GEORGIA DOT RESEARCH PROJECT 23-22

Final Report

SAFETY EFFECTIVENESS OF INSIDE SHOULDER WIDTHS ON FREEWAYS IN GEORGIA

Georgia Department of Transportation

Office of Performance-based Management and Research
600 W Peachtree NW | Atlanta, GA 30308

October 2025

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-GA-25-2322	N/A	N/A

4. Title and Subtitle Safety Effectiveness of Inside Shoulder Widths on Freeways in Georgia	**5. Report Date** October 2025 **6. Performing Organization Code** N/A
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9. Performing Organization Name and Address University of Georgia Research Foundation, Inc. 310 East Campus Rd, Tucker Hall, Rm 409 Athens, GA 30602; The Board of Trustees of The University of Alabama, 152 Rose Administration Building, Box 870104, Tuscaloosa, AL 35401	**10. Work Unit No.** N/A **11. Contract or Grant No.** RP 23-22
12. Sponsoring Agency Name and Address Georgia Department of Transportation Office of Performance-based Management and Research 600 W Peachtree St. NW | Atlanta, GA 30308	**13. Type of Report and Period Covered** Final Report (November 2023–October 2025) **14. Sponsoring Agency Code** N/A

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract
This report presents a comprehensive analysis of the safety effectiveness of inside (left) shoulder widths on Georgia freeways, conducted as part of Georgia Department of Transportation (GDOT) Research Project 23-22. The study integrates six years (2018–2023) of traffic crash data, traffic volume data (annual average daily traffic [AADT] and truck percentages), and roadway inventory data to quantify the relationship between left shoulder width and crash outcomes across diverse freeway configurations. Covering over 1,800 freeway segments (2,400+ directional route miles) and 255,000+ georeferenced crashes, the research categorizes freeways into three types: statewide freeways without barrier, statewide freeways with barrier, and Atlanta urban freeways, further stratified by lane count (two lanes vs. three-plus lanes), traffic volume, and truck percentage. Safety performance functions (SPFs) and crash modification factors (CMFs) are developed using negative binomial regression to model crash frequencies for total crashes (KABCO), fatal/injury crashes (KAB), median-related crashes, and median-related KAB crashes, with a baseline of left shoulder width ≥10 ft. Key findings indicate that wider shoulders (6–8 ft) consistently reduce crash frequency, particularly for severe and median-related crashes, whereas narrow shoulders (<4 ft) correlate with elevated crash frequency – especially at high AADT (>60,000 vpd) and high truck percentages (>10 percent). Atlanta urban freeways with high truck percentages (>15 percent) require 8–10 ft shoulders to reduce crash frequency. The study aimed to provide evidence-based insights on when narrower shoulder widths may still achieve acceptable safety outcomes. These findings are intended to guide context-sensitive design decisions, especially when they differ from current GDOT and AASHTO/FHWA standards. Where recommendations deviate from prior research, such as the Highway Safety Manual (HSM) or NCHRP Web-Only Document 306, they should be carefully validated and critically examined.

17. Key Words	18. Distribution Statement
Freeway Safety, Safety Performance Functions, SPFs, Crash Modification Factors, CMFs, Inside Shoulder Width	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	152	Free

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

GDOT Research Project 23-22

Final Report

EFFECTIVENESS OF INSIDE SHOULDER WIDTHS ON FREEWAYS IN GEORGIA

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Contract with
Georgia Department of Transportation

In cooperation with
U.S. Department of Transportation, Federal Highway Administration

October 2025

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
CHAPTER 1. INTRODUCTION 5
BACKGROUND 5
PROJECT OBJECTIVES 6
CHAPTER 2. LITERATURE REVIEW 8
FEDERAL OR NATIONAL EFFORTS 8
Highway Safety Manual (HSM) 9
Federal Highway Administration 10
STATE-LED OR LOCAL PRACTICES 12
Houston 12
Dallas, Houston, and San Antonio 14
Los Angeles 17
Los Angeles (County), Orange, Marin, Alameda, Contra Costa, and San Diego Counties 17
Florida 19
Washington State 20
SCHOLARLY RESEARCH 21
Studies Using Traffic Crash Data 21
Studies Not Using Traffic Crash Data 24
CHAPTER 3. DATA AND METHODS 29
TRAFFIC CRASH DATA 29
TRAFFIC COUNT DATA 31
ROADWAY DATA 34
DATA PREPARATION 38
SAFETY PERFORMANCE FUNCTIONS 42
CRASH MODIFICATION FACTORS 46
CHAPTER 4. DESCRIPTIVE ANALYSIS 48
CRASH RATE ANALYSIS 48
DESCRIPTIVE STATISTICS OF SELECTED FREEWAY GROUPS 54
VISUALIZATION OF FREEWAY SEGMENTS WITH KEY FEATURES 62
CHAPTER 5. SAFETY PERFORMANCE FUNCTION RESULTS 69
RESULTS OF SPFS 69
VISUALIZATION OF SPF-PREDICTED CRASH FREQUENCY 86
CHAPTER 6. CRASH MODIFICATION FACTOR RESULTS 87
CMFS FOR TOTAL CRASHES (KABCO) 89
CMFS FOR FATAL AND INJURY CRASHES (KAB) 99

CMFS FOR MEDIAN-RELATED CRASHES 109
TAKEAWAYS OF CMF RESULTS 131

CHAPTER 7. POLICY IMPLICATIONS... 133

STATEWIDE FREEWAYS WITHOUT BARRIERS 133
STATEWIDE FREEWAYS WITH BARRIERS 134
ATLANTA URBAN FREEWAYS 135
SOME INSIGHTS 136

CHAPTER 8. CONSLUSIONS AND RECOMMENDATIONS 138

APPENDIX. SUMMARY OF SCHOLARLY RESEARCH ON THE SAFETY IMPACT OF LEFT (INSIDE) SHOULDER WIDTHS. 141

ACKNOWLEDGEMENTS 145

REFERENCES 146

APPENDIX A 150

LIST OF FIGURES

Figure 1. Graph. CMFs for inside shoulder widths from the HSM. 10
Figure 2. Graphs. Pre-implementation and post-implementation crash frequencies from Hale et al. (2021). 12
Figure 3. Diagrams. US 59 four general-purpose lanes (left) converted to five general-purpose lanes with reduced shoulder width (right). 14
Figure 4. Screenshot. FDOT Inside Shoulder Width Transportation Data & Analytics (TDA). 20
Figure 5. Bar chart. Change in crash rate on US 2 in Washington State from Neudorff et al. (2016). 21
Figure 6. Equation. Fatal and injury crash SPF from Dixon et al. (2016). 23
Figure 7. Graph. Average lateral position versus inside shoulder width from Zhao et al. (2015). 25
Figure 8. Graph. Average speed in left lane versus shoulder width for various lane widths from Liu et al. (2016). 26
Figure 9. Graph. Predicted crashes versus inside shoulder width from Zhao et al. (2022). 27
Figure 10. Graph. Inner lateral clearance versus speed from Zhong et al. (2014). 28
Figure 11. Map. Locations of freeway crashes in Georgia (2018–2023). 30
Figure 12. Map. Georgia segment-level traffic count data for freeways (2021). 32
Figure 13. Map. Georgia point-level traffic count data for freeways (2022). 33
Figure 14. Map. Freeways in Georgia. 35
Figure 15. Flow chart. SPF development framework. 45
Figure 16. Map. Locations of freeways with left shoulder widths <2 ft. 62
Figure 17. Map. Locations of freeways with left shoulder widths of 2–4 ft. 63
Figure 18. Map. Locations of freeways with left shoulder widths of 4–6 ft. 63
Figure 19. Map. Locations of freeways with left shoulder widths of 6–8 ft. 64
Figure 20. Map. Locations of freeways with left shoulder widths of 8–10 ft. 64
Figure 21. Map. Locations of freeways with left shoulder widths ⩾10 ft. 65
Figure 22. Map. Locations of freeways without barrier on the left shoulders. 65
Figure 23. Map. Locations of freeways with barrier on the left shoulders. 66
Figure 24. Map. Locations of freeways with two lanes. 66
Figure 25. Map. Locations of freeways with three or more lanes. 67
Figure 26. Map. Locations of Atlanta urban freeways with barrier on the left shoulders. 67
Figure 27. Map. Locations of Atlanta urban freeways with truck percentage. 68
Figure 28. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (two-lane statewide with barrier). 71
Figure 29. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (three-or-more–lane statewide with barrier). 71
Figure 30. Graph. SPF-based predictions for KAB crashes across different traffic volumes (two-lane statewide with barrier). 72
Figure 31. Graph. SPF-based predictions for KAB crashes across different traffic volumes (three-or-more–lane statewide with barrier). 72
Figure 32. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (two-lane statewide without barrier). 73
Figure 33. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (three-or-more–lane statewide without barrier). 73

Figure 34. Graph. SPF-based predictions for KAB crashes across different traffic volumes (two-lane statewide without barrier). 74
Figure 35. Graph. SPF-based predictions for KAB crashes across different traffic volumes (three-or-more–lane statewide without barrier). 74
Figure 36. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: ≤5). 75
Figure 37. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: 5–10). 75
Figure 38. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: 10–15). 76
Figure 39. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: >15). 76
Figure 40. Graph. SPF-based predictions for KAB crashes across different traffic volumes (Atlanta with barrier; truck percentage: ≤5). 77
Figure 41. Graph. SPF-based predictions for KAB crashes across different traffic volumes (Atlanta with barrier; truck percentage: 5–10). 77
Figure 42. Graph. SPF-based predictions for KAB crashes across different traffic volumes (Atlanta with barrier; truck percentage: 10–15). 78
Figure 43. Graph. SPF-based predictions for KAB crashes across different traffic volumes: (Atlanta with barrier; truck percentage: >15). 78
Figure 44. Graph. Average CMFs for all crashes on freeways without barrier (two-lane statewide). 91
Figure 45. Graph. Average CMFs for all crashes on freeways without barrier (three-or-more–lane statewide). 91
Figure 46. Graph. Average CMFs for all crashes on freeways with barrier (two-lane statewide). 94
Figure 47. Graph. Average CMFs for all crashes on freeways with barrier (three-or-more–lane statewide). 94
Figure 48. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: ≤5). 97
Figure 49. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10). 98
Figure 50. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15). 98
Figure 51. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: >15). 99
Figure 52. Graph. Average CMFs for KAB crashes on freeways without barrier (two-lane statewide). 101
Figure 53. Graph. Average CMFs for KAB crashes on freeways without barrier (three-or-more–lane statewide. 101
Figure 54. Graph. Average CMFs for KAB crashes on freeways with barrier (two-lane statewide). 104
Figure 55. Graph. Average CMFs for KAB crashes on freeways with barrier (three-or-more–lane statewide). 104
Figure 56. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: ≤5). 107
Figure 57. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10). 108

Figure 58. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15). 108
Figure 59. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: >15). 109
Figure 60. Graph. Average CMFs for median-related crashes on freeways without barrier (two-lane statewide). 112
Figure 61. Graph. Average CMFs for median-related crashes on freeways without barrier (three-or-more–lane statewide). 112
Figure 62. Graph. Average CMFs for median-related crashes on freeways with barrier (two-lane statewide). 115
Figure 63. Graph. Average CMFs for median-related crashes on freeways with barrier (three-or-more–lane statewide). 115
Figure 64. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: ⩽5). 118
Figure 65. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10). 119
Figure 66. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15). 119
Figure 67. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: >15). 120
Figure 68. Graph. Average CMFs for median-related KAB crashes on freeways without barrier (two-lane statewide). 123
Figure 69. Graph. Average CMFs for median-related KAB crashes on freeways without barrier (three-or-more–lane statewide). 123
Figure 70. Graph. Average CMFs for median-related KAB crashes on freeways with barrier (two-lane statewide). 126
Figure 71. Graph. Average CMFs for median-related KAB crashes on freeways with barrier (three-or-more–lane statewide). 126
Figure 72. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: ⩽5). 129
Figure 73. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10). 130
Figure 74. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15). 130
Figure 75. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: >15). 131

LIST OF TABLES

Table 1. Coefficients for inside shoulder width CMF–freeway segments.................................. 10
Table 2. Summary of geometric scenarios for the lane-narrowing safety model. 11
Table 3. Texas distribution of sites by geometry changes during the analysis period................. 15
Table 4. Texas summary statistics for available dataset for 2010–2013 (n = 536). 15
Table 5. Texas final reduced model estimates for total crashes. 15
Table 6. Texas final model estimates for KAB crashes... 16
Table 7. Texas freeway crash prediction models for lane and shoulder width changes. 16
Table 8. Overall accident rates on California freeways where inside shoulders were removed. 18
Table 9. Average travel speeds before and after I-95 conversion.. 19
Table 10. Data acquisition summary. 29
Table 11. Annual crash count for Georgia (2018–2023). 31
Table 12. Distribution of traffic volumes and truck percentages on sampled freeways. 34
Table 13. Characteristics of sampled freeway segments (n = 1829). 37
Table 14. Characteristics of crashes on sampled road segments (2018–2023)............................ 40
Table 15. Overall crash rate per 100 million VMT by severity groups (2018–2023). 50
Table 16. Crash rate per 100 million VMT for all crashes (KABCO) and KAB crashes (all locations). 52
Table 17. Crash rate per 100 million VMT for all crashes (KABCO) and KAB crashes (medians). 53
Table 18. Descriptive statistics for AADT (statewide samples). 55
Table 19. Descriptive statistics for segment length (statewide samples).................................... 56
Table 20. Descriptive statistics for KABCO crash frequency (statewide samples)...................... 57
Table 21. Descriptive statistics for KAB crash frequency (statewide samples). 58
Table 22. Descriptive statistics for median-related KABCO crash frequency (statewide samples).. 59
Table 23. Descriptive statistics for median-related KAB crash frequency (statewide samples).. 60
Table 24. Descriptive statistics for Atlanta urban freeways (with barrier). 61
Table 25. SPFs for statewide freeways with left shoulder widths <2 ft. 79
Table 26. SPFs for statewide freeways with left shoulder widths of 2–4 ft. 80
Table 27. SPFs for statewide freeways with left shoulder widths of 4–6 ft. 81
Table 28. SPFs for statewide freeways with left shoulder widths of 6–8 ft. 82
Table 29. SPFs for statewide freeways with left shoulder widths of 8–10 ft. 83
Table 30. SPFs for statewide freeways with left shoulder widths ⩾10 ft................................. 84
Table 31. SPFs for Atlanta urban freeways. 84
Table 32. Average CMFs for all crashes on freeways without barrier (statewide). 90
Table 33. Average CMFs for all crashes on freeways with barrier (statewide)........................... 93
Table 34. Average CMFs for all crashes on freeways with barrier (Atlanta urban)..................... 95
Table 35. Average CMFs for KAB crashes on freeways without barrier (statewide)............... 100
Table 36. Average CMFs for KAB crashes on freeways with barrier (statewide). 103
Table 37. Average CMFs for KAB crashes on freeways with barrier (Atlanta urban). 106
Table 38. Average CMFs for median-related crashes on freeways without barrier (statewide). 111
Table 39. Average CMFs for median-related crashes on freeways with barrier (statewide). 114

Table 40. Average CMFs for median-related crashes on freeways with barrier (Atlanta urban). 117
Table 41. Average CMFs for median-related KAB crashes on freeways without barrier (statewide). 122
Table 42. Average CMFs for median-related KAB crashes on freeways with barrier (statewide). 125
Table 43. Average CMFs for median-related KAB crashes on freeways with barrier (Atlanta urban). 128
Table 44. Statewide freeways without barrier. 134
Table 45. Statewide freeways with barrier. 134
Table 46. Atlanta urban freeways with barrier. 136
Table 47. Summary of scholar research on the safety impact of left (inside) shoulder widths. 141

LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
CMF	Crash Modification Factor
CRIS	Crash Records Information System
DDHV	Designated Daily Heavy Vehicle
DOT	Department of Transportation
EB	Empirical Bayes
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FI	Fatal and Injury
GDOT	Georgia Department of Transportation
GIS	Geographic Information System
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HSM	*Highway Safety Manual*
NB	Negative Binomial
NRC	National Research Council
PDO	Property Damage Only
RF	Random Forest
SPF	Safety Performance Function
TxDOT	Texas Department of Transportation
VMT	Vehicle Miles Traveled
vpd	Vehicles Per Day
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

The inside (left) shoulder of freeways is a critical safety feature, serving multiple roles: providing emergency space for disabled vehicles, enabling evasive maneuvers to avoid collisions, improving sight distance at curves, and acting as a recovery zone for vehicles drifting from travel lanes. The inside shoulder width directly impacts crash potential—narrow shoulders limit these safety buffers, particularly in high-traffic, high-speed, or truck-heavy environments—making evidence-based design guidelines for shoulder width essential for reducing crash frequency and severity. The primary objective of this project (RP 23-22) was to develop data-driven recommendations for left shoulder widths on Georgia freeways, tailored to different facility types, traffic volumes, and operational conditions. Specifically, the research aimed to quantify the safety effectiveness of varying left shoulder widths using crash data, traffic volumes, and roadway characteristics; develop safety performance functions (SPFs) and crash modification factors (CMFs) to model relationships between shoulder width and crash outcomes; and provide context-sensitive guidance for statewide and urban freeways.

TO ACHIEVE THESE GOALS, THE STUDY ANALYZED SIX YEARS (2018–2023) OF TRAFFIC CRASH DATA (OVER 255,000 GEOREFERENCED CRASHES), TRAFFIC VOLUME DATA (ANNUAL AVERAGE DAILY TRAFFIC [AADT] AND TRUCK PERCENTAGES), AND ROADWAY INVENTORY DATA (LANE COUNT, BARRIER PRESENCE, SHOULDER WIDTH, ETC.) ACROSS GEORGIA. THE DATASET INCLUDED OVER 1800 FREEWAY SEGMENTS COVERING 2400+ DIRECTIONAL MILES, CATEGORIZED INTO: STATEWIDE FREEWAYS WITHOUT BARRIER, STATEWIDE FREEWAYS WITH BARRIER, AND ATLANTA URBAN FREEWAYS (WITH BARRIER), FURTHER STRATIFIED BY LANE COUNT (TWO LANES VERSUS THREE-PLUS LANES) AND TRUCK PERCENTAGE. DETAILED METHODOLOGIES FOR DATA PROCESSING, SPF DEVELOPMENT, AND CMF CALCULATION ARE AVAILABLE IN CHAPTER 3 OF THE REPORT. SPFS WERE DEVELOPED USING NEGATIVE BINOMIAL REGRESSION TO PREDICT AVERAGE CRASH FREQUENCIES FOR SEGMENTS WITH DIFFERENT SHOULDER WIDTHS, TRAFFIC VOLUMES, AND SEGMENT TYPES, ACCOUNTING FOR OVERDISPERSION IN CRASH DATA. CMFS WERE

CALCULATED BY COMPARING PREDICTED CRASH FREQUENCIES FOR NARROWER SHOULDERS TO A BASELINE CONDITION (LEFT SHOULDER WIDTH ≥10 FT), QUANTIFYING RELATIVE CRASH POTENTIAL FOR EACH WIDTH CATEGORY. COMPREHENSIVE RESULTS FOR SPFS AND CMFS, INCLUDING COEFFICIENTS, STATISTICAL SIGNIFICANCE, AND VISUALIZATIONS, ARE PRESENTED IN CHAPTER 5 AND

chapter 6 of the report, respectively.

This study aimed to provide evidence-based insights into appropriate inside (left) shoulder widths that balance safety outcomes with practical design considerations on Georgia freeways. In particular, the study aims to identify conditions under which narrower shoulders may be acceptable (e.g., design exceptions) and highlight circumstances where wider shoulders are critical for safety. These insights are intended to inform GDOT's design practices, especially in cases where the findings differ from AASHTO or FHWA standards and past HSM research. Key findings highlight the critical role of left shoulder width in freeway safety:

- Wider left shoulders (6–8 ft) consistently reduced crash potential across all facility types, particularly for fatal/injury (KAB) and median-related crashes.
- Narrow shoulders (<4 ft) were associated with elevated crash potential, especially at high AADT (>60,000 vehicles per day [vpd]) and high truck percentages (>10 percent), with CMFs often exceeding 1.0 (indicating higher crash potential than the baseline).
- Median-related crashes showed unique patterns: 4–6-ft shoulders frequently underperformed compared to both narrower (2–4 ft) and wider (6–8 ft) alternatives, potentially due to insufficient space for emergencies.
- Atlanta urban freeways with high truck percentages (>15 percent) required 8–10-ft shoulders to reduce crash potential, even at moderate AADT.

Based on these findings, the project provides evidence-based policy recommendations for left shoulder widths, tailored to three facility types (detailed in chapter 7):

- *Statewide freeways without barrier*: For two-lane segments, 4–6 ft may be considered for low AADT (<30,000 vpd), transitioning to 6–8 ft for moderate volumes (30,000–50,000 vpd) and 8–10 ft for high AADT (>50,000 vpd). For three-plus–lane segments, 2–4 ft suffices for low volumes (<40,000 vpd), but 6–8 ft should be required for higher traffic, with narrower widths permitted only with safety justification.

- *Statewide freeways with barrier*: Wider shoulders are prioritized to offset barrier proximity, with 8–10 ft recommended at low AADT (<30,000 vpd), 4–6 ft permitted for constrained urban retrofits at moderate volumes (30,000–60,000 vpd), and 6–8 ft required for higher AADT (>60,000 vpd).
- *Atlanta urban freeways*: Recommendations vary by truck percentage. For low-truck routes (<100,000 vpd), ≥10 ft is *suggested*. For moderate truck volumes (5–15%) and AADT of 75,000–150,000 vpd, 8–10 ft is recommended. In very high AADT corridors (>150,000 vpd), 4–6 ft may be acceptable in constrained areas. However, for high-truck corridors (>15%), 8–10 ft is *suggested* at AADT levels below 150,000 vpd, with narrower widths (<2 ft) permitted only in dense urban conditions and with rigorous safety justification.

Key insights emphasize that narrow shoulders (<4 ft) are exceptions, allowed only in low-AADT rural areas, constrained urban retrofits, or with documented safety mitigations. Design approaches should respond to regional contexts: rural districts may consider cost-effective narrow shoulders for low traffic, whereas urban areas may favor wider shoulders in new constructions, with flexibility in retrofits to balance safety and right-of-way constraints. Post-construction monitoring, including systematic crash data analysis in elevated crash frequency corridors, is critical to validate design effectiveness and refine standards over time.

This report provides a data-driven framework to enhance freeway safety across Georgia, aligning left shoulder width with traffic volume, barrier presence, and truck dynamics. By prioritizing wider shoulders in elevated crash frequency scenarios, the guidelines balance safety optimization with contextual constraints, supporting the Georgia Department of Transportation's mission to deliver efficient, safe transportation infrastructure. Detailed analyses, including SPF coefficients, CMF values, and supplementary visuals, are available in the full report.

CHAPTER 1. INTRODUCTION

BACKGROUND

The inside shoulder of a freeway is a critical component of the highway system and provides several essential functions for safety and efficient traffic operations. One of the primary purposes of an inside shoulder is to serve as emergency storage space for disabled vehicles. This feature is particularly critical on high-speed, high-volume highways such as urban freeways. Moving a disabled vehicle off the travel lanes in that setting may reduce the occurrence of rear-end crashes and prevent lane closures, which lead to severe congestion and safety issues. Another essential function of the inside shoulder is to improve stopping sight distance at horizontal curves. By offsetting features like barriers and bridge piers, the inside shoulder increases visibility for drivers, allowing them to see potential conflicts and react accordingly, reducing the occurrence of crashes. Moreover, the inside shoulder offers an area for drivers to maneuver to avoid crashes. This feature is particularly crucial on high-speed highways or locations with limited stopping sight distance. With a width of about 8 ft or greater, the inside shoulder provides a recovery zone for drivers to take evasive action and avoid collisions. In addition, the inside shoulder provides space for maintenance activities, enabling routine work without closing a travel lane.

The minimum width requirements for inside shoulders depend on the number of lanes and the level of truck traffic on the roadway (Neudorff et al. 2016, American Association of State Highway and Transportation Officials [AASHTO] 2010). For four-lane freeways (i.e., two lanes per direction), the paved width of the left shoulder is recommended to be at least 4 ft. For freeways of six lanes or more (i.e., three or more lanes per direction), a 10-ft paved width for the left shoulder should be provided. In addition, if truck traffic exceeds 250 designated daily heavy vehicle (DDHV), a paved width of 12 ft is recommended.

The Georgia Department of Transportation (GDOT) has adopted the AASHTO criteria as the standard for shoulder width options for roadways in Georgia (GDOT, 2025). Specifically, for high-speed freeways and interstates in Georgia, the typical inside shoulder width is 12 ft, with 10 ft paved adjacent to the traveled way. On high-speed freeway sections with six or more lanes where truck traffic exceeds 250 DDHV, a 12-ft paved inside shoulder width should be considered. However, the GDOT *Design Policy Manual* (GDOT, 2025) allows for exceptions in cases where the roadway environment or rights-of-way present constraints that make significant roadway widening impractical. In such cases, a comprehensive study by an engineer and the prior approval of a design variance from the chief engineer are required. This project evaluated the safety effectiveness of inside shoulder widths currently used on Georgia freeways, as well as strategies to improve safety for substandard conditions.

PROJECT OBJECTIVES

This project aimed to develop data-driven guidance for determining appropriate inside (left) shoulder widths on Georgia's freeways based on crash performance, traffic volumes, roadway configurations, and operational characteristics. Specifically, the project aims to assess the safety effectiveness of different inside shoulder widths by analyzing crash data in combination with roadway inventory and traffic volume data across a range of freeway types, including those with and without barriers, and in both urban and rural settings. By developing safety performance functions (SPFs) and crash modification factors (CMFs), the study provides quantitative tools for evaluating the relationship between inside shoulder width and crash frequency and severity. The final goal is to inform context-sensitive design policies that enhance freeway safety, optimize operational performance, and guide GDOT in updating design standards and project planning criteria.

CHAPTER 2. LITERATURE REVIEW

The project team conducted a comprehensive literature review to synthesize federal efforts, state practices, and scholarly research on the safety effectiveness of inside shoulder widths on the highway system with a focus on freeways. The team searched extensively for relevant literature and reports on the safety impact of inside shoulder width on highway systems, including state practices and guidelines on the safety impact of left shoulder width, as well as scholarly research focus on the safety impact of the left shoulder. Discussions in this chapter are divided into three sections: (1) federal or national efforts on safety assessment of the reduced width shoulder, (2) state-led or local practices on the safety assessment of the reduced width shoulder, and (3) scholarly research on the evaluation of the safety impacts of inside shoulder width using multiple data sources (e.g., crash data, driving simulation data) and methodologies (e.g., statistics modeling, experiments).

FEDERAL OR NATIONAL EFFORTS

Research and practice have already shown that the width of the left shoulder (i.e., inner shoulder) has a significant impact on the safety performance of the roads (Bauer et al. 2004, Zhao et al. **Error! Reference source not found.**, Neudorff et al. 2016). Generally, wider left shoulders are associated with better safety performance regarding crash frequency and severity (Dixon et al. 2016, Bauer et al. 2004, Zhao et al. **Error! Reference source not found.**, Chimba et al. 2017). However, due to constrained environments and/or rights-of-way where significant widening of the roadway is not practical due to adjacent developments and land use, physical constraints, along with limited availability of funding, evaluation of the safety impact of different shoulder widths (especially narrow shoulder width) can provide information for the state department of transportation (DOT) and practitioners when designing a road or making safety improvements (Neudorff et al. 2016).

Highway Safety Manual **(HSM)**

The federal *Highway Safety Manual* (HSM; AASHTO 2010) defines inside shoulder width as follows: "Measure the inside shoulder width at successive points along the roadway. Compute an average shoulder width for each point and round this average to the nearest 1.0 ft. Begin a new segment if the rounded value for the current point changes from that of the previous point (e.g., from 6 to 5 ft)." Chapter 18 of the HSM shows the predictive method for freeways. In that chapter, the paved 6-ft inside shoulder width serves as the base in the SPF function for predicting the crash frequency for highway segments. Four CMFs are used to describe the relationship between inside shoulder width and predicted crash frequency in four types of crashes, including fatal-and-injury (FI) multiple-vehicle crashes, property-damage-only (PDO) multiple-vehicle crashes, FI single-vehicle crashes, and PDO single-vehicle crashes. The base condition is the 6-ft inside shoulder width. The CMFs are described using the following equation:

$$CMF_{3,fs,ac,y,z} = \exp\left(a * [W_{is} - 6]\right) \tag{1}$$

where, $CMF_{3,fs,ac,y,z}$ = CMF for inside shoulder width in a freeway segment with any cross-section ac, crash type y, and severity z; and W_{is} = paved inside shoulder width (ft).

The coefficient for equation 1 is provided in table 1. For a given severity, the coefficient values are the same for both crash types listed in the table, which indicates that the CMF value is the same for the corresponding SPFs. The CMF applies to shoulder widths ranging 2–12 ft, according to equation 1. Figure 1 shows the variation of the CMF for inside shoulder widths as the shoulder width changes (AASHTO 2010).

Table 1. Coefficients for inside shoulder width CMF–freeway segments.

Cross Section (x)	Crash Type (y)	Crash Severity (z)	CMF Variable	CMF Coefficient (a)
Any cross section (ac)	Multiple vehicle (mv)	Fatal and injury (fi)	$CMF_{3, fs, ac, mv, fi}$	–0.0172
		Property damage only (pdo)	$CMF_{3, fs, ac, mv, pdo}$	–0.0153
	Single vehicle (sv)	Fatal and injury (fi)	$CMF_{3, fs, ac, sv, fi}$	–0.0172
		Property damage only (pdo)	$CMF_{3, fs, ac, sv, pdo}$	–0.0153

Source: HSM (AASHTO 2010)

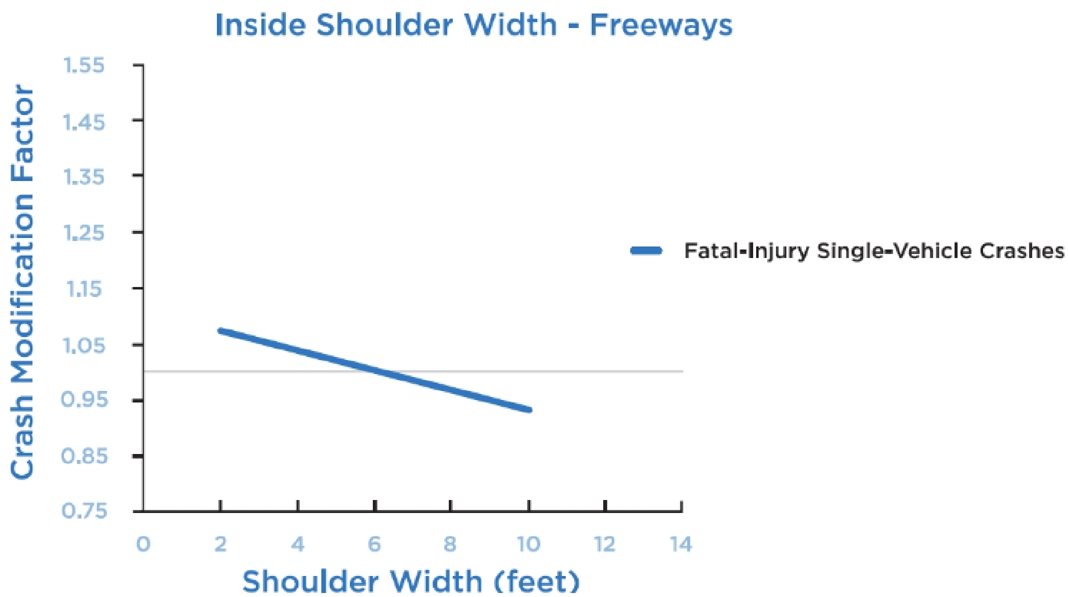


Figure 1. Graph. CMFs for inside shoulder widths from the HSM.

The HSM suggests that every state should either calibrate HSM SPFs or develop justification-specific SPFs/CMFs using local data to improve the effectiveness of SPFs/CMFs because the geometric and operational conditions vary significantly from one state to another (AASHTO 2010). This report presents the selected state-led practices on this topic in State-led or Local Practices.

Federal Highway Administration

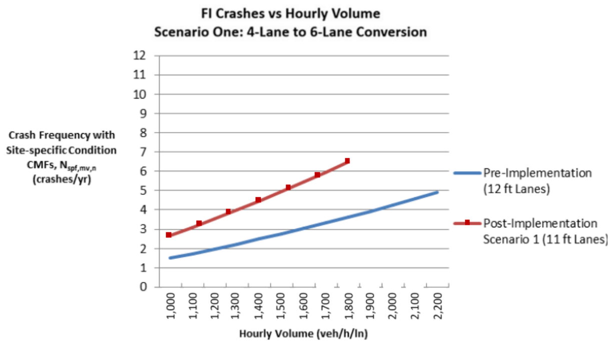
The Federal Highway Administration (FHWA) investigated narrowing freeway lanes and shoulders as a cost-effective mobility strategy. The safety model is incorporated in its technical report FHWA-HRT-21-005, *Narrowing Freeway Lanes and Shoulders to Create Additional*

Travel Lanes (Hale et al., 2021). Three scenarios (as shown in table 2) were analyzed using the HSM's SPF and CMFs (only for FI and PDO crashes), with the CMFs applied only to FI and PDO crashes, based on the predicted crashes in the base scenario. The crash frequencies for pre-implementation and post-implementation are shown in figure 2(a)–(f).

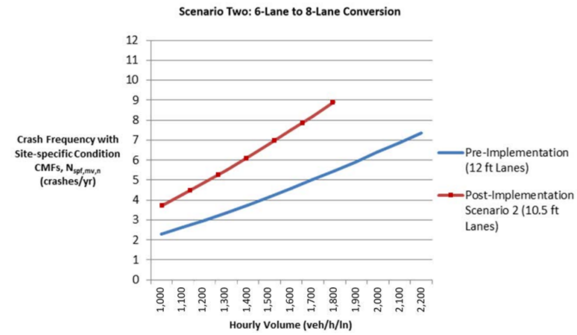
Table 2. Summary of geometric scenarios for the lane-narrowing safety model.

Geometric Scenario	Lane Width Type	Number of Lanes (Both Directions)	Lane Width (ft)	Inside Shoulder Width (ft) (One Direction)	Outside Shoulder Width (ft) (One Direction)	Total Pavement Width (ft)
One	Standard	4	12	8	8	80
One	Narrow	6	11	4	3	80
Two	Standard	6	12	12	8	112
Two	Narrow	8	10.5	8	6	112
Three	Standard	8	12	12	8	136
Three	Narrow	10	10	10	8	136

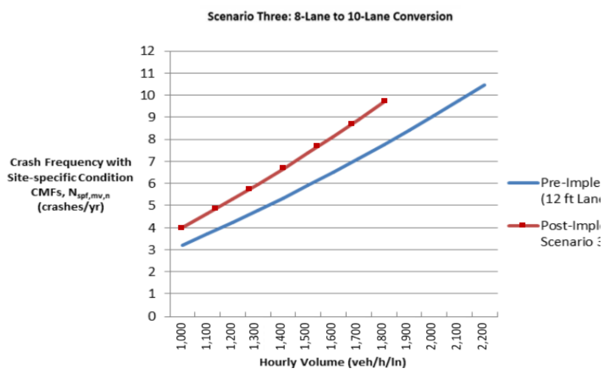
Source: Hale et al (2021)



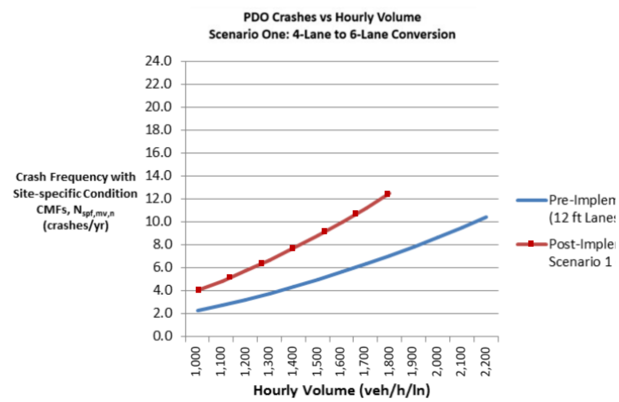
(a) FI crashes for scenario 1



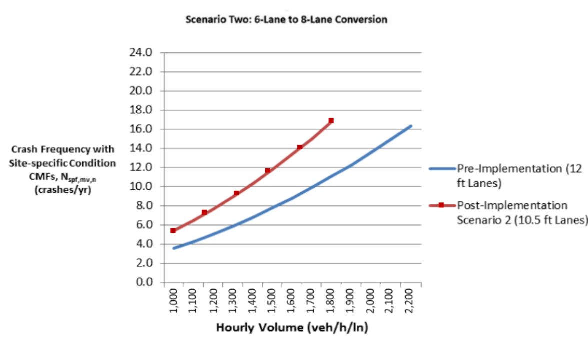
(b) FI crashes for scenario 2



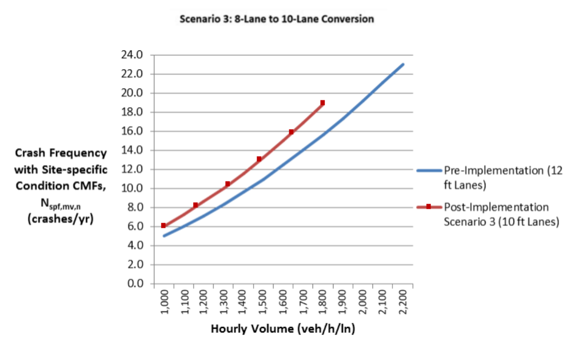
(c) FI crashes for scenario 3



(d) PDO crashes for scenario 1



(e) PDO crashes for scenario 2



(f) PDO crashes for scenario 3

Figure 2. Graphs. Pre-implementation and post-implementation crash frequencies from Hale et al. (2021).

