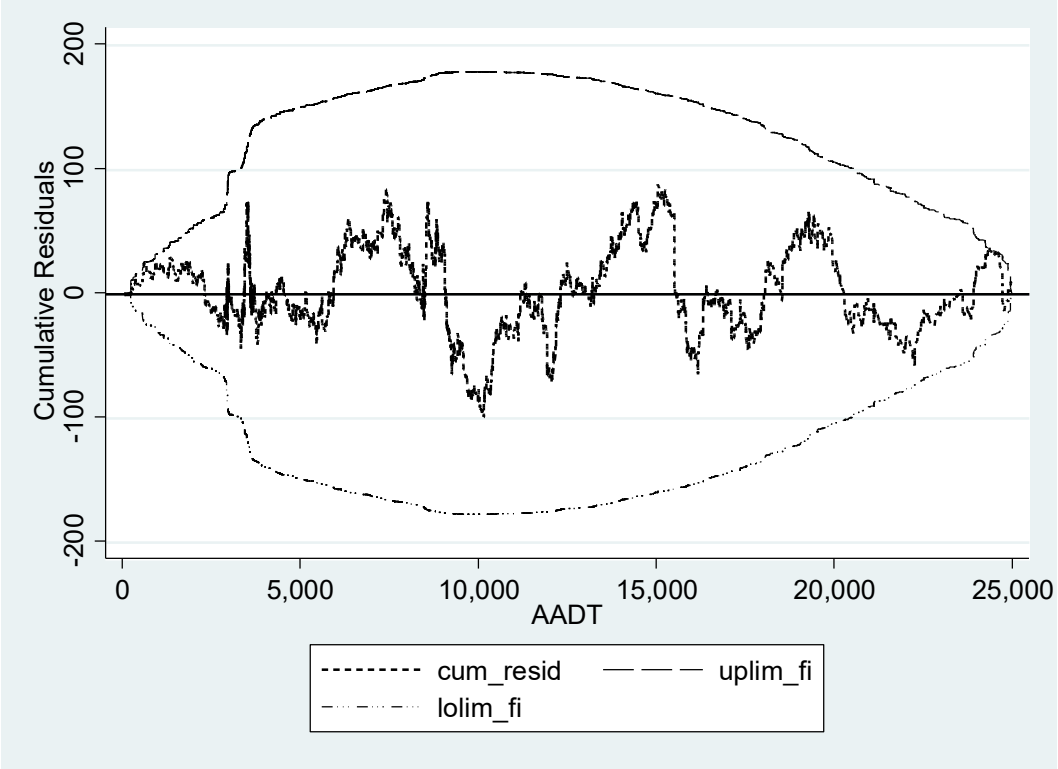

Figure 11 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 2-lane Segments (District 4)

Urban, Undivided 2-lane (District 5)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =     14,362
                                                LR chi2(6)        =    2746.63
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -32892.102                     Pseudo R2         =     0.0401
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.306436	.0244837	25.63	0.000	.3817701	.4449908
aadt_5_75k	.8749421	.1003563	3.51	0.000	.0506871	.1786195
aadt_75_125k	.2802714	.0604772	7.30	0.000	.1823022	.3160984
aadt_125_16k	.8719994	.0869635	12.12	0.000	.4736574	.6563554
aadt_16_19k	.4837399	.0743876	10.87	0.000	.5586706	.8044233
aadt_19kplus	.7376431	.0768936	13.76	0.000	.7782015	1.036791
_cons	-3.98715	.1427186	-34.54	0.000	-3.458294	-3.086869
ln(num_ye~s)	1	(exposure)				
/lnalpha	.2983514	.0161491			.2666998	.330003
alpha	1.347635	.0217631			1.305648	1.390972

LR test of alpha=0: chibar2(01) = 3.7e+04 Prob >= chibar2 = 0.000

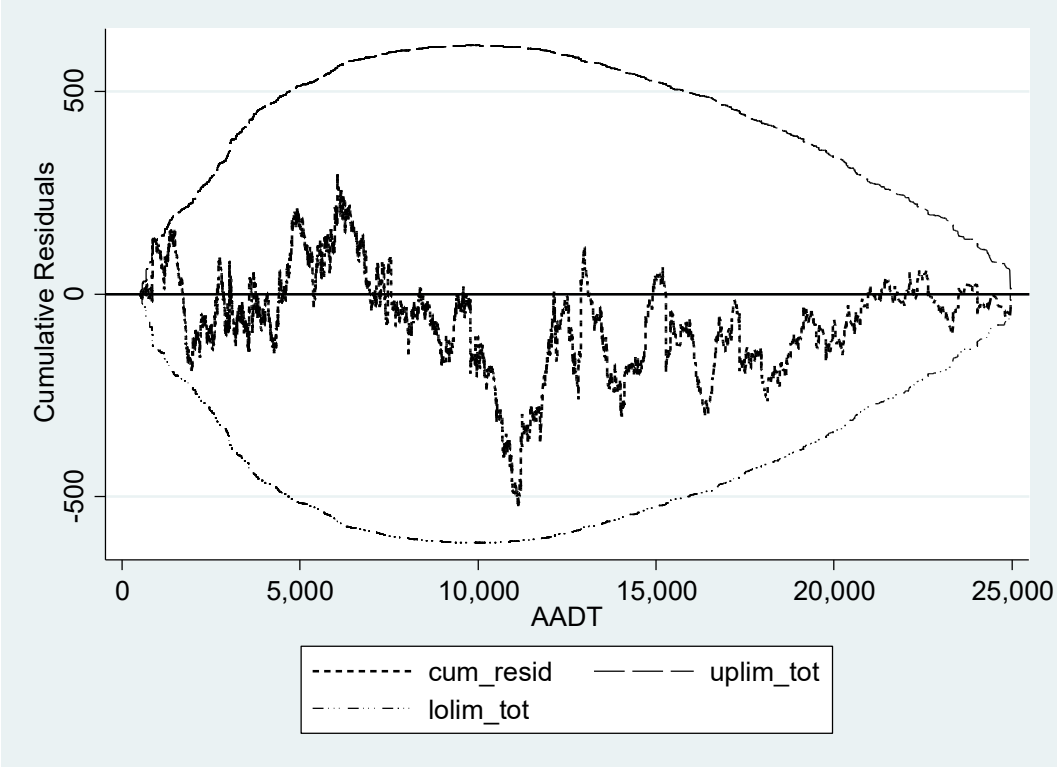

Figure 12 CURE Plot by AADT for Total Crashes on Urban, Undivided 2-lane Segments (District 5)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =     14,362
                                                LR chi2(6)        =    2055.92
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -19519.025                     Pseudo R2         =     0.0500
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.42982	.0198443	21.66	0.000	.3909258	.4687142
aadt_5_75k	.1130514	.040629	2.78	0.005	.0334201	.1926828
aadt_75_125k	.2660716	.0414969	6.41	0.000	.1847392	.3474041
aadt_125_16k	.5866922	.054631	10.74	0.000	.4796175	.693767
aadt_16_19k	.7334105	.0715075	10.26	0.000	.5932584	.8735627
aadt_19kplus	.9334789	.0743845	12.55	0.000	.787688	1.07927
_cons	-4.604081	.1180347	-39.01	0.000	-4.835425	-4.372738
ln(num_ye~s)	1	(exposure)				
/lnalpha	.3526292	.0255668			.3025192	.4027392
alpha	1.422804	.0363765			1.353264	1.495917

LR test of alpha=0: chibar2(01) = 7233.26 Prob >= chibar2 = 0.000

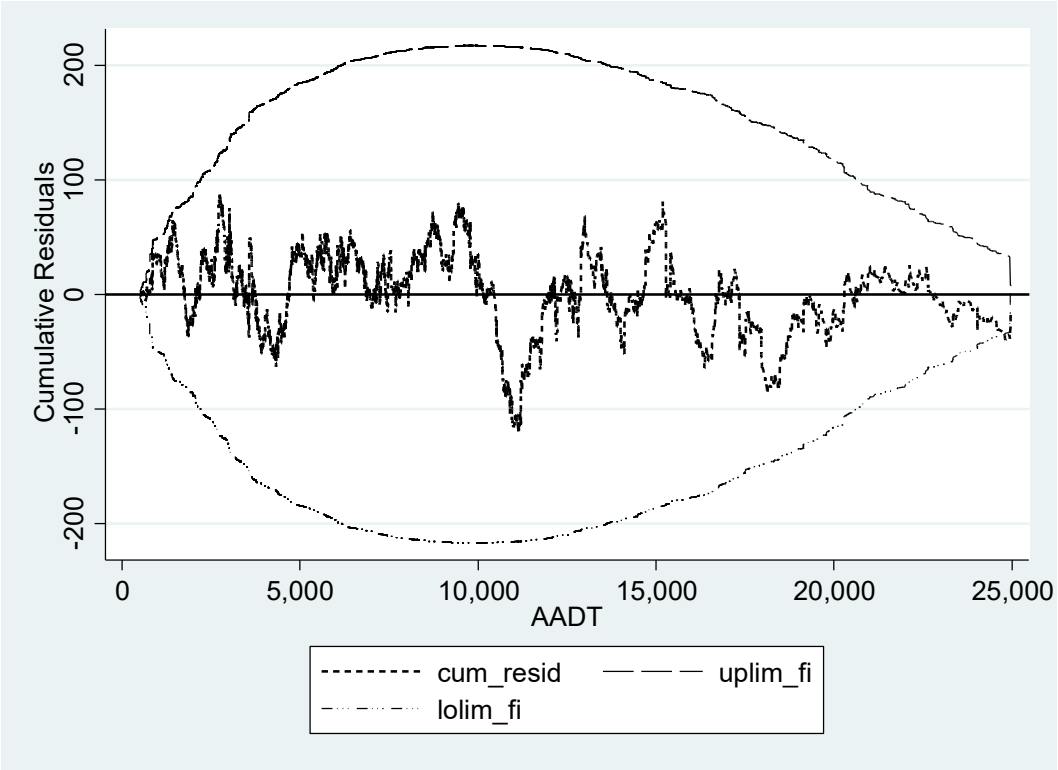

Figure 13 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 2-lane Segments (District 5)