STATE-LED OR LOCAL PRACTICES

Houston

In Houston, Texas, US 59 (about 3.1 miles, in both directions) was converted from four general-purpose lanes to five general-purpose lanes in 1976 (see figure 3). The right shoulder was reduced from 10 to 5.5 ft. The safety changes after the conversion include the following (Neudorff et al. 2016, McCasland 1978):

1. In the sections that underwent modifications, there was a significant decrease in both the number of crashes and the crash rates over the two years following the changes. This improvement was consistent across all four time periods analyzed: 24-hour, peak, daytime, and nighttime.
2. The most substantial reductions in crash frequency were observed during peak hours, coinciding with the periods of greatest operational improvements.
3. There was no marked change in the frequency or rate of severe crash.
4. The segment leading into the modified area, characterized by narrower lanes and shoulders, also saw a decrease in accidents and accident rates. This is likely due to improved conditions in the downstream segments, where capacity had been enhanced by the addition of an extra lane.
5. Conversely, the section downstream of the modified areas experienced a significant uptick in crash rates, particularly during the two peak hours. This increase is probably due to increased traffic demand and flow originating from the modified segments, coupled with no corresponding increase in capacity.

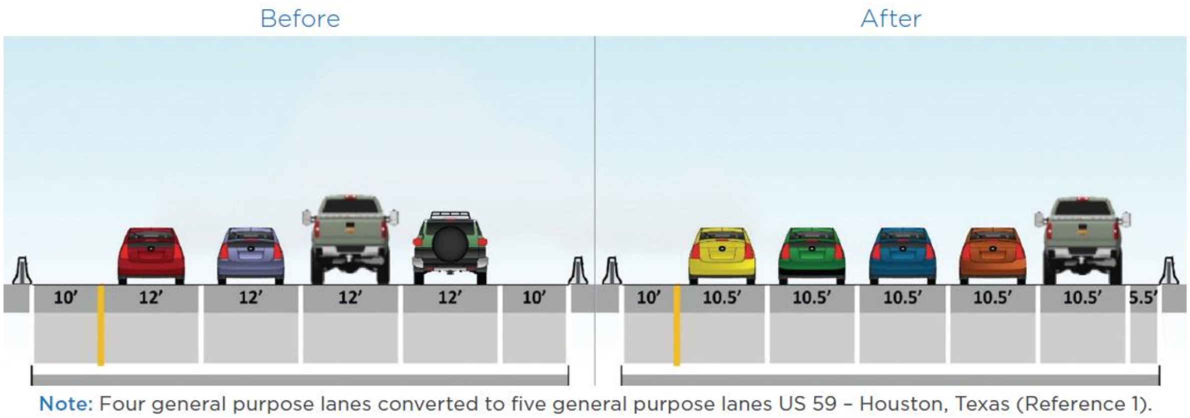


Figure 3. Diagrams. US 59 four general-purpose lanes (left) converted to five general-purpose lanes with reduced shoulder width (right). Neudorff et al. (2016)

Dallas, Houston, and San Antonio

Texas DOT (TxDOT)-supported research identified the operational and safety implications of using reduced lane and shoulder widths for a variety of freeway configurations. The research team used speed, crash, and geometric data for freeways in Dallas, Houston, and San Antonio (Dixon et al. 2015).

Table 3 shows the distribution of sites by geometry changes during the analysis period. The research team retrieved crash data from the TxDOT Crash Records Information System (CRIS) for the years 2010–2013 from all freeways in the three cities under study. Table 3 shows the distribution of sites by geometry changes during the analysis period. Table 4 shows the summary statistics for the available dataset for the years 2010–2013 (n = 536). A Poisson-lognormal generalized linear mixed model was used due to its ability to account for both random and fixed effects simultaneously. Table 5 and table 6 show the final reduced model estimates for total crashes and KAB crashes[1], separately. Crash reductions are associated with increased left

[1] In their study, KAB included fatal, serious injury, and minor injuries.

shoulder widths and increased right shoulder widths. The final SPF for predicting the total crash frequency and KAB crash frequency is shown in table 7.

Table 3. Texas distribution of sites by geometry changes during the analysis period.

Type of Change within Period of Analysis	Number of Sites Originally Identified	Number of Sites After Revision
None	61	62
Lane or Shoulder Reduction	8	7
Lane or Shoulder Expansion	3	0
Total:	72	69

Source: Dixon et al. (2015)

Table 4. Texas summary statistics for available dataset for 2010–2013 (n = 536).

Variable	Mean	Std. Dev	Min	Max	Total	N
Total Crashes	4.1	4.85	0	37	2202	536
KAB Crashes	0.8	1.08	0	6	407	536
Period Length (yr)	0.48	0.07	0.08	0.50	-	536
AADT (vpd)	152,163.0	59,511.34	200	281,450	-	536
Segment Length (ft)	1897.2	735.82	618	4510	-	536
Number of Lanes	3.8	0.98	2	6	-	536
All Lanes Width (ft)	45.2	11.78	24	73	-	536
Average Lane Width (ft)	11.8	0.48	10.8	12.5	-	536
Left Shoulder Width (ft)	9.1	4.87	1.3	22.9	-	536
Right Shoulder Width (ft)	10.3	1.46	2.0	14.8	-	536
Closest Downstream Ramp (ft)	1861.2	1503.32	17	6938	-	536
Closest Upstream Ramp (ft)	1738.7	1208.59	320	7170	-	536

Source: Dixon et al. (2015)

Table 5. Texas final reduced model estimates for total crashes.

Parameter	Estimate	Std. Error	z-val	p-val	Pr(>|z|)
α	5.39×10^{-01}	2.19×10^{-01}	2.459	0.014	*
All_Lanes_W	-2.41×10^{-02}	1.30×10^{-02}	−1.854	0.064	~
R_Shld_W	-7.35×10^{-02}	4.33×10^{-02}	−1.696	0.090	~
L_Shld_W	-6.46×10^{-02}	2.20×10^{-02}	−2.933	0.003	**
Ramp_Up_D	-1.94×10^{-04}	1.02×10^{-04}	−1.901	0.057	~
Ramp_Dwn_D	-2.06×10^{-04}	9.21×10^{-05}	−2.238	0.025	*
$\mu_{\ln(RE)}$	-5.73×10^{-01}	2.66	−3.44	5.76×10^{-04}	
$\sigma^2_{\ln(RE)}$	1.151329				
Significance values are as follows: ~ p<0.1; * p < 0.05; ** p < 0.01; and *** p < 0.001					

Source: Dixon et al. (2015)

Table 6. Texas final model estimates for KAB crashes.

Parameter	Estimate	Std. Error	z-val	p-val	Pr(>|z|)
α	6.62×10^{-01}	2.65×10^{-01}	2.495	0.013	*
All_Lanes_W	-2.53×10^{-02}	1.10×10^{-02}	−2.295	0.022	*
R_Shld_W	-9.56×10^{-02}	5.08×10^{-02}	−1.883	0.060	~
L_Shld_W	-5.47×10^{-02}	2.23×10^{-02}	−2.455	0.014	*
Ramp_Up_D	-2.99×10^{-04}	9.36×10^{-05}	−3.195	0.001	**
Ramp_Dwn_D	-1.64×10^{-04}	7.29×10^{-05}	−2.249	0.024	*
$\mu_{\ln(RE)}$	−3.18	3.05	−3.85	1.17×10^{-04}	
$\sigma^2_{\ln(RE)}$	0.4186				
Significance values are as follows: ~ p<0.1; * p < 0.05; ** p < 0.01; and *** p < 0.001					

Source: Dixon et al. (2015)

Table 7. Texas freeway crash prediction models for lane and shoulder width changes.

Variable Definitions

N_{Total} = Total number of predicted crashes (crashes per year)
N_{KAB} = Total number of predicted KAB crashes (crashes mile per year)
$AADT$ = Annual Average Daily Traffic in one direction (vpd)
L = Length of study segment (mi)
$NLane$ = Number of travel lanes in a single direction
Ave_Lane_W = Average lane width (ft)
$RShld_W$ = Width of right shoulder (ft)
$RampUp_{Dist}$ = Distance to closest upstream ramp (ft)
$RampDn_{Dist}$ = Distance to closest downstream ramp (ft)

Boundary Conditions for Freeway Crash Prediction Equations

Applies to homogeneous segment from 0.10 to 1.25 miles in length
Applicable to freeway corridors with AADT values up to 280,000 vpd
$2 \leq NLane \leq 5$
$11.0 \text{ ft} \leq Ave\_Lane\_W \leq 12.0 \text{ ft}$
$2.0 \text{ ft} \leq RShld_W \leq 15.0 \text{ ft}$
$1.0 \text{ ft} \leq LShld_W \leq 10.0 \text{ ft}$
$0.0 \text{ mi} \leq RampUp_{Dist} \leq 1.5 \text{ mi}$
$0.0 \text{ mi} \leq RampDn_{Dist} \leq 1.5 \text{ mi}$

Equation to Predict Total Texas Freeway Crashes due to Lane and Shoulder Width Changes

$$N_{Total} = 1.0027 \times L \times AADT^{0.539} \times e^{[-1.0243(RampUp_{Dist})-1.0877(RampDn_{Dist})-0.0241(NLane\times Lane\_W_{Avg})-0.0735(RShld)-0.0646(LShld)]}$$

Equation to Predict KAB Texas Freeway Crashes due to Lane and Shoulder Width Changes

$$N_{KAB} = 0.0514 \times L \times AADT^{0.662} \times e^{[-1.5787(RampUp_{Dist})-0.8659(RampDn_{Dist})-0.0253(NoLn\times LaneW_{Avg})-0.0956(RShld)-0.0547(LShld)]}$$

Source: Dixon et al. (2015)

Los Angeles

In Los Angeles, California, four general-purpose lanes were converted to four general-purpose lanes and a high-occupancy vehicle (HOV) lane with reduced left shoulder width from 10 to 3 ft. An observational before-and-after evaluation with the empirical Bayes (EB) method was done to examine the safety effects of projects involving narrower lanes or shoulder conversions on existing urban freeways. The projects, on average, resulted in increases of 10 percent to 11 percent in crash frequency, which was found to be statistically significant. The use of the added lanes as HOV lanes—and the associated increase in speed differential between the HOV and general-purpose lanes—may be an explanation for the increased crash frequency (Bauer et al. 2004).

Los Angeles (County), Orange, Marin, Alameda, Contra Costa, and San Diego Counties

California has been using shoulders to increase the capacity of freeway segments since 1970. Freeway segments that went from full shoulders to reduced shoulders were selected for a before-and-after accident analysis. Seven of the segments were located in Los Angeles County, and one each was located in Orange, Marin, Alameda, Contra Costa, and San Diego Counties. Many of these segments were under 1 mile in length, and, except for I-405, all continuous subsegments were under 2 miles in length. The I-10 segments were each taken as the sum of eastbound and westbound subsegments to provide enough accidents for statistical analysis. Table 8 presents accident rates for each case. Mean rates are given for the periods before and after restriping. Results of the t-test to determine how the after accidents compare with the before accidents are also included. These results are the I-value, the probability that the t-value is greater in absolute value for the after accidents, and whether the test is statistically significant. The results show that the experience with inside shoulder removals was either a nonsignificant change or a significant reduction in overall accidents at all freeway segments studied in California, with one exception.

A significant increase at I-405 was determined to be related to a lane balance problem at the downstream terminus. In addition, total accidents in the first subsegment were reduced. Reduced accidents appear to be related to the lowered levels of congestion (Urbanik and Bonilla 1987).

Table 8. Overall accident rates on California freeways where inside shoulders were removed.

Seg. No.	Freeway, County Length, Direction	Period	Samples[1]	Mean (Acc/MVM)	T-Value	Probability of Greater T[2]
1.	I-5, Los Angeles	Before 7/15-6/78	12	1.066	1.08	0.29
	(1.34 mi., SB)	After 7/79-6/82	12	1.288		
2.	I-5, Los Angeles	Before 7/75-6/78	6	1.178	-1.65	0.13
	(0.69 mi., NB)	After 7/79-6/82	6	0.784		
3.	CA-22, Orange	Before 1/77-6/80	14	0.829	-2.33	0.03 *
	(3.25 mi., WB)	After 4/82-12/84	11	0.617		
4.	CA-60, Los Angeles	Before 1/79-6 81	5	0.905	-2.00	0.09
	(0.68 mi., EB)	After 1/83-12/84	4	0.683		
5.	CA-22, Orange	Before 1/77-6/80	12	0.789	-0.65	0.53
	(0.67 mi., NB)	After 10/82-12/84	9	0.685		
6.	I-405, Los Angeles	Before 1/74-3/75	5	0.793	-2.90	0.01 *
	(7.72 mi., NB)	After 4/77-12/79	11	1.058[3]		
7.	US-101, Marin	Before 1/80-6/82	5	0.649	-0.82	
	(0.31 mi., SB)	After 1/83-12/84	4	0.422		
8.	I-580, Alameda	Before 1/79-9/81	11	1.964	-2.33	0.03 *
	(0.61 mi., EB)	After 4/82-12/84	11	1.436[4]		
9.	I-680, Contra Costa	Before 1/80-12/81	4	1.066	-0.22	0.84
	(0.38 mi., SB)	After 7/82-12/83	3	1.015		
10.	CA-94, San Diego	Before 1/79-9/81	8	0.621	-0.69	0.50
	(1.13 mi., EB)	After 1/81-12/84	8	0.556		

[1]Each sample corresponds to the accident rate for a three month period.

[2]One asterisk (*) means statistically significant at the 0.05 level, and two asterisks (**) means statistically significant at the 0.01 level.

[3]See text for explanation of increase

[4]See text for description of project.

Source: Urbanik and Bonilla (1987)

Florida

I-95 from I-395 in Downtown Miami to I-595 in Broward County comprised four general-purpose lanes and a single HOV lane, with the separation of the HOV and general-purpose lanes via striping only. The HOV lanes had an occupancy requirement of 2+ during peak hours (7–9 AM and 4–6 PM). The HOV and general-purpose lanes on I-95 were operating at level of service (LOS) F during peak periods. Additionally, the violation rates on the HOV lane were very high, exceeding 30 percent in many segments. Florida DOT (FDOT) implemented a conversion of the lanes as follows (Neudorff et al. 2016):

- Existing HOV lanes were converted to a high-occupancy toll (HOT) lane.
- A second HOT lane was added by restriping the entire facility with narrower lanes and shoulders. No new pavement was added.
- The separation of the HOT lanes and the general-purpose lanes is via delineators spaced 10 ft apart within a 1–2-ft painted buffer.
- The occupancy limit was raised to three.

The converted I-95 Express lanes have improved overall traffic conditions along the project corridor since its inception, as shown in table 9. Regarding the safety effect, several news outlets reported that severe crashes happened due to the implementation of narrow shoulders (WLRN 2011). FDOT provides an open-data portal in WebGIS format to show the shoulder width information in its roadway inventory, as shown in figure 4 (FDOT 2024).

Table 9. Average travel speeds before and after I-95 conversion.

	Am Peak – Southbound		PM Peak – Northbound	
	Before (2008 HOV Study)	After (12 months – FY 2009-2010)	Before (2008 HOV Study)	After (12 months – FY 2009-2010)
General Purpose Lanes	15 mph	51 mph	15 mph	41 mph
HOV lane (Before) / Express Lane (After)	20 mph	64 mph	18 mph	56 mph

Source: (FDOT 2024)

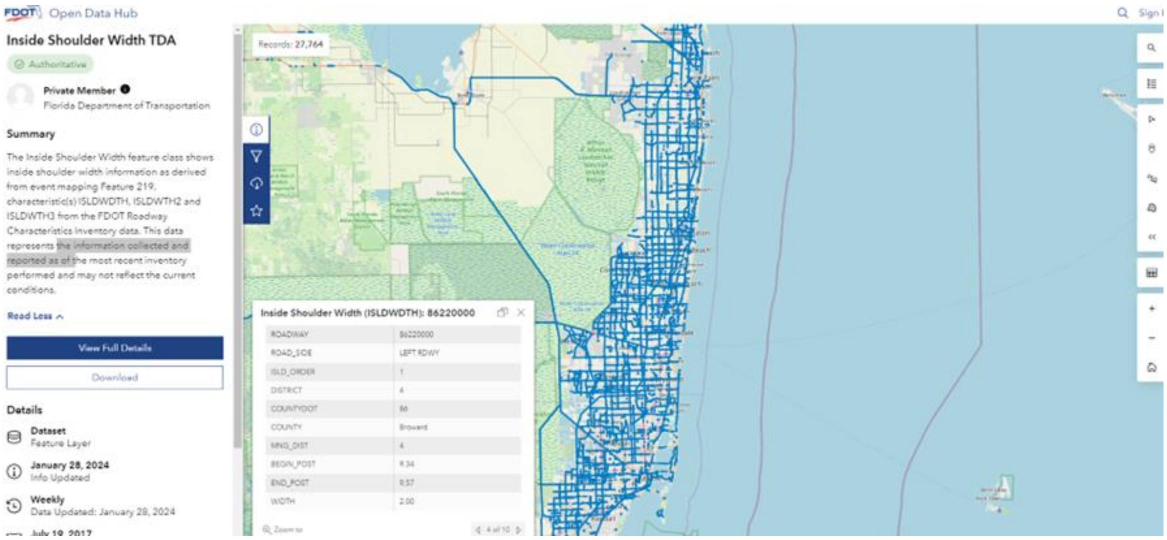
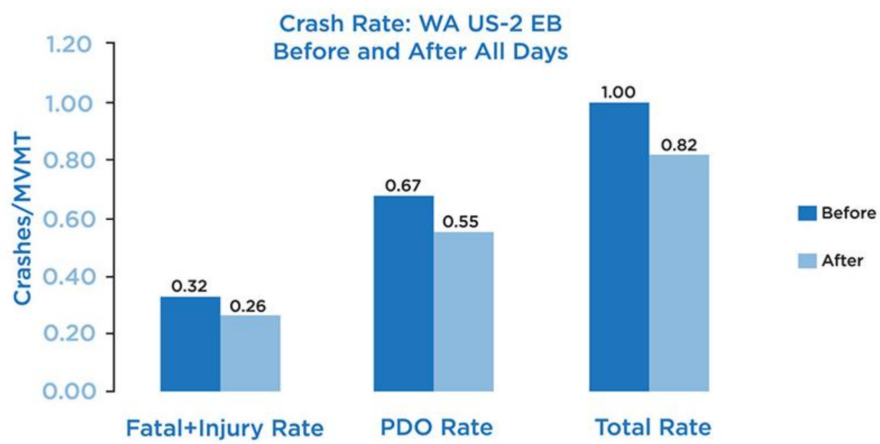


Figure 4. Screenshot. FDOT Inside Shoulder Width Transportation Data & Analytics (TDA).FDOT (2024)

Washington State

Washington State uses narrow lanes and a narrow left shoulder to accommodate part-time shoulder use on US 2. This site is located on the US 2 eastbound trestle between the I-5 and SR 204 interchanges (milepost [MP] 0.66 to MP 2.22). This segment was restriped from a configuration consisting of a 4-ft left shoulder, two 12-ft general-purpose lanes, and a 10-ft right shoulder to a 2-ft left shoulder, two 11-ft general-purpose lanes, and a 14-ft auxiliary lane/shoulder on the right. Washington State DOT (WSDOT) primarily developed this static shoulder use to (1) reduce collisions within the I-5 / US 2 interchange and (2) keep the traffic on the ramp from I-95 northbound (NB) to US 2 from backing up onto the mainline of I-5 NB. The shoulder was first opened to traffic on April 6, 2009. The shoulder use operates in the PM peak period from 3:00 PM to 7:00 PM Monday through Friday. The shoulder is not open to traffic during all other periods. The average speeds on the I-5 NB connector to US 2 eastbound (EB) have improved from 10 mph to 37 mph during the PM period of heaviest traffic. The capacity in the narrower general-purpose lanes along US 2 is approximately 2000 vehicles per hour per lane (vphpl), and the corresponding speed is approximately 50 mph. The capacity on the shoulder is approximately 1400 vphpl, and the corresponding speed is approximately 40 mph. When considered in terms of crash rates, because the shoulder was opened to traffic in the EB direction of US 2, the rate of crashes in terms of crashes per million vehicle miles traveled (crashes/MVMT) has decreased overall as shown in figure 5 (Neudorff et al., 2016).



Source: WSDOT

Figure 5. Bar chart. Change in crash rate on US 2 in Washington State from Neudorff et al. (2016).

SCHOLARLY RESEARCH

The project team conducted a review of scholarly literature that discusses the safety impacts of inside shoulders of various widths. These studies generally use either (1) traffic crash data or (2) non-crash data (e.g., driving/traffic simulations or field observation). For reference, the most recent works related to the scope of this study are summarized in the appendix.

Studies Using Traffic Crash Data

Much of the literature concludes that crash frequency is expected to decrease as inside shoulder width increases, including the following studies:

- Chimba et al. (2017) explored the effectiveness of median cable rails in Tennessee, discovering that wider shoulder widths correlate with a reduction in crash incidents and injury severity. This correlation was evidenced by a negative coefficient in their model.
- Guo et al. (2021) examined the potential of phone usage data to predict distracted driving–related crashes, including inside shoulder width in their crash estimation model.
- Hadi et al. (1995), Noland and Oh (2004), and Thomson et al. (2006) investigated the correlation between shoulder width variations and accident rates. Their collective findings suggest a decrease in accident rates with the expansion of the left hard shoulder.
- Bisht and Tiwari (2022) evaluated the influence of paved shoulder width on fatal crash frequencies on a rural four-lane divided highway in India. Their study illustrated that paved shoulders up to 1.5 m wide enhance safety for all road users, reducing fatal crashes and augmenting pedestrian and slow-moving vehicle safety.
- In a study of crashes on divided urban freeways in Colorado before and after converting an inside shoulder to an additional travel lane, Bauer et al. (2004) found that converting a freeway from four to five lanes resulted in an average increase in total fatal and injury crashes of 11 percent. Their study did not consider inside shoulder width changes separately from their corresponding roadway cross-section changes, but in all four- to five-lane conversions, inside shoulder width shrunk from 10 ft or more to 2 ft or less. Thus, their study may support the conclusion that higher crash frequencies are associated with narrower inside shoulders.
- Dixon et al. (2016) echoed this conclusion in their study on urban divided freeway crashes in Texas. The SPF developed by their study (see figure 6) found that, when all other variables are unchanged, a 1-ft increase in inside shoulder width results in an expected decrease of fatal and injury crashes of about 5 percent.

$$N_{\mathrm{KAB}} = 0.0514 \times L \times \mathrm{AADT}^{0.662} \times \exp\begin{bmatrix} -1.5787(\mathrm{RampUp_{Dist}}) - 0.8659(\mathrm{RampDn_{Dist}}) \\ -0.0253(\mathrm{NoLn} \times \mathrm{LaneW_{Avg}}) - 0.0956(\mathrm{RShld}) \\ -0.0547(\mathrm{LShld}) \end{bmatrix}$$

Note: the LShld variable refers to the inside shoulder width in feet.

Figure 6. Equation. Fatal and injury crash SPF from Dixon et al. (2016).

- Similarly, Fitzpatrick et al. (2008) found that median-related crash frequency on freeways with barriers decreases by 1.6 percent for every 1 ft of additional total barrier offset, which includes inside shoulder width. Their study found that this relationship held for both four-lane and six-lane divided freeways.
- Jafari Anarkooli et al. (2021) also investigated median-related crashes, finding that increased inside shoulder widths decrease expected crashes. They found inside shoulder width to have a large impact on median-related crashes and a relatively smaller impact on multi-vehicle crashes.
- Kitali et al. (2020) studied inside shoulder widths on express lanes in California, finding that the probability of fatal and injury crashes was 2.87 percent lower on segments with inside shoulder widths >6 ft, as opposed to shoulder widths <6 ft.
- Hadi et al. (1995) suggest that on rural freeways, 6-ft shoulder widths reduce crash rates by up to 15.7 percent.
- Fitzpatrick et al. (2010) found that a 1-ft increase in inside shoulder width can decrease crashes by 0.9 percent, indicating that wider inside shoulders may be especially helpful on rural freeway horizontal curves.

Other studies, however, complicate this point. Chen et al. (2019) delved into the risk factors of accidents on highways, categorizing them into three classes within the United States and employing a bivariate modeling approach to assess two levels of accident severity. Notably, their findings indicate a greater sensitivity of casualty accidents to traffic volume and average vertical grade rather than inside shoulder and median widths for Interstate highways.

Haleem et al. (2013) showed that increasing inside shoulder width from 10 ft to 11 and 12 ft could decrease expected crashes by 2 and 33 percent, respectively, but they also found that *reducing* inside shoulder width from 10 to 4 ft had the largest expected crash reduction at 55 percent. They explained this potentially unusual finding as a result of vehicles no longer being able to use the smaller inside shoulder as emergency parking, thus reducing potential conflicts with stopped vehicles on the left-side shoulder.

Also showing that increasing inside shoulder widths does not always decrease crash frequency, Dong et al. (2018) found that inside shoulders between 5 and 15 ft wide have randomly distributed impacts on crashes on Colorado freeways. Their results show that wider inside shoulders increase the probability of multi-vehicle crashes on 75 percent of studied segments but decrease this probability on the other 25 percent of segments. They argue that wider shoulders could encourage more risky driving behaviors.

Finally, Noland and Oh (2004) found that inside shoulder width has no significant impact on safety, although they did find that wider outside shoulders decreased crashes.

Studies Not Using Traffic Crash Data

Although traditional research methods utilizing traffic crash data are useful in assessing the effectiveness of left hard shoulders, they face limitations in precisely comparing different left hard shoulder configurations under identical conditions. Driving simulations, increasingly employed in recent years, can overcome these limitations by mitigating the influence of extraneous variables on experimental data. This method has proven effective in examining the impacts of various roadway features on driver behaviors that provide implications for safety outcomes.

Using driving data from volunteers participating in a driving simulation of an eight-lane, two-way divided freeway, Zhao et al. (2015) tested the optimal width of the inside shoulder based on average lateral position. They tested inside shoulder widths of 0, 0.5, 0.75, 1.5, and 2.5 m, finding via analysis of variance (ANOVA) that drivers in the simulated freeway with inside shoulder widths of 0 m had the farthest average lateral position from the center of the lane of all the simulation scenarios. On the other hand, they found that drivers in the 2.5 m inside shoulder simulated highway had the nearest average lateral position to the center of the lane. Thus, the study may indicate that inside shoulder widths of 0 m had the highest crash frequency, and the largest inside shoulder widths at 2.5 m had the lowest crash frequency.

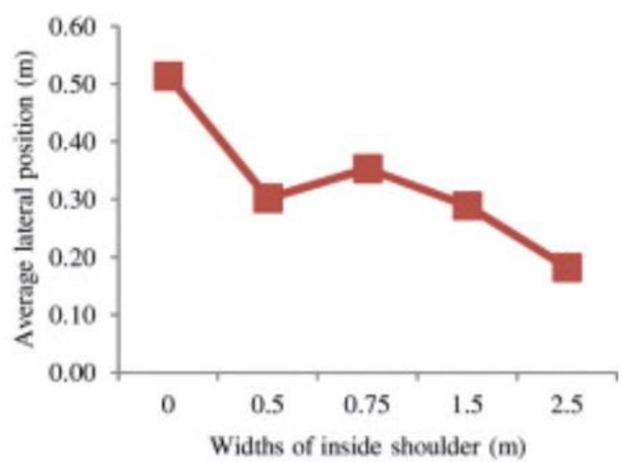


Figure 7. Graph. Average lateral position versus inside shoulder width from Zhao et al. (2015).

Several researchers have conducted similar driving simulation studies. Liu et al. (2016) simulated underground three-lane one-way expressways with inside shoulder widths of 0.5, 0.75, and 1 m. Using ANOVA, they found shoulder width to have a significant impact on both average speed and average lane deviation in the left lane. More specifically, they found that increasing shoulder width increases the speed in the left lane regardless of lane width, as shown in figure 8. Ni et al. (2023) simulated ten-lane two-way highways with inside hard shoulders both open and closed to traffic. Three inside shoulder widths were considered: 2.5, 3, and 3.5 m. In both the open and closed shoulder scenarios, the 3 m inside shoulder was found to be the optimal shoulder width. This width provided the least average lateral deviance from the center of the lane, the highest average speed, and the most stable yaw velocity in both scenarios.

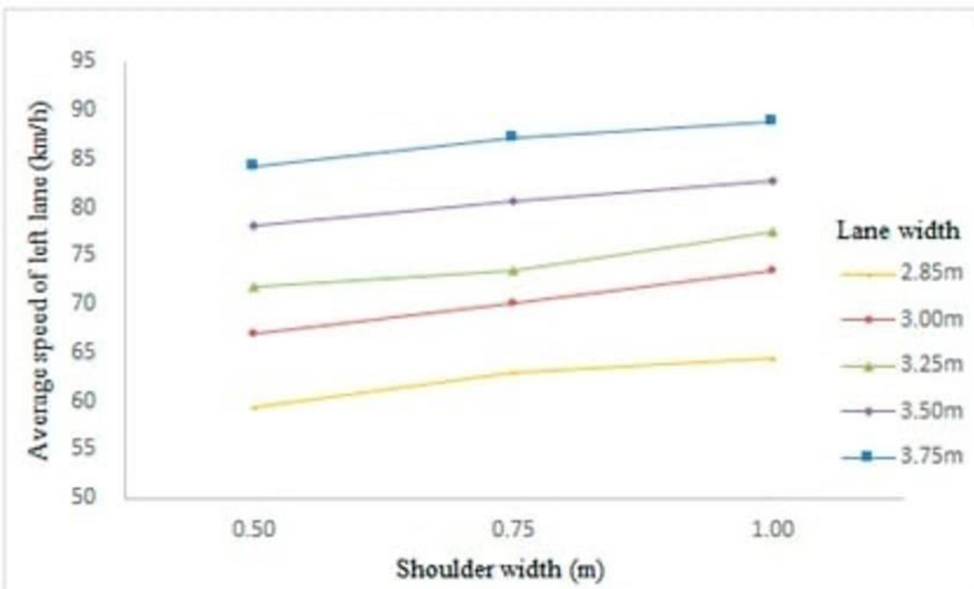


Figure 8. Graph. Average speed in left lane versus shoulder width for various lane widths from Liu et al. (2016).

Other researchers have approached inside shoulder safety using traffic simulations. Zhao et al. (2022) combined crash data with traffic microsimulations to develop a CMF for inside shoulder width on six-lane, two-way divided highways. They found that for values of inside shoulder width between 0 and 4 m, crash rate can be reduced by 1.5 percent for each additional 0.5 m of inside hard shoulder. Additionally, they found that having an inside hard shoulder provided a reduction in crashes of 2.9 percent compared to not having an inside hard shoulder.

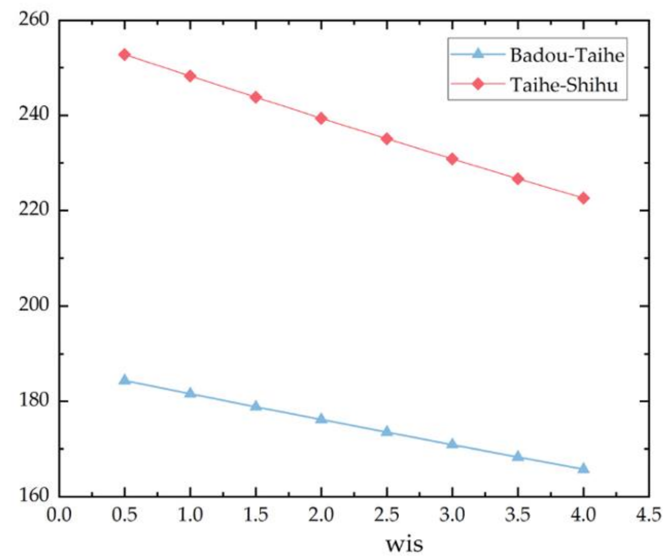


Figure 9. Graph. Predicted crashes versus inside shoulder width from Zhao et al. (2022).

Further, some researchers have approached inside shoulder width and safety through field observation. Zhong et al. (2014) observed operations on a six-lane, two-way divided freeway in Liaoning, China, to determine the impact of lateral clearance from parked cars in the left shoulder on safe operations in the left lane. Through linear regression, they found that speed in the left lane increases as lateral clearance increases. They recommended that in scenarios where cars are parked on the left shoulder, the minimum design width of inside shoulders should be 3 m.

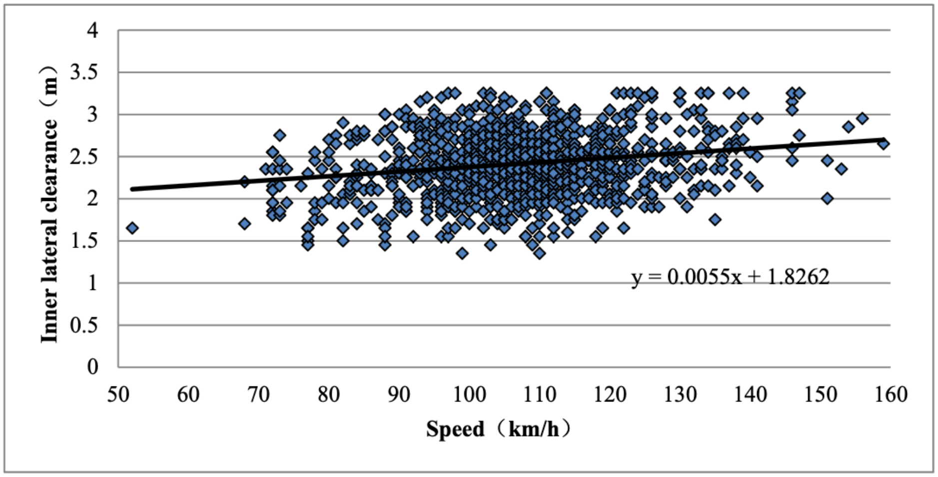


Figure 10. Graph. Inner lateral clearance versus speed from Zhong et al. (2014).

CHAPTER 3. DATA AND METHODS

This chapter summarizes the data acquisition process undertaken by the project team in collaboration with GDOT. The data collected are critical for the development of SPFs and CMFs, which are used to show the safety effectiveness of inside shoulder widths on freeways. The primary datasets required for this project include roadway data, traffic crash data, and traffic volume data.

Table 1010. Data acquisition summary.

Data	Source	Use of the Data
2018–2023 Traffic Crash Data	GDOT	Obtain crash frequencies by type and severity at sites of interest
2021 Traffic Count Data (segment level)	GDOT	Obtain traffic exposure information at segment level
2018–2023 Traffic Count Data (point level)	GDOT	Obtain annual traffic exposure information at point level
Road Inventory Data	GDOT	Identify freeways in Georgia
Freeway Feature Data	Collected using Google Maps	Identify key freeway features, such as shoulder width and presence of barriers

TRAFFIC CRASH DATA

With support from GDOT, the team successfully accessed traffic crash data from 2018 to 2023 using the AASHTO are Safety website.[2] The majority of crash records included accurate geographic coordinates; however, a small subset lacked geocoding. Georeferencing plays a critical role in this study, as it enables spatial linkage of crash events to specific freeway segments. Through spatial joining, the research team identified a total of 255,846 crashes that occurred on freeway segments between 2018 and 2023, as illustrated in figure 11.

[2] https://gdot.aashtowaresafety.com

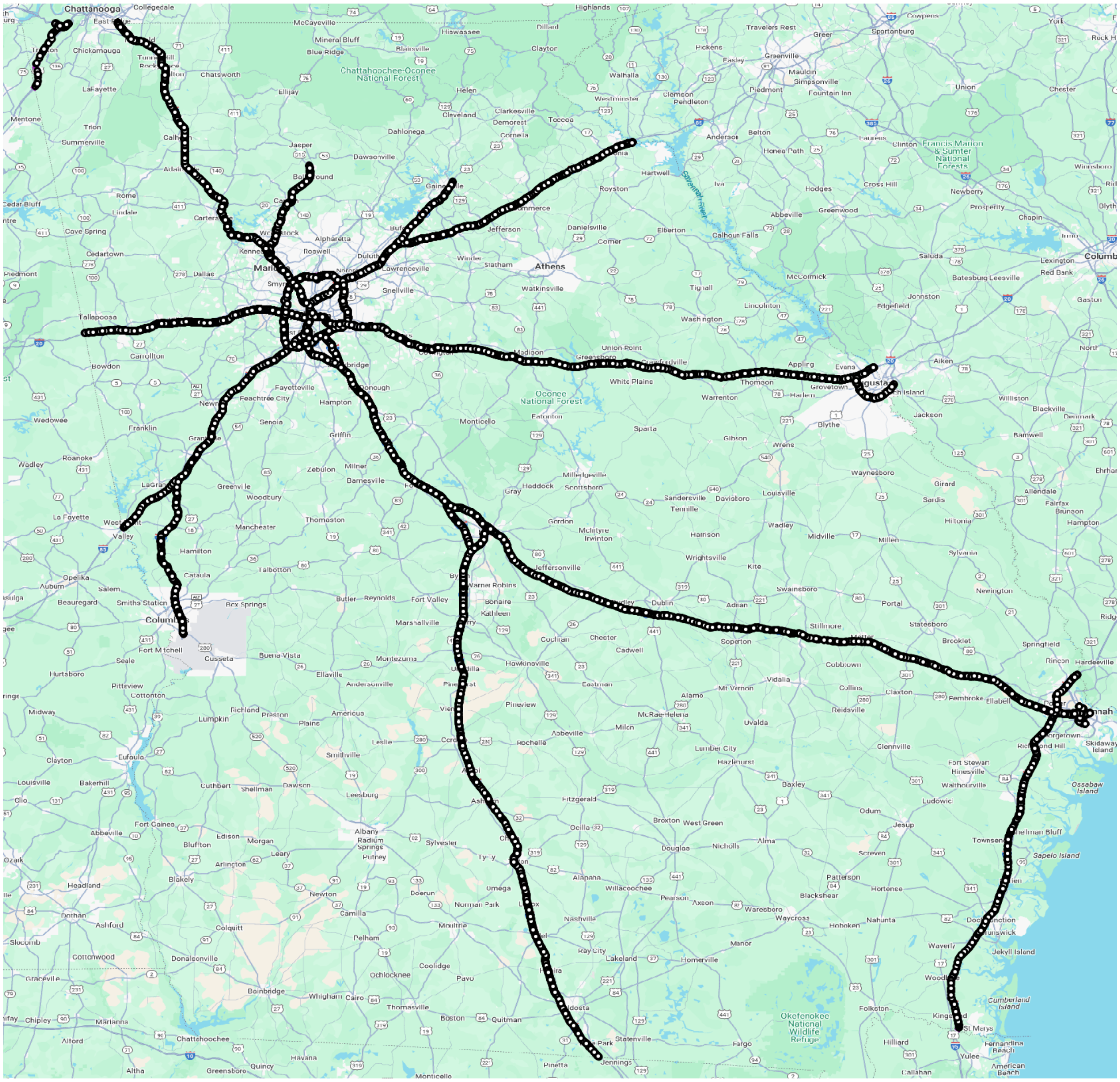


Figure 11. Map. Locations of freeway crashes in Georgia (2018–2023).

This dataset reflects all georeferenced crashes assigned to freeway facilities during the six-year study period. Table 1111 presents annual crash counts. In 2018, there were 44,560 crashes, accounting for 17.42 percent of the total. This figure rose slightly to 45,670 in 2019 (17.85 percent) before declining markedly in 2020 to 36,314 (14.19 percent), likely influenced by reduced travel during the coronavirus disease 2019 (COVID-19) pandemic. Crash counts rebounded in 2021 to 44,658 (17.46 percent), followed by 42,960 in 2022 (16.79 percent), and 41,684 in 2023 (16.29 percent).

Table 1111. Annual crash count for Georgia (2018–2023).

Crash Year	Frequency	Percentage (%)
2018	44,560	17.42
2019	45,670	17.85
2020	36,314	14.19
2021	44,658	17.46
2022	42,960	16.79
2023	41,684	16.29

TRAFFIC COUNT DATA

The research team received segment-level traffic count data in shapefile for 2021 from GDOT. The data can provide valuable insights into the spatial extent that a traffic count station represents. Figure 12 shows the 2021 freeway segment-level traffic counts. In addition, to account for the potential annual traffic variation in analysis and modeling, the team downloaded point-level traffic count data for additional years from the GDOT traffic data website.[3] The team obtained the point-level data for all stations from 2018 to 2023 via the “All Station AADT and Truck Percent Statistics.” Figure 13 shows the 2022 point-level traffic counts on Georgia roadways. The data appear to be reasonable, as high-volume roads are observed to be concentrated in or near urban areas, particularly within the Atlanta metropolitan region. This trend is expected because urban areas typically experience higher traffic volumes due to their higher population densities and higher levels of economic activity. The point-level traffic count dataset can be merged with the segment-level dataset because unique Station IDs in both datasets represent the same locations for traffic data tabulation.

[3] https://gdottrafficdata.drakewell.com/publicmultinodemap.asp

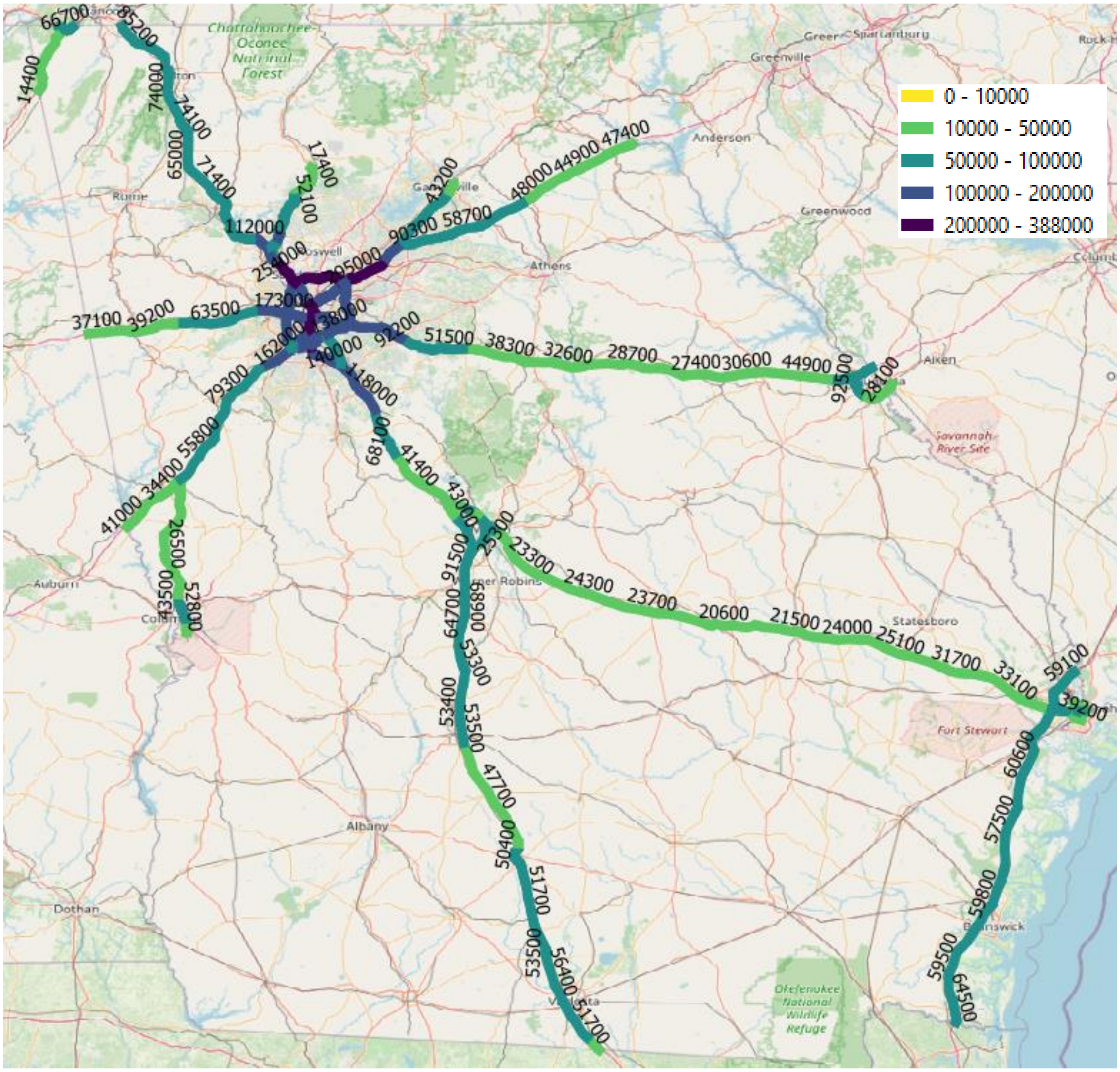


Figure 12. Map. Georgia segment-level traffic count data for freeways (2021).

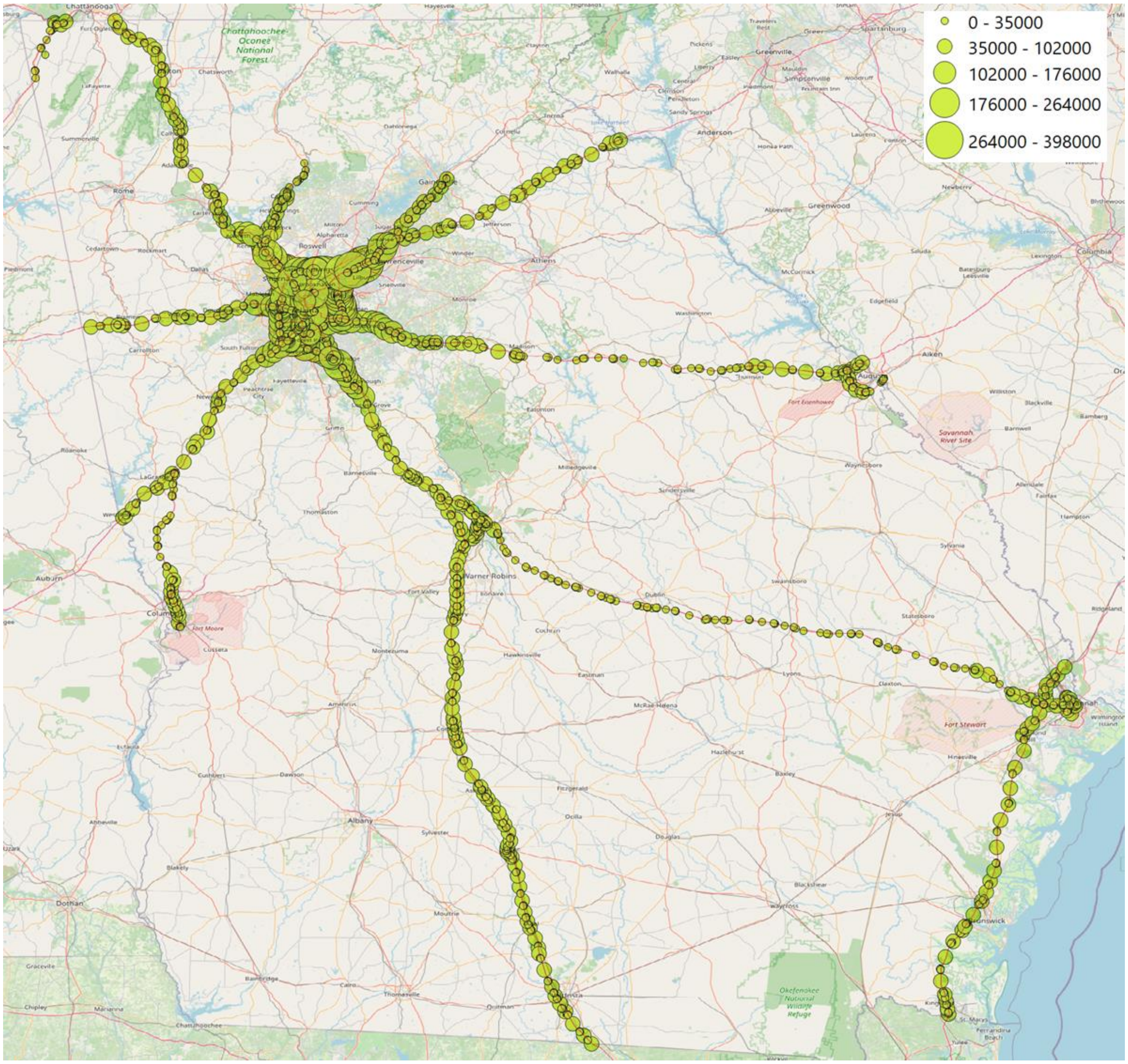


Figure 13. Map. Georgia point-level traffic count data for freeways (2022).

Table displays the distribution of traffic volumes and truck percentages on the sampled freeways, providing key metrics such as annual average daily traffic (AADT) and truck percentages over the years. Starting in 2018, the mean AADT was recorded at 100,669 vehicles per day (vpd). This figure indicates the baseline traffic volume before witnessing a slight increase in 2019 to 102,751 vpd. However, in 2020, there was a noticeable decrease in traffic, with the mean AADT dropping to 90,375. This reduction is likely attributable to the travel restrictions and economic slowdown caused by the COVID-19 pandemic. The subsequent years saw a recovery in traffic volumes: 99,499 vehicles in 2021 and a further increase to 102,637 in 2022. By 2023, the mean AADT reached its peak for the studied period at 104,079 vpd, possibly due to a resurgence in travel and economic activities. The traffic data are crucial for understanding traffic contexts while assessing the impact of freeway features (e.g., left shoulder width) on crash rates of Georgia's freeways.

Table 12. Distribution of traffic volumes and truck percentages on sampled freeways.

	Year	Mean	Standard Deviation	Min	Max	N
AADT	2018	100,669	72,271	2,700	403,000	1,829
	2019	102,751	74,364	2,670	420,000	1,829
	2020	90,375	63,856	2,030	352,000	1,829
	2021	99,499	69,081	2,410	388,000	1,829
	2022	102,637	70,827	2,690	398,000	1,829
	2023	104,079	72,831	2,930	397,000	1,829
Truck Percentage	2018	13.7	7.7	2.9	31.7	1,829
	2019	13.6	7.9	2.0	31.5	1,829
	2020	14.5	8.4	2.7	32.3	1,829
	2021	14.4	8.4	2.7	32.3	1,829
	2022	14.7	8.5	2.6	32.8	1,829
	2023	14.8	8.3	3.0	31.4	1,829

ROADWAY DATA

As part of the data support for RP 22-27, the GDOT team provided the 2021 road inventory data, which includes several georeferenced shapefile layers capturing essential road characteristics such as functional class, facility type, number of through lanes, median type, median width, shoulder type, shoulder width, urban code, and more. Using functional class layer data, the team identified the freeways in Georgia (see figure 14), spanning over 1400 miles,[4] including Interstate freeways and other freeways and expressways.

[4] https://www.fhwa.dot.gov/policyinformation/statistics/2017/hm20.cfm

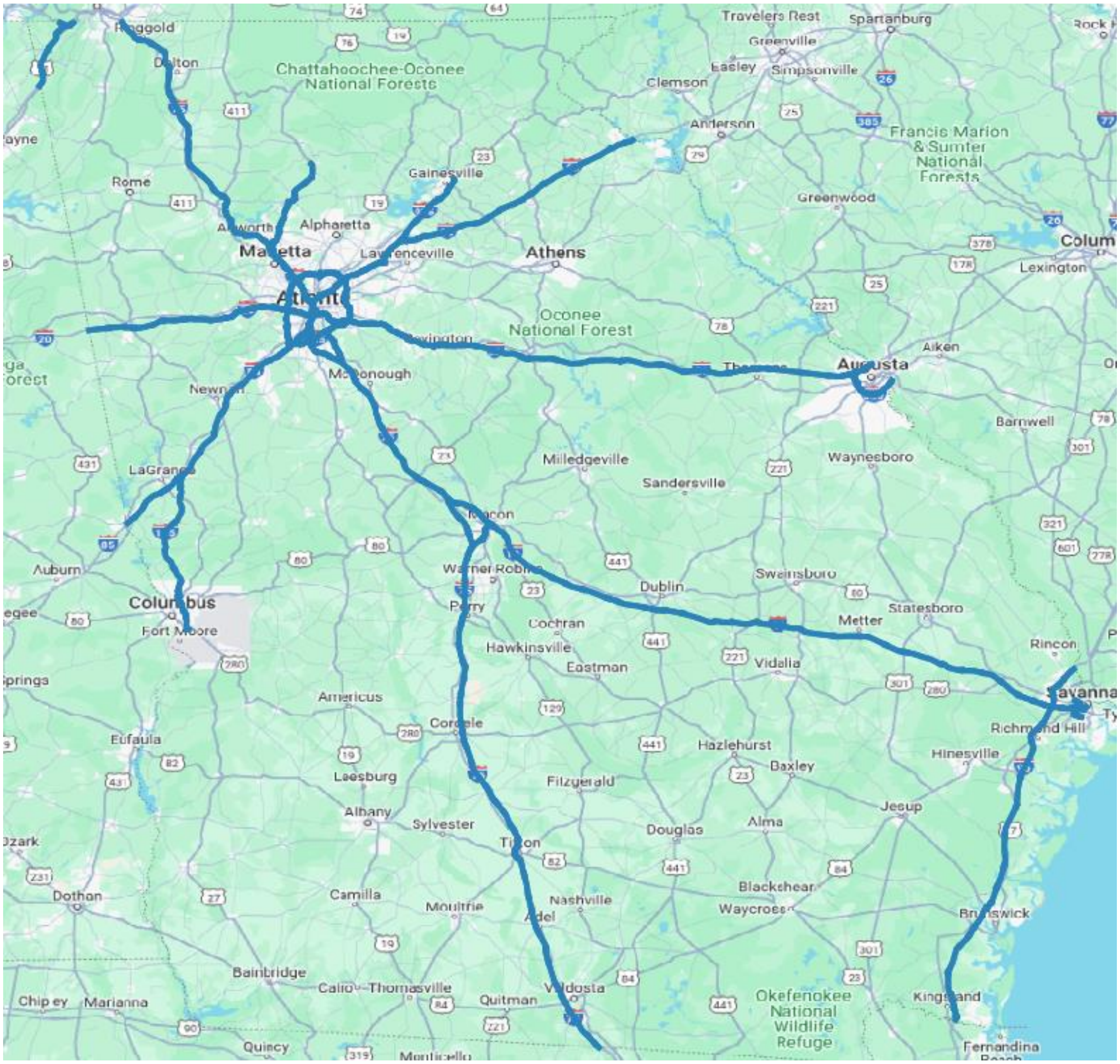


Figure 14. Map. Freeways in Georgia.

The raw roadway data contained segments of varying lengths, including some that were extremely long or short. To address this, the researchers processed the data by aggregating the shorter segments and splitting the longer ones at interchanges. As a result, the majority of the processed freeway segments now represent the stretches of road between two interchanges. Although the road inventory data provided by GDOT include some roadway features, they represent only a small sample size. To augment this, the team undertook significant efforts to manually collect freeway features using Street View in Google Maps. This effort yielded data on 1829 freeway segments across Georgia, covering a total of 2402.5 directional route miles. The collected attributes include the number of through lanes, widths of left and right shoulders, median type (either raised or depressed), the presence of HOV lanes, bridges, barriers (on both left and right sides), and the horizontal and vertical alignment of each segment.

Table presents detailed statistics on the characteristics of 1829 sampled freeway segments. The distribution of through lanes across the segments indicates a prevalence of three-lane configurations, present in 40.84 percent of the segments, followed by two lanes at 28.59 percent. Four lanes are found in 16.35 percent of the segments, with five lanes and six or more lanes being less common. This variety in lane numbers highlights differing traffic capacities and potential congestion levels across the sampled roadways. Regarding speed limits, the majority of segments, 58.39 percent, have a speed limit of 70 mph, supporting high-speed travel. The 65-mph limit is also significant, covering 27.88 percent of the segments. Lower speed limits of 55 and 60 mph are less frequent. In terms of shoulder widths, left shoulders most frequently measure 6 ft (19.74 percent), with a noticeable progression in widths from 2 ft to more than 12 ft. Right shoulders, however, show a different pattern, with the most common widths being 10 ft (24.82 percent) and 12 ft (23.89 percent), suggesting a tendency for wider right shoulders compared to the left.

Table 13. Characteristics of sampled freeway segments (n = 1829).

Roadway Characteristics		Frequency	Percentage (%)
Number of through lanes	2	523	28.59
	3	747	40.84
	4	299	16.35
	5	168	9.19
	6 or more	92	5.03
Speed limit	55 mph	208	11.37
	60 mph	43	2.35
	65 mph	510	27.88
	70 mph	1,068	58.39
Left shoulder width	2 ft	285	15.58
	4 ft	311	17.00
	6 ft	361	19.74
	8 ft	317	17.33
	10 ft	251	13.72
	12 ft	239	13.07
	>12 ft	65	3.55
Right shoulder width	2 ft	49	2.68
	4 ft	99	5.41
	6 ft	345	18.86
	8 ft	304	16.62
	10 ft	454	24.82
	12 ft	437	23.89
	>12 ft	141	7.71
Median type	Raised	1,024	55.99
	Depressed	517	28.27
	Wide Separation	288	15.75
Presence of HOV lanes	No	1,726	94.37
	Yes	103	5.63
With bridge	No	1,513	82.72
	Yes	316	17.28
Within an interchange	No	895	48.93
	Yes	934	51.07
Presence of barriers (left)	No	1,484	81.14
	Yes	345	18.86
Presence of barriers (right)	No	1,138	62.22
	Yes	691	37.78
Horizontal alignment	Straight	1,246	68.12
	Not straight	583	31.88
Vertical alignment	Level	1,477	80.75
	Upgrade	217	11.86
	Downgrade	135	7.38

Medians are predominantly raised, found in 55.99 percent of the segments, which helps prevent cross-median accidents. Depressed medians and wide separations are observed in 28.27 and 15.75 percent of the segments, respectively. Only 5.63 percent of the segments incorporate

HOV lanes. Bridges are found in 17.28 percent of the segments. Nearly half of the segments are located within interchanges, highlighting significant interactions with merging and diverging traffic, which are critical areas for potential traffic incidents. Barriers are more common on the right side (37.78 percent) than on the left (18.86 percent). Most of the segments are straight (68.12 percent), facilitating easier navigation and potentially safer high-speed travel. The vertical alignment shows that 80.75 percent of the segments are level.

DATA PREPARATION

With the integration of roadway data, the research team successfully linked two pivotal datasets—crash data and traffic data—to the sampled road segments based on their geographic locations. A total of 245,836 crashes were effectively linked to freeway segments. This extensive aggregation of crash records allowed the team to derive detailed crash counts across various categories. These categories encompass total crashes (KABCO), fatal injury crashes (K), suspected serious injury crashes (A), suspected minor or visible injury crashes (B), potential injury or complaint crashes (C), and crashes with no apparent injuries (O). Additionally, the crash data were segregated based on distinct crash types, differentiating between single- and multiple-vehicle incidents. Given the focus of this project on the safety impacts of left shoulders on freeway safety, particular attention was paid to the crashes occurring on freeway medians. Notably, while there are also data on crashes that occurred on shoulders, the specific side (left or right) of these shoulder crashes remains unclear. However, it is presumed that these incidents predominantly occurred on the right shoulder.

Table from the data analysis provides a detailed year-to-year comparison of crash characteristics on sampled freeway segments from 2018 to 2023, dividing the data into two primary locations: all locations and medians.

For crashes at all locations, the data reveal fluctuations in total crashes (KABCO), with a noticeable dip in 2020, likely due to the pandemic-induced reduction in traffic. The average crash counts peaked in 2019 with 24.05 crashes and showed a gradual recovery post-2020. Fatal and serious injury crashes (K and A categories) have remained relatively low, indicating that while crashes are frequent, those resulting in serious injuries or fatalities are rare. The minor and possible injuries (B and C categories) followed a similar trend to total crashes, decreasing in 2020 and rebounding thereafter. Notably, no apparent injury crashes (O category) consistently accounted for the majority, albeit with a slight decrease in 2020. The comparison between single- and multi-vehicle crashes shows that multi-vehicle incidents are more prevalent and variable, suggesting higher complexity and likelihood in these situations.

In contrast, crashes that occurred in the medians presented a different pattern. The average crash counts were significantly lower than in general locations, with the high numbers in 2020 and 2021 at 1.08 and 1.09, respectively. This suggests that although medians are less common sites for crashes, the fluctuations loosely mirror the broader traffic trends. Severe crashes, including fatal and serious injuries, were exceedingly rare in median settings, emphasizing the lower severity outcome compared to other freeway areas. Minor and possible injury crashes in medians were also minimal and showed only slight annual variations. Interestingly, median crashes were predominantly single-vehicle incidents, indicating that crashes in these areas might typically involve drivers losing control rather than colliding with other vehicles.

Table 14. Characteristics of crashes on sampled road segments (2018–2023).

Year	Crash Location	Crash Type	Average Crash Count	St. Dev.	Total Crashes
2018	All locations	KABCO	23.36	36.51	42,787
		K (Fatal)	0.09	0.32	159
		A (Serious)	0.27	0.60	495
		B (Minor)	1.52	2.36	2,781
		C (Possible)	4.23	7.45	7,750
		O (No Injury)	17.25	27.49	31,602
		Single-vehicle	4.04	5.06	7,396
		Multi-vehicle	19.32	34.40	35,391
	Median	KABCO	0.95	1.71	1,743
		K (Fatal)	0.01	0.07	10
		A (Serious)	0.02	0.14	33
		B (Minor)	0.11	0.37	193
		C (Possible)	0.17	0.50	315
		O (No Injury)	0.65	1.30	1,192
		Single-vehicle	0.82	1.52	1,501
		Multi-vehicle	0.13	0.43	242
2019	All locations	KABCO	24.05	38.24	44,065
		K (Fatal)	0.09	0.31	171
		A (Serious)	0.30	0.67	544
		B (Minor)	1.36	2.18	2,497
		C (Possible)	4.51	8.10	8,267
		O (No Injury)	17.79	28.72	32,586
		Single-vehicle	3.85	4.86	7,060
		Multi-vehicle	20.20	36.21	37,005
	Median	KABCO	0.92	1.57	1,685
		K (Fatal)	0.01	0.09	15
		A (Serious)	0.02	0.15	41
		B (Minor)	0.10	0.34	192
		C (Possible)	0.18	0.48	323
		O (No Injury)	0.61	1.17	1,114
		Single-vehicle	0.79	1.41	1,446
		Multi-vehicle	0.13	0.41	239

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Table 14. Characteristics of crashes on sampled road segments (2018–2023). (Continued)

2020	All locations	KABCO	19.09	27.40	34,967
		K (Fatal)	0.11	0.35	209
		A (Serious)	0.34	0.70	615
		B (Minor)	1.39	2.13	2,547
		C (Possible)	3.64	6.36	6,669
		O (No Injury)	13.61	19.94	24,927
		Single-vehicle	4.19	5.46	7,681
		Multi-vehicle	14.89	24.57	27,286
	Median	KABCO	1.08	2.11	1,984
		K (Fatal)	0.00	0.06	7
		A (Serious)	0.03	0.16	47

		B (Minor)	0.13	0.41	231
		C (Possible)	0.21	0.64	383
		O (No Injury)	0.72	1.47	1,316
		Single-vehicle	0.95	1.92	1,745
		Multi-vehicle	0.13	0.41	239
2021	All locations	KABCO	23.38	34.51	42,841
		K (Fatal)	0.12	0.37	227
		A (Serious)	0.37	0.78	677
		B (Minor)	1.48	2.18	2,713
		C (Possible)	4.48	7.90	8,211
		O (No Injury)	16.93	25.29	31,013
		Single-vehicle	4.03	5.00	7,383
		Multi-vehicle	19.35	32.40	35,458
	Median	KABCO	1.09	2.16	1,999
		K (Fatal)	0.01	0.10	18
		A (Serious)	0.03	0.16	47
		B (Minor)	0.12	0.39	223
		C (Possible)	0.20	0.55	360
		O (No Injury)	0.74	1.60	1,351
		Single-vehicle	0.95	1.99	1740
		Multi-vehicle	0.14	0.43	259

Continued on next page.

Table 14. Characteristics of crashes on sampled road segments (2018–2023). (Continued)

2022	All locations	KABCO	22.54	33.23	41,286
		K (Fatal)	0.12	0.36	213
		A (Serious)	0.37	0.79	683
		B (Minor)	1.38	2.18	2,530
		C (Possible)	4.32	7.95	7,922
		O (No Injury)	16.34	24.10	29,938
		Single-vehicle	3.59	4.43	6,573
		Multi-vehicle	18.95	31.33	34,713
	Median	KABCO	0.97	1.89	1,773
		K (Fatal)	0.01	0.10	20
		A (Serious)	0.03	0.18	59
		B (Minor)	0.10	0.36	191
		C (Possible)	0.18	0.55	327
		O (No Injury)	0.64	1.33	1,176
		Single-vehicle	0.84	1.68	1,537
		Multi-vehicle	0.13	0.42	236

2023	All locations	KABCO	21.83	32.81	39,993
		K (Fatal)	0.11	0.35	199
		A (Serious)	0.33	0.71	597
		B (Minor)	1.26	2.01	2,305
		C (Possible)	4.22	7.64	7,735
		O (No Injury)	15.92	24.05	29,157
		Single-vehicle	3.49	4.36	6,402
		Multi-vehicle	18.34	30.90	33,591
	Median	KABCO	0.84	1.55	1,541
		K (Fatal)	0.01	0.08	11
		A (Serious)	0.02	0.15	40
		B (Minor)	0.10	0.36	181
		C (Possible)	0.14	0.47	259
		O (No Injury)	0.57	1.13	1,050
		Single-vehicle	0.72	1.37	1,319
		Multi-vehicle	0.12	0.41	222

SAFETY PERFORMANCE FUNCTIONS

According to the HSM, the standard or most common form of SPF for roadway segments is described below (AASHTO 2010):

$$N_{SPF} = L \times \mathrm{e}^{a+b\times\ln(AADT)} \quad \text{or} \quad N_{SPF} = \mathrm{e}^{a+b\times\ln(AADT)+\ln(L)} \tag{2}$$

where N_{SPF} is the predicted number of crashes on a segment; L is the length of the segment; $AADT$ is the AADT volume; and a and b are regression coefficients to be estimated using historical crash data.

In equation 2, the segment length L is included as a multiplier, which assumes that the crash frequency on a segment is simply proportional to the segment length. However, this assumption may be inappropriate in some cases. Driving on a relatively longer road segment with unchanging circumstances may differ from driving on a relatively shorter road segment with frequent variations of circumstances. Therefore, another common form of SPFs is also suggested by transportation professionals:

$$N_{SPF} = e^{a+b\times\ln(AADT)+c\times\ln(L)} \tag{3}$$

where c is a parameter indicating the relationship between crash frequency and segment length. If the estimate of c is close to 1, equation 3 is identical to equation 2. If c is significantly different from 1, then the road segment length is not simply proportional to crash frequencies. In the HSM, it is assumed that crash frequencies follow an NB distribution (AASHTO 2010). The NB distribution is an extension (capturing overdispersion) of the Poisson model:

$$Y_i \sim NB\ (N_{SPF\ i}, \alpha) \tag{4}$$

where Y_i is the observed crash frequency on a segment[5], $N_{SPF\ i}$ is the expected crash frequency, and α is the NB overdispersion parameter. A larger value of α implies greater overdispersion in data. If α = 0, then the data follow a Poisson distribution (where mean = variance). In such a situation, the Poisson and NB model provide identical estimates of parameters (a, b, c, d, e). If α is significantly greater than 0, an NB model is preferred. Formally, $N_{SPF\ i}$ can be viewed as a log link function of a set of independent variables (Liu et al., 2016):

$$Ln\ (N_{SPF\ i}) = a + b \times \ln(AADT_i) + c \times \ln(L_i) \tag{5}$$

Equation 6 is specifically developed for the Atlanta area to consider the influence of truck percentage and its interaction with AADT:

$$Ln\ (N_{SPF\ i}) = a + b \times \ln(AADT_i) + c \times \ln(L_i) + d \times TP_i + e\ \times [\ln(AADT_i) * TP_i] \tag{6}$$

[5] In this study, the annual crash frequencies between 2018 and 2023 were used.

Figure 15 shows the overall framework of SPF development in this project. The Atlanta urban freeway data were excluded from the statewide analysis and modeled separately. SPFs were developed for selected segment groups formed by the following key attributes:

- Left shoulder width: <2 ft, 2–4 ft, 4–6 ft, 6–8 ft, 8–10 ft, and ≥10 ft.
- Area and left roadside barrier type: statewide without barrier, statewide with barrier, and Atlanta urban segments with barrier.
- Number of through lanes for statewide without barrier and statewide with barrier: two-lane statewide without barrier, two-lane statewide with barrier, three-or-more–lane statewide without barrier, and three-or-more–lane statewide with barrier.

Separate SPFs were developed for different crash severity groups, including:

- KABCO: All crashes.
- KAB: Crashes that led to injuries at any level, including fatal injury crash, suspected serious injury crash, and suspected minor or visible injury crash.
- Median KABCO: Total freeway median-related crashes.
- Median KAB: Median-related crashes that led to injuries at any level, including fatal injury crash, suspected serious injury crash, and suspected minor or visible injury crash.