Urban, Undivided 2-lane (District 6)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =      4,767
                                                LR chi2(9)        =     621.47
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -10831.541                     Pseudo R2         =     0.0279
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.372237	.0292966	12.71	0.000	.3148168	.4296573
func_3	1.59974	.2993807	5.34	0.000	1.012964	2.186515
func_5	1.306506	.2952997	4.42	0.000	.7277292	1.885283
func_6	1.193361	.2918515	4.09	0.000	.6213428	1.76538
aadt_33_36	.1880994	.059207	3.18	0.001	.0720557	.304143
aadt_40_42	-1.329286	.1586291	-8.38	0.000	-1.640193	-1.018379
aadt_8_10k	.1401512	.0643153	2.18	0.029	.0140956	.2662067
aadt_10_12k	-.4972837	.0646738	-7.69	0.000	-.6240421	-.3705254
aadt_18_22k	.1576899	.0743089	2.12	0.034	.0120471	.3033327
_cons	-4.127703	.3238407	-12.75	0.000	-4.762419	-3.492987
ln(num_ye~s)	1	(exposure)				
/lnalpha	.3141359	.0281239			.259014	.3692578
alpha	1.369076	.0385038			1.295652	1.446661

LR test of alpha=0: chibar2(01) = 1.1e+04 Prob >= chibar2 = 0.000

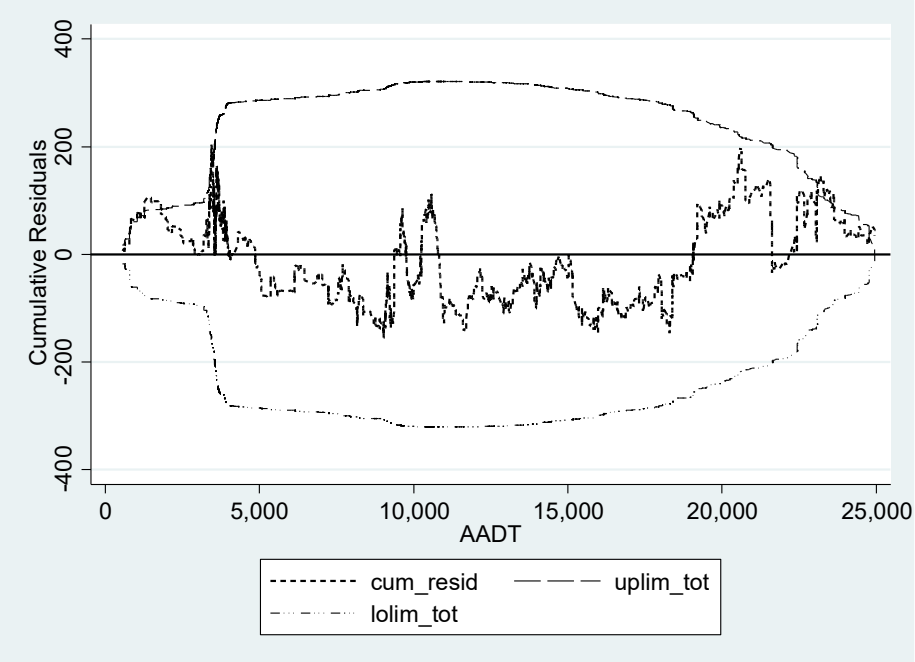

Figure 14 CURE Plot by AADT for Total Crashes on Urban, Undivided 2-lane Segments (District 6)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      4,767
                                                LR chi2(8)        =     406.70
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -6557.1916                     Pseudo R2         =     0.0301
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3600451	.0340356	10.58	0.000	.2933365	.4267537
func_3	1.633165	.4335838	3.77	0.000	.7833567	2.482974
func_5	1.365528	.4296165	3.18	0.001	.5234951	2.207561
func_6	1.07717	.4268393	2.52	0.012	.24058	1.91376
aadt_33_36	.1422633	.073769	1.93	0.054	-.0023213	.2868479
aadt_40_42	-.8887444	.2031994	-4.37	0.000	-1.287008	-.4904808
aadt_10_12k	-.3757901	.0745681	-5.04	0.000	-.521941	-.2296393
aadt_12_16k	-.1415245	.0721166	-1.96	0.050	-.2828704	-.0001786
_cons	-5.162118	.4567805	-11.30	0.000	-6.057391	-4.266845
ln(num_ye~s)	1	(exposure)				
/lnalpha	.3266323	.0443375			.2397324	.4135321
alpha	1.386292	.0614647			1.270909	1.512149

LR test of alpha=0: chibar2(01) = 2151.93 Prob >= chibar2 = 0.000

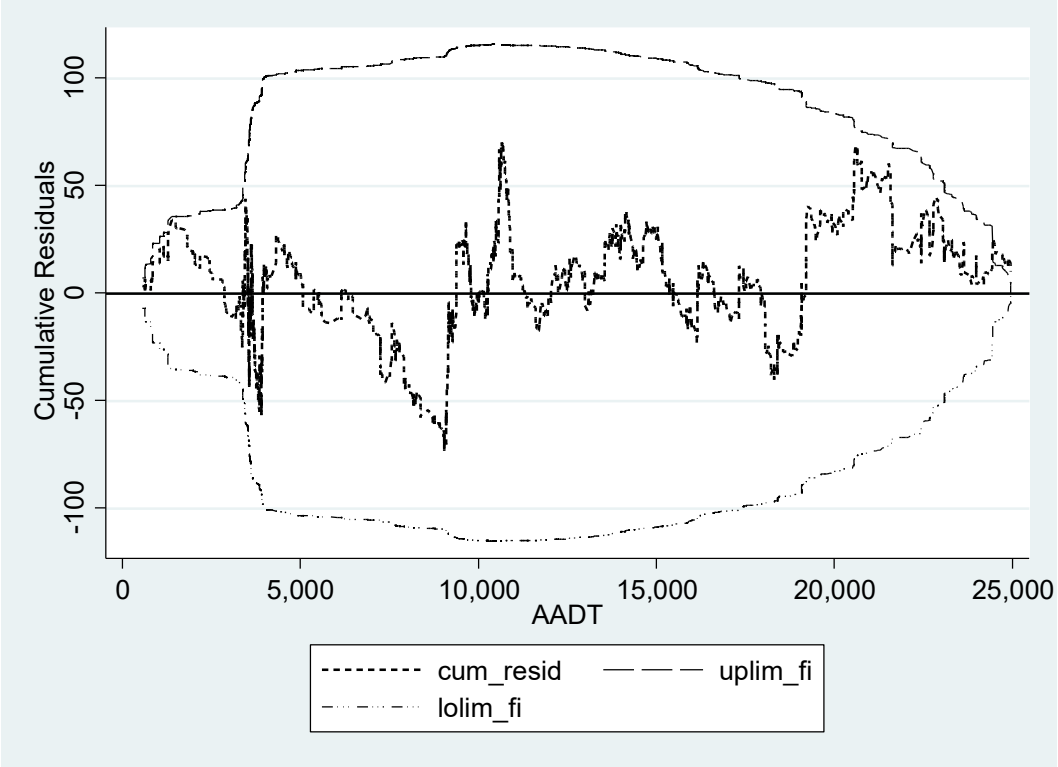

Figure 15 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 2-lane Segments (District 6)

Rural, Undivided 2-lane (District 1)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =      2,066
                                                LR chi2(2)        =     364.23
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -2111.6915                     Pseudo R2         =     0.0794
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.7168518	.0384909	18.62	0.000	.641411	.7922926
aadt_4_7k	-.4659482	.137985	-3.38	0.001	-.736394	-.1955025
_cons	-6.28157	.2348945	-26.74	0.000	-6.741955	-5.821186
ln(num_ye~s)	1	(exposure)				
/lnalpha	.0804095	.0952373			-.1062522	.2670712
alpha	1.083731	.1032116			.8991978	1.306133

LR test of alpha=0: chibar2(01) = 361.25 Prob >= chibar2 = 0.000

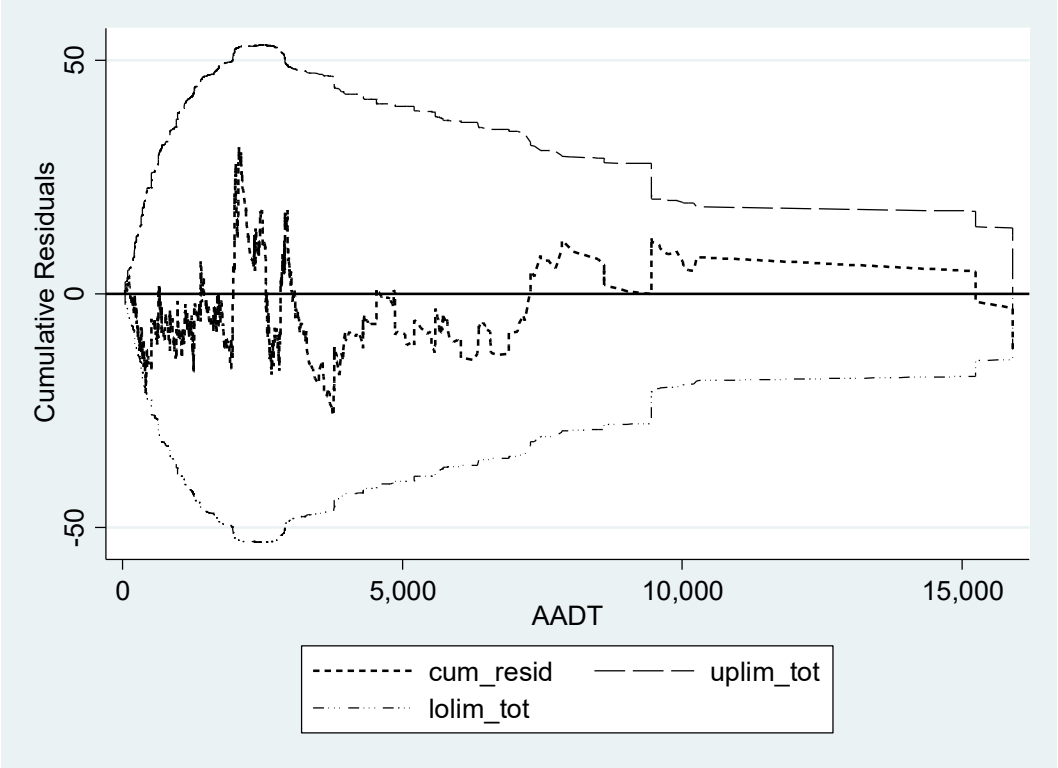

Figure 16 CURE Plot by AADT for Total Crashes on Rural, Undivided 2-lane Segments (District 1)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      2,066
                                                LR chi2(2)        =     149.63
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1057.2998                     Pseudo R2         =     0.0661
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.6620081	.0564641	11.72	0.000	.5513406	.7726757
aadt_4_7k	-.8292206	.2336254	-3.55	0.000	-1.287118	-.3713233
_cons	-7.090057	.350715	-20.22	0.000	-7.777446	-6.402668
ln(num_ye~s)	1	(exposure)				
/lnalpha	.1562084	.2065877			-.248696	.5611128
alpha	1.16907	.2415154			.779817	1.752622

LR test of alpha=0: chibar2(01) = 51.31 Prob >= chibar2 = 0.000

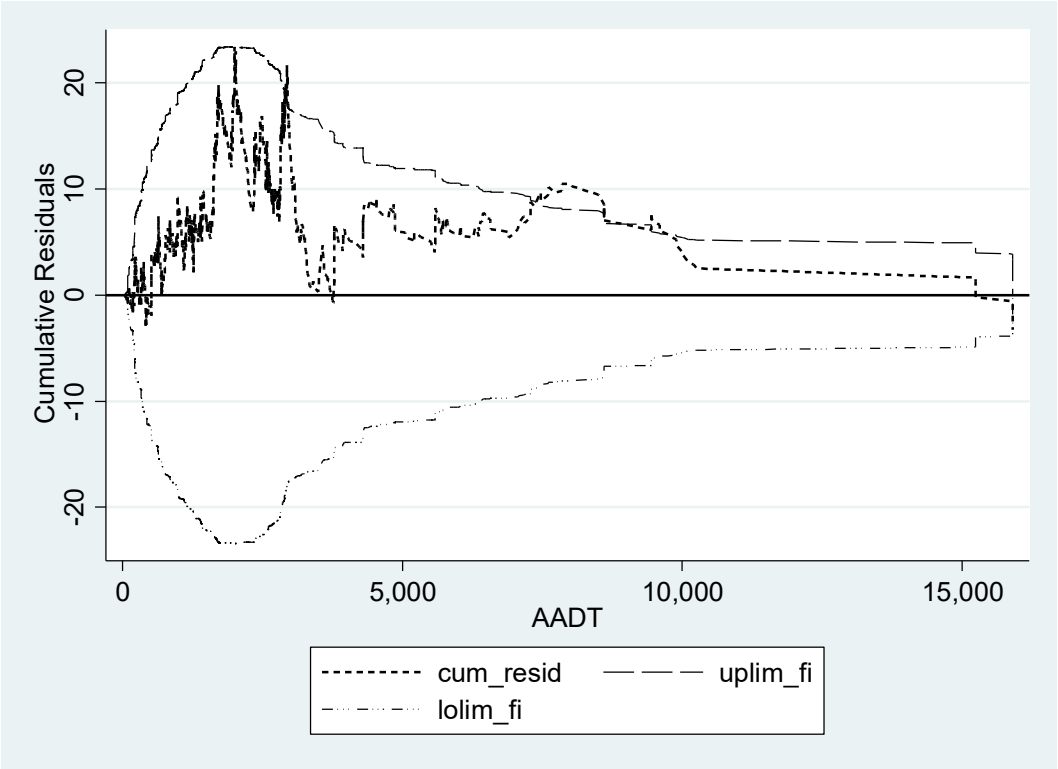

Figure 17 CURE Plot by AADT for Fatal and Injury Crashes on Rural, Undivided 2-lane Segments (District 1)

Rural, Undivided 2-lane (District 2)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =      1,827
                                                LR chi2(6)        =     426.90
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -2434.8546                     Pseudo R2         =     0.0806
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.6406178	.0422873	15.15	0.000	.5577363	.7234994
aadt_18less	-.4981694	.129215	-3.86	0.000	-.7514261	-.2449127
aadt_18_3k	-.6416257	.1382121	-4.64	0.000	-.9125165	-.3707349
aadt_4k_45	-1.010674	.1984824	-5.09	0.000	-1.399692	-.6216557
aadt_45_75	-.3035808	.1516196	-2.00	0.045	-.6007498	-.0064119
aadt_75plus	-.2933348	.1654451	-1.77	0.076	-.6176013	.0309316
_cons	-5.0709	.2993843	-16.94	0.000	-5.657683	-4.484118
ln(num_ye~s)	1	(exposure)				
/lnalpha	.1899293	.0741205			.0446559	.3352027
alpha	1.209164	.0896238			1.045668	1.398224

LR test of alpha=0: chibar2(01) = 888.56 Prob >= chibar2 = 0.000

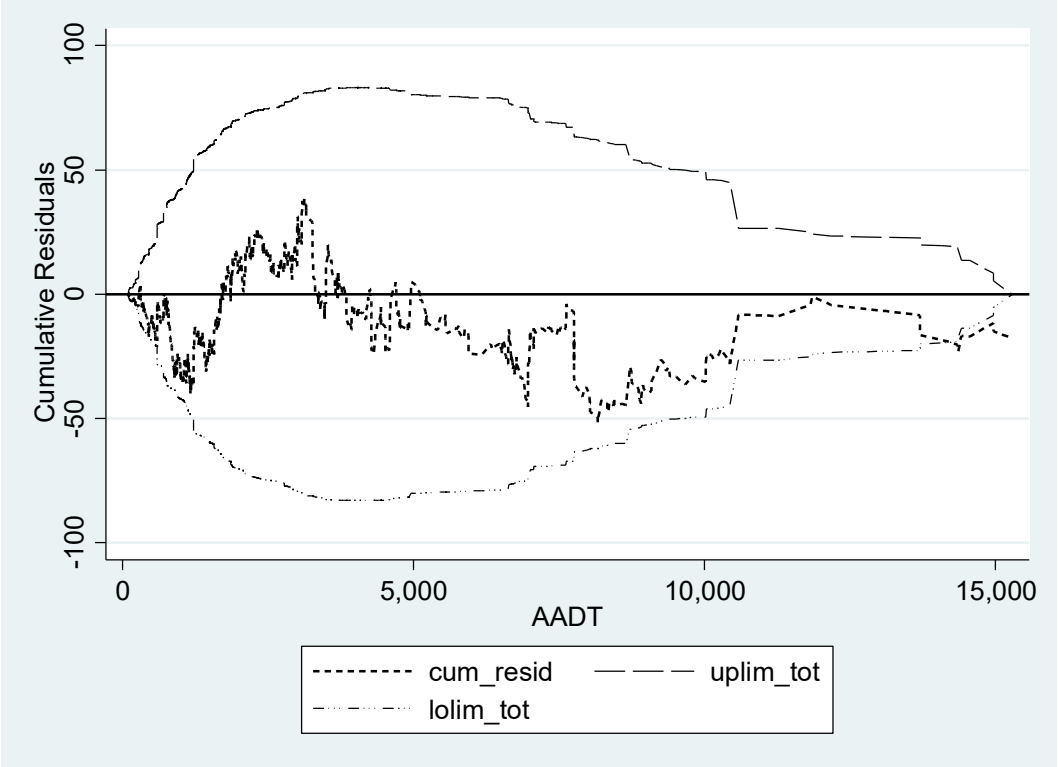

Figure 18 CURE Plot by AADT for Total Crashes on Rural, Undivided 2-lane Segments (District 2)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      1,827
                                                LR chi2(4)        =     221.34
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1267.9769                     Pseudo R2         =     0.0803
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.6170155	.0593617	10.39	0.000	.5006688	.7333623
aadt_18less	-.333941	.1436928	-2.32	0.020	-.6155736	-.0523083
aadt_18_3k	-.3971518	.151227	-2.63	0.009	-.6935513	-.1007523
aadt_4k_45	-.6499364	.2433597	-2.67	0.008	-1.126913	-.1729602
_cons	-6.325872	.4312429	-14.67	0.000	-7.171092	-5.480651
ln(num_ye~s)	1	(exposure)				
/lnalpha	.314999	.1391071			.0446559	.5876439
alpha	1.370258	.1906126			1.045668	1.799743