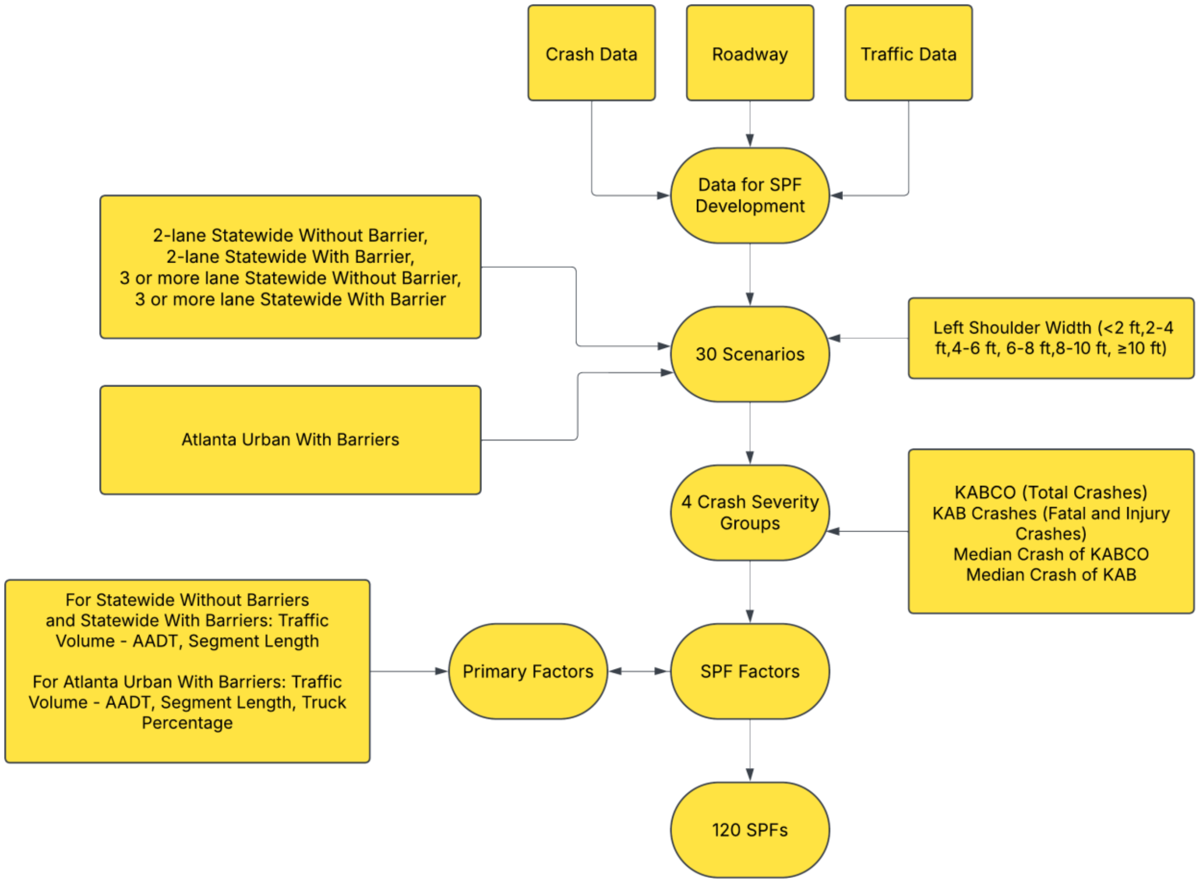

Figure 15. Flow chart. SPF development framework.

In theory, a total of 120 SPFs could be developed, accounting for four crash severity groups; six shoulder width categories (<2 ft, 2–4 ft, 4–6 ft, 6–8 ft, 8–10 ft, and ≥10 ft); and five segment types based on barrier type, number of through lanes for statewide (two-lane statewide without barrier, two-lane statewide with barrier, three-or-more–lane statewide without barrier, three-or-more–lane statewide with barrier), and geographical area (statewide without barrier, statewide with barrier, and Atlanta urban segments with barrier). In practice, some segment groups had a sufficient number of observations, resulting in well-performing models (e.g., model coefficients with *p*-values <0.05). However, other segment groups—particularly those less common in Georgia or the Atlanta area—had limited sample sizes, leading to relatively weaker model performance. Moreover, the key dependent variable in SPF modeling is crash frequency. For certain severity levels, particularly KAB crashes (fatal and injury crashes), the number of such crashes is frequently low. This limited variability in the dependent variable can result in reduced statistical power, as reflected in weaker model performance and less significant model coefficients (e.g., higher *p*-values).

CRASH MODIFICATION FACTORS

A CMF is a metric used to quantify the expected change in average crash frequency resulting from a geometric or operational modification at a site relative to a defined base condition. It reflects the relative difference in crash frequency attributable to a specific roadway feature while holding all other site characteristics constant. In essence, a CMF represents the ratio of expected crash frequencies under two different conditions, allowing for an assessment of the impact on the frequency and severity of crashes of a particular treatment or design element. This project primarily focuses on estimating the impact on the frequency and severity of crashes of varying left shoulder widths on freeways. A CMF value >1.00 indicates an expected increase in crash frequency, suggesting an increase in the frequency and severity of crashes associated with the narrower shoulder width. Conversely, a CMF value <1.00 implies an expected reduction in crash frequency, indicating a potential safety benefit. This approach quantifies the relative effectiveness of different shoulder widths in improving or reducing safety performance.

To support the CMF estimation, separate SPFs were developed for predicting average crash frequencies on freeways with different left shoulder widths. These SPFs were stratified by area and left roadside barrier types: statewide without barrier, statewide with barrier, and Atlanta urban segments with barrier. Each SPF reflects crash frequency as a function of traffic exposure (AADT) and allows for estimating the average number of crashes under specific roadway and traffic characteristics.

CMFs were calculated by applying the SPFs to predict the expected crash frequencies for different left shoulder widths and then computing the ratio of these predictions relative to a baseline condition. The baseline used in this analysis is a freeway segment with a left shoulder width of 10 ft or more. The formula used to calculate the CMF is:

$$CMF = \frac{N_{SPF}\ for\ Facility\ B}{N_{SPF}\ for\ Facility\ A} \tag{7}$$

where N_{SPF} is the expected average crash frequency based on SPF; Facility A refers to the baseline segment (≥10 ft shoulder); and Facility B refers to a segment with a narrower shoulder width. In addition, the impact on the frequency and severity of crashes of a roadway feature may vary across different contexts. In this study, we illustrate the variations in estimated CMFs across different traffic volume conditions (AADT) and area and left roadside barrier types. These variations highlight how the effectiveness of a particular roadway design element—such as left shoulder width—can change depending on surrounding conditions. Understanding the connection between geometric elements and localized conditions can provide valuable insights for data-driven decisions when considering or selecting appropriate freeway shoulder width treatments in various traffic and roadway environments.

CHAPTER 4. DESCRIPTIVE ANALYSIS

This chapter presents a descriptive analysis in two primary sections: crash rate analysis and model-based descriptive analysis for the selected freeway segments. In addition, this chapter includes visualizations of the spatial locations of the targeted freeways, highlighting their key characteristics.

CRASH RATE ANALYSIS

The research team utilized two methods to scrutinize the collected data on freeway segments. First, they calculated the crash rates per 100 million vehicle miles traveled (VMT) for various segment categories such as the number of through lanes, speed limits, shoulder widths, and median types. Second, they applied NB regression to explore potential correlations between crash frequencies and various contributing factors outlined in table 1. The formula used to determine the crash rate per 100 million VMT for each sampled segment is given by:

$$\text{RMVM} = \frac{Crash\ Count \times 100{,}000{,}000}{365 \times AADT \times Segment\ Length} \tag{8}$$

Initially, the team assessed the aggregate crash rates annually from 2018 to 2023, where the crash count refers to the total number of crashes linked to the sampled roadway segments and the VMT is derived from the cumulative daily traffic across all sampled segments for each year. Subsequently, they computed crash rates at the segment level, where the crash count pertains to the frequency of crashes observed on individual segments and the VMT is the product of the AADT and the length of each segment for a full year. Table provides a detailed view of the crash rates per 100 million VMT across different severity groups from 2018 to 2023, both at all locations and specifically on medians.

The total crash rate (KABCO) at all locations was 133.55 in 2018, slightly increasing to 135.19 in 2019 before experiencing a notable drop to 120.74 in 2020. This reduction likely reflects the decreased traffic volumes during the COVID-19 pandemic. The rates partially rebounded to 133.19 in 2021, suggesting a return to pre-pandemic traffic conditions, but gradually declined to 118.73 by 2023. This downward trend could indicate effective enhancements in roadway safety or ongoing adjustments in driving behaviors. Fatal crashes (K) remained consistently low, peaking slightly in 2020 at 0.72, possibly due to the higher impact of incidents during reduced traffic levels, and subsequently stabilized below earlier figures by 2023, reflecting potentially successful safety measures. Serious injury crashes (A) mirrored this trend, peaking in 2020 and stabilizing thereafter. The differentiation between single-vehicle and multi-vehicle crashes revealed a general decline for single-vehicle incidents, indicating possibly improved road conditions or heightened driver awareness. Multi-vehicle crashes generally followed the total crash trend, highlighting them as a significant contributor to overall crash rates.

Crash rates on medians are markedly lower than the broader locations but showed a significant increase in 2020 to 6.85, perhaps reflecting the disproportionate impact of less frequent but more severe crashes in these areas. This peak was followed by a steady decline in subsequent years, which aligns with the broader downward trend in crash rates. Single-vehicle crashes are more prevalent in median incidents, which align with the typical nature of median crashes often involving a single vehicle losing control rather than multi-vehicle interactions. These crashes peaked in 2020 and have since shown a decreasing trend.

Table 15. Overall crash rate per 100 million VMT by severity groups (2018–2023).

Crash Location	Crash Type	2018	2019	2020	2021	2022	2023
All locations	KABCO	133.55	135.19	120.74	133.19	124.12	118.73
	K (Fatal)	0.50	0.52	0.72	0.71	0.64	0.59
	A (Serious)	1.55	1.67	2.12	2.11	2.05	1.77
	B (Minor)	8.68	7.66	8.80	8.44	7.61	6.84
	C (Possible)	24.19	25.36	23.03	25.53	23.82	22.96
	O (No Injury)	98.63	99.97	86.06	96.40	90.00	86.55
	Single-vehicle	23.08	21.66	26.51	22.95	19.75	19.01
	Multi-vehicle	110.47	113.53	94.23	110.23	104.37	99.72
Median	KABCO	5.44	5.17	6.85	6.22	5.33	4.58
	K (Fatal)	0.03	0.05	0.02	0.06	0.06	0.03
	A (Serious)	0.10	0.13	0.16	0.15	0.18	0.12
	B (Minor)	0.60	0.59	0.80	0.69	0.57	0.54
	C (Possible)	0.98	0.99	1.32	1.12	0.98	0.77
	O (No Injury)	3.72	3.42	4.55	4.20	3.54	3.12
	Single-vehicle	4.69	4.44	6.03	5.41	4.62	3.92
	Multi-vehicle	0.75	0.73	0.83	0.81	0.71	0.66

Table showcases the crash rates per 100 million VMT for different roadway characteristics at all locations, divided into overall crashes (KABCO) and more severe crashes (KAB). As the number of through lanes increases, the crash rates also rise. For example, two-lane segments have a mean KABCO crash rate of 23.93, which escalates significantly to 105.79 for segments with six or more lanes. This suggests higher crash rates are associated with busier, broader freeways. Interestingly, higher speed limits are correlated with lower crash rates. For segments with a 55-mph speed limit, the KABCO crash rate stands at 81.14, which decreases to 22.71 for those with a 70-mph limit. This could indicate that roads designed to accommodate higher speeds may also include better safety features or less congested conditions.

Shoulder width also impacts crash rates, with narrower shoulders generally associated with higher rates. Segments with 2-ft left shoulders have a KABCO rate of 29.53, which decreases as the shoulder width increases, reflecting possibly safer conditions for vehicle recovery and emergency stops on wider shoulders. The presence of medians and barriers similarly influences crash rates. Segments with raised medians have higher crash rates (44.74) compared to those with depressed medians (21.58) or wide separation (37.98). The presence of barriers, particularly on the right, correlates with higher crash rates, suggesting that while barriers may prevent cross-median crashes, they might contribute to other types of accidents.

The configuration of the road, such as whether it includes HOV lanes, bridges, or is within an interchange, also plays a role. Segments within interchanges and those with HOV lanes generally exhibit higher crash rates, perhaps due to the complexity of traffic movements and increased vehicle interactions in these areas.

Table focuses on median-specific crash rates and follows a similar pattern but with generally lower values across all categories, reflecting the potentially lower occurrence of severe crashes in median areas compared to mainline segments. However, the data still underscore the influence of structural features like shoulder width and the presence of barriers on safety, with narrower shoulders and the absence of barriers generally correlating with higher crash rates even in median areas. This comprehensive analysis of crash rates by roadway features helps pinpoint critical areas for safety improvements and informs targeted interventions to reduce crash occurrences on freeways.

Table 16. Crash rate per 100 million VMT for all crashes (KABCO) and KAB crashes (all locations).

Roadway Characteristics		KABCO		KAB	
		Mean	St. Dev.	Mean	St. Dev.
Number of through lanes	2	23.93	31.08	2.43	3.88
	3	24.91	36.96	2.35	6.08
	4	46.69	53.60	3.77	5.24
	5	77.97	223.10	4.77	9.61
	6 or more	105.79	294.69	6.91	32.52
Speed limit	55 mph	81.14	210.21	4.95	10.01
	60 mph	53.87	50.45	4.30	4.39
	65 mph	47.96	52.98	3.86	7.54
	70 mph	22.71	87.82	2.26	9.98
Left shoulder width	2 ft	29.53	33.40	2.87	4.55
	4 ft	45.80	170.78	3.32	10.68
	6 ft	43.15	155.91	3.57	16.90
	8 ft	39.81	47.23	3.15	4.43
	10 ft	32.98	40.77	2.84	3.98
	12 ft	28.39	30.79	2.42	3.68
	>12 ft	30.63	33.42	2.50	3.37
Right shoulder width	2 ft	48.73	49.50	3.65	4.40
	4 ft	50.54	101.59	3.94	14.36
	6 ft	35.69	155.65	2.79	7.07
	8 ft	30.15	34.73	2.69	4.15
	10 ft	33.27	46.72	2.88	4.39
	12 ft	44.19	139.65	3.58	15.45
	>12 ft	32.82	39.13	2.62	3.53
Median type	Raised	44.74	102.77	3.37	6.92
	Depressed	21.58	25.19	2.26	3.64
	Wide Separation	37.98	170.12	3.40	18.87
Presence of HOV lanes	No	35.30	104.68	2.95	9.49
	Yes	67.81	78.97	4.91	5.57
With bridge	No	35.72	111.15	3.00	10.02
	Yes	43.90	54.77	3.34	4.70
Within an interchange	No	30.57	46.60	2.64	5.94
	Yes	43.42	137.43	3.45	11.66
Presence of barriers (left)	No	38.01	87.21	3.04	6.10
	Yes	33.36	155.75	3.12	17.34
Presence of barriers (right)	No	31.02	93.57	2.66	6.37
	Yes	47.19	117.77	3.72	12.75
Horizontal alignment	Straight	36.72	120.35	3.06	10.88
	Not straight	38.01	52.59	3.04	4.43
Vertical alignment	Level	36.62	111.96	3.04	10.10
	Upgrade	38.03	54.25	3.07	4.81
	Downgrade	41.22	61.06	3.27	4.96

Table 17. Crash rate per 100 million VMT for all crashes (KABCO) and KAB crashes (medians).

Roadway Characteristics		KABCO		KAB	
		Mean	St. Dev.	Mean	St. Dev.
Number of through lanes	2	1.91	3.55	0.19	1.00
	3	1.50	4.19	0.26	2.62
	4	1.86	3.10	0.29	1.15
	5	1.82	3.41	0.33	1.00
	6 or more	2.28	9.70	0.24	0.66
Speed limit	55 mph	2.01	4.38	0.29	1.24
	60 mph	2.20	3.05	0.33	1.04
	65 mph	1.85	4.35	0.37	3.17
	70 mph	1.63	4.24	0.19	0.84
Left shoulder width	2 ft	2.07	3.84	0.26	1.26
	4 ft	1.84	5.28	0.31	3.87
	6 ft	1.73	5.60	0.26	1.05
	8 ft	1.60	2.93	0.23	0.90
	10 ft	1.72	3.89	0.26	1.09
	12 ft	1.48	2.70	0.20	0.79
	>12 ft	1.75	3.48	0.20	0.79
Right shoulder width	2 ft	1.48	2.57	0.30	1.20
	4 ft	2.18	7.51	0.60	6.81
	6 ft	1.93	4.00	0.23	1.06
	8 ft	1.61	3.46	0.24	1.06
	10 ft	1.65	2.96	0.21	0.84
	12 ft	1.73	5.37	0.25	1.00
	>12 ft	1.71	3.36	0.22	0.88
Median type	Raised	1.84	4.17	0.32	2.32
	Depressed	1.44	2.97	0.16	0.84
	Wide Separation	1.96	6.12	0.20	1.13
Presence of HOV lanes	No	1.73	4.29	0.25	1.89
	Yes	1.97	3.85	0.34	0.89
With bridge	No	1.74	4.42	0.26	1.98
	Yes	1.77	3.40	0.23	1.00
Within an interchange	No	1.71	3.92	0.27	2.46
	Yes	1.78	4.57	0.23	0.95
Presence of barriers (left)	No	1.76	3.86	0.27	1.98
	Yes	1.69	5.69	0.19	1.10
Presence of barriers (right)	No	1.67	3.92	0.25	2.20
	Yes	1.87	4.77	0.26	1.05
Horizontal alignment	Straight	1.69	4.51	0.25	2.12
	Not straight	1.87	3.69	0.27	1.07
Vertical alignment	Level	1.69	4.32	0.25	1.98
	Upgrade	1.91	3.98	0.25	1.09
	Downgrade	2.08	4.03	0.31	1.19

DESCRIPTIVE STATISTICS OF SELECTED FREEWAY GROUPS

This section provides descriptive statistics for the 30 selected segment groups, defined by combinations of six left shoulder width categories (<2 ft, 2–4 ft, 4–6 ft, 6–8 ft, 8–10 ft, and ≥10 ft), number of through lanes for statewide (two lanes, three or more lanes) and roadside barrier types (statewide without barrier, statewide with barrier, and Atlanta urban segments with barrier). For each segment group, the descriptive statistics are summarized for the dependent variables—crash frequencies for four severity categories: KABCO (all crashes), KAB (fatal and injury crashes), median-related KABCO crashes, and median-related KAB crashes—along with the primary SPF variables, including traffic volume (AADT) and segment length (see table , table , table , table , table , table , and table). In addition, this section presents visualizations of key freeway geometric features on maps.

Table 18. Descriptive statistics for AADT (statewide samples).

Left Shoulder Width	Statewide Freeway Group	Sample Size	Mean	Min	Max
<2 ft	2-lane statewide without barrier	419	34,620.53	17,400	70,500
	2-lane statewide with barrier	100	39,391.00	17,400	92,600
	3-or-more–lane statewide without barrier	71	40,409.86	20,900	80,200
	3-or-more–lane statewide with barrier	59	56,003.39	34,400	94,600
2–4 ft	2-lane statewide without barrier	371	37,425.88	14,100	59,600
	2-lane statewide with barrier	253	36,338.74	15,700	66,300
	3-or-more–lane statewide without barrier	117	71,116.24	23,400	93,600
	3-or-more–lane statewide with barrier	184	66,120.27	10,370	95,300
4–6 ft	2-lane statewide without barrier	137	41,292.70	14,200	68,600
	2-lane statewide with barrier	76	50,893.42	22,500	97,200
	3-or-more–lane statewide without barrier	169	77,214.79	15,700	116,000
	3-or-more–lane statewide with barrier	663	63,782.65	20,500	103,000
6–8 ft	2-lane statewide without barrier	71	30,340.85	19,200	48,000
	2-lane statewide with barrier	98	34,780.61	19,200	70,500
	3-or-more–lane statewide without barrier	134	64,292.54	34,300	96,600
	3-or-more–lane statewide with barrier	462	67,746.75	33,800	93,400
8–10 ft	2-lane statewide without barrier	73	35,060.27	19,500	93,600
	2-lane statewide with barrier	170	31,064.12	14,200	66,300
	3-or-more–lane statewide without barrier	138	67,169.57	39,400	97,700
	3-or-more–lane statewide with barrier	486	60,023.46	38,600	115,000
≥10 ft	2-lane statewide without barrier	187	35,816.58	12,800	68,500
	2-lane statewide with barrier	222	47,818.02	12,800	96,200
	3-or-more–lane statewide without barrier	216	65,708.80	34,400	116,000
	3-or-more–lane statewide with barrier	676	60,289.05	26,900	95,800

Table 19. Descriptive statistics for segment length (statewide samples).

Left Shoulder Width	Statewide Freeway Group	Sample Size	Mean	Min	Max
<2 ft	2-lane statewide without barrier	419	2.59	0.23	9.35
	2-lane statewide with barrier	100	1.24	0.14	5.85
	3-or-more–lane statewide without barrier	71	0.73	0.33	1.46
	3-or-more–lane statewide with barrier	59	0.63	0.14	1.02
2–4 ft	2-lane statewide without barrier	371	2.23	0.15	10.24
	2-lane statewide with barrier	253	2.13	0.15	9.37
	3-or-more–lane statewide without barrier	117	2.37	0.20	7.93
	3-or-more–lane statewide with barrier	184	1.25	0.14	4.45
4–6 ft	2-lane statewide without barrier	137	2.93	0.28	9.50
	2-lane statewide with barrier	76	2.27	0.13	8.34
	3-or-more–lane statewide without barrier	169	1.68	0.24	8.59
	3-or-more–lane statewide with barrier	663	1.38	0.18	8.74
6–8 ft	2-lane statewide without barrier	71	2.77	0.18	7.14
	2-lane statewide with barrier	98	1.20	0.34	3.99
	3-or-more–lane statewide without barrier	134	1.56	0.14	6.99
	3-or-more–lane statewide with barrier	462	1.25	0.13	5.65
8–10 ft	2-lane statewide without barrier	73	1.74	0.30	5.36
	2-lane statewide with barrier	170	2.47	0.17	9.33
	3-or-more–lane statewide without barrier	138	2.81	0.22	8.49
	3-or-more–lane statewide with barrier	486	1.49	0.13	7.54
≥10 ft	2-lane statewide without barrier	187	2.82	0.17	7.16
	2-lane statewide with barrier	222	1.13	0.15	4.18
	3-or-more–lane statewide without barrier	216	1.68	0.16	7.28
	3-or-more–lane statewide with barrier	676	1.53	0.20	8.00

Table 20. Descriptive statistics for KABCO crash frequency (statewide samples).

Left Shoulder Width	Statewide Freeway Group	Sample Size	Mean	Min	Max
<2 ft	2-lane statewide without barrier	419	9.13	0	41
	2-lane statewide with barrier	100	6.29	0	43
	3-or-more–lane statewide without barrier	71	4.13	0	23
	3-or-more–lane statewide with barrier	59	4.25	0	18
2–4 ft	2-lane statewide without barrier	371	9.49	0	63
	2-lane statewide with barrier	253	8.42	0	54
	3-or-more–lane statewide without barrier	117	15.03	0	77
	3-or-more–lane statewide with barrier	184	9.58	0	79
4–6 ft	2-lane statewide without barrier	137	15.20	0	87
	2-lane statewide with barrier	76	11.42	0	54
	3-or-more–lane statewide without barrier	169	14.04	0	73
	3-or-more–lane statewide with barrier	663	6.84	0	110
6–8 ft	2-lane statewide without barrier	71	9.54	0	63
	2-lane statewide with barrier	98	4.57	0	16
	3-or-more–lane statewide without barrier	134	8.61	0	49
	3-or-more–lane statewide with barrier	462	9.13	0	76
8–10 ft	2-lane statewide without barrier	73	5.86	0	20
	2-lane statewide with barrier	170	7.72	0	38
	3-or-more–lane statewide without barrier	138	14.34	0	56
	3-or-more–lane statewide with barrier	486	7.35	0	44
≥10 ft	2-lane statewide without barrier	187	10.16	0	64
	2-lane statewide with barrier	222	5.86	0	65
	3-or-more–lane statewide without barrier	216	9.66	0	79
	3-or-more–lane statewide with barrier	676	8.72	0	75

Table 21. Descriptive statistics for KAB crash frequency (statewide samples).

Left Shoulder Width	Statewide Freeway Group	Sample Size	Mean	Min	Max
<2 ft	2-lane statewide without barrier	419	1.17	0	8
	2-lane statewide with barrier	100	0.65	0	7
	3-or-more–lane statewide without barrier	71	0.41	0	3
	3-or-more–lane statewide with barrier	59	0.51	0	3
2–4 ft	2-lane statewide without barrier	371	0.96	0	10
	2-lane statewide with barrier	253	1.02	0	8
	3-or-more–lane statewide without barrier	117	1.67	0	9
	3-or-more–lane statewide with barrier	184	0.99	0	11
4–6 ft	2-lane statewide without barrier	137	1.78	0	9
	2-lane statewide with barrier	76	1.28	0	7
	3-or-more–lane statewide without barrier	169	1.43	0	12
	3-or-more–lane statewide with barrier	663	0.82	0	12
6–8 ft	2-lane statewide without barrier	71	1.21	0	7
	2-lane statewide with barrier	98	0.71	0	5
	3-or-more–lane statewide without barrier	134	1.02	0	7
	3-or-more–lane statewide with barrier	462	1.00	0	10
8–10 ft	2-lane statewide without barrier	73	0.74	0	4
	2-lane statewide with barrier	170	0.89	0	7
	3-or-more–lane statewide without barrier	138	1.68	0	8
	3-or-more–lane statewide with barrier	486	0.85	0	10
≥10 ft	2-lane statewide without barrier	187	1.37	0	11
	2-lane statewide with barrier	222	0.59	0	9
	3-or-more–lane statewide without barrier	216	1.07	0	8
	3-or-more–lane statewide with barrier	676	0.96	0	11

Table 22. Descriptive statistics for median-related KABCO crash frequency (statewide samples).

Left Shoulder Width	Statewide Freeway Group	Sample Size	Mean	Min	Max
<2 ft	2-lane statewide without barrier	419	1.13	0	11
	2-lane statewide with barrier	100	0.45	0	6
	3-or-more–lane statewide without barrier	71	0.46	0	4
	3-or-more–lane statewide with barrier	59	0.46	0	4
2–4 ft	2-lane statewide without barrier	371	0.82	0	10
	2-lane statewide with barrier	253	0.98	0	12
	3-or-more–lane statewide without barrier	117	0.51	0	5
	3-or-more–lane statewide with barrier	184	0.69	0	8
4–6 ft	2-lane statewide without barrier	137	1.35	0	15
	2-lane statewide with barrier	76	0.87	0	8
	3-or-more–lane statewide without barrier	169	0.66	0	6
	3-or-more–lane statewide with barrier	663	0.51	0	8
6–8 ft	2-lane statewide without barrier	71	0.70	0	7
	2-lane statewide with barrier	98	0.47	0	3
	3-or-more–lane statewide without barrier	134	0.24	0	3
	3-or-more–lane statewide with barrier	462	0.66	0	10
8–10 ft	2-lane statewide without barrier	73	0.66	0	4
	2-lane statewide with barrier	170	1.04	0	7
	3-or-more–lane statewide without barrier	138	0.83	0	6
	3-or-more–lane statewide with barrier	486	0.55	0	6
≥10 ft	2-lane statewide without barrier	187	1.03	0	8
	2-lane statewide with barrier	222	0.57	0	8
	3-or-more–lane statewide without barrier	216	0.64	0	10
	3-or-more–lane statewide with barrier	676	0.78	0	10

Table 23. Descriptive statistics for median-related KAB crash frequency (statewide samples).

Left Shoulder Width	Statewide Freeway Group	Sample Size	Mean	Min	Max
<2 ft	2-lane statewide without barrier	419	0.09	0	1
	2-lane statewide with barrier	100	0.07	0	1
	3-or-more–lane statewide without barrier	71	0.01	0	1
	3-or-more–lane statewide with barrier	59	0.10	0	1
2–4 ft	2-lane statewide without barrier	371	0.03	0	1
	2-lane statewide with barrier	253	0.09	0	1
	3-or-more–lane statewide without barrier	117	0.02	0	1
	3-or-more–lane statewide with barrier	184	0.06	0	1
4–6 ft	2-lane statewide without barrier	137	0.11	0	1
	2-lane statewide with barrier	76	0.07	0	1
	3-or-more–lane statewide without barrier	169	0.08	0	1
	3-or-more–lane statewide with barrier	663	0.08	0	1
6–8 ft	2-lane statewide without barrier	71	0.03	0	1
	2-lane statewide with barrier	98	0.06	0	1
	3-or-more–lane statewide without barrier	134	0.01	0	1
	3-or-more–lane statewide with barrier	462	0.04	0	1
8–10 ft	2-lane statewide without barrier	73	0.03	0	1
	2-lane statewide with barrier	170	0.06	0	1
	3-or-more–lane statewide without barrier	138	0.12	0	1
	3-or-more–lane statewide with barrier	486	0.08	0	1
≥10 ft	2-lane statewide without barrier	187	0.07	0	1
	2-lane statewide with barrier	222	0.06	0	1
	3-or-more–lane statewide without barrier	216	0.07	0	1
	3-or-more–lane statewide with barrier	616	0.08	0	1

Table 24. Descriptive statistics for Atlanta urban freeways (with barrier).

Left Shoulder Width	Variables	Sample Size	Mean	Min	Max
<2 ft	AADT	324	155,234.57	23,000	329,000
	Segment Length	324	0.60	0.14	3.55
	Truck Percentage	324	8.25	2.00	21.30
	KABCO Crash Frequency	324	21.73	0	243
	KAB Crash Frequency	324	1.69	0	14
	Median-related KABCO Crash Frequency	324	0.79	0	11
	Median-related KAB Crash Frequency	324	0.09	0	3
2–4 ft	AADT	306	181,933.33	26,500	329,000
	Segment Length	306	0.73	0.12	2.28
	Truck Percentage	306	7.64	2.70	18.30
	KABCO Crash Frequency	306	46.97	1	220
	KAB Crash Frequency	306	3.44	0	18
	Median-related KABCO Crash Frequency	306	1.14	0	7
	Median-related KAB Crash Frequency	306	0.25	0	3
4–6 ft	AADT	978	168,359.13	20,300	388,000
	Segment Length	978	0.83	0.13	5.73
	Truck Percentage	978	9.74	2.00	21.50
	KABCO Crash Frequency	978	44.19	0	356
	KAB Crash Frequency	978	3.22	0	21
	Median-related KABCO Crash Frequency	978	1.28	0	20
	Median-related KAB Crash Frequency	978	0.23	0	3
6–8 ft	AADT	709	192,772.36	35,300	388,000
	Segment Length	709	0.74	0.13	3.73
	Truck Percentage	709	7.74	2.70	19.30
	KABCO Crash Frequency	709	49.55	0	311
	KAB Crash Frequency	709	3.31	0	26
	Median-related KABCO Crash Frequency	709	1.34	0	14
	Median-related KAB Crash Frequency	709	0.20	0	5
8–10 ft	AADT	286	165,683.22	68,600	255,000
	Segment Length	286	0.87	0.16	3.51
	Truck Percentage	286	10.04	2.70	18.00
	KABCO Crash Frequency	286	40.66	0	288
	KAB Crash Frequency	286	2.87	0	17
	Median-related KABCO Crash Frequency	286	1.53	0	19
	Median-related KAB Crash Frequency	286	0.13	0	2
≥10 ft	AADT	570	153,202.46	53,700	307,000
	Segment Length	570	0.94	0.13	5.84
	Truck Percentage	570	10.69	2.70	19.30
	KABCO Crash Frequency	570	37.57	0	307
	KAB Crash Frequency	570	2.97	0	24
	Median-related KABCO Crash Frequency	570	1.17	0	9
	Median-related KAB Crash Frequency	570	0.16	0	2

VISUALIZATION OF FREEWAY SEGMENTS WITH KEY FEATURES

Figure 16, figure 17, figure 18, figure 19, figure 20, and figure 21 present maps showing the spatial distribution of roadway segments categorized by different left shoulder widths (<2 ft, 2–4 ft, 4–6 ft, 6–8 ft, 8–10 ft, and ≥10 ft). Figure 22 and figure 23 display the distribution of segments located statewide without any barrier and with barrier, respectively. In addition, figure 24 shows the locations of freeways with two lanes, and figure 25 shows the locations of freeways with three or more lanes. Figure 26 illustrates the distribution of segments with barrier specifically within the Atlanta area. The blue color indicates the presence of the target left shoulder width or left barrier type. Figure 27 shows the locations of Atlanta urban freeways with different truck percentages.

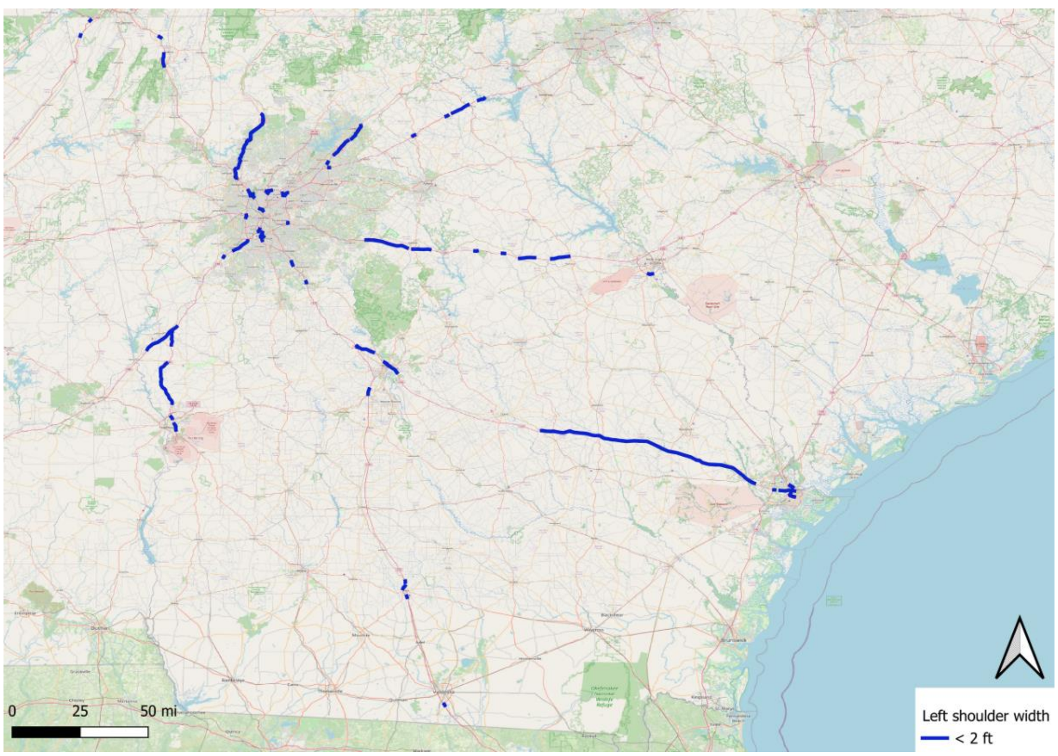

Figure 16. Map. Locations of freeways with left shoulder widths <2 ft.

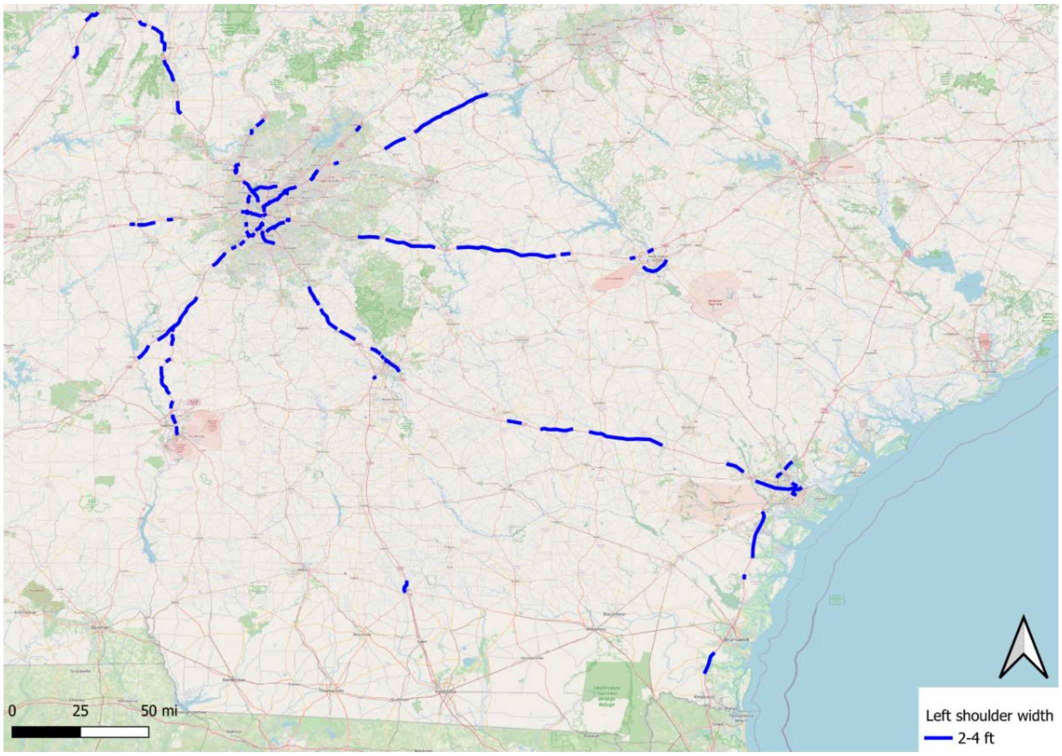

Figure 17. Map. Locations of freeways with left shoulder widths of 2–4 ft.