LR test of alpha=0: chibar2(01) = 153.96 Prob >= chibar2 = 0.000

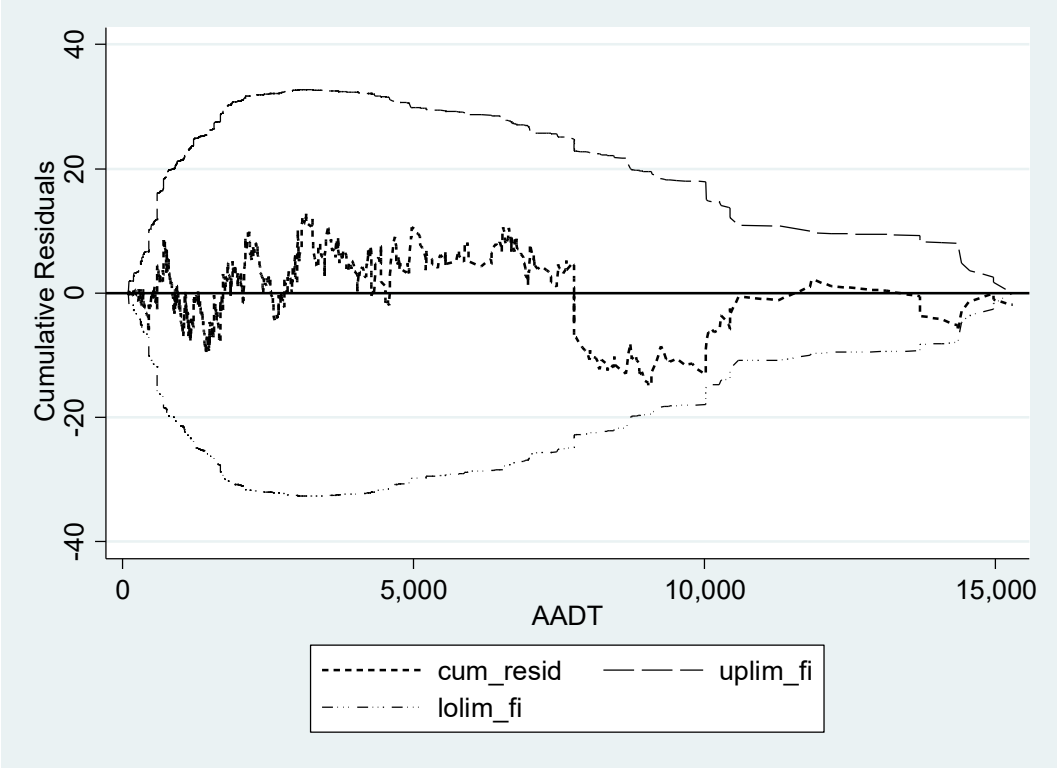

Figure 19 CURE Plot by AADT for Fatal and Injury Crashes on Rural, Undivided 2-lane Segments (District 2)

Rural, Undivided 2-lane (Districts 3, 4, 5)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =      1,409
                                                LR chi2(4)        =     373.07
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -2343.8625                     Pseudo R2         =     0.0737
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.6170155	.0389949	15.79	0.000	.5394953	.6923526
dist_3	-.333941	.0793135	7.23	0.000	.4180851	.7289882
aadt_45less	-.3971518	.0954591	1.98	0.048	.001884	.3760768
aadt_45_5k	-.6499364	.2023505	-2.75	0.006	-.9525418	-.1593425
_cons	-6.325872	.2929268	-18.86	0.000	-6.098323	-4.950071
ln(num_ye~s)	1	(exposure)				
/lnalpha	.0054224	.073119			-.1378882	.1487331
alpha	1.005437	.0735166			.8711961	1.160363

LR test of alpha=0: chibar2(01) = 940.28 Prob >= chibar2 = 0.000

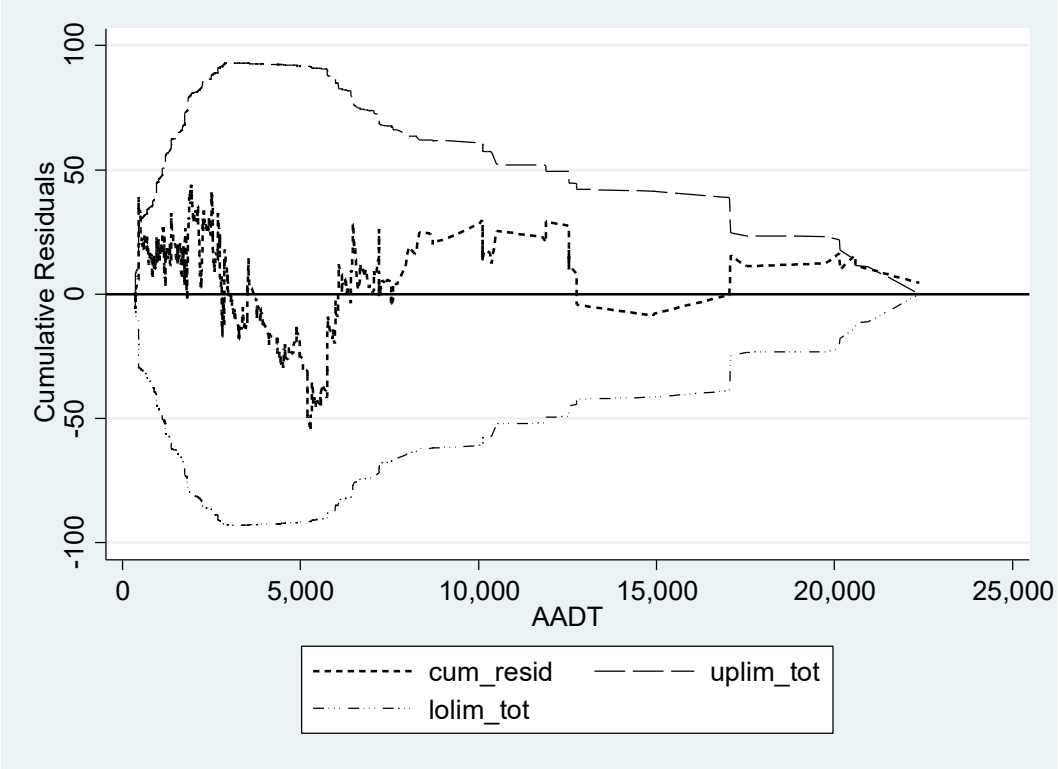

Figure 20 CURE Plot by AADT for Total Crashes on Rural, Undivided 2-lane Segments (Districts 3, 4, 5)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      1,409
                                                LR chi2(3)        =     175.07
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1256.7697                     Pseudo R2         =     0.0651
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.5990837	.0539671	11.10	0.000	.4933101	.7048574
dist_3	.4726813	.1129807	4.18	0.000	.2512433	.6941193
aadt_45less	.285056	.12403	2.30	0.022	.0419616	.5281504
_cons	-6.672638	.4045359	-16.49	0.000	-7.465514	-5.879762
ln(num_ye~s)	1	(exposure)				
/lnalpha	.0886982	.1365368			-.1789089	.3563054
alpha	1.092751	.1492007			.8361821	1.428044

LR test of alpha=0: chibar2(01) = 156.82 Prob >= chibar2 = 0.000

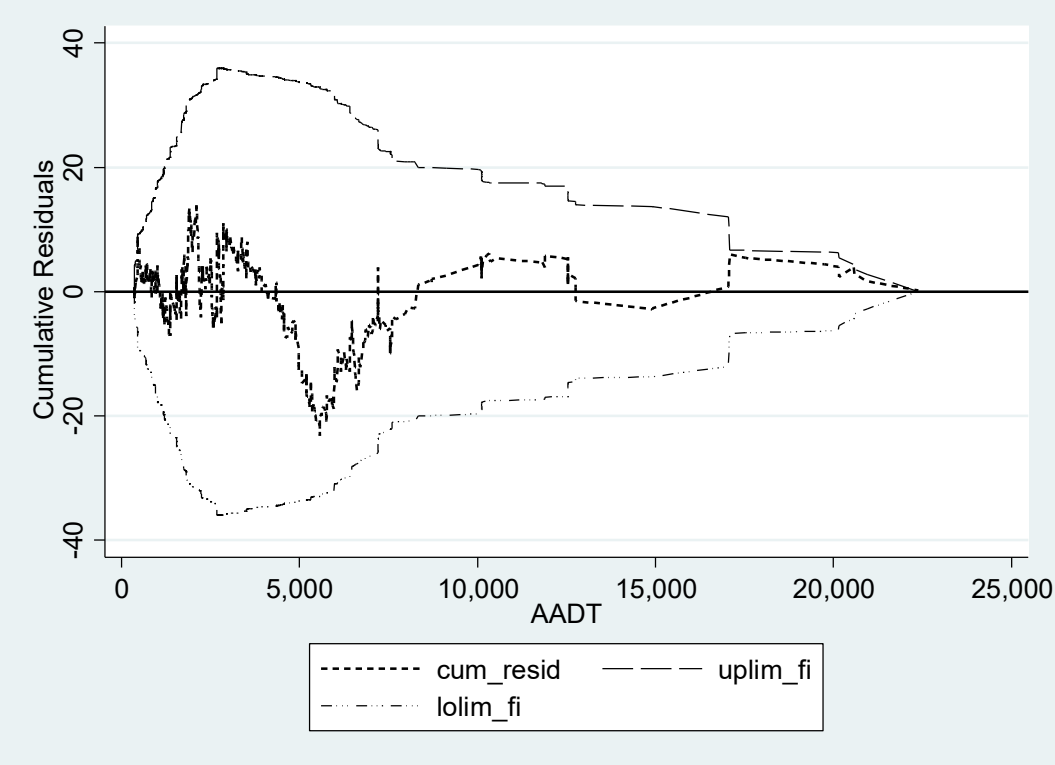

Figure 21 CURE Plot by AADT for Fatal and Injury Crashes on Rural, Undivided 2-lane Segments (Districts 3, 4, 5)

Urban, Divided 4-lane (Districts 1, 2, 3)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =        378
                                                LR chi2(3)        =      24.34
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1252.4847                     Pseudo R2         =     0.0096
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3735573	.0875214	4.27	0.000	.2020185	.5450961
dist_3	-.3440945	.1378325	-2.50	0.013	-.6142411	-.0739478
aadt_12_17k	.2779824	.1507252	1.84	0.065	-.0174335	.5733983
_cons	-1.942461	.6573411	-2.96	0.003	-3.230826	-.6540961
ln(num_ye~s)	1	(exposure)				
/lnalpha	.4606003	.0774058			.3088876	.6123129
alpha	1.092751	.1492007			1.361909	1.844693

LR test of alpha=0: chibar2(01) = 3847.08 Prob >= chibar2 = 0.000

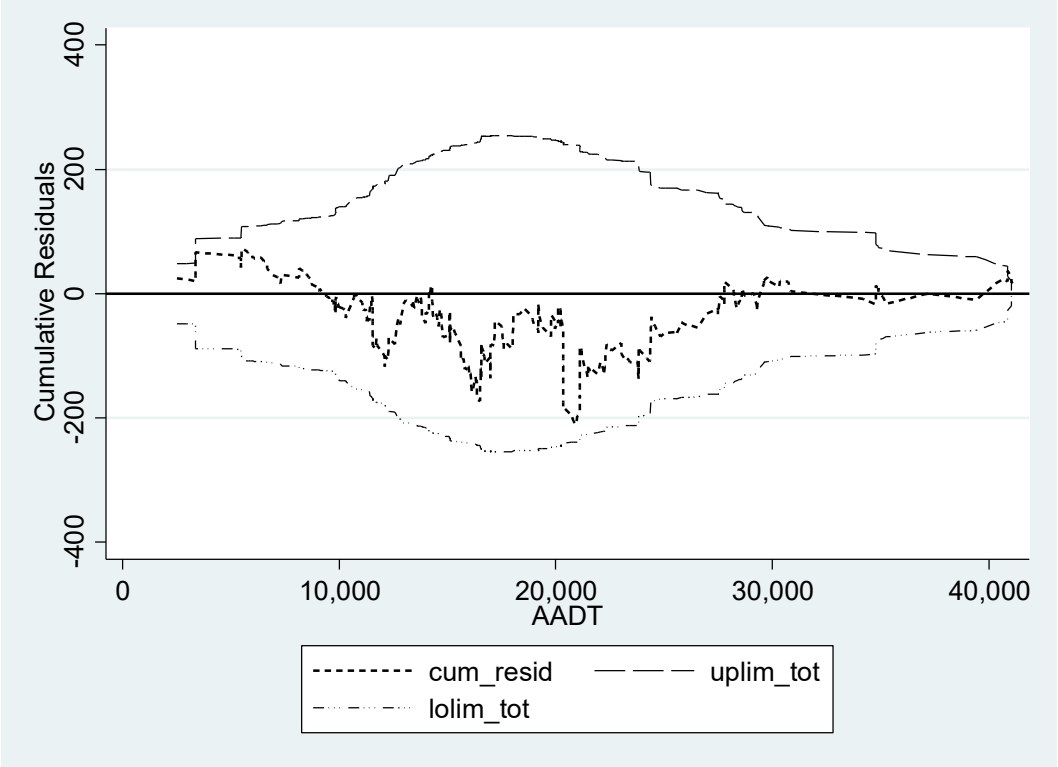

Figure 22 CURE Plot by AADT for Total Crashes on Urban, Divided 4-lane Segments (Districts 1, 2, 3)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =        375
                                                LR chi2(3)        =      32.57
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -806.21429                     Pseudo R2         =     0.0198
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3080769	.1000223	3.08	0.002	.1120367	.504117
dist_3	-.7464332	.149319	-5.00	0.000	-1.039093	-.4537732
aadt_12_15k	.4055565	.2171798	1.87	0.062	-.020108	.8312211
_cons	-2.495568	.7535797	-3.31	0.001	-3.972557	-1.018579
ln(num_ye~s)	1	(exposure)				
/lnalpha	.493718	.1038805			.2901159	.6973201
alpha	1.638396	.1701975			1.336582	2.008363

LR test of alpha=0: chibar2(01) = 819.07 Prob >= chibar2 = 0.000

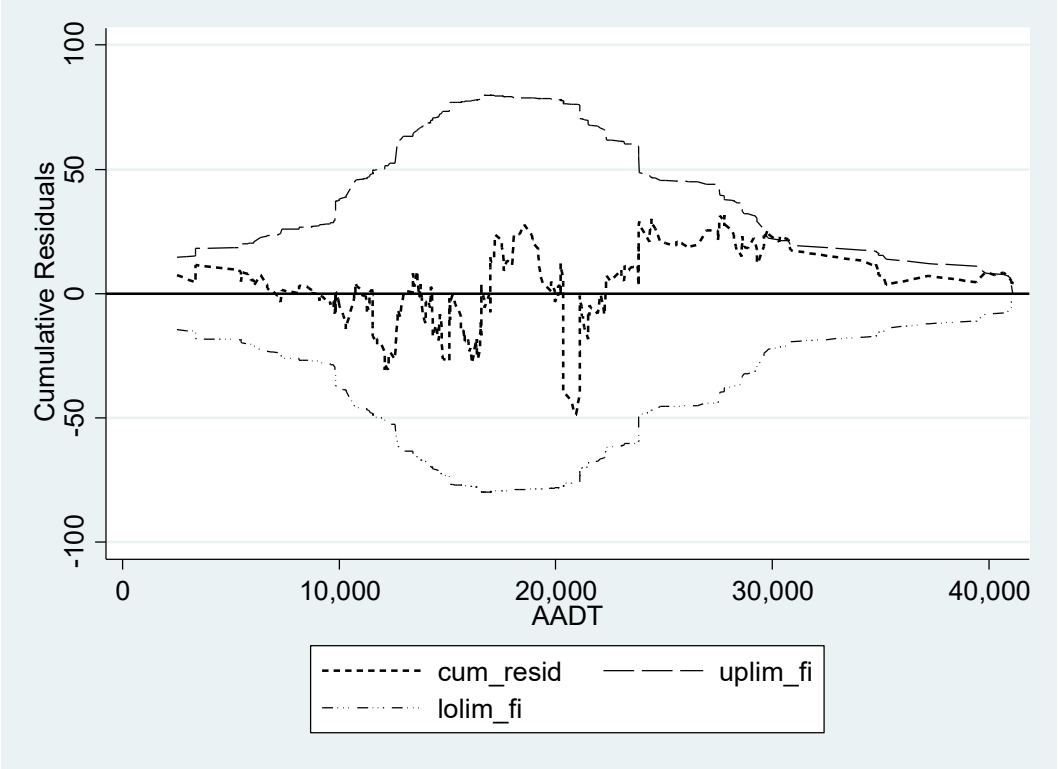

Figure 23 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Divided 4-lane Segments (Districts 1, 2, 3)

Urban, Divided 4-lane (Districts 4, 5, 6)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =      1,201
                                                LR chi2(4)        =     119.17
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -3440.0161                     Pseudo R2         =     0.0170
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.2162538	.0499793	4.33	0.000	.1182962	.3142113
aadt_14_16k	.6297184	.18057	3.49	0.000	.2758077	.9836291
dist_4	.792753	.1136415	6.98	0.000	.5700198	1.015486
dist_5	.7744238	.0914324	8.47	0.000	.5952196	.953628
_cons	-1.915781	.3879998	-4.9	0.000	-2.676247	-1.155315
ln(num_ye~s)	1	(exposure)				
/lnalpha	.5852921	.0465061			.4941419	.6764423
alpha	1.795515	.0835024			1.639091	1.966868