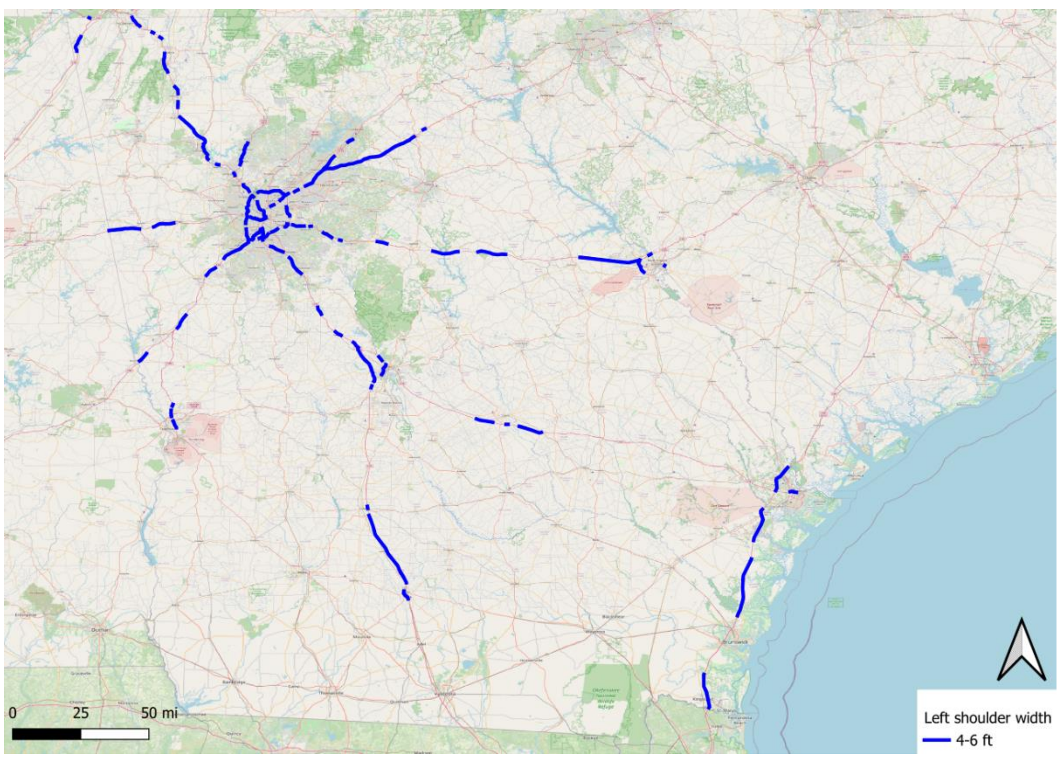

Figure 18. Map. Locations of freeways with left shoulder widths of 4–6 ft.

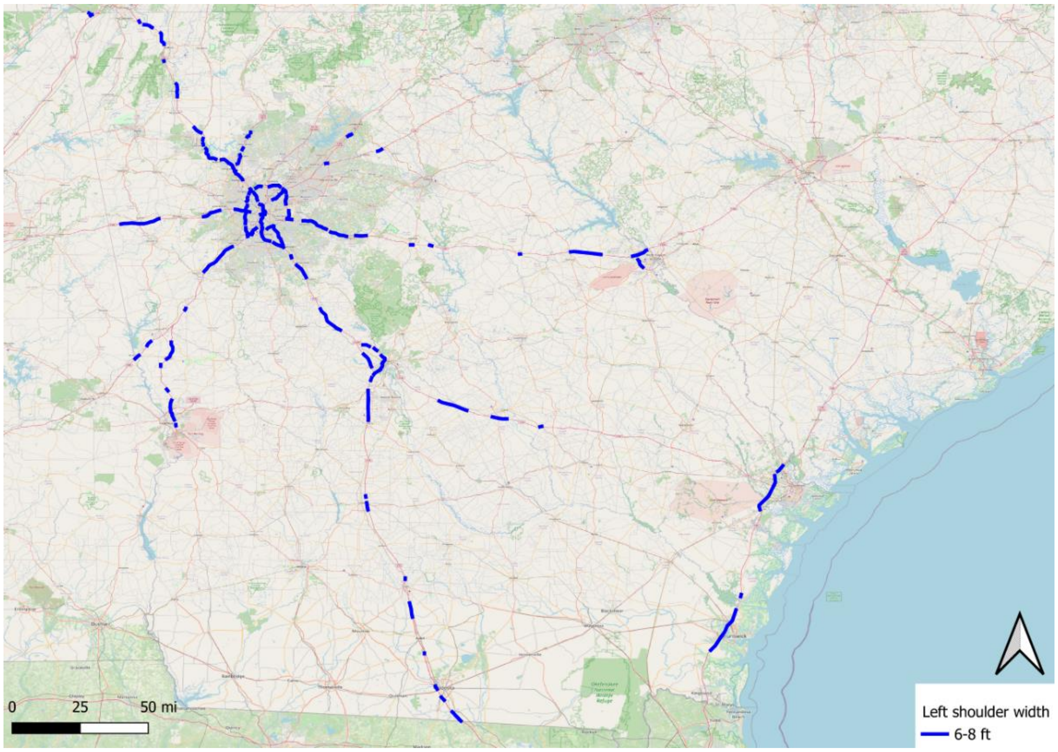

Figure 19. Map. Locations of freeways with left shoulder widths of 6–8 ft.

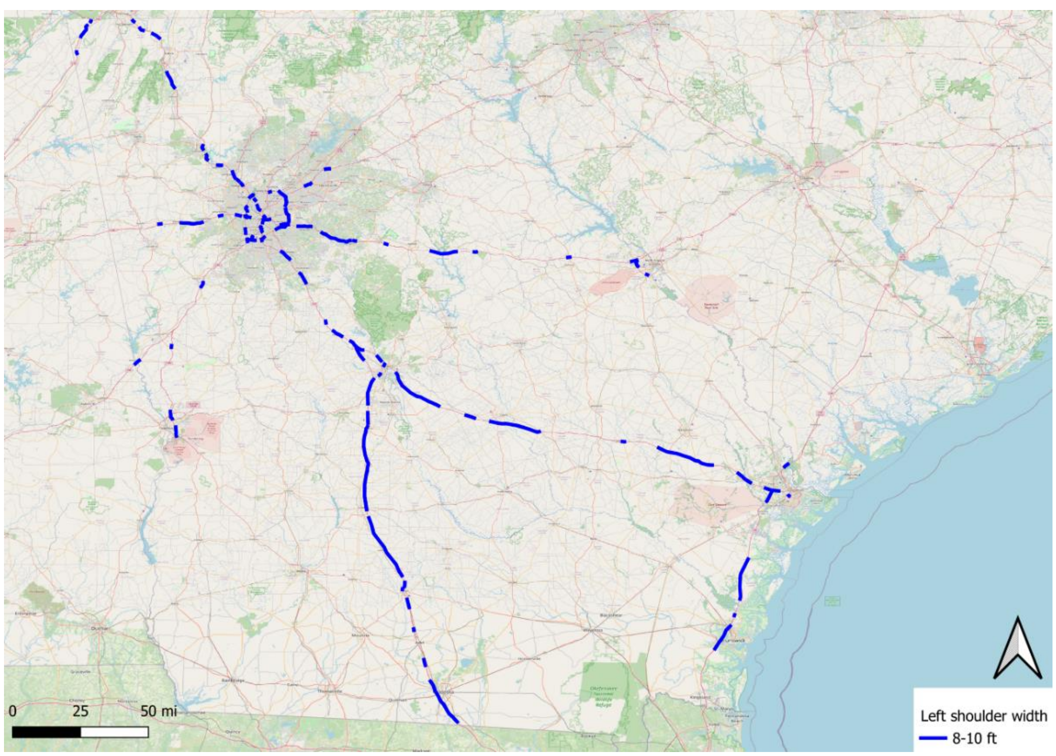

Figure 20. Map. Locations of freeways with left shoulder widths of 8–10 ft.

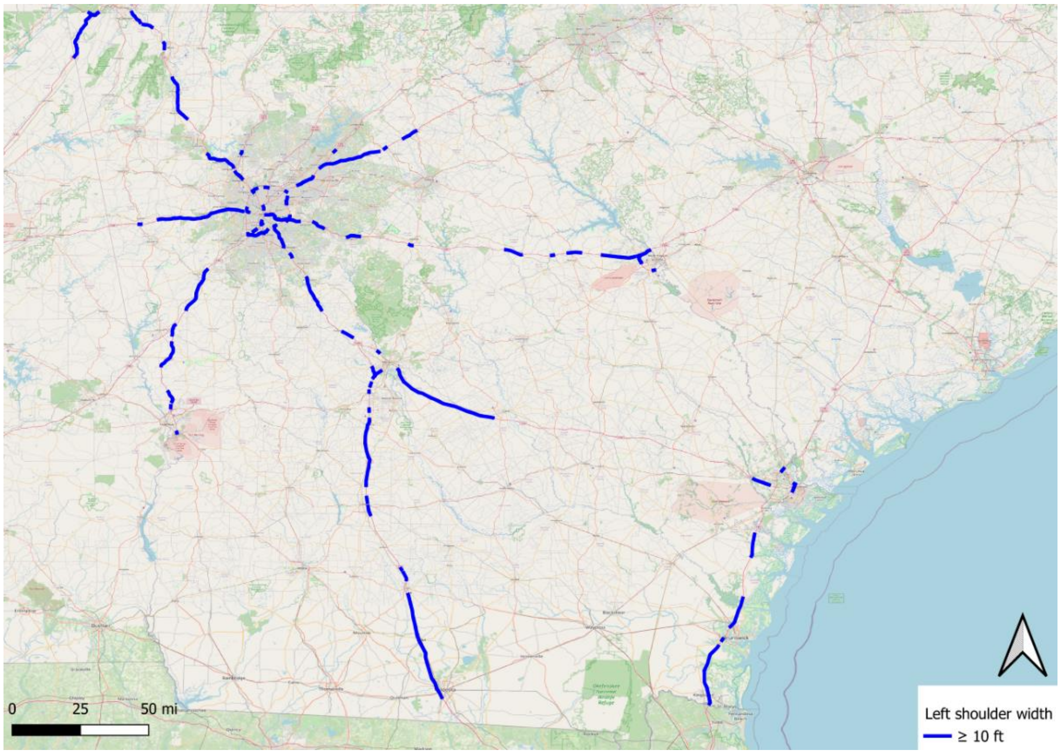

Figure 21. Map. Locations of freeways with left shoulder widths ≥10 ft.

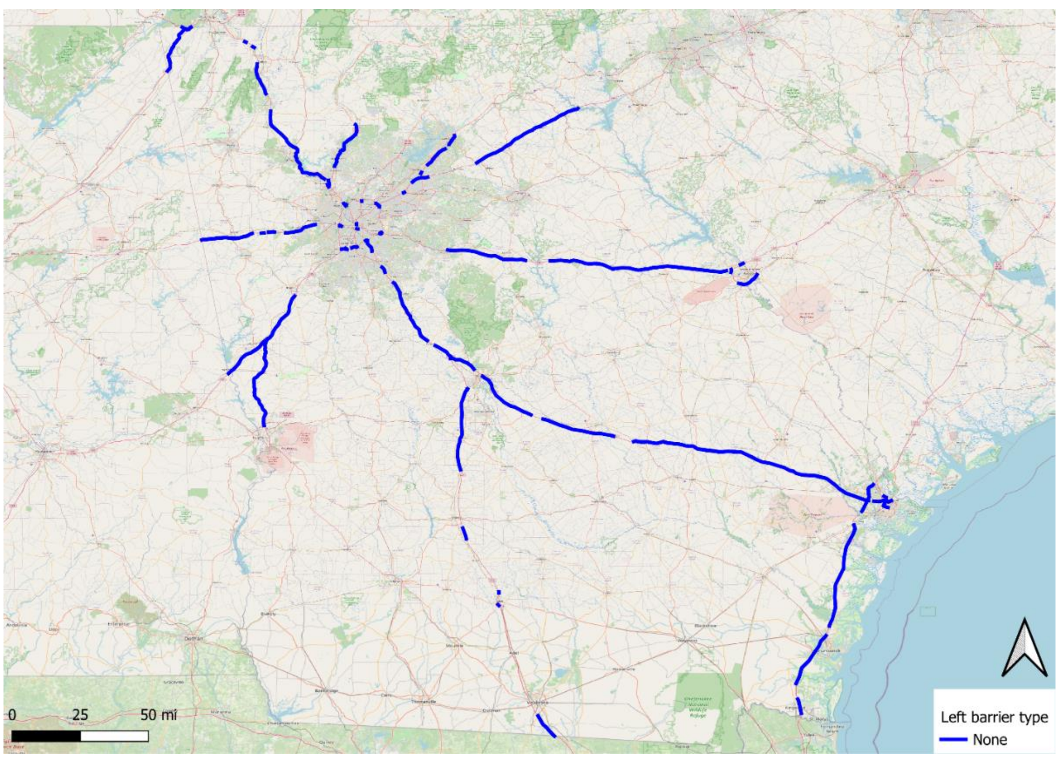

Figure 22. Map. Locations of freeways without barrier on the left shoulders.

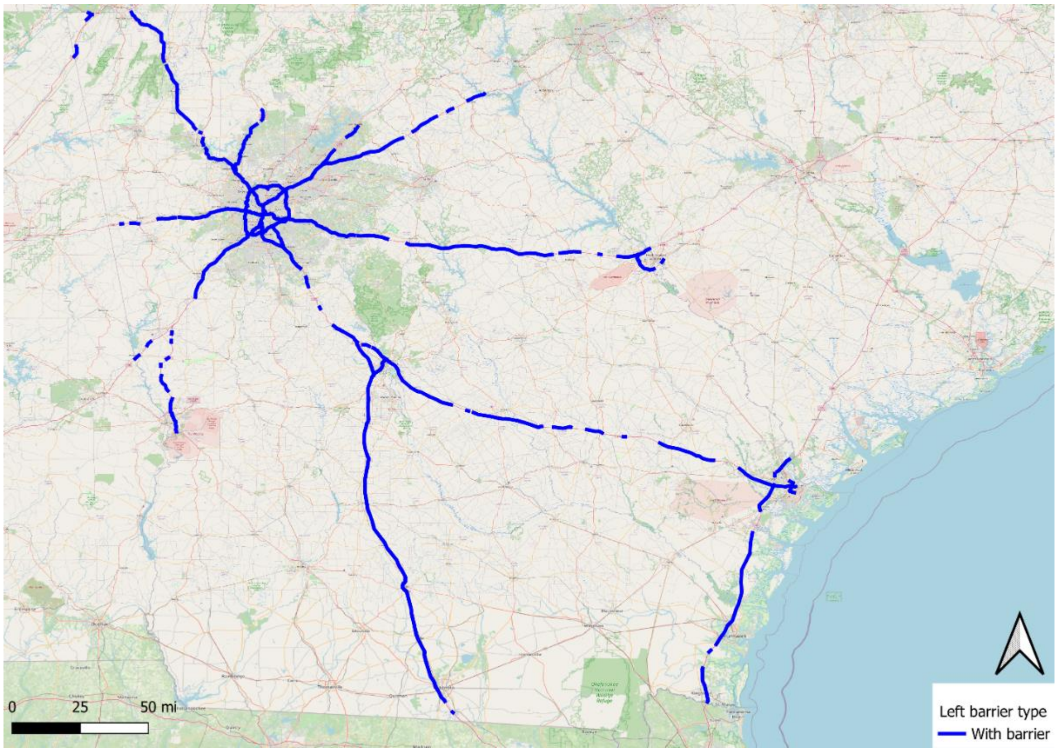

Figure 23. Map. Locations of freeways with barrier on the left shoulders.

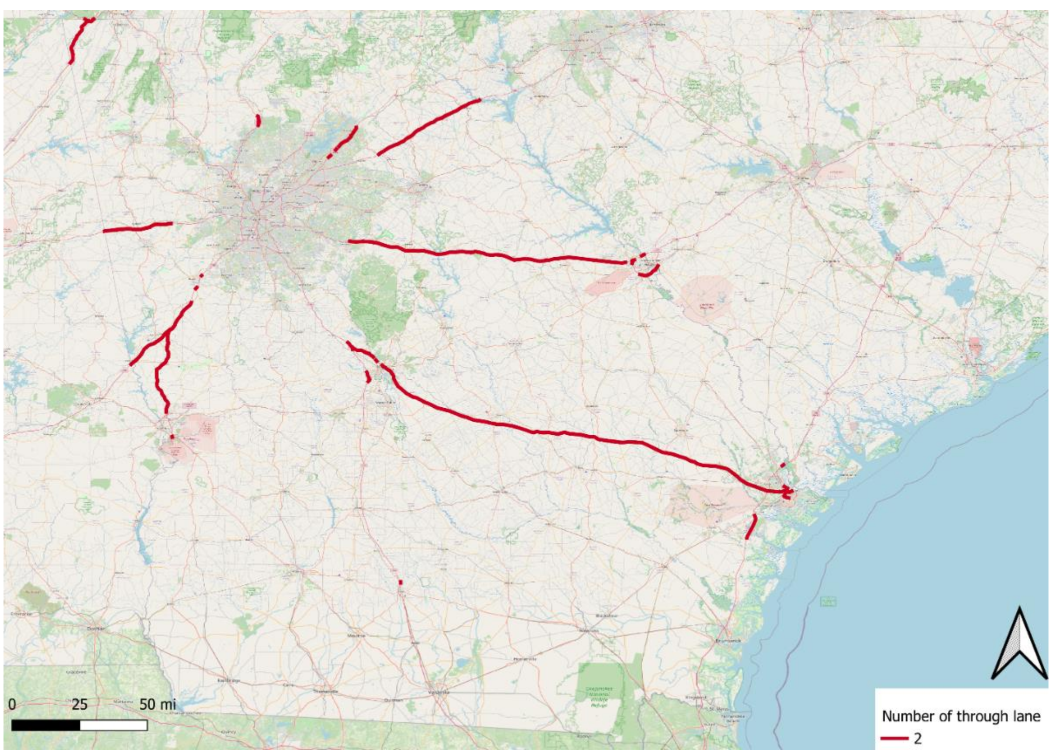

Figure 24. Map. Locations of freeways with two lanes.

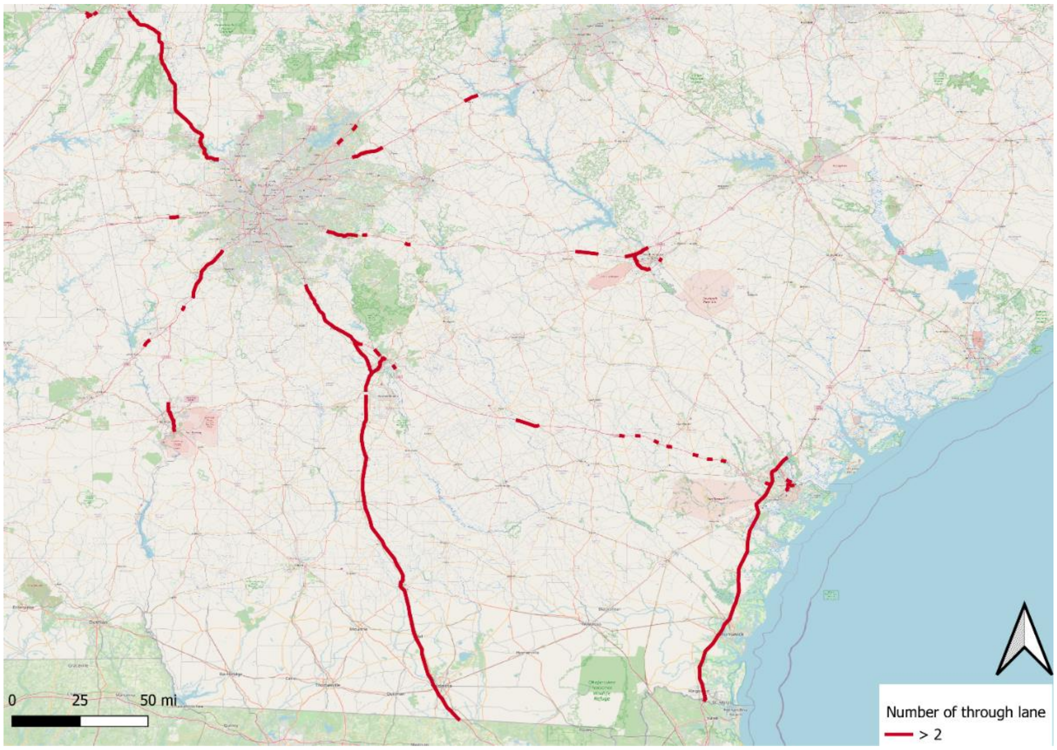

Figure 25. Map. Locations of freeways with three or more lanes.

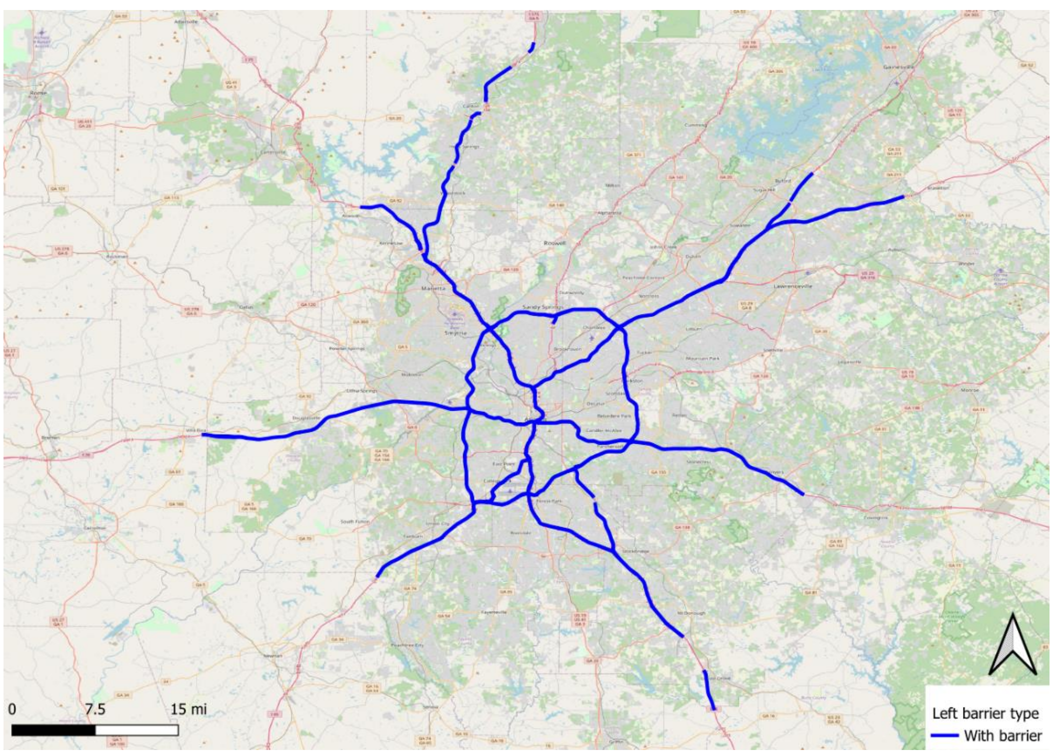

Figure 26. Map. Locations of Atlanta urban freeways with barrier on the left shoulders.

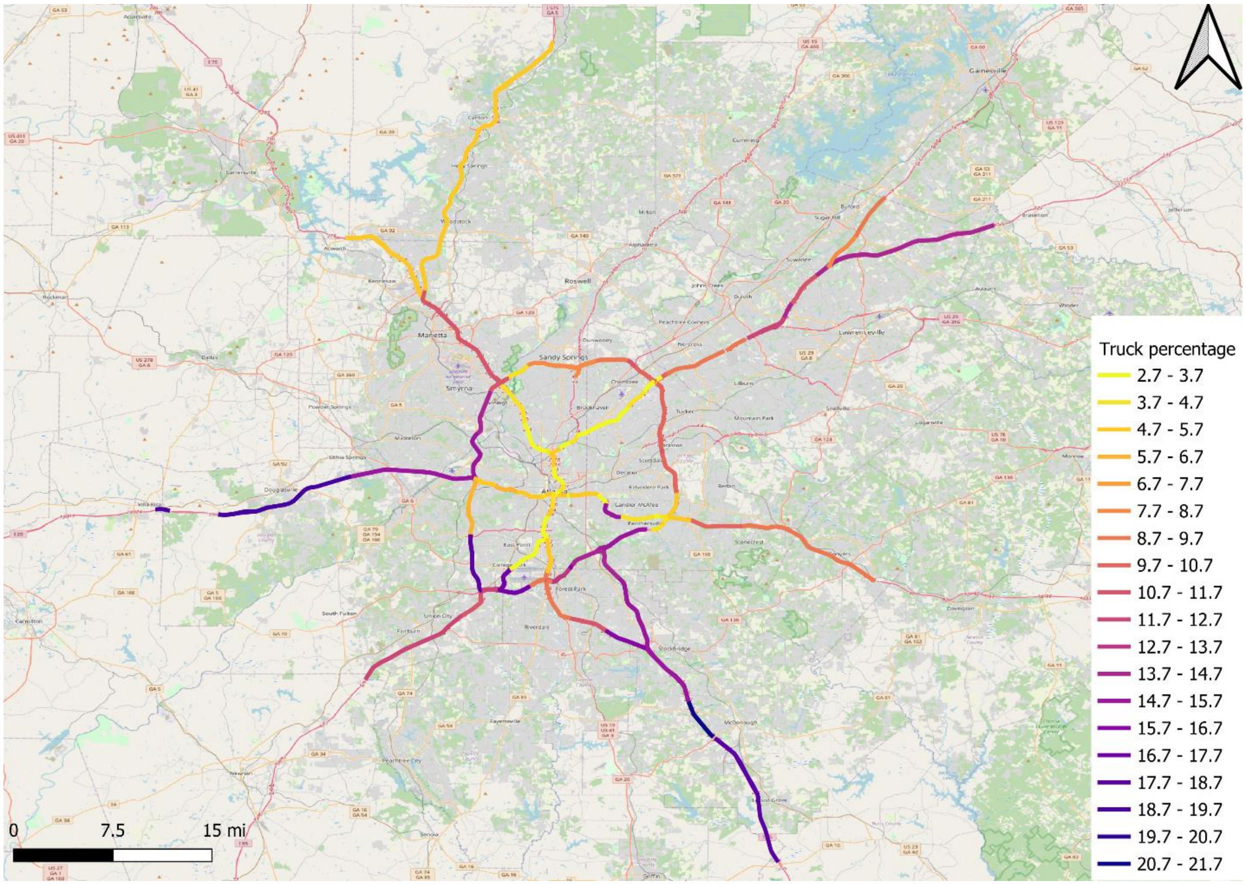

Figure 27. Map. Locations of Atlanta urban freeways with truck percentage.

CHAPTER 5. SAFETY PERFORMANCE FUNCTION RESULTS

This chapter presents the results of the SPFs developed for the 30 selected segment groups. The SPFs were estimated to use crash data from 2018 to 2023. Separate SPFs were developed for each of the four crash severity categories: KABCO (all crashes), KAB (fatal and injury crashes), median-related KABCO crashes, and median-related KAB crashes.

RESULTS OF SPFS

Figure 28, Figure 29, Figure 30, Figure 31, Figure 32, Figure 33, Figure 34, and Figure 35 display the SPFs for freeways with varying left shoulder widths by controlling segment length. Figure 36, Figure 37, Figure 38, Figure 39, Figure 40, Figure 41, Figure 42, and Figure 43 display the SPFs for freeways with varying left shoulder widths by truck percentage in the Atlanta area. The tables report the estimated coefficients for contributing factors included in each SPF and their corresponding *p*-values (see Table , Table , Table , Table , Table , Table , and Table). The coefficients reflect the magnitude and direction of the effect of each variable on crash frequency, and the *p*-values indicate the statistical significance of those effects. A *p*-value <0.05 denotes statistical significance at the 95 percent confidence level.

In general, the variable AADT exhibits a positive association with crash frequency across nearly all models. This consistent trend across different shoulder widths, barrier types, and geographical areas suggests that higher traffic volumes strongly correlate with an increased likelihood of crash occurrences. Similarly, segment length consistently shows a positive relationship with crash frequency, reflecting the effect of greater exposure over longer roadway segments. The effect of truck percentage on crash frequency on Atlanta urban freeways varies by left shoulder width and crash type. In general, the truck percentage variable is positively associated with crash frequency, particularly for narrower shoulders (<2 ft and 4–6 ft). However, for wider shoulders (≥6 ft), the truck percentage effect is smaller.

When comparing modeling outcomes across different crash types, models developed for KABCO crashes (all crashes) tend to yield larger and more statistically significant AADT coefficients compared to models for KAB crashes (fatal and injury crashes). This finding indicates that AADT exerts a more substantial influence on the overall frequency of crashes than on the subset of more severe crashes. In contrast, models developed for median-related crashes (Median KABCO and Median KAB) often produce smaller AADT coefficients and exhibit weaker statistical significance, as reflected by larger *p*-values. This finding suggests that whereas traffic volume remains a contributing factor, it has a more limited predictive role for median-related crash occurrences. One explanation is that severe (KAB) and median-related crashes, although influenced by traffic exposure, are more random than total crashes. Although all crash occurrences involve a degree of randomness, severe and median-related crashes may be driven by more complex and less frequent events—such as high-speed impacts or unusual driver behaviors, which are less directly tied to general traffic volume levels.

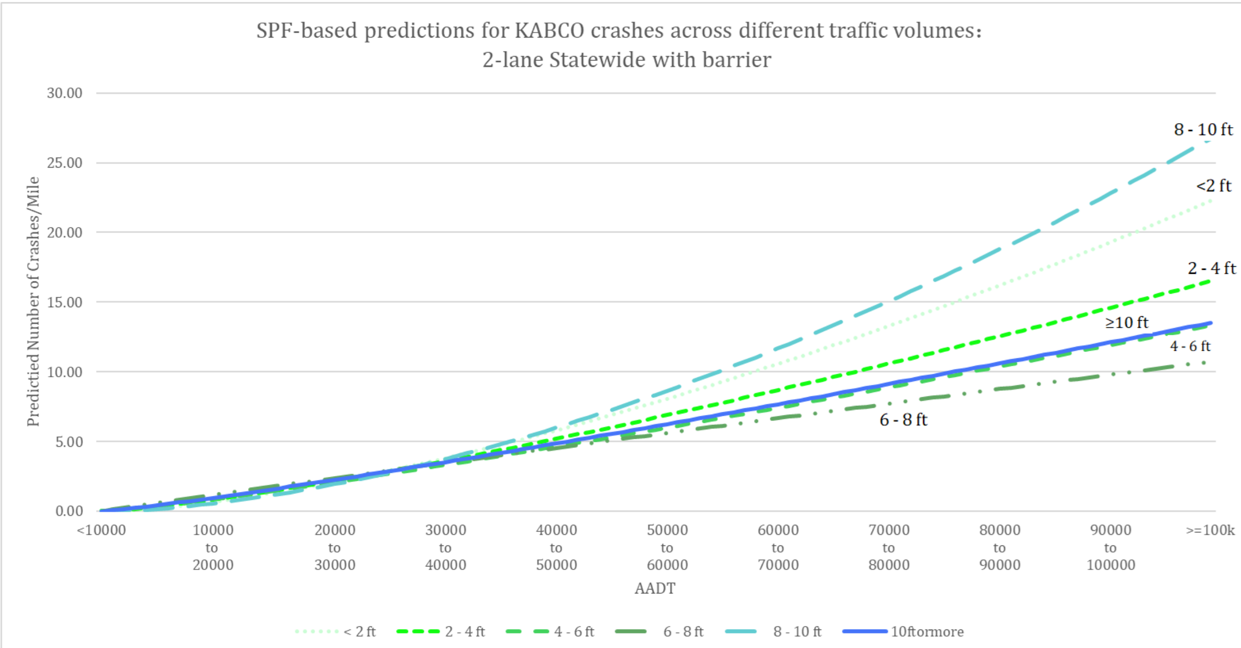

Figure 28. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (two-lane statewide with barrier).

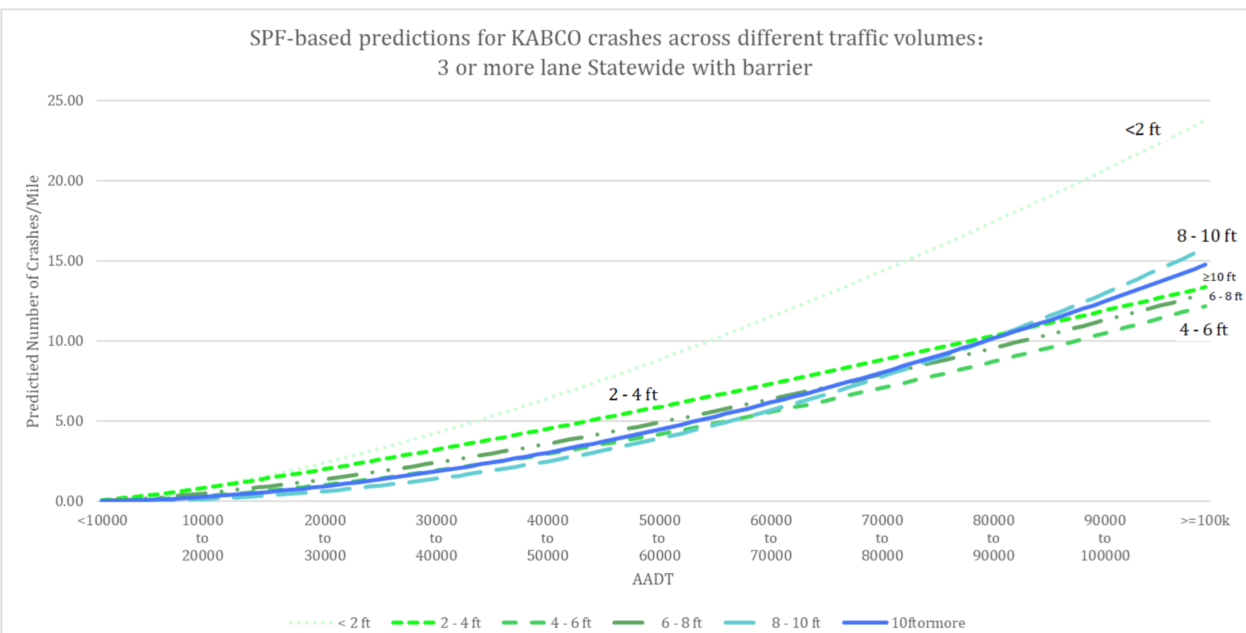

Figure 29. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (three-or-more–lane statewide with barrier).