LR test of alpha=0: chibar2(01) = 8826.11 Prob >= chibar2 = 0.000

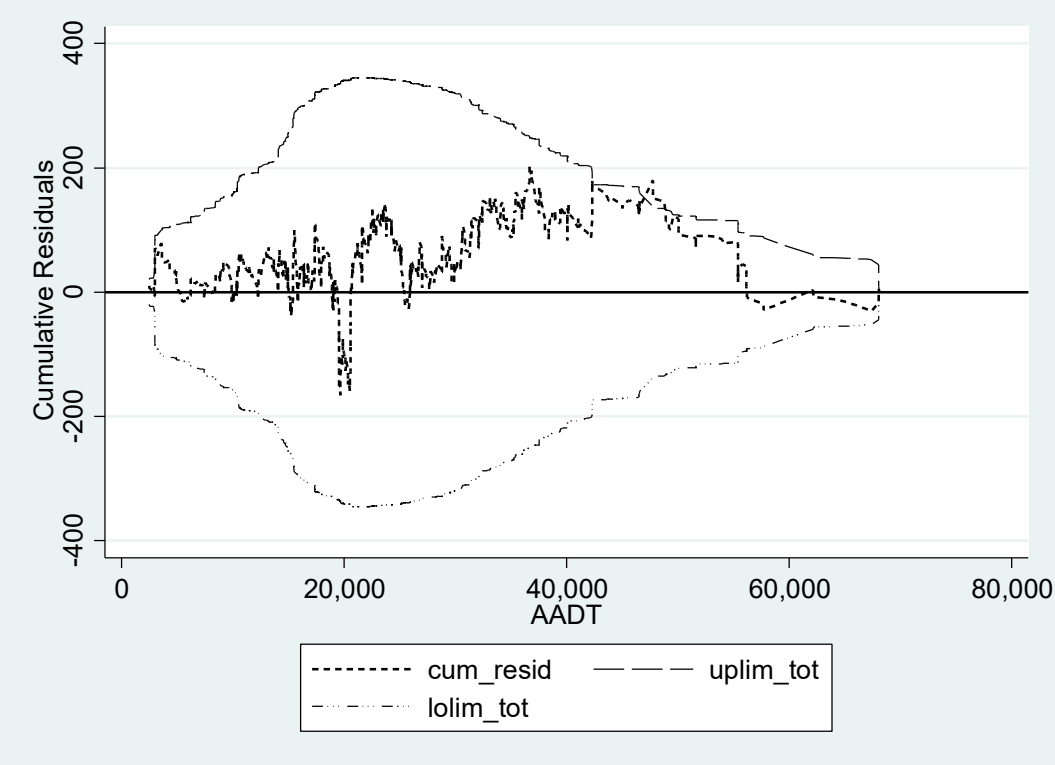

Figure 24 CURE Plot by AADT for Total Crashes on Urban, Divided 4-lane Segments (Districts 4, 5, 6)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =      1,201
                                                LR chi2(6)        =      64.74
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -2274.6682                     Pseudo R2         =     0.0140
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.1951364	.0532872	3.66	0.000	.0906954	.2995775
aadt_14_16k	.5711286	.1888707	3.02	0.002	.2009488	.9413084
aadt_16_20k	-.2012807	.1211041	-1.66	0.097	-.4386403	.036079
aadt_20_22k	.3513941	.1607866	2.19	0.029	.0362581	.6665301
dist_4	.4166887	.1209499	3.45	0.001	.1796313	.6537462
dist_5	.4525089	.0994335	4.55	0.000	.2576228	.6473951
_cons	-2.694215	.4158575	-6.48	0.000	-3.509281	1.879149
ln(num_ye~s)	1	(exposure)				
/lnalpha	.5338475	.063238			.4099033	.6577918
alpha	1.705482	.1078513			1.506672	1.930525

LR test of alpha=0: chibar2(01) = 1818.40 Prob >= chibar2 = 0.000

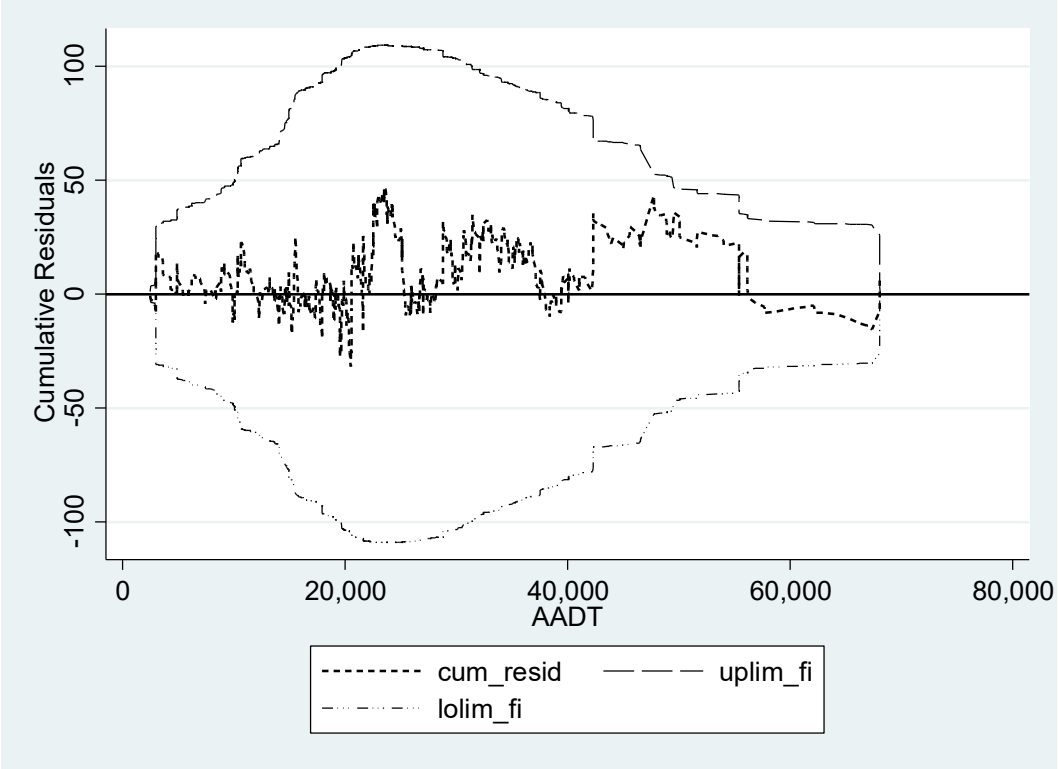

Figure 25 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Divided 4-lane Segments (Districts 4, 5, 6)

Urban, Undivided 4-lane (Districts 2, 3, 4)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =        601
                                                LR chi2(6)        =      64.74
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -2265.1805                     Pseudo R2         =     0.0098
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3175829	.0591689	5.37	0.000	.2016141	.4335518
aadt_7_10k	-.5629676	.2148057	-2.62	0.009	-.9839791	-.1419562
_cons	-1.214	.4467149	-2.72	0.007	-2.089545	-.338455
ln(num_ye~s)	1	(exposure)				
/lnalpha	-.1315975	.0604328			-.2500437	-.0131514
alpha	.8766938	.0529811			.7787667	.9869348