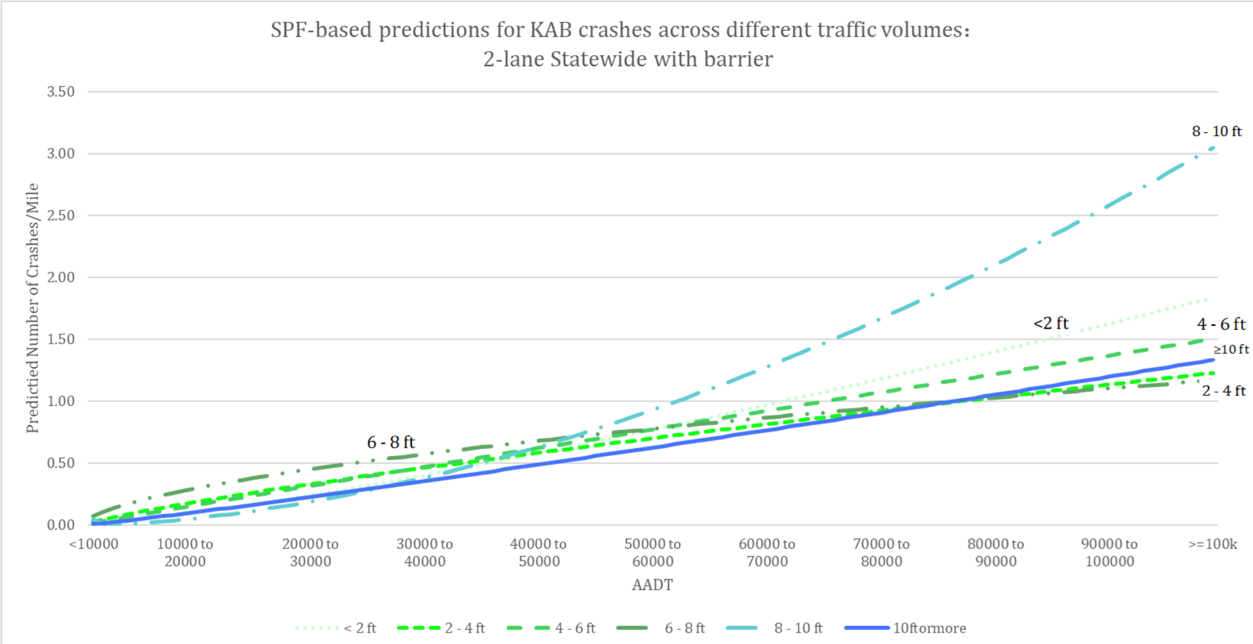

Figure 30. Graph. SPF-based predictions for KAB crashes across different traffic volumes (two-lane statewide with barrier).

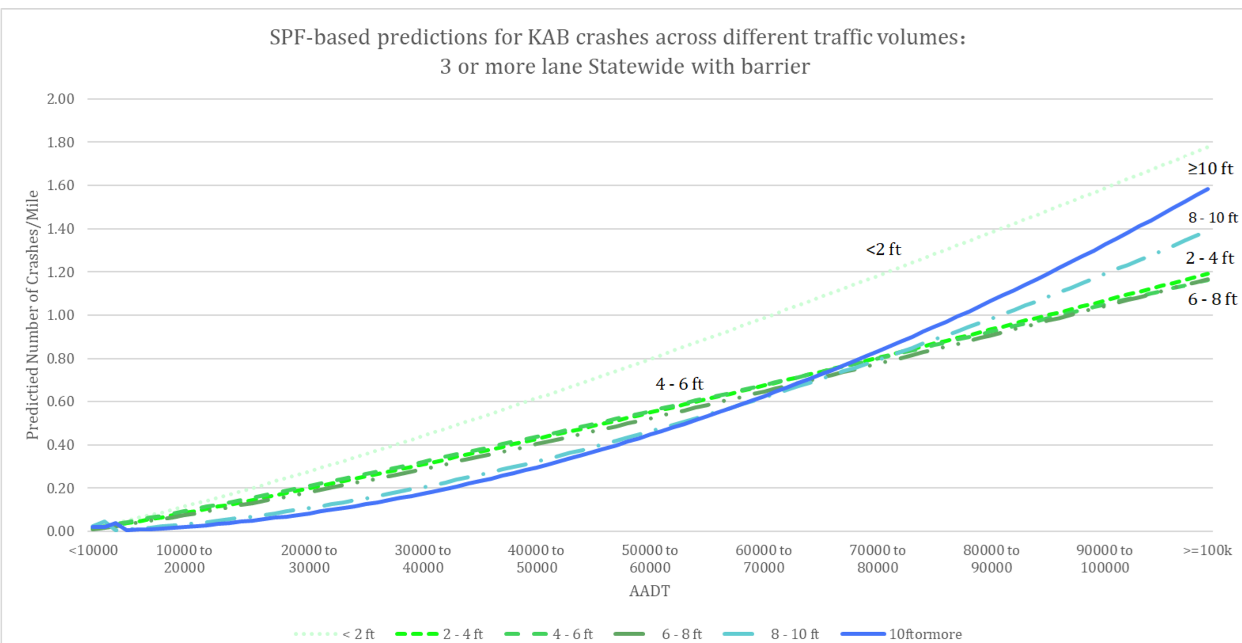

Figure 31. Graph. SPF-based predictions for KAB crashes across different traffic volumes (three-or-more–lane statewide with barrier).

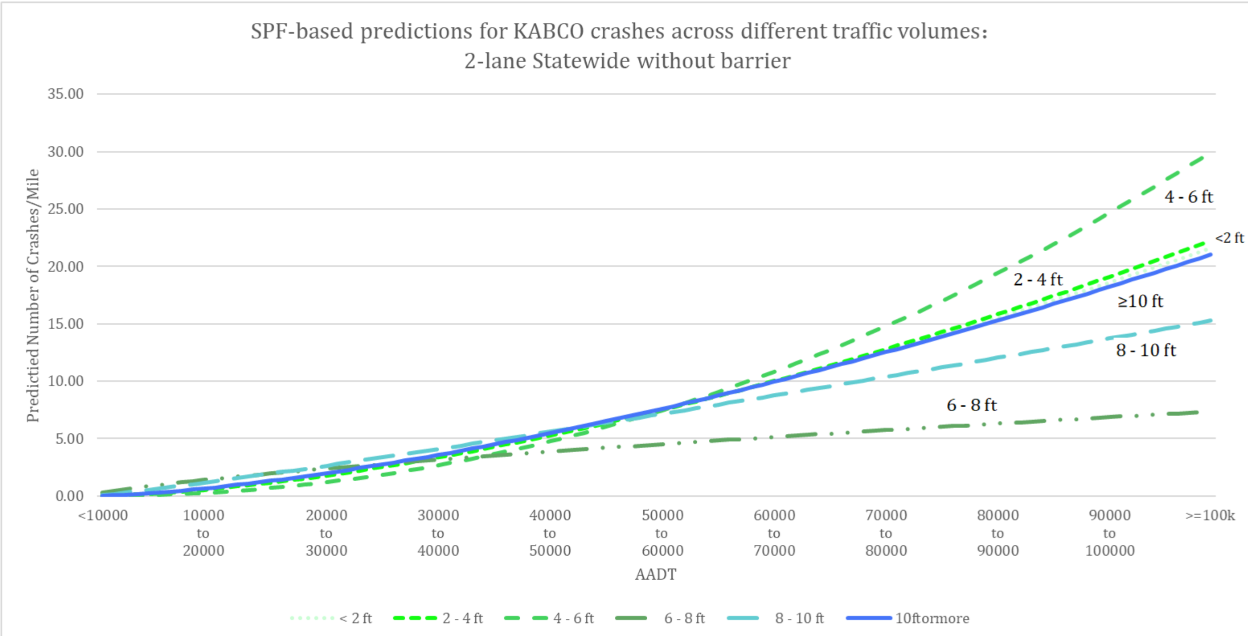

Figure 32. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (two-lane statewide without barrier).

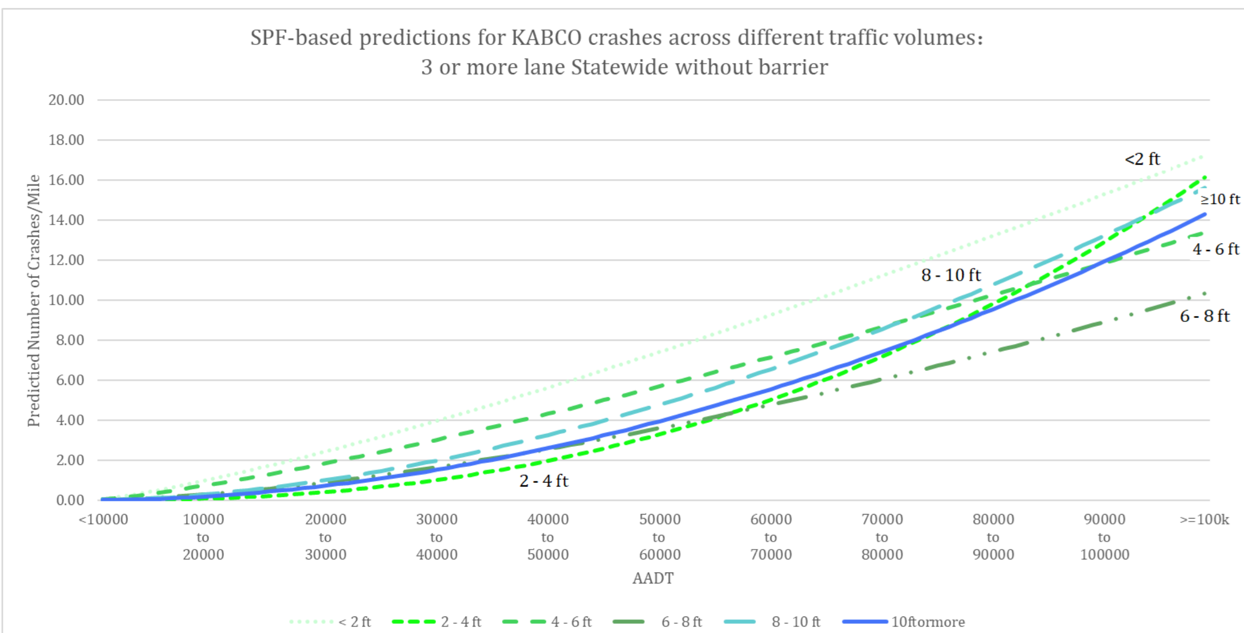

Figure 33. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (three-or-more–lane statewide without barrier).

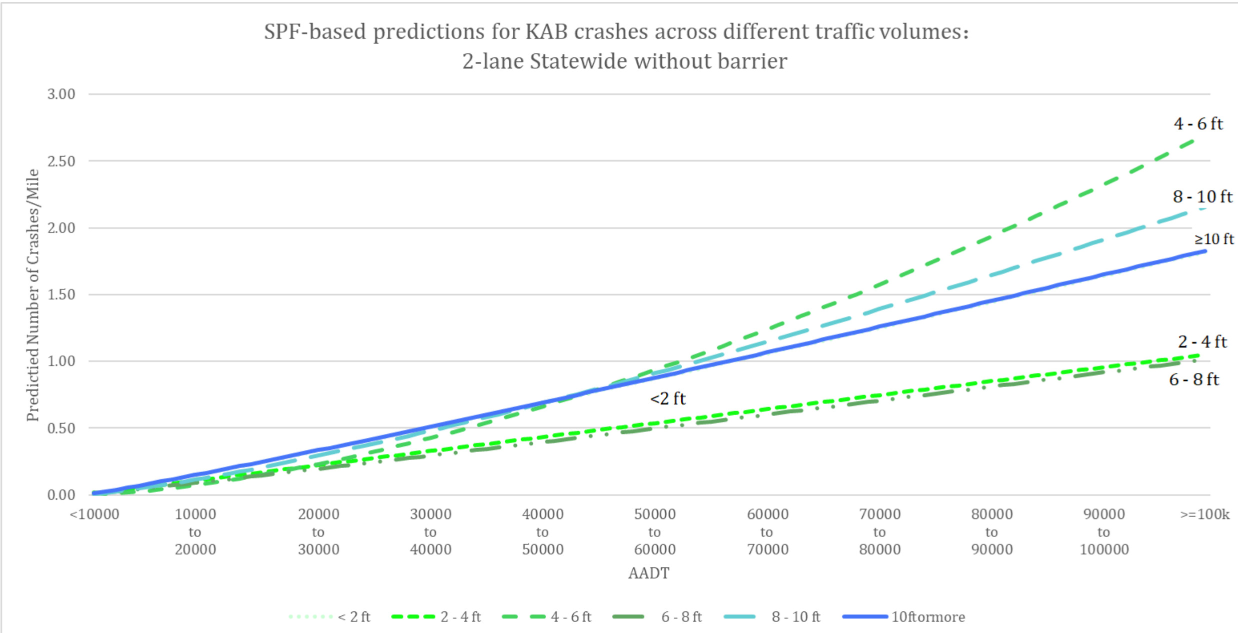

Figure 34. Graph. SPF-based predictions for KAB crashes across different traffic volumes (two-lane statewide without barrier).

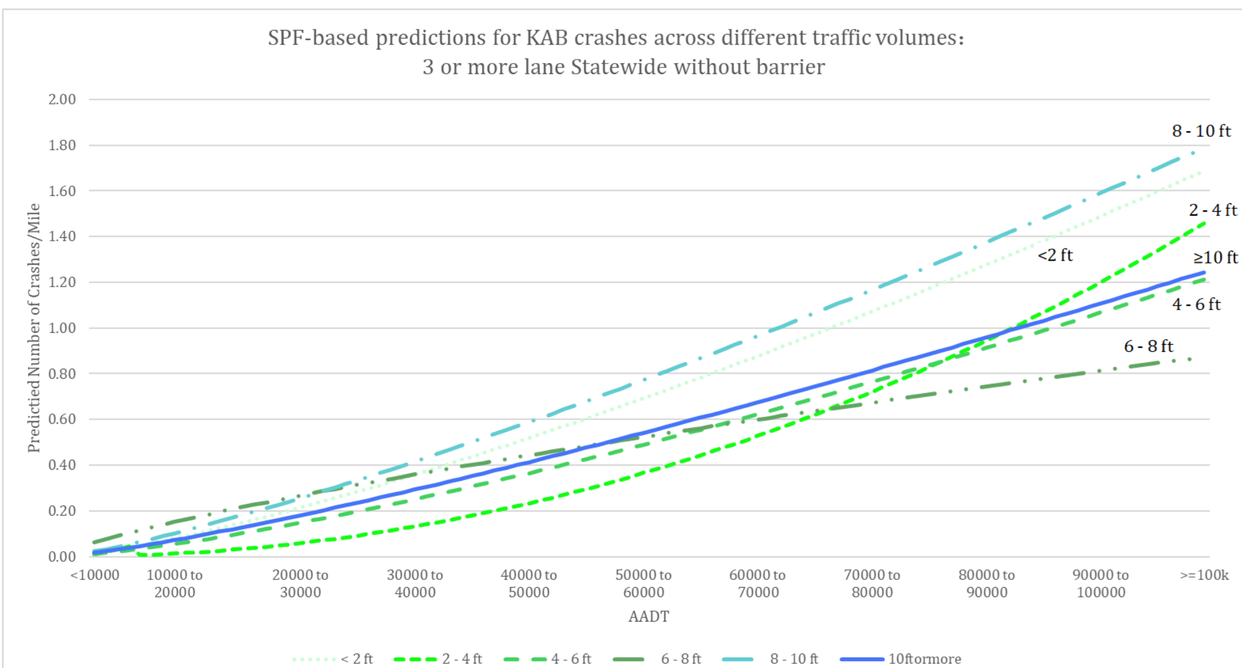

Figure 35. Graph. SPF-based predictions for KAB crashes across different traffic volumes (three-or-more–lane statewide without barrier).

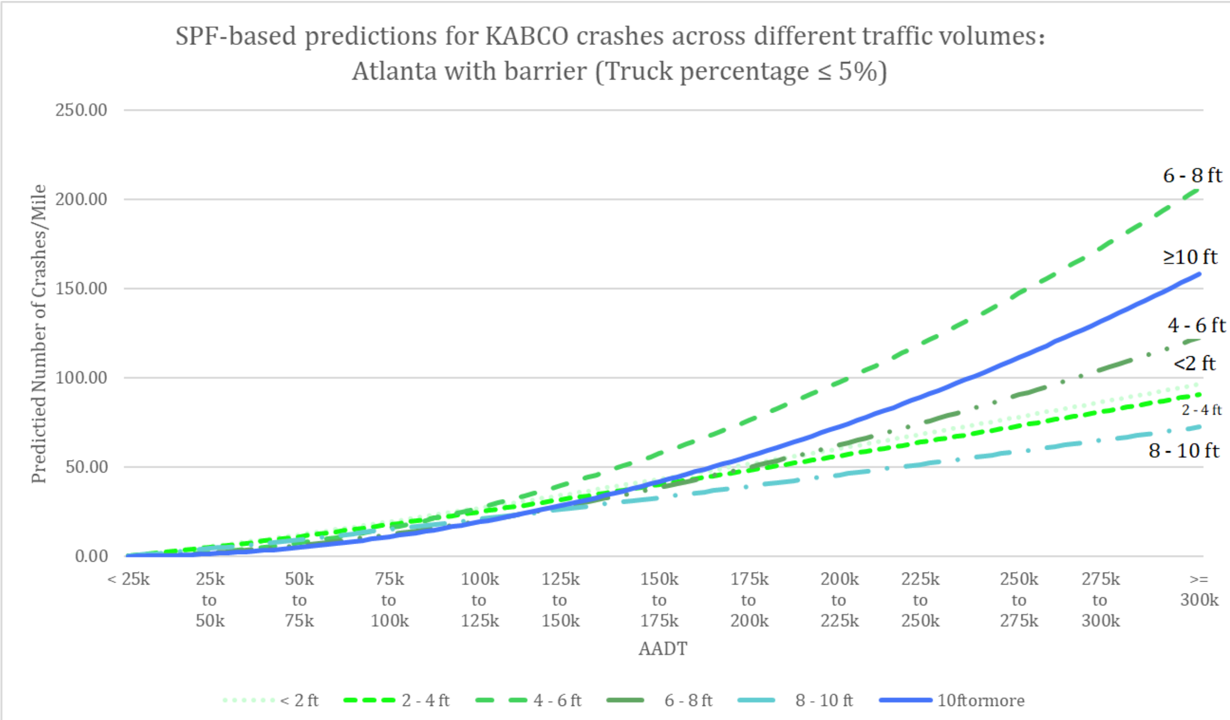

Figure 36. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: ≤5).

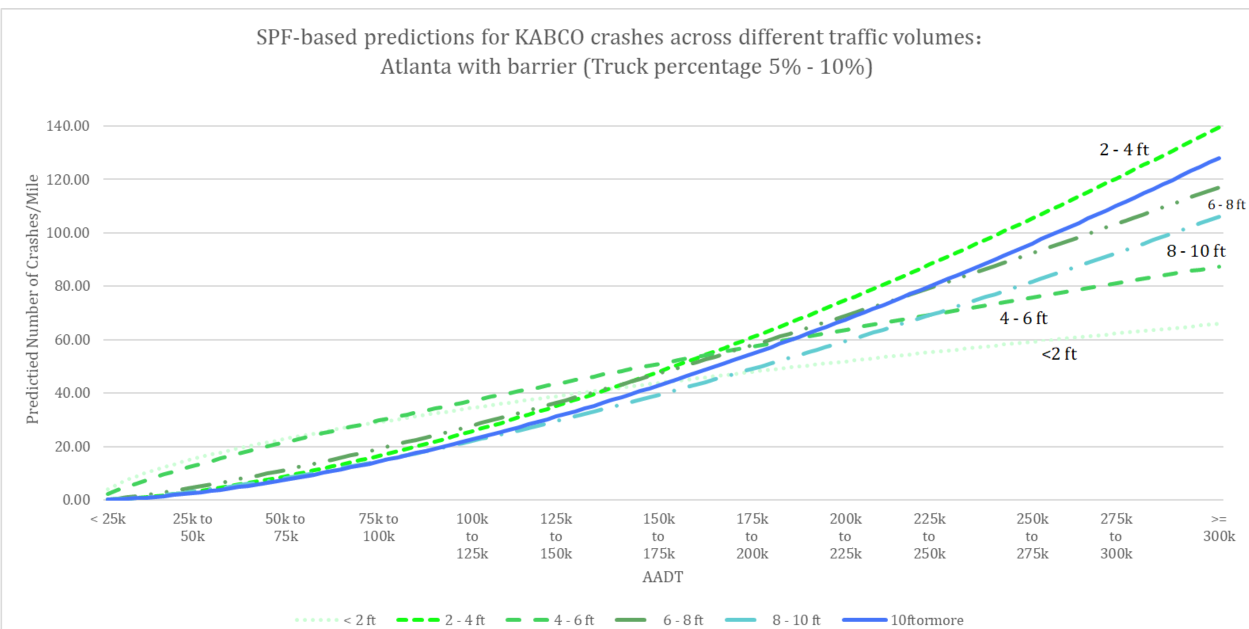

Figure 37. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: 5–10).

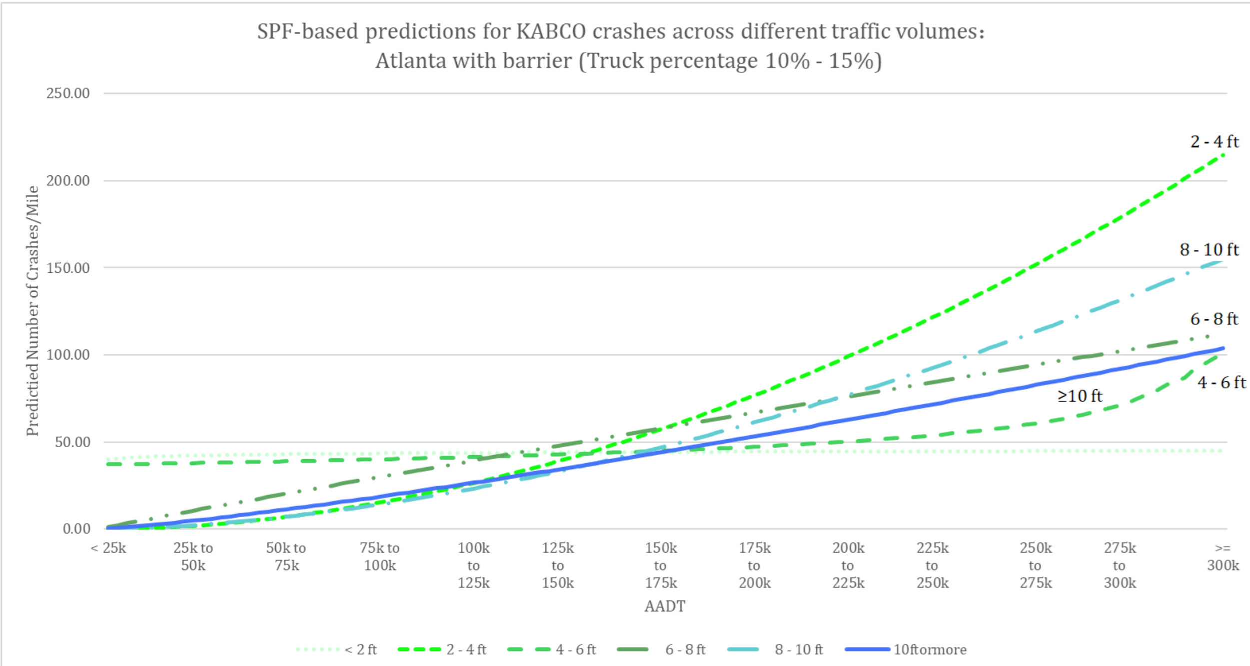

Figure 38. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: 10–15).

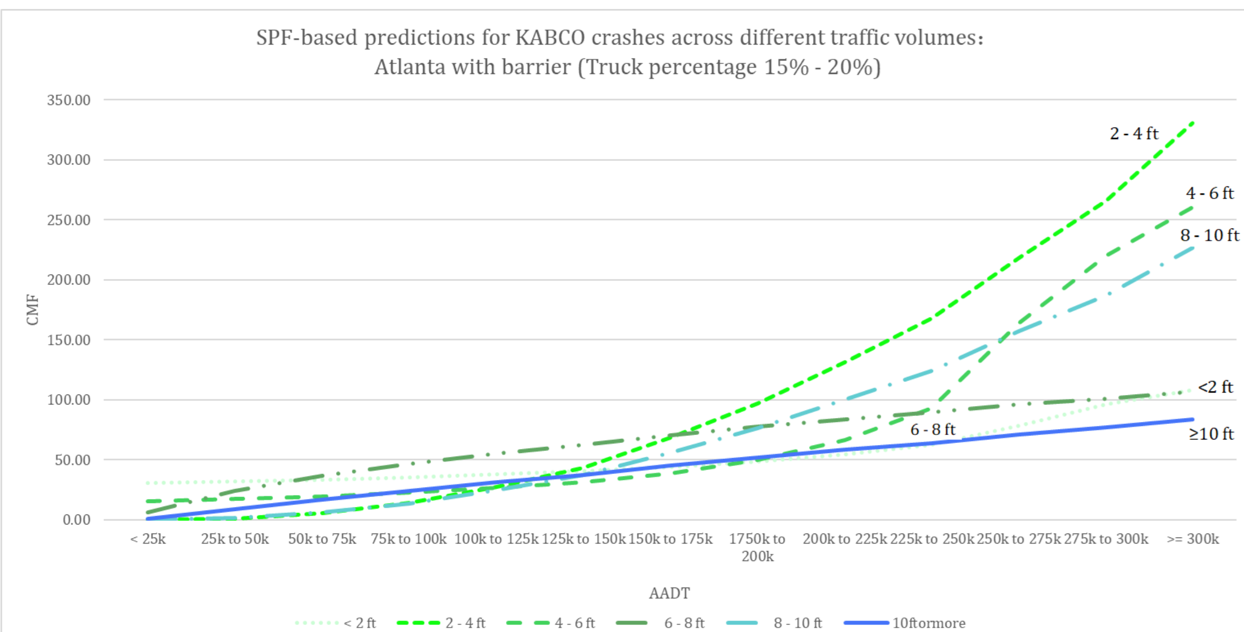

Figure 39. Graph. SPF-based predictions for KABCO crashes across different traffic volumes (Atlanta with barrier; truck percentage: >15).

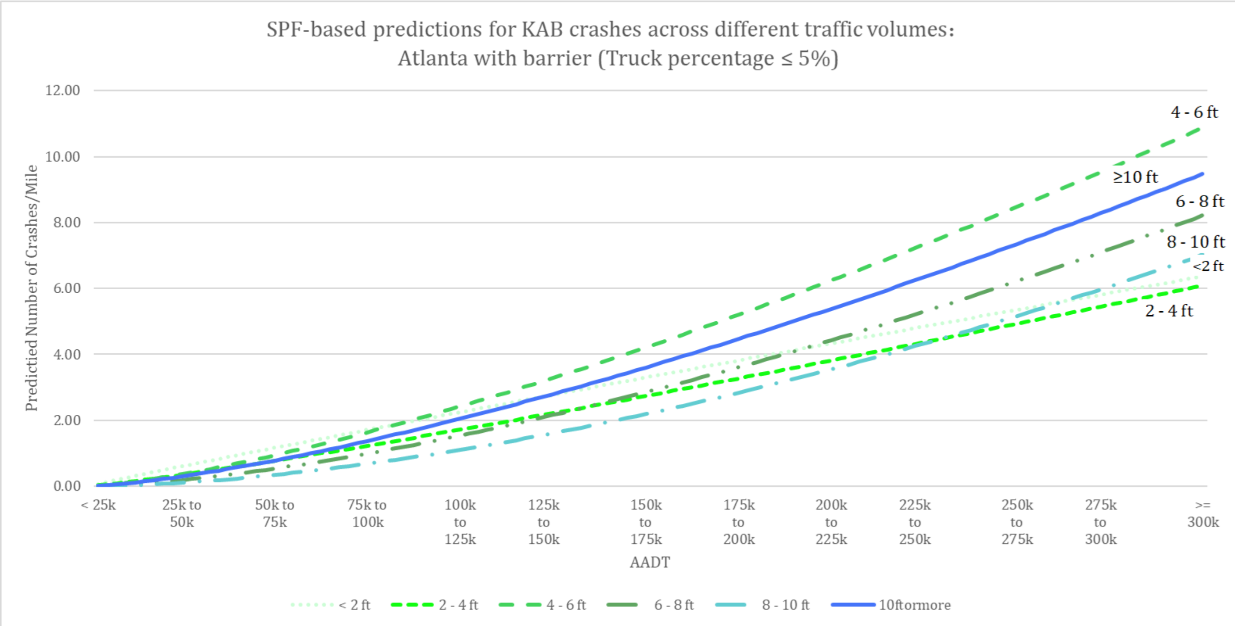

Figure 40. Graph. SPF-based predictions for KAB crashes across different traffic volumes (Atlanta with barrier; truck percentage: ≤5).

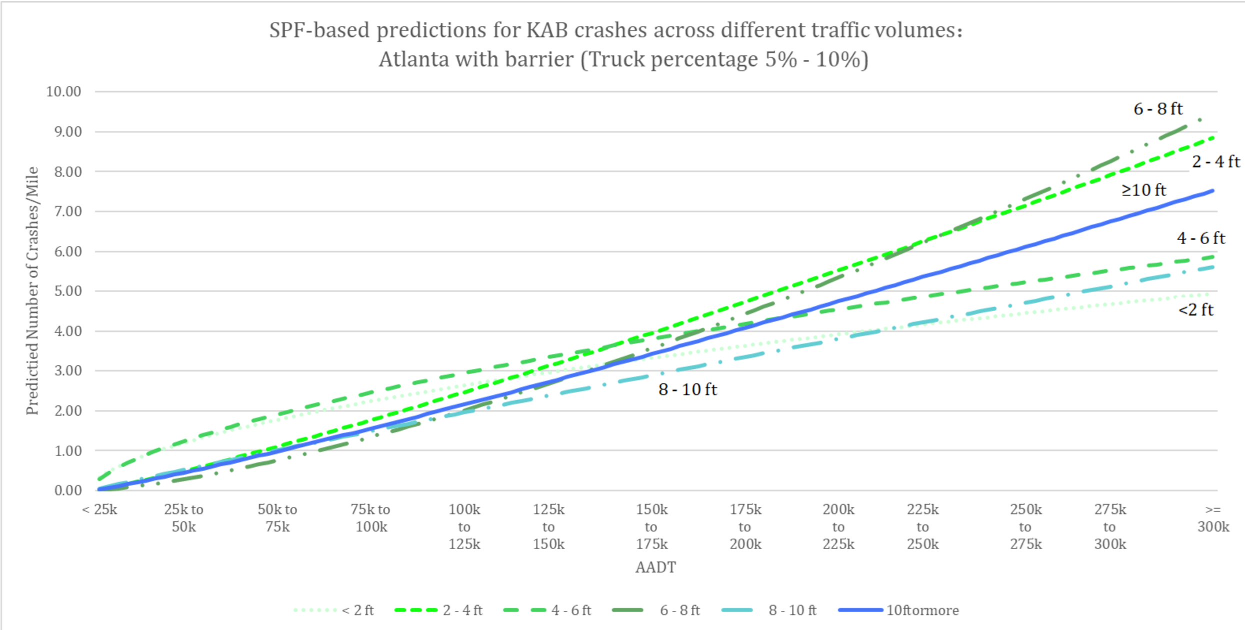

Figure 41. Graph. SPF-based predictions for KAB crashes across different traffic volumes (Atlanta with barrier; truck percentage: 5–10).

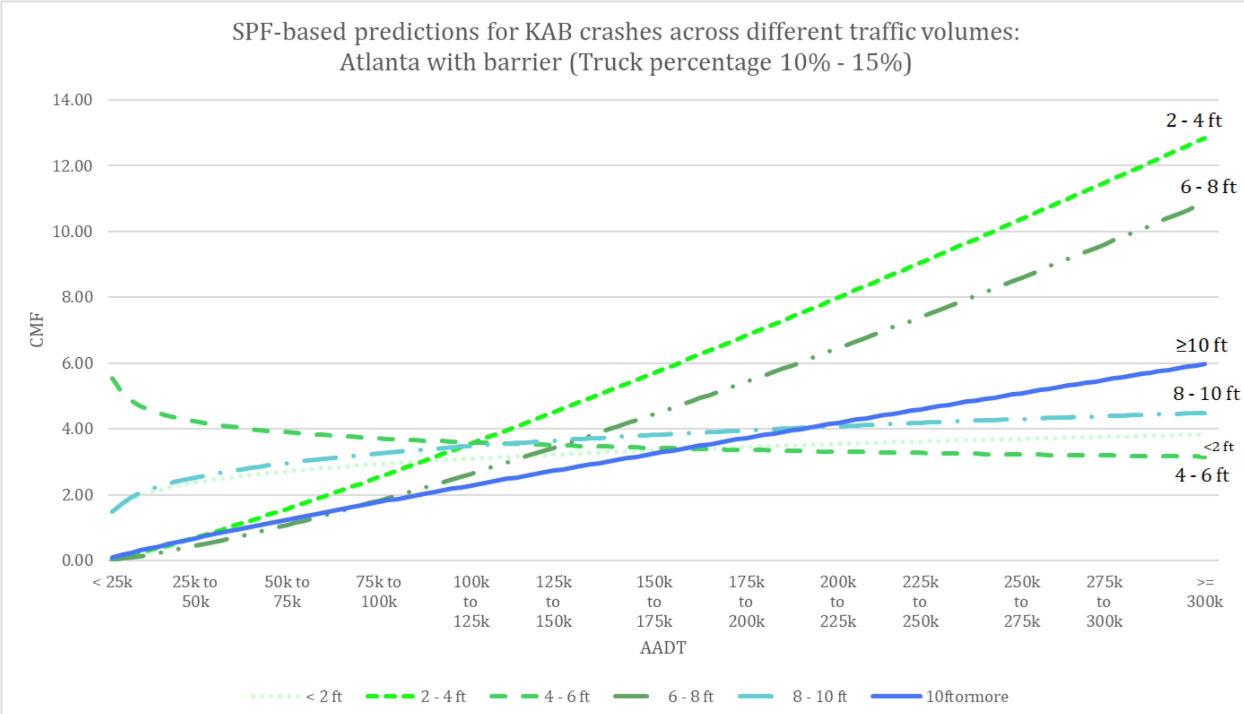

Figure 42. Graph. SPF-based predictions for KAB crashes across different traffic volumes (Atlanta with barrier; truck percentage: 10–15).

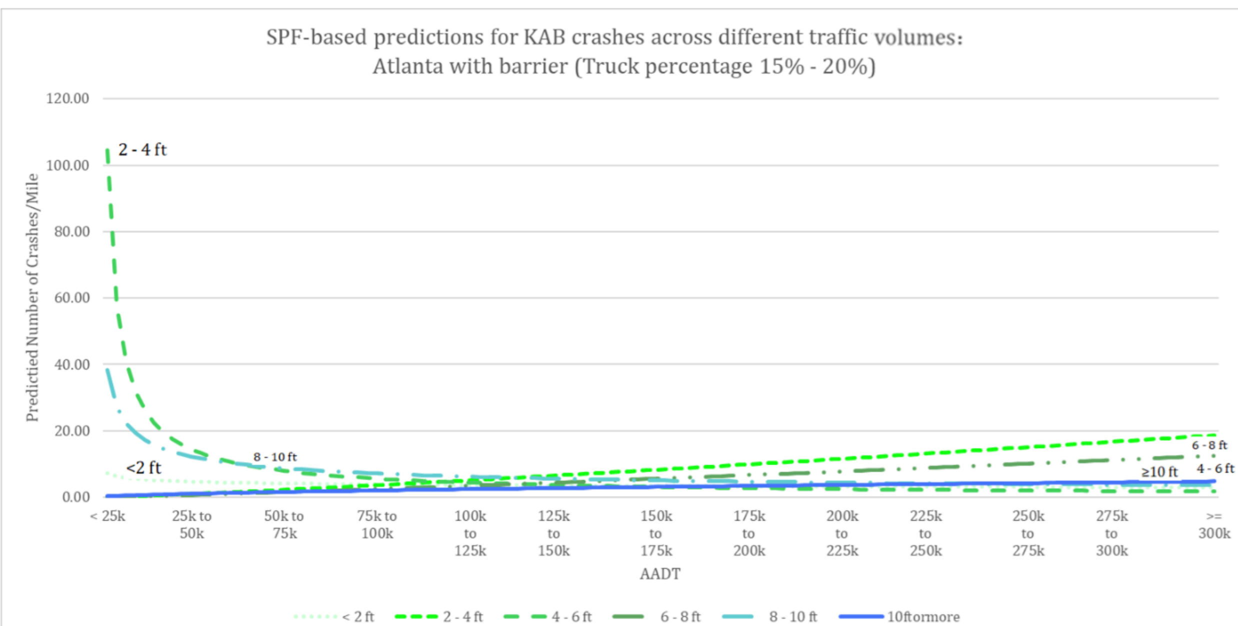

Figure 43. Graph. SPF-based predictions for KAB crashes across different traffic volumes: (Atlanta with barrier; truck percentage: >15).

Table 25. SPFs for statewide freeways with left shoulder widths <2 ft.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	***p*-value**	**Coef.**	***p*-value**	**Coef.**	***p*-value**	**Coef.**	***p*-value**
2-lane statewide without barrier								
Intercept	−14.86	<0.01	−11.97	<0.01	−5.35	0.02	−15.10	0.02
Ln(AADT)	1.56	<0.01	1.09	<0.01	0.44	0.05	1.11	0.08
Ln(Segment length)	0.99	<0.01	0.90	<0.01	1.01	<0.01	1.19	<0.01
N	419		419		419		419	
Akaike Information Criterion (AIC)	2,113.88		1,074.76		1,060.77		233.88	
2-lane statewide with barrier								
Intercept	−14.26	<0.01	−14.00	<0.01	−13.54	<0.01	−8.61	0.37
Ln(AADT)	1.51	<0.01	1.27	<0.01	1.19	<0.01	0.55	0.54
Ln(Segment length)	0.94	<0.01	0.98	<0.01	0.99	<0.01	0.91	0.02
N	100		100		100		100	
AIC	432.63		180.85		154.66		53.35	
3-or-more–lane statewide without barrier								
Intercept	−11.60	<0.01	−14.71	<0.01	−1.44	0.794	−15.14	0.578
Ln(AADT)	1.25	<0.01	1.33	<0.01	1.11	0.773	1.06	0.672
Ln(Segment length)	1.12	<0.01	0.84	0.132	2.48	<0.001	1.74	0.542
N	71		71		71		71	
AIC	295.07		157.32		125.22		87.86	
3-or-more–lane statewide with barrier								
Intercept	−13.74	<0.01	−13.11	0.26	−20.54	0.13	−19.02	0.46
Ln(AADT)	1.47	<0.01	1.19	0.27	1.90	0.12	1.61	0.50
Ln(Segment length)	1.97	<0.01	1.17	0.08	2.44	<0.01	2.02	0.19
N	59		59		59		59	
AIC	264.95		116.15		105.57		45.49	

Table 26. SPFs for statewide freeways with left shoulder widths of 2–4 ft.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
2-lane statewide without barrier								
Intercept	−15.49	<0.01	−11.37	<0.01	−8.71	<0.01	−25.97	<0.01
Ln(AADT)	1.62	<0.01	0.99	<0.01	0.74	<0.01	1.76	0.13
Ln(Segment length)	0.91	<0.01	1.06	<0.01	0.97	<0.01	2.83	<0.01
N	371		371		371		371	
AIC	1,888.41		1,091.96		784.14		370.78	
2-lane statewide with barrier								
Intercept	−12.11	<0.01	−9.21	<0.01	−8.22	<0.01	−15.21	0.05
Ln(AADT)	1.30	<0.01	0.82	<0.01	0.71	<0.01	1.12	0.12
Ln(Segment length)	0.93	<0.01	0.93	<0.01	1.06	<0.01	1.22	<0.01
N	253		253		253		253	
AIC	1,263.03		580.15		565.02		133.83	
3-or-more–lane statewide without barrier								
Intercept	−24.41	<0.01	−23.27	<0.01	−6.51	0.39	−10.47	0.84
Ln(AADT)	2.36	<0.01	2.05	<0.01	0.49	0.47	0.35	0.94
Ln(Segment length)	0.80	<0.01	0.93	<0.01	0.57	<0.01	2.09	0.31
N	117		117		117		117	
AIC	709.46		508.61		220.19		124.26	
3-or-more–lane statewide with barrier								
Intercept	−11.41	<0.01	−13.04	<0.01	−1.10	0.98	−7.00	0.56
Ln(AADT)	1.22	<0.01	1.15	<0.01	0.04	0.92	0.35	0.75
Ln(Segment length)	0.89	<0.01	1.07	<0.01	0.95	<0.01	1.15	<0.01
N	184		184		184		184	
AIC	977.04		504.07		375.36		180.39	

Table 27. SPFs for statewide freeways with left shoulder widths of 4–6 ft.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
2-lane statewide without barrier								
Intercept	−20.35	<0.01	−17.09	<0.01	−21.38	<0.01	−37.12	<0.01
Ln(AADT)	2.06	<0.01	1.57	<0.01	1.90	<0.01	3.11	0.01
Ln(Segment length)	1.09	<0.01	0.98	<0.01	1.32	<0.01	1.52	<0.01
N	137		137		137		137	
AIC	783.20		374.55		149.72		83.26	
2-lane statewide with barrier								
Intercept	−11.04	<0.01	−10.78	<0.01	−3.27	0.51	−8.11	0.60
Ln(AADT)	1.18	<0.01	0.97	<0.01	0.25	0.59	0.35	0.80
Ln(Segment length)	1.06	<0.01	0.89	<0.01	0.73	<0.01	1.58	0.06
N	76		76		76		76	
AIC	401.37		200.63		111.79		36.54	
3-or-more–lane statewide without barrier								
Intercept	−12.01	<0.01	−15.31	<0.01	−4.89	0.40	−5.25	0.72
Ln(AADT)	1.27	<0.01	1.35	<0.01	0.37	0.47	0.22	0.87
Ln(Segment length)	0.88	<0.01	1.01	<0.01	0.73	<0.01	0.79	<0.01
N	169		169		169		169	
AIC	1,021.62		444.11		347.88		97.79	
3-or-more–lane statewide with barrier								
Intercept	−15.82	<0.01	−12.46	<0.01	−6.08	0.06	−4.37	0.48
Ln(AADT)	1.59	<0.01	1.10	<0.01	0.48	0.10	0.16	0.78
Ln(Segment length)	0.90	<0.01	0.87	<0.01	0.67	<0.01	0.59	<0.01
N	663		663		663		663	
AIC	3,421.45		1,430.21		1,195.69		353.04	

Table 28. SPFs for statewide freeways with left shoulder widths of 6–8 ft.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
2-lane statewide without barrier								
Intercept	−6.34	<0.01	−12.10	<0.01	−13.14	<0.01	−16.97	0.43
Ln(AADT)	0.72	<0.01	1.05	<0.01	1.43	<0.01	1.44	0.32
Ln(Segment length)	1.06	<0.01	1.27	<0.01	1.09	<0.01	1.05	0.40
N	71		71		71		71	
AIC	351.91		160.50		141.98		19.47	
2-lane statewide with barrier								
Intercept	−8.71	<0.01	−6.69	0.18	−11.47	0.07	−24.85	0.25
Ln(AADT)	0.96	<0.01	0.60	0.21	1.01	0.10	2.05	0.31
Ln(Segment length)	1.04	<0.01	0.93	<0.01	1.02	<0.01	1.88	0.03
N	98		98		98		98	
AIC	430.05		213.51		171.08		45.86	
3-or-more–lane statewide without barrier								
Intercept	−15.71	<0.01	−8.89	<0.01	−5.82	0.44	−3.08	0.38
Ln(AADT)	1.57	<0.01	0.76	<0.01	0.37	0.58	5.20	0.42
Ln(Segment length)	1.01	<0.01	1.08	<0.01	0.77	<0.01	0.13	0.89
N	134		134		134		134	
AIC	685.58		293.62		156.41		18.65	
3-or-more–lane statewide with barrier								
Intercept	−14.01	<0.01	−13.56	<0.01	−20.44	<0.01	−16.73	0.16
Ln(AADT)	1.44	<0.01	1.19	<0.01	1.79	<0.01	1.07	0.31
Ln(Segment length)	0.94	<0.01	1.10	<0.01	0.68	<0.01	2.34	<0.01
N	462		462		462		462	
AIC	2,374.81		980.71		539.10		114.66	

Table 29. SPFs for statewide freeways with left shoulder widths of 8–10 ft.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
2-lane statewide without barrier								
Intercept	−10.21	<0.01	−13.96	<0.01	−15.75	<0.01	−18.94	0.05
Ln(AADT)	1.12	<0.01	1.28	<0.01	1.44	<0.01	3.26	0.07
Ln(Segment length)	0.71	<0.01	0.79	<0.01	0.78	<0.01	1.36	0.38
N	73		73		73		73	
AIC	346.91		161.98		154.55		21.74	
2-lane statewide with barrier								
Intercept	−16.01	<0.01	−18.85	<0.01	−3.48	0.34	−19.70	0.18
Ln(AADT)	1.68	<0.01	1.74	<0.01	0.26	0.45	1.49	0.29
Ln(Segment length)	0.97	<0.01	1.01	<0.01	0.94	<0.01	1.46	<0.01
N	170		170		170		170	
AIC	797.63		390.88		351.87		68.39	
3-or-more–lane statewide without barrier								
Intercept	−17.52	<0.01	−13.78	<0.01	−26.82	<0.01	−22.35	0.07
Ln(AADT)	1.76	<0.01	1.25	<0.01	2.34	<0.01	1.79	0.10
Ln(Segment length)	0.76	<0.01	0.57	<0.01	0.75	<0.01	0.53	0.07
N	138		138		138		138	
AIC	869.11		433.16		326.22		108.43	
3-or-more–lane statewide with barrier								
Intercept	−21.10	<0.01	−18.46	<0.01	−19.87	<0.01	−6.90	0.38
Ln(AADT)	2.07	<0.01	1.63	<0.01	1.73	<0.01	0.38	0.60
Ln(Segment length)	0.93	<0.01	0.99	<0.01	0.86	<0.01	0.86	<0.01
N	486		486		486		486	
AIC	2,432.14		1,007.86		875.49		266.17	

Table 30. SPFs for statewide freeways with left shoulder widths ≥10 ft.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
2-lane statewide without barrier								
Intercept	−14.34	<0.01	−11.92	<0.01	−11.14	<0.01	−6.80	0.38
Ln(AADT)	1.51	<0.01	1.09	<0.01	0.99	<0.01	0.21	0.78
Ln(Segment length)	0.95	<0.01	0.96	<0.01	0.96	<0.01	1.63	0.01
N	187		187		187		187	
AIC	990.40		497.27		459.08		86.97	
2-lane statewide with barrier								
Intercept	−10.58	<0.01	−3.27	0.18	−12.42	<0.01	−18.86	<0.01
Ln(AADT)	1.15	<0.01	0.25	0.27	1.10	<0.01	1.50	0.02
Ln(Segment length)	1.13	<0.01	0.93	<0.01	1.12	<0.01	0.91	<0.01
N	222		222		222		222	
AIC	1,013.76		406.86		386.00		101.72	
3-or-more–lane statewide without barrier								
Intercept	−19.36	<0.01	−14.01	<0.01	−17.74	<0.01	−10.73	0.42
Ln(AADT)	1.91	<0.01	1.24	<0.01	1.52	<0.01	0.69	0.56
Ln(Segment length)	0.84	<0.01	0.84	<0.01	0.92	<0.01	0.89	<0.01
N	216		216		216		216	
AIC	1,192.31		519.16		409.91		105.80	
3-or-more–lane statewide with barrier								
Intercept	−17.71	<0.01	−21.16	<0.01	−0.49	0.89	−10.30	0.18
Ln(AADT)	1.77	<0.01	1.88	<0.01	−0.01	0.98	0.69	0.32
Ln(Segment length)	0.97	<0.01	1.05	<0.01	0.91	<0.01	0.77	<0.01
N	676		676		676		676	
AIC	3,567.96		1,496.10		1,064.10		365.50	

Table 31. SPFs for Atlanta urban freeways.

	KABCO		KAB		Median KABCO		Median KAB	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
Left lane width: <2 ft								
Intercept	−16.75	<0.01	−14.63	<0.01	−16.94	0.03	−25.28	0.13
Ln(AADT)	1.72	<0.01	1.53	0.02	1.33	<0.01	2.02	0.16
Ln(Segment length)	1.07	<0.01	1.00	<0.01	1.00	<0.01	0.72	0.03
Truck percentage	1.35	<0.01	1.39	0.15	0.90	0.14	2.31	0.25
Ln(AADT) * Truck percentage	−0.11	<0.01	−0.13	0.12	−0.08	0.15	−0.20	0.24
N	324		324		324		324	
AIC	2,482.37		1,060.51		727.55		202.19	

Continued on next page.

Table 31. SPFs for Atlanta urban freeways. (Continued)

Left lane width: 2–4 ft								
Intercept	−6.07	0.01	−13.01	<0.01	−8.51	0.11	−41.14	<0.01
Ln(AADT)	0.81	<0.01	1.15	<0.01	0.69	0.11	3.27	<0.01
Ln(Segment length)	0.98	<0.01	0.85	<0.01	0.86	<0.01	0.89	<0.01
Truck percentage	0.84	<0.01	0.05	0.91	0.64	0.23	3.87	<0.01
Ln(AADT) * Truck percentage	−0.07	<0.01	0.002	−0.96	−0.05	−0.29	−0.32	<0.01
N	306		306		306		306	
AIC	2,544.45		1,233.87		792.82		342.92	
Left lane width: 4–6 ft								
Intercept	−30.45	<0.01	−23.61	<0.01	−7.72	0.02	−12.43	0.04
Ln(AADT)	2.91	<0.01	2.11	<0.01	0.69	0.01	0.93	0.06
Ln(Segment length)	0.88	<0.01	0.81	<0.01	0.75	<0.01	0.67	<0.01
Truck percentage	2.51	<0.01	1.75	<0.01	0.46	0.13	0.61	0.28
Ln(AADT) * Truck percentage	−0.21	<0.01	−0.15	<0.01	−0.04	0.13	−0.05	0.28
N	978		978		978		978	
AIC	8,926.47		4,217.00		2,847.92		1,089.11	
Left lane width: 6–8 ft								
Intercept	−20.57	<0.01	−18.76	<0.01	−8.37	<0.01	−23.34	<0.01
Ln(AADT)	2.02	<0.01	1.64	<0.01	0.68	<0.01	1.76	<0.01
Ln(Segment length)	0.61	<0.01	0.75	<0.01	0.97	<0.01	1.05	<0.01
Truck percentage	0.89	<0.01	0.33	0.19	0.04	0.88	1.09	0.09
Ln(AADT) * Truck percentage	−0.07	<0.01	−0.02	0.25	−0.01	0.66	−0.08	0.11
N	709		709		709		709	
AIC	6,541.46		2,933.44		1,879.25		693.14	
Left lane width: 8–10 ft								
Intercept	−6.68	0.19	−28.21	<0.01	−13.89	0.24	−51.42	0.08
Ln(AADT)	0.84	0.05	2.41	<0.01	1.17	0.24	4.11	0.09
Ln(Segment length)	0.97	<0.01	0.93	<0.01	1.05	<0.01	1.87	<0.01
Truck percentage	0.67	0.16	1.79	0.01	0.23	0.83	4.11	0.11
Ln(AADT) * Truck percentage	−0.06	0.13	−0.15	0.01	−0.02	0.86	−0.34	0.10
N	286		286		286		286	
AIC	2,328.64		1,072.60		829.55		177.03	
Left lane width: >10 ft								
Intercept	−23.22	<0.01	−18.38	<0.01	−19.13	<0.01	−46.93	<0.01
Ln(AADT)	2.26	<0.01	1.65	<0.01	1.65	<0.01	3.74	<0.01
Ln(Segment length)	0.93	<0.01	0.91	<0.01	1.12	<0.01	1.41	<0.01
Truck percentage	0.82	0.01	0.61	0.11	0.18	0.71	1.47	0.23

Ln(AADT) * Truck percentage	−0.07	0.01	−0.05	0.10	−0.02	0.66	−0.12	0.24
N	570		570		570		570	
AIC	4,860.77		2,243.54		1,396.71		438.88	

VISUALIZATION OF SPF-PREDICTED CRASH FREQUENCY

Figure 28 through Figure 43 presents the predicted average crash frequencies across varying AADT levels, stratified by barrier type, number of through lanes, crash severity, and truck percentage in the Atlanta area. In Figure 28 and Figure 29, which show KABCO crashes on statewide freeway segments with barrier, crash frequencies rise steadily with increasing AADT, with shoulders 8–10 ft wide showing the highest predicted crash occurrence, followed by <2-ft-wide shoulders. A similar trend is observed in Figure 30 and Figure 31 for KAB crashes under the same conditions. In Figure 32 and Figure 33 representing KABCO crashes on statewide freeway segments without barrier, the crash frequencies still increase with AADT; however, the differences between shoulder width categories become less pronounced. Figure 34 and Figure 35 display the different lanes for KAB crashes, with shoulders of 4–6 and 8–10 ft generally showing higher crash frequencies, but with smaller margins relative to wider shoulders. Figure 36, Figure 37, Figure 38, and Figure 39 show KABCO crash predictions for Atlanta urban segments with barrier, across four truck percentage scenarios (≤5, 5–10, 10–15, and >15 percent). Shoulders 2–4 ft wide show the highest predicted crash frequencies across AADT levels. Figure 40, Figure 41, Figure 42, and Figure 43 show a pattern for KAB crashes, with the relative crash frequency difference between shoulder widths being more obvious at lower AADT and higher truck percentages.

CHAPTER 6. CRASH MODIFICATION FACTOR RESULTS

This chapter presents the results of the estimated CMFs, which reflect the potential impact on the frequency and severity of crashes of different left shoulder widths on freeways. The CMFs were calculated relative to baseline conditions specific to each segment group. At the same time, the baseline conditions vary depending on the area and barrier type, including statewide segments without barriers (two-lane statewide without barrier, three-or-more–lane statewide without barrier), statewide segments with barriers (two-lane statewide with barrier, three-or-more–lane statewide with barrier), and Atlanta urban segments with barriers. They all share a common feature: the baseline segments have left shoulder widths of 10 ft or more. In other words, the CMFs represent the relative change in expected crash frequency associated with narrower left shoulder widths compared to the safety performance of segments with shoulders 10 ft or wider under similar traffic and roadway conditions. The CMFs in various areas and barrier types may provide insights into the potential impact on the frequency and severity of crashes related to those contextual factors, even when the left shoulder widths are identical. By comparing CMFs relative to the 10-ft-or-wider baseline, the results help illustrate how area type or the presence of barriers may influence crash frequency for a given shoulder width.

CMFs were estimated for four crash severity types, including all crashes (KABCO), fatal and injury crashes (KAB), median-related KABCO crashes, and median-related KAB crashes. These CMFs were derived based on the predicted average crash frequencies (of particular crash severity types) across a range of AADT values. As a result, the analysis captures how CMFs vary with traffic volume, reflecting differences in freeway traffic environments. The results indicate that the same left shoulder width may have different safety implications under different traffic conditions. This variation supports the need for localized consideration of inside shoulder widths when assessing their impact on the frequency and severity of crashes and making context-sensitive design decisions.

To improve the applicability of the estimated CMFs, the results are displayed by defined AADT ranges instead of specific AADT values. Reporting CMFs for discrete values may limit their generalizability, whereas using ranges (e.g., 20,000–25,000 vpd) allows for broader applicability. For each AADT range, approximately 5,000 possible AADT values were randomly simulated to represent a realistic spectrum of traffic conditions. The CMFs were calculated using SPFs developed for two conditions: (1) a baseline condition with a left shoulder width of 10 ft or more and (2) an alternative condition with a narrower left shoulder width. For each simulated AADT value, the SPFs were applied to estimate the expected average crash frequencies under both conditions, assuming a 1-mile freeway segment length. The CMF was then computed as the ratio of the predicted crash frequency for the narrower shoulder condition to that of the baseline. This simulation-based approach enables the estimation of average CMFs across a continuum of traffic volumes within each AADT range. As a result, the CMFs are more stable, robust, and representative of the expected impact on the frequency and severity of crashes under varying traffic conditions.

Some combinations of AADT ranges, area types, and left shoulder barrier conditions may be underrepresented or even missing in real-world data. The tables also provide the number of observed freeway segments within each AADT range and specific area/barrier type to address this issue. These observation counts provide context for evaluating the reliability of the estimated CMFs. For cells with few or no observations, the corresponding CMFs should be regarded carefully. In such cases, the CMFs are based solely on model predictions and may not reflect real-world conditions observed in Georgia during the data collection period (2018–2023). These theoretical values can offer insights, but they should be used carefully and with acknowledgment of their limited empirical support.

CMFS FOR TOTAL CRASHES (KABCO)

Table shows the average CMFs for all crashes on statewide freeways without barrier, categorized by left shoulder width, AADT range, and number of lanes (two-lane vs. three-or-more–lane). For two-lane freeways, the data show that wider shoulders (6–10 ft) generally offer improved safety performance as AADT increases. In particular, 6–8 ft shoulders tend to perform better at higher volumes (above 40,000 vpd), with CMFs decreasing as traffic volume rises. In contrast, narrower shoulders (particularly 4–6 ft and below) exhibit increasing CMFs at higher volumes, indicating reduced safety effectiveness.

On three-or-more–lane freeways, the influence of shoulder width is even more pronounced. Very narrow shoulders (<2 ft and 4–6 ft) show extremely high CMFs at low AADT levels (below 30,000 vpd), implying substantial safety concerns under light traffic conditions—likely due to high speeds and limited lateral clearance. As AADT increases, the CMFs for these narrow widths gradually decline but remain less favorable than those for 6–8 ft shoulders, which consistently maintain lower CMFs across all traffic levels. Shoulders in the 6–8-ft range appear to be the most stable and effective option for managing crash occurrence on multi-lane freeways, especially above 50,000 vpd. Figure 44 and figure 45 show trends for statewide freeways without barrier.

Table 32. Average CMFs for all crashes on freeways without barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	0.89	0	0.79	0	0.32	0	3.08	0	2.07	0
10,000–20,000	0.94	19	0.88	12	0.51	6	1.54	1	1.50	2
20,000–30,000	0.97	138	0.92	90	0.67	16	1.04	40	1.24	38
30,000–40,000	0.98	155	0.95	109	0.80	47	0.80	22	1.09	12
40,000–50,000	0.99	68	0.97	125	0.92	34	0.65	8	0.99	12
50,000–60,000	1.00	18	1.00	35	1.03	28	0.56	0	0.92	3
60,000–70,000	1.01	20	1.01	0	1.13	6	0.49	0	0.86	1
70,000–80,000	1.01	1	1.03	0	1.22	0	0.44	0	0.81	1
80,000–90,000	1.02	0	1.04	0	1.30	0	0.40	0	0.77	4
90,000–100,000	1.02	0	1.05	0	1.39	0	0.36	0	0.74	1
≥100,000	1.03	0	1.07	0	1.47	0	0.34	0	0.71	0
3-or-more–lane statewide freeways										
<10,000	6.96	0	0.35	0	5.23	0	1.82	0	1.63	0
10,000–20,000	4.11	0	0.50	0	3.12	5	1.38	0	1.45	0
20,000–30,000	2.99	31	0.61	5	2.27	0	1.16	0	1.35	0
30,000–40,000	2.39	12	0.71	0	1.83	0	1.03	6	1.28	1
40,000–50,000	2.03	8	0.80	5	1.57	0	0.95	34	1.24	23
50,000–60,000	1.78	6	0.87	19	1.37	27	0.89	23	1.20	32
60,000–70,000	1.60	6	0.93	19	1.23	15	0.84	15	1.16	27
70,000–80,000	1.45	7	0.99	30	1.13	40	0.80	22	1.14	14
80,000–90,000	1.34	1	1.05	28	1.04	41	0.77	23	1.12	23
90,000–100,000	1.25	0	1.10	11	0.97	31	0.73	11	1.10	18
≥100,000	1.17	0	1.16	0	0.91	10	0.71	0	1.09	0

Base condition: Statewide freeways without barrier and left shoulder width ≥10 ft

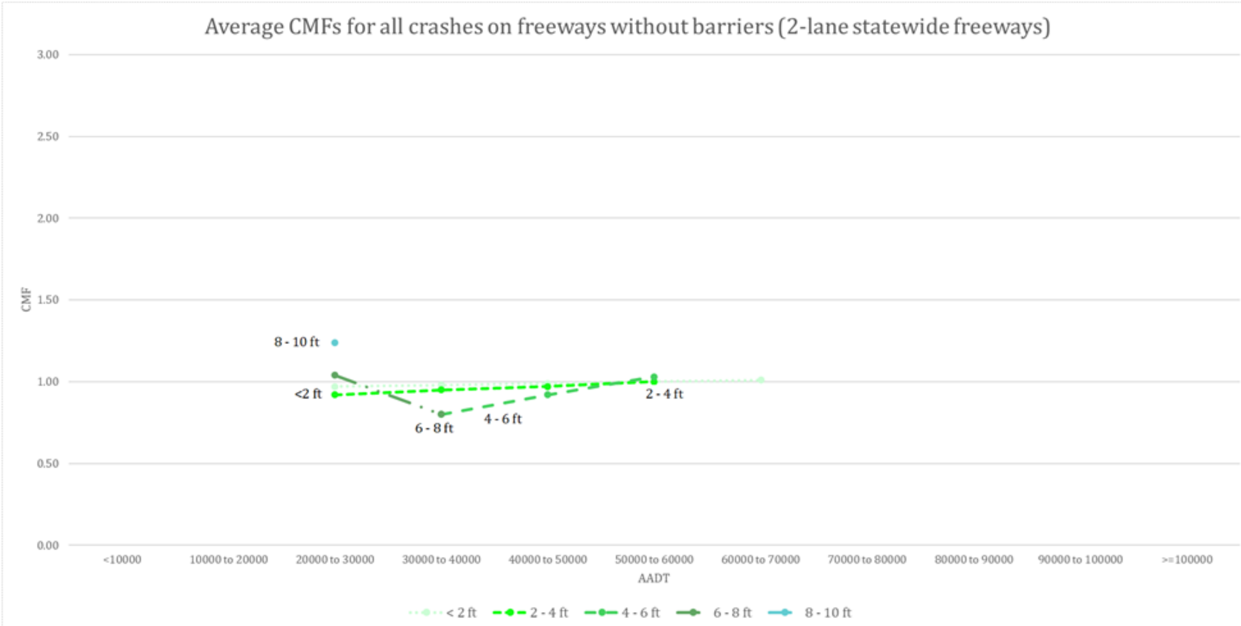

Figure 44. Graph. Average CMFs for all crashes on freeways without barrier (two-lane statewide).

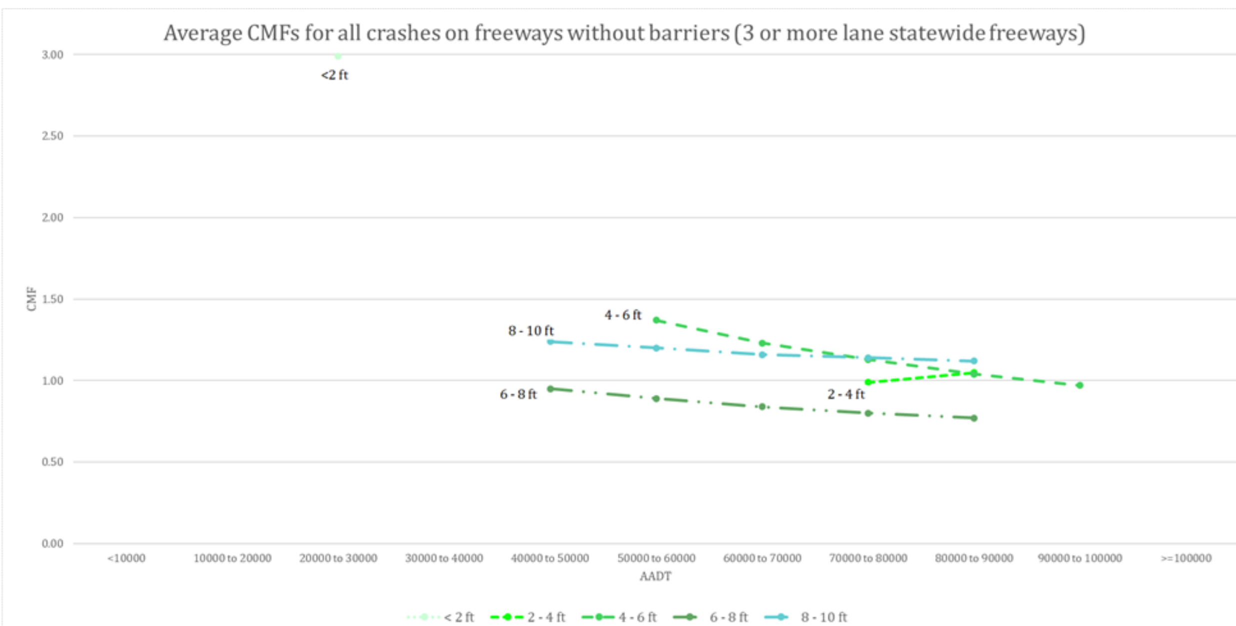

Figure 45. Graph. Average CMFs for all crashes on freeways without barrier (three-or-more–lane statewide).

Table summarizes the average CMFs for all crashes on statewide freeways with barrier. The findings indicate that the safety effectiveness of left shoulder width changes substantially with traffic volume and that wider shoulders consistently provide enhanced safety outcomes as AADT increases. For two-lane freeways, shoulder widths of 6–8 ft and 8–10 ft tend to perform more safely at higher volumes. As AADT increases from 10,000 vpd to above 100,000 vpd, these wider shoulders generally show decreasing or stable CMFs, suggesting improved or sustained safety benefits under growing traffic demand. In contrast, shoulders narrower than 4 ft (i.e., <2 ft and 2–4 ft) demonstrate increasing CMFs with rising AADT, indicating reduced safety effectiveness. For example, <2-ft shoulders shift from moderate CMFs at AADT 10,000–20,000 to noticeably elevated CMFs as AADT exceeds 50,000.

On three-or-more–lane freeways, the patterns are even more pronounced. Narrow shoulders (<2 ft and 2–4 ft) are associated with consistently high CMFs across all AADT levels—from below 10,000 to over 100,000—reflecting a persistent safety disadvantage on wider, higher-speed roadways. While CMFs do gradually decline with increasing AADT, they remain substantially higher than for wider shoulders. In contrast, shoulders in the 6–10-ft range perform better across all volume levels. For instance, as AADT increases from 30,000 to over 100,000, 6–8-ft shoulders show steadily improving safety performance, and 8–10-ft shoulders maintain relatively low CMFs throughout. Figure 46 and figure 47 display CMFs for statewide freeways with barrier.

Table 33. Average CMFs for all crashes on freeways with barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	0.61	0	0.81	0	0.90	0	1.33	0	0.47	0
10,000–20,000	0.84	8	0.92	9	0.91	0	1.12	2	0.73	6
20,000–30,000	0.98	31	0.99	91	0.93	8	1.02	36	0.95	94
30,000–40,000	1.13	16	1.04	67	0.95	24	0.96	38	1.14	39
40,000–50,000	1.23	20	1.08	53	0.96	19	0.92	15	1.30	16
50,000–60,000	1.33	14	1.12	25	0.96	7	0.89	2	1.44	10
60,000–70,000	1.41	8	1.15	8	0.97	1	0.86	4	1.58	5
70,000–80,000	1.48	1	1.17	0	0.97	4	0.84	1	1.70	0
80,000–90,000	1.55	0	1.19	0	0.98	4	0.82	0	1.81	0
90,000–100,000	1.62	2	1.21	0	0.98	10	0.80	0	1.92	0
≥100,000	1.68	0	1.23	0	0.99	0	0.79	0	2.03	0
3-or-more–lane statewide freeways										
<10,000	3.59	0	4.05	2	1.34	0	2.13	0	0.48	0
10,000–20,000	2.83	0	2.56	0	1.15	6	1.63	0	0.61	0
20,000–30,000	2.44	3	1.95	6	1.06	2	1.39	12	0.71	2
30,000–40,000	2.21	11	1.62	30	1.00	123	1.24	33	0.78	130
40,000–50,000	2.05	34	1.41	34	0.95	153	1.14	113	0.84	208
50,000–60,000	1.93	5	1.26	39	0.92	156	1.07	100	0.90	37
60,000–70,000	1.83	1	1.15	23	0.89	129	1.01	93	0.94	38
70,000–80,000	1.75	4	1.06	36	0.87	62	0.97	82	0.98	33
80,000–90,000	1.69	1	0.99	14	0.85	29	0.93	29	1.02	29
90,000–100,000	1.63	0	0.93	0	0.83	3	0.89	0	1.05	9
≥100,000	1.59	0	0.88	2	0.82	0	0.86	0	1.09	0

Base condition: Statewide freeways with barrier and left shoulder width ≥10 ft

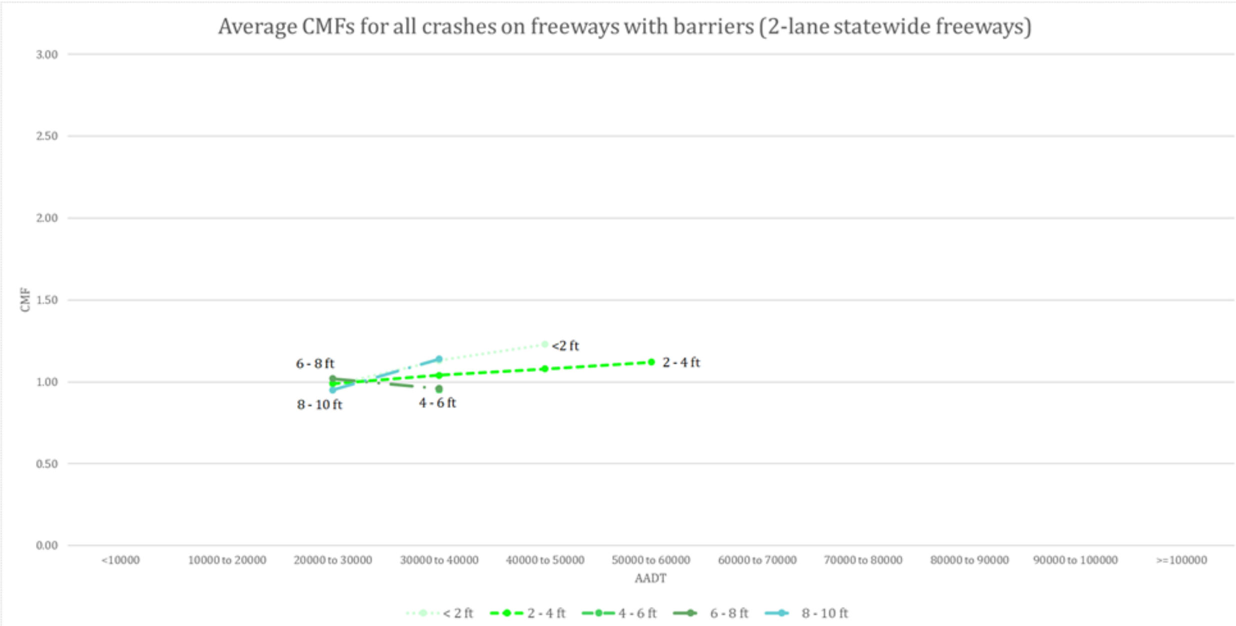

Figure 46. Graph. Average CMFs for all crashes on freeways with barrier (two-lane statewide).