LR test of alpha=0: chibar2(01) = 5523.52 Prob >= chibar2 = 0.000

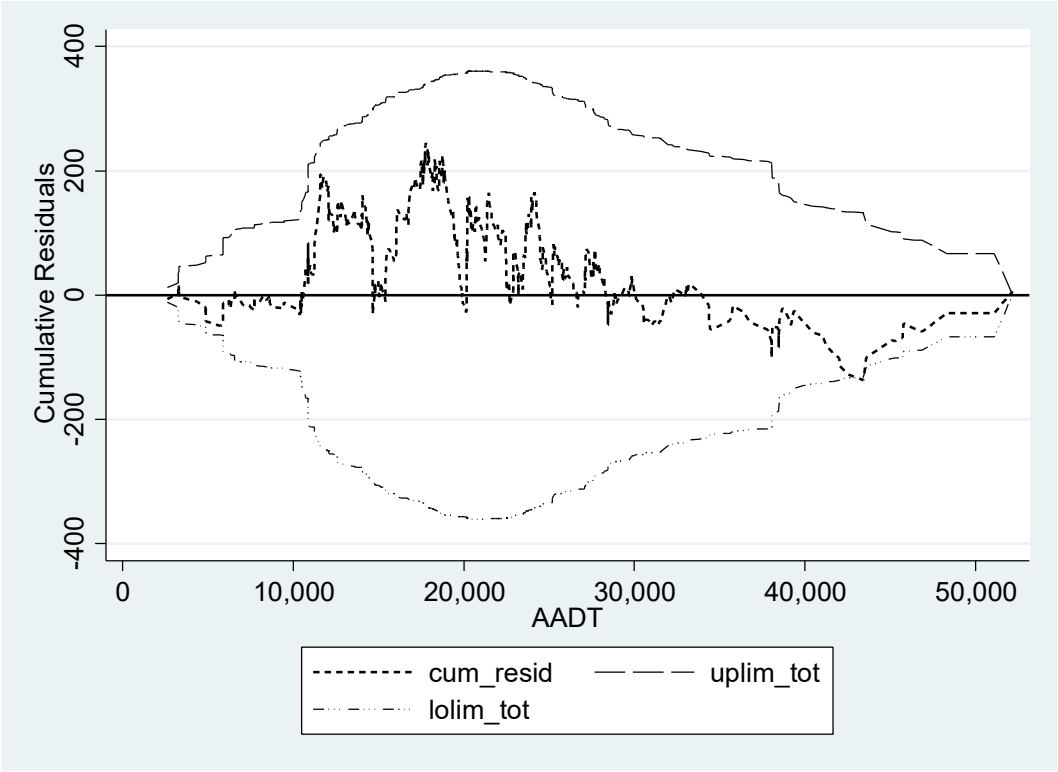

Figure 26 CURE Plot by AADT for Total Crashes on Urban, Undivided 4-lane Segments (Districts 2, 3, 4)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =        601
                                                LR chi2(2)        =      35.56
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1602.7562                     Pseudo R2         =     0.0110
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.3750253	.0650345	5.77	0.000	.2475602	.5024905
aadt_10_17k	.3494475	.0994814	3.51	0.000	.1544676	.5444274
_cons	-2.932145	.4981239	-5.89	0.000	-3.90845	-1.95584
ln(num_ye~s)	1	(exposure)				
/lnalpha	-.141749	.0762908			-.2912762	.0077783
alpha	.8678391	.0662081			.7473092	1.007809

LR test of alpha=0: chibar2(01) = 1257.44 Prob >= chibar2 = 0.000

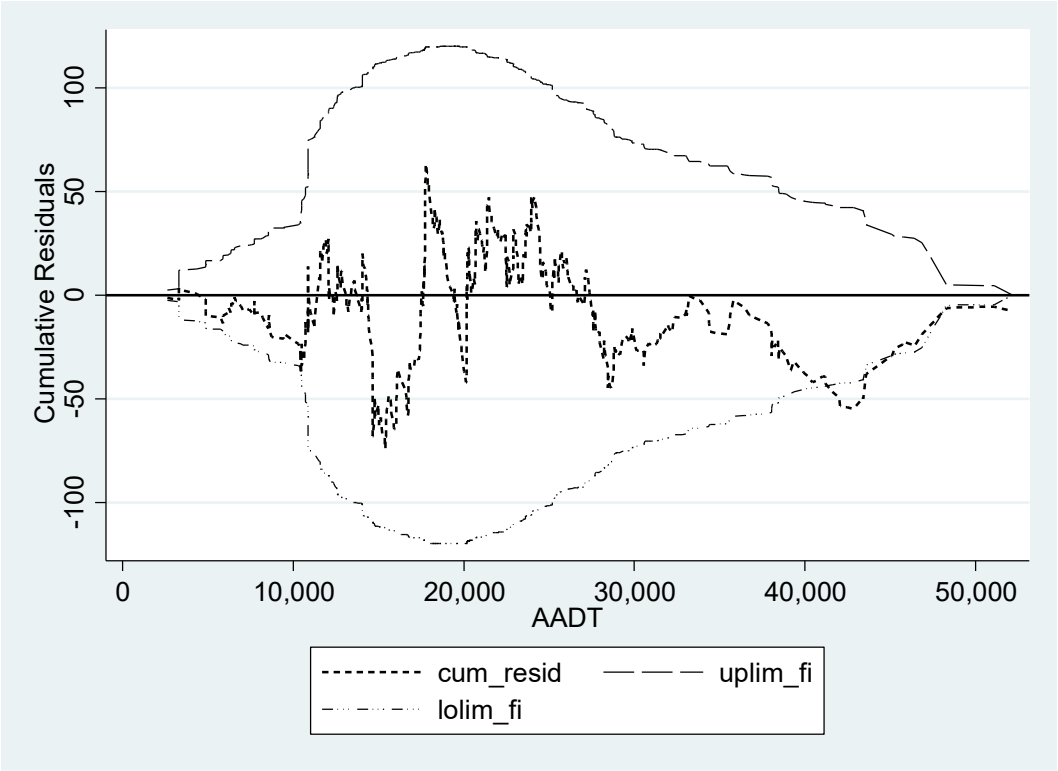

Figure 27 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 4-lane Segments (Districts 2, 3, 4)

Urban, Undivided 4-lane (District 5)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =        374
                                                LR chi2(2)        =      46.94
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1333.906                      Pseudo R2         =     0.0173
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.5003436	.0854251	5.86	0.000	.3329134	.6677738
aadt_8kless	-.4400177	.2024227	-2.17	0.030	-.8367588	-.0432766
_cons	-2.802363	.6520833	-4.30	0.000	-4.080423	-1.524304
ln(num_ye~s)	1	(exposure)				
/lnalpha	.0901627	.0792081			-.0650822	.2454077
alpha	1.094352	.0866815			.9369904	1.278142

LR test of alpha=0: chibar2(01) = 3133.64 Prob >= chibar2 = 0.000

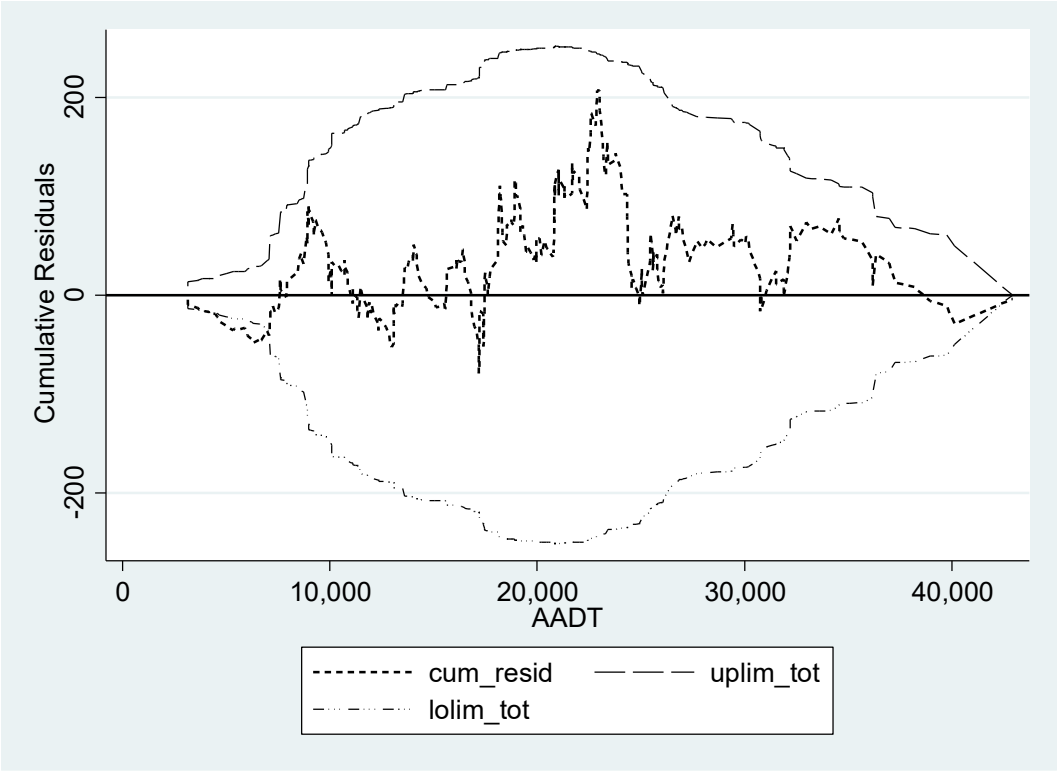

Figure 28 CURE Plot by AADT for Total Crashes on Urban, Undivided 4-lane Segments (District 5)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =        374
                                                LR chi2(2)        =      48.97
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -917.72134                     Pseudo R2         =     0.0260
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.5200037	.0914429	5.69	0.000	.3407789	.6992285
aadt_8kless	-.6684424	.2325711	-2.87	0.004	-1.124273	-.2126114
_cons	-4.133821	.7001961	-5.90	0.000	-5.50618	-2.761462
ln(num_ye~s)	1	(exposure)				
/lnalpha	.0557211	.1014818			-.1431795	.2546217
alpha	1.057303	.1072969			.8665985	1.289973

LR test of alpha=0: chibar2(01) = 744.10 Prob >= chibar2 = 0.000

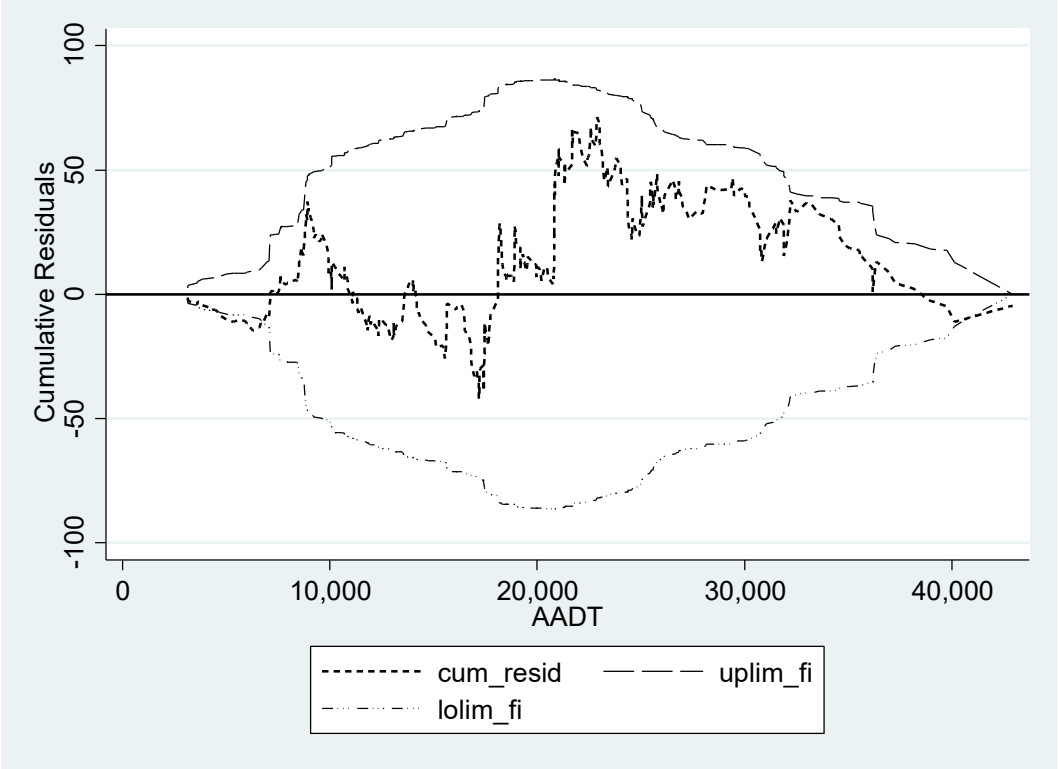

Figure 29 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 4-lane Segments (District 5)

Urban, Undivided 4-lane (District 6)

Model parameters for Total crashes

```
Negative binomial regression                    Number of obs     =        391
                                                LR chi2(3)        =      48.28
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -1210.1536                     Pseudo R2         =     0.0196
```

tot_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.5497304	.1122653	4.90	0.000	.3296945	.7697664
aadt_9_10k	.7642416	.2324786	3.29	0.001	.3085919	1.219891
aadt_10_18k	-.5073955	.1658414	-3.06	0.002	-.8324386	-.1823524
_cons	-3.703251	.8771236	-4.22	0.000	-5.422382	-1.98412
ln(num_ye~s)	1	(exposure)				
/lnalpha	.2384555	.0810376			.0796247	.3972864
alpha	1.269287	.10286			1.082881	1.487782

LR test of alpha=0: chibar2(01) = 2467.61 Prob >= chibar2 = 0.000

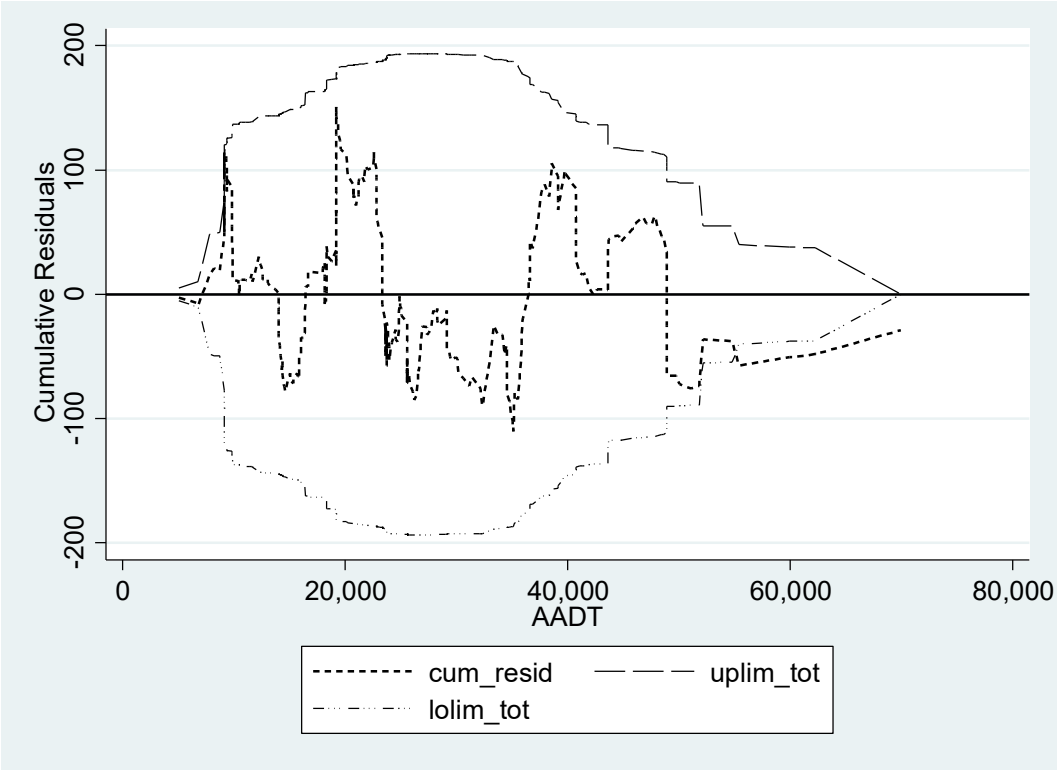

Figure 30 CURE Plot by AADT for Total Crashes on Urban, Undivided 4-lane Segments (District 6)

Model parameters for Fatal and Injury crashes

```
Negative binomial regression                    Number of obs     =        391
                                                LR chi2(3)        =      49.54
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -821.09513                     Pseudo R2         =     0.0293
```

fi_crash	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
log_vehmiles	.559261	.1066601	5.24	0.000	.3502109	.768311
aadt_9_10k	.6694683	.2205982	3.03	0.003	.2371039	1.101833
aadt_10_16k	-.4427968	.1797828	-2.46	0.014	-.7951646	-.090429
_cons	-4.916948	.8384375	-5.86	0.000	-6.560255	-3.27364
ln(num_ye~s)	1	(exposure)				
/lnalpha	-.1367725	.1179627			-.3679751	.0944302
alpha	.8721687	.1028834			.6921344	1.099032

LR test of alpha=0: chibar2(01) = 353.62 Prob >= chibar2 = 0.000

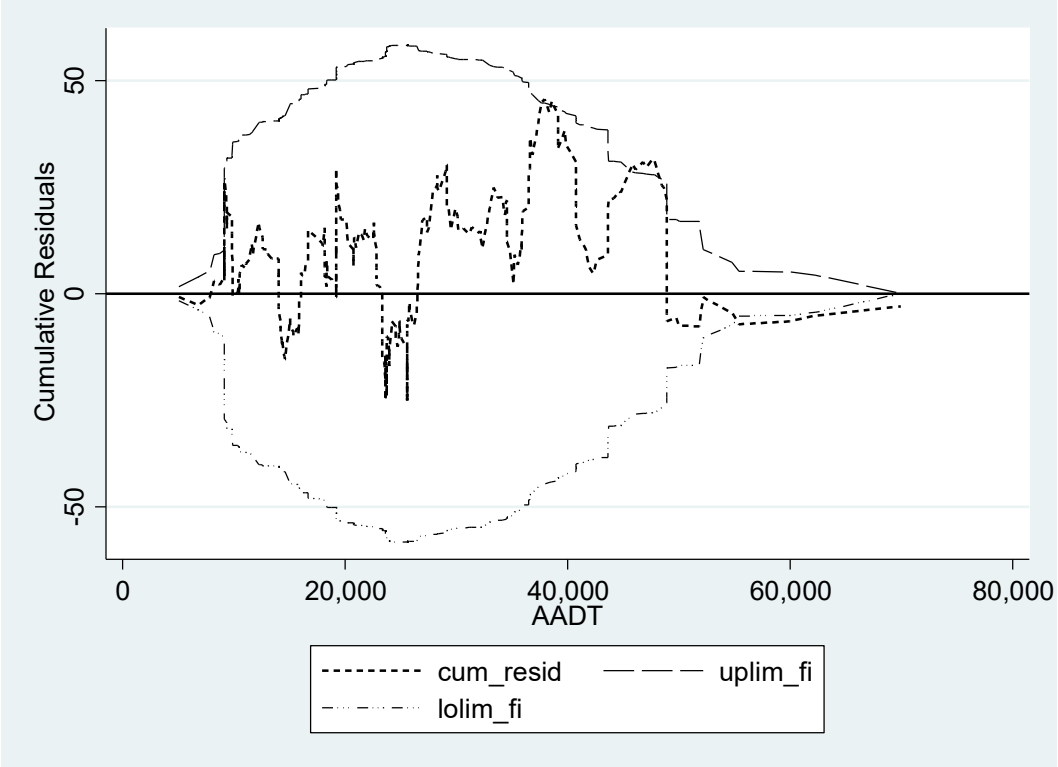

Figure 31 CURE Plot by AADT for Fatal and Injury Crashes on Urban, Undivided 4-lane Segments (District 6)