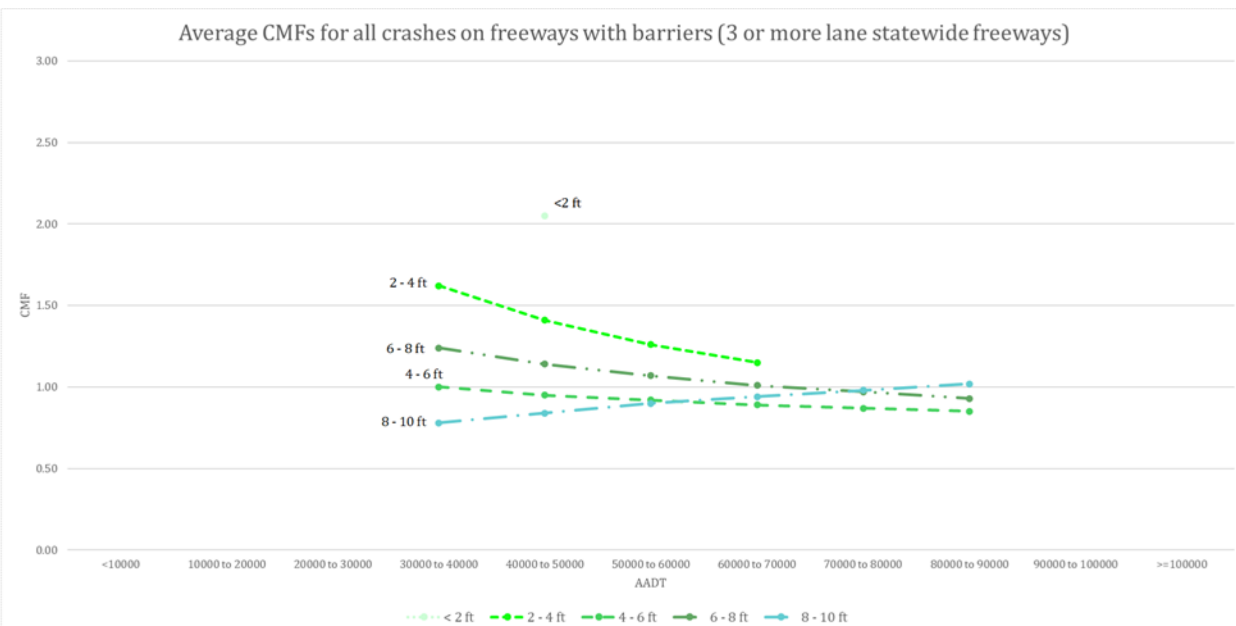

Figure 47. Graph. Average CMFs for all crashes on freeways with barrier (three-or-more–lane statewide).

Table presents the average CMFs for all crashes on Atlanta urban freeways with barrier. The results show that wider shoulders—particularly those between 6 and 10 ft—tend to provide more favorable safety performance, especially as AADT increases and truck percentage remains moderate (e.g., ≤10 percent). For instance, at AADT levels above 100,000 vpd, CMFs for 6–8-ft and 8–10-ft shoulders typically fall below 1.0, indicating safety improvements relative to the baseline. This trend persists across most truck percentage categories, even up to 15 percent, though the benefit begins to diminish slightly at higher truck percentages. In contrast, narrow shoulders (<4 ft) exhibit poor safety performance across nearly all traffic and truck scenarios. At lower AADT (e.g., <50,000) and low truck percentage (≤5 percent), CMFs are exceptionally high, especially for <2-ft shoulders. Although CMFs for these narrow shoulders decline as AADT increases, they generally remain higher than for wider shoulders, particularly when truck percentages exceed 10 percent. Notably, CMFs for <2-ft shoulders remain above 1.0 even at the highest AADT levels—up to and beyond 300,000 vpd—and the presence of more trucks tends to worsen their safety performance. Another critical insight is that left shoulders in the 4–6-ft range offer mixed results. Whereas they perform better than the narrowest shoulders, their safety effectiveness declines under increasing truck percentages, especially when AADT exceeds 150,000. This suggests that 4–6-ft shoulders may not provide sufficient buffer space for large vehicles in dense urban freeway conditions. Figure 48, figure 49, figure 50, and figure 51 show the CMFs for Atlanta urban freeways with barrier under varying ranges of truck percentages (≤5, 5–10, 10–15, and >15 percent).

Table 34. Average CMFs for all crashes on freeways with barrier (Atlanta urban).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
Truck percentage: ≤5										
<25,000	5.50	0	4.91	0	1.63	0	1.61	0	4.45	0
25,000–50,000	2.88	0	2.62	0	1.52	0	1.30	0	2.26	0
50,000–75,000	2.01	0	1.84	0	1.47	0	1.16	0	1.56	0
75,000–100,000	1.55	2	1.43	0	1.43	0	1.06	0	1.20	0
100,000–125,000	1.29	6	1.19	3	1.40	17	0.99	3	0.98	2
125,000–150,000	1.10	12	1.02	12	1.38	51	0.95	19	0.84	3
150,000–175,000	0.97	6	0.91	19	1.37	23	0.91	15	0.74	4
175,000–200,000	0.87	11	0.81	28	1.35	15	0.87	49	0.66	13

200,000–225,000	0.79	16	0.74	43	1.34	23	0.85	50	0.60	9
225,000–250,000	0.73	1	0.68	13	1.33	18	0.82	14	0.55	1
250,000–275,000	0.67	0	0.63	2	1.32	2	0.80	16	0.51	1
275,000–300,000	0.63	0	0.59	0	1.31	2	0.78	15	0.47	0
≥300,000	0.59	0	0.56	0	1.30	22	0.77	92	0.44	0
Truck percentage: 5–10										
<25,000	9.63	3	1.21	0	7.13	0	1.98	0	1.24	0
25,000–50,000	3.93	9	1.18	4	3.53	0	1.60	0	1.13	0
50,000–75,000	2.39	7	1.15	0	2.36	29	1.39	1	1.04	3
75,000–100,000	1.73	34	1.14	17	1.82	33	1.27	23	0.99	9
100,000–125,000	1.35	19	1.13	5	1.49	18	1.19	22	0.96	16
125,000–150,000	1.11	13	1.12	7	1.27	28	1.13	51	0.93	16
150,000–175,000	0.94	41	1.12	18	1.11	75	1.08	54	0.91	14
175,000–200,000	0.82	2	1.11	6	0.99	47	1.04	31	0.89	6
200,000–225,000	0.72	13	1.11	17	0.90	69	1.00	29	0.87	12
225,000–250,000	0.65	16	1.10	6	0.82	39	0.97	11	0.86	0
250,000–275,000	0.59	1	1.09	0	0.76	3	0.95	3	0.84	0
275,000–300,000	0.54	0	1.09	2	0.71	0	0.92	0	0.83	0
≥300,000	0.49	0	1.09	1	0.66	2	0.90	0	1.24	0
Truck percentage: 10–15										
<25,000	9.52	0	0.30	0	9.58	6	2.53	0	0.37	0
25,000–50,000	5.37	6	0.53	0	8.47	0	1.94	5	0.55	0
50,000–75,000	2.91	4	0.74	0	3.90	4	1.69	1	0.70	5
75,000–100,000	1.93	8	0.91	7	2.33	32	1.53	16	0.83	19
100,000–125,000	1.43	2	1.08	1	1.59	3	1.43	4	0.93	0
125,000–150,000	1.12	21	1.23	12	1.17	47	1.35	15	1.03	10
150,000–175,000	0.91	13	1.38	20	0.91	91	1.29	33	1.11	15
175,000–200,000	0.77	4	1.52	5	0.73	53	1.24	43	1.19	54
200,000–225,000	0.66	4	1.65	4	0.60	32	1.19	19	1.27	19
225,000–250,000	0.58	4	1.77	10	0.51	33	1.16	13	1.34	15
250,000–275,000	0.51	7	1.90	13	0.44	8	1.12	0	1.40	2
275,000–300,000	0.46	10	2.01	8	0.38	2	1.09	0	1.47	0
≥300,000	0.41	11	2.13	4	0.34	7	1.07	0	1.53	0

Continued on next page.

Table 34. Average CMFs for all crashes on freeways with barrier (Atlanta urban). (Continued)

Truck percentage: >15										
<25,000	12.08	0	0.07	0	9.85	0	3.19	0	0.10	0
25,000–50,000	7.40	0	0.24	0	21.10	0	2.37	0	0.27	0
50,000–75,000	3.51	0	0.47	1	6.49	4	2.04	9	0.47	1
75,000–100,000	2.16	6	0.73	1	3.01	8	1.85	6	0.68	0
100,000–125,000	1.50	0	1.03	1	1.70	22	1.71	1	0.90	3
125,000–150,000	1.12	6	1.35	12	1.08	69	1.61	28	1.13	15
150,000–175,000	0.89	6	1.70	4	0.74	41	1.53	15	1.36	12
175,000–200,000	0.72	0	2.07	0	0.54	0	1.47	3	1.60	7
200,000–225,000	0.60	0	2.46	0	0.41	0	1.42	0	1.84	0
225,000–250,000	0.51	0	2.86	0	0.32	0	1.37	0	2.08	0
250,000–275,000	0.44	0	3.28	0	0.25	0	1.33	0	2.33	0

275,000–300,000	0.39	0	3.72	0	0.21	0	1.29	0	2.58	0
≥300,000	0.35	0	4.17	0	0.17	0	1.26	0	2.84	0

Base condition: Atlanta urban freeways with barrier and left shoulder width ≥10 ft

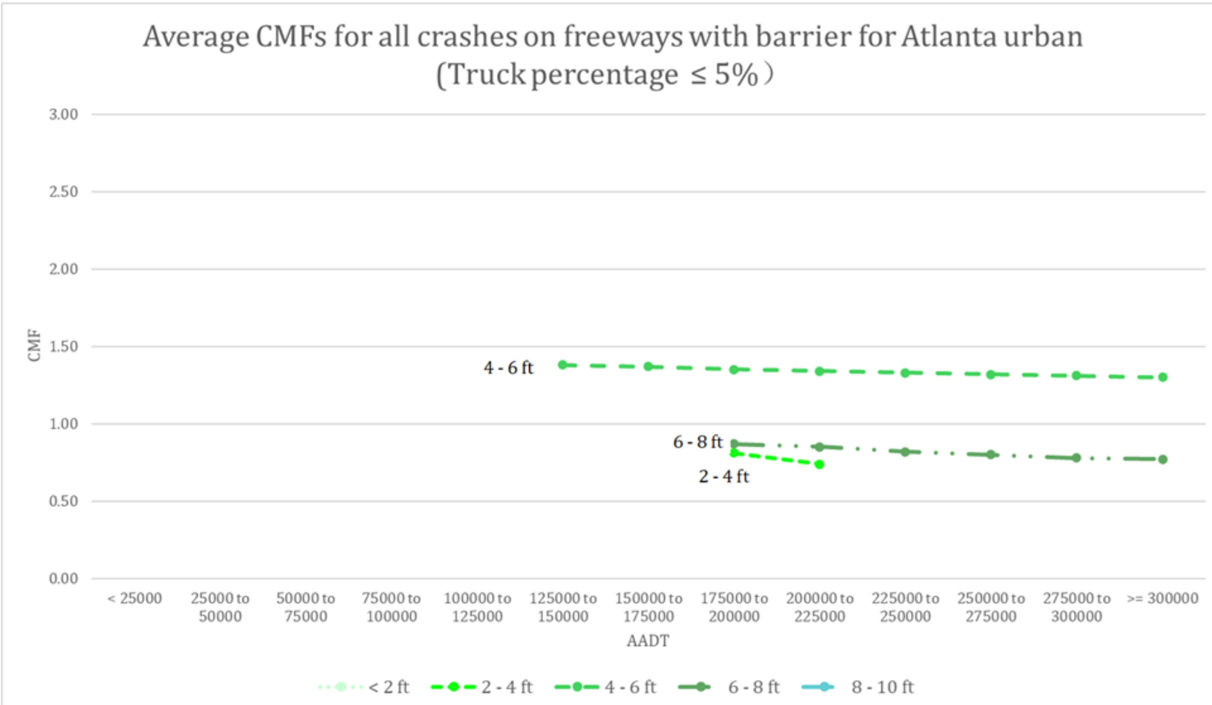

Figure 48. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: ≤5).

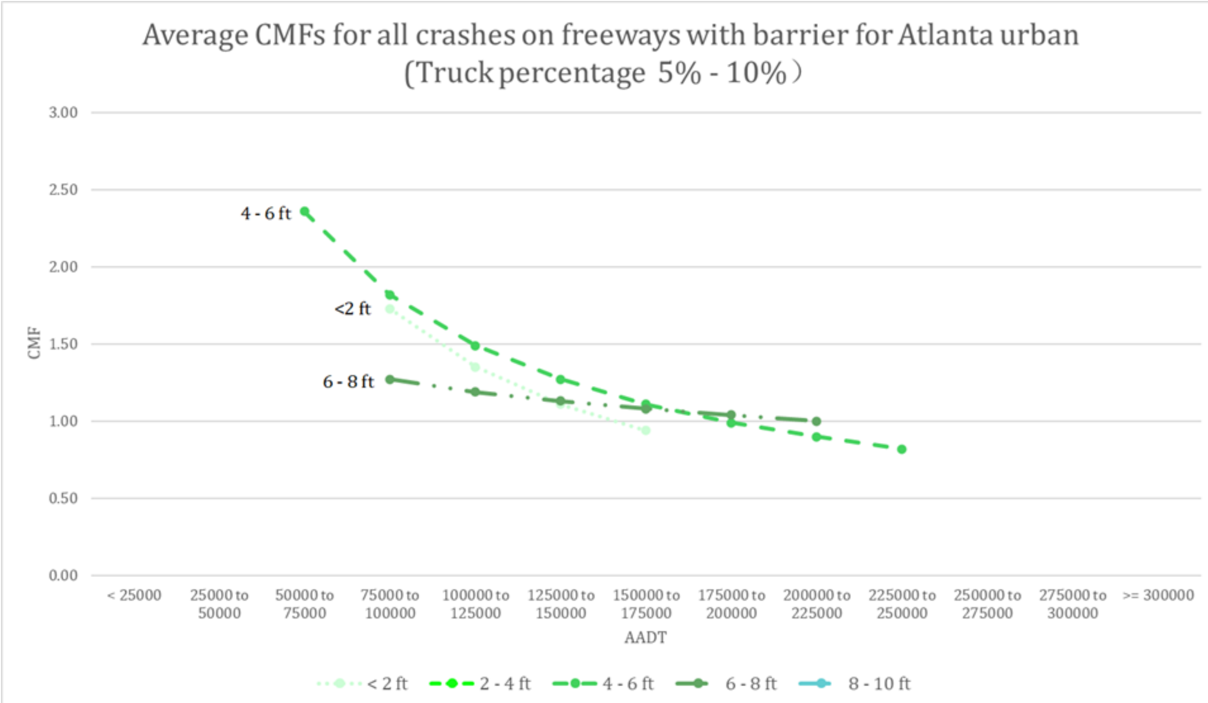

Figure 49. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10).

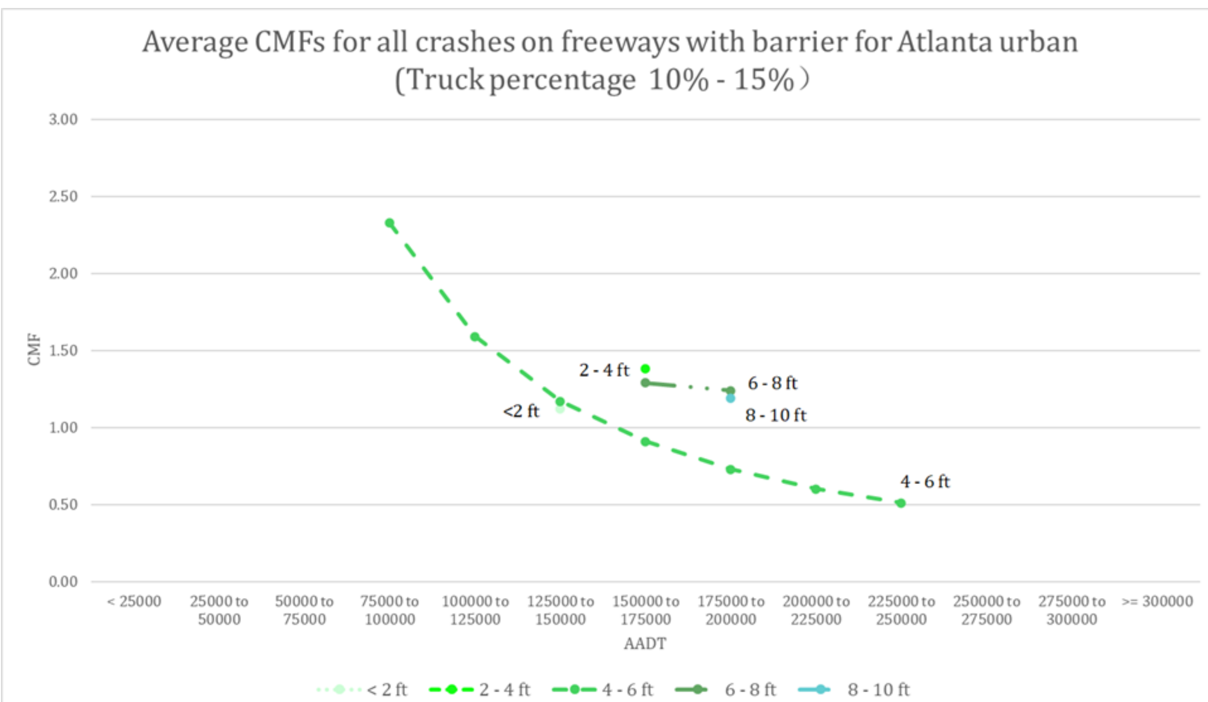

Figure 50. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15).

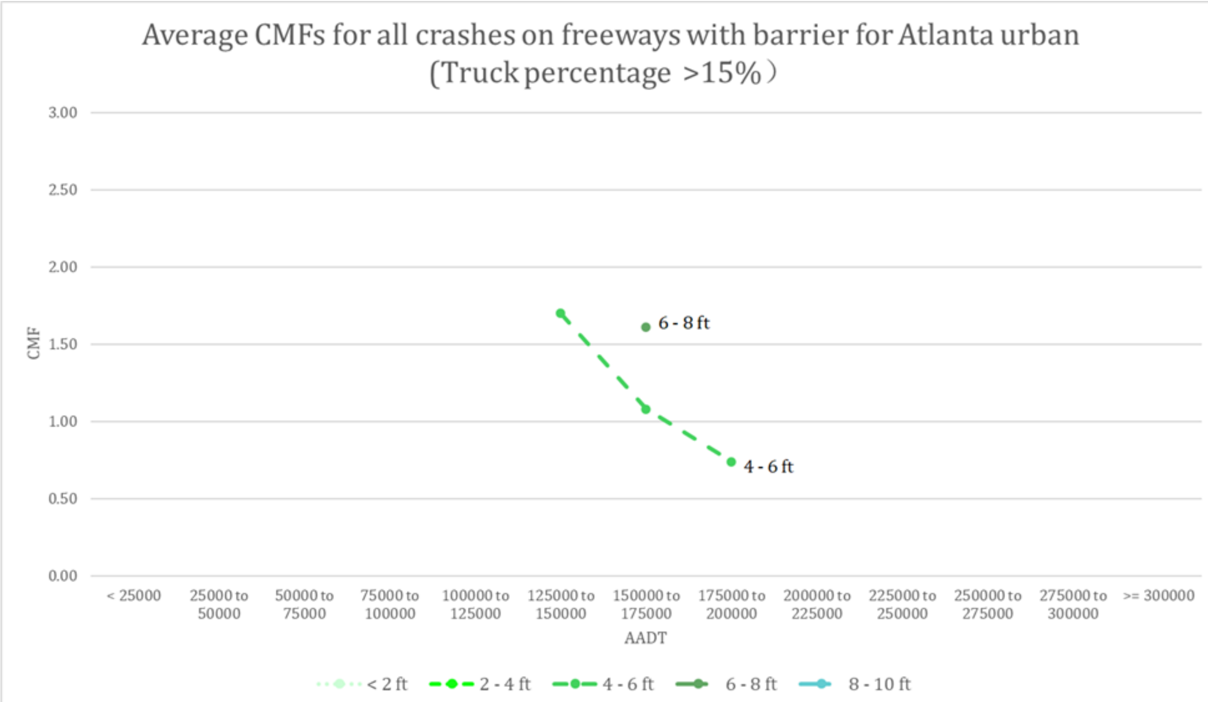

Figure 51. Graph. Average CMFs for all crashes on freeways with barrier for Atlanta urban (truck percentage: >15).

CMFS FOR FATAL AND INJURY CRASHES (KAB)

Table presents average CMFs for KAB crashes (fatal and injury crashes) on freeways without barrier. For two-lane freeway segments, left shoulder widths of 2–4 ft and 6–8 ft consistently yield CMFs below 1.0 across most AADT ranges, suggesting enhanced safety effectiveness for fatal and injury crashes compared to the ≥10 ft baseline. Even shoulder widths <2 ft often exhibit CMFs slightly below 1.0, though the magnitude of the effect is smaller and count values are limited in low- and high-AADT bins. In contrast, shoulder widths of 4–6 ft show more variability. At lower AADT levels (<50,000), they sometimes reflect safety benefits, but for higher AADT (≥50,000), the CMFs trend upward, sometimes exceeding 1.0—indicating reduced effectiveness or potential safety disbenefits in those conditions.

For freeways with three or more lanes, the CMFs show a markedly different pattern, often exceeding 1.0 for most shoulder width categories, especially at higher AADT levels. Shoulder widths of <2 ft and 2–4 ft tend to have significantly higher CMFs, particularly as AADT increases. For instance, <2-ft shoulders show CMFs rising from ~1.08 at AADT <10,000 to 1.36 at AADT ≥100,000. CMFs for 4–6-ft shoulder widths hover close to 1.0 or slightly below across many AADT ranges but do not display a strong safety benefit. Interestingly, 6–8-ft shoulder widths yield CMFs below 1.0 across multiple AADT bins, suggesting some safety advantage; however, this benefit appears modest and inconsistent. Figure 52 and figure 53 illustrate the average CMFs for KAB crashes on statewide freeways without barrier for two-lane and three-or-more–lane roadways, respectively.

Table 35. Average CMFs for KAB crashes on freeways without barrier (statewide).

	<2 ft		**2–4 ft**		**4–6 ft**		**6–8 ft**		**8–10 ft**	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	0.98	0	0.75	0	0.39	0	0.61	0	0.69	0
10,000–20,000	0.99	19	0.69	12	0.60	6	0.59	1	0.82	2
20,000–30,000	0.98	138	0.65	90	0.76	16	0.58	40	0.90	38
30,000–40,000	0.98	155	0.63	109	0.89	47	0.57	22	0.96	12
40,000–50,000	0.99	68	0.62	125	1.01	34	0.57	8	1.01	12
50,000–60,000	0.95	18	0.61	35	1.10	28	0.57	0	1.05	3
60,000–70,000	0.94	20	0.60	0	1.20	6	0.56	0	1.09	1
70,000–80,000	0.92	1	0.59	0	1.28	0	0.56	0	1.12	1
80,000–90,000	0.93	0	0.58	0	1.36	0	0.56	0	1.14	4
90,000–100,000	0.94	0	0.58	0	1.44	0	0.56	0	1.17	1
≥100,000	0.90	0	0.57	0	1.51	0	0.55	0	1.19	0
3-or-more–lane statewide freeways										
<10,000	1.08	0	0.13	0	0.72	0	2.66	0	1.39	0
10,000–20,000	1.16	0	0.26	0	0.80	5	1.72	0	1.41	0
20,000–30,000	1.21	31	0.38	5	0.84	0	1.35	0	1.42	0
30,000–40,000	1.24	12	0.50	0	0.87	0	1.15	6	1.42	1
40,000–50,000	1.26	8	0.61	5	0.89	0	1.03	34	1.44	23
50,000–60,000	1.29	6	0.72	19	0.91	27	0.93	23	1.44	32
60,000–70,000	1.31	6	0.82	19	0.93	15	0.86	15	1.43	27
70,000–80,000	1.32	7	0.93	30	0.94	40	0.80	22	1.43	14
80,000–90,000	1.34	1	1.03	28	0.96	41	0.76	23	1.42	23
90,000–100,000	1.35	0	1.13	11	0.97	31	0.72	11	1.42	18
≥100,000	1.36	0	1.22	0	0.98	10	0.69	0	1.40	0

Base condition: Statewide freeways without barrier and left shoulder width ≥10 ft

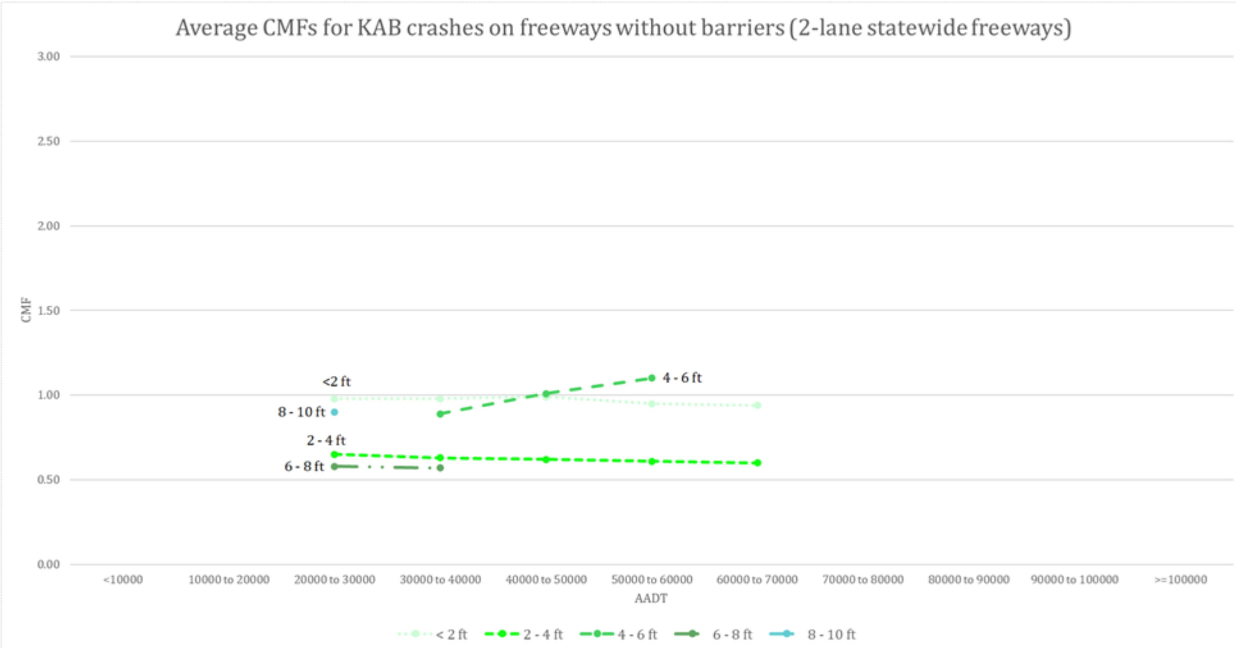

Figure 52. Graph. Average CMFs for KAB crashes on freeways without barrier (two-lane statewide).

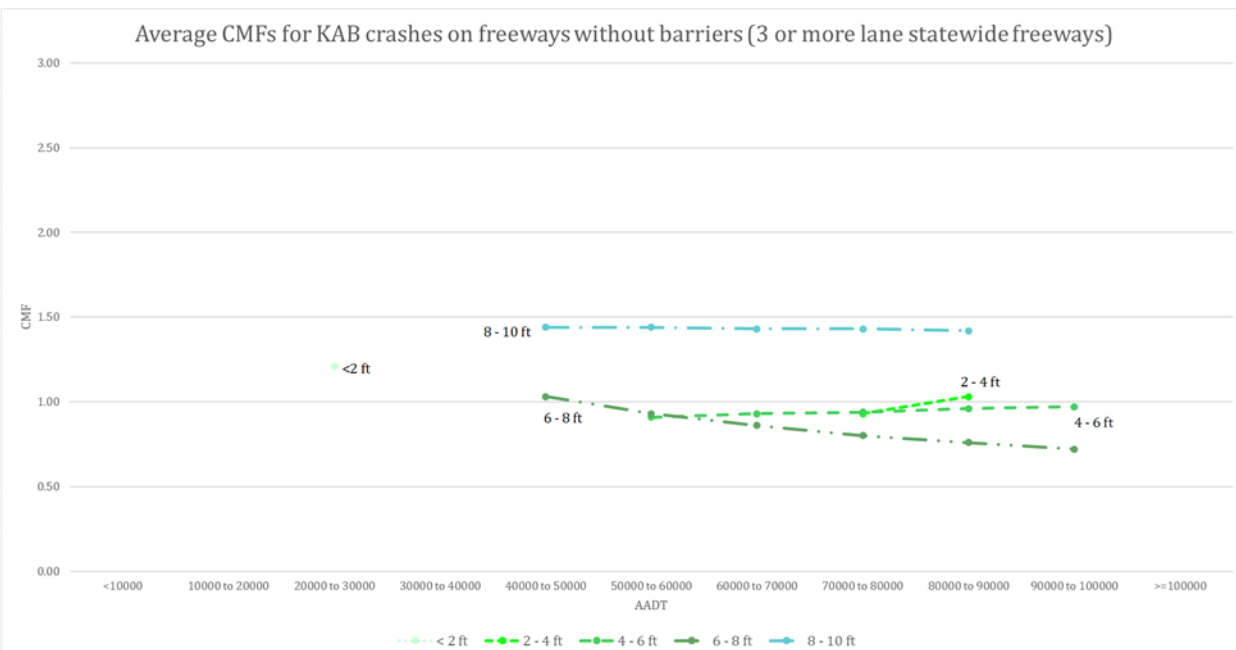

Figure 53. Graph. Average CMFs for KAB crashes on freeways without barrier (three-or-more–lane statewide.

Table presents the average CMFs for KAB crashes on statewide freeways with barrier. For two-lane freeway segments, CMFs for all shoulder width categories generally exceed 1.0 across the AADT spectrum, suggesting that narrower shoulders are associated with increased crash potential relative to the 10-ft shoulder baseline. The increase in CMFs with AADT is particularly noticeable for very narrow shoulders (e.g., <2 ft), where the CMF rises from 1.01 in the 10,000–20,000 AADT range to 1.39 at AADT levels of 100,000 or more. Shoulder widths in the 2–8-ft range also consistently show CMFs >1.0, reinforcing the limited safety effectiveness of narrow shoulders on two-lane barrier-separated freeways. An exception is seen for the 8–10-ft category at AADT <10,000, which shows a CMF below 1.0; however, this is based on limited or no observed data.

In contrast, three-or-more–lane freeway segments show a more favorable safety pattern as AADT increases. Whereas narrow shoulder widths are associated with very high CMFs at lower traffic volumes (e.g., CMFs as high as 7.19 for <2-ft shoulders at AADT <10,000), there is a consistent decline in CMFs for wider shoulder widths at higher traffic volumes. Starting from ~50,000 AADT and above, CMFs for shoulders in the 6–10-ft range drop below 1.0, indicating improved safety performance. Even shoulders between 4 and 6 ft begin to show CMFs close to or slightly below 1.0 at higher AADT ranges. This suggests that on high-volume, multi-lane freeways, moderate shoulder widths (especially those ≥6 ft) can still provide reasonable safety benefits, even with the presence of barriers. Figure 54 and figure 55 present the CMF trends for statewide freeways with barrier.

Table 36. Average CMFs for KAB crashes on freeways with barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	0.87	0	2.04	0	1.61	0	3.72	0	0.41	0
10,000–20,000	1.01	8	1.58	9	1.44	0	2.28	2	0.72	6
20,000–30,000	1.10	31	1.36	91	1.35	8	1.76	36	0.96	94
30,000–40,000	1.16	16	1.24	67	1.29	24	1.49	38	1.19	39
40,000–50,000	1.21	20	1.15	53	1.25	19	1.31	15	1.39	16
50,000–60,000	1.25	14	1.09	25	1.22	7	1.18	2	1.58	10
60,000–70,000	1.29	8	1.04	8	1.19	1	1.09	4	1.75	5
70,000–80,000	1.32	1	1.00	0	1.17	4	1.01	1	1.92	0
80,000–90,000	1.34	0	0.96	0	1.15	4	0.95	0	2.08	0
90,000–100,000	1.37	2	0.93	0	1.13	10	0.90	0	2.23	0
≥100,000	1.39	0	0.91	0	1.12	0	0.85	0	2.38	0
3-or-more–lane statewide freeways										
<10,000	7.19	0	5.44	2	6.15	0	4.68	0	1.69	0
10,000–20,000	4.03	0	2.91	0	3.13	6	2.62	0	1.37	0
20,000–30,000	2.89	3	2.05	6	2.16	2	1.89	12	1.23	2
30,000–40,000	2.30	11	1.60	30	1.66	123	1.50	33	1.13	130
40,000–50,000	1.94	34	1.34	34	1.37	153	1.27	113	1.06	208
50,000–60,000	1.69	5	1.16	39	1.17	156	1.11	100	1.01	37
60,000–70,000	1.51	1	1.03	23	1.03	129	0.99	93	0.97	38
70,000–80,000	1.37	4	0.93	36	0.92	62	0.90	82	0.94	33
80,000–90,000	1.25	1	0.85	14	0.83	29	0.82	29	0.91	29
90,000–100,000	1.16	0	0.78	0	0.76	3	0.76	0	0.89	9
≥100,000	1.08	0	0.72	2	0.71	0	0.71	0	0.86	0

Base condition: Statewide freeways with barrier and left shoulder width ≥10 ft

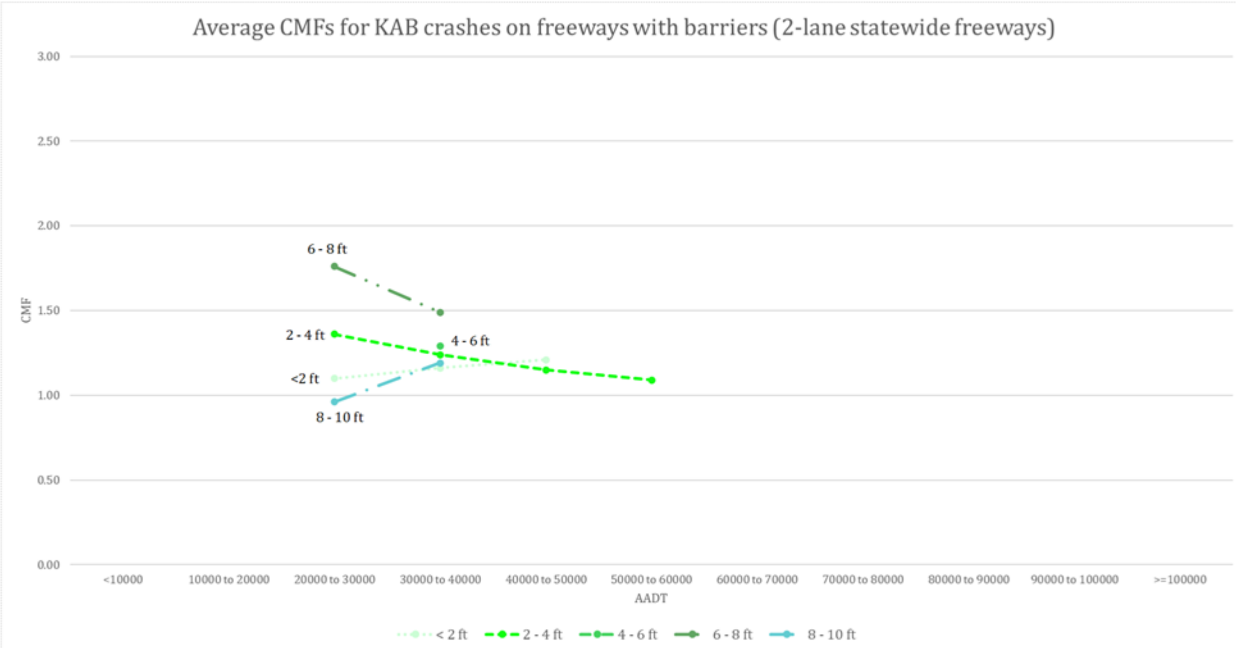

Figure 54. Graph. Average CMFs for KAB crashes on freeways with barrier (two-lane statewide).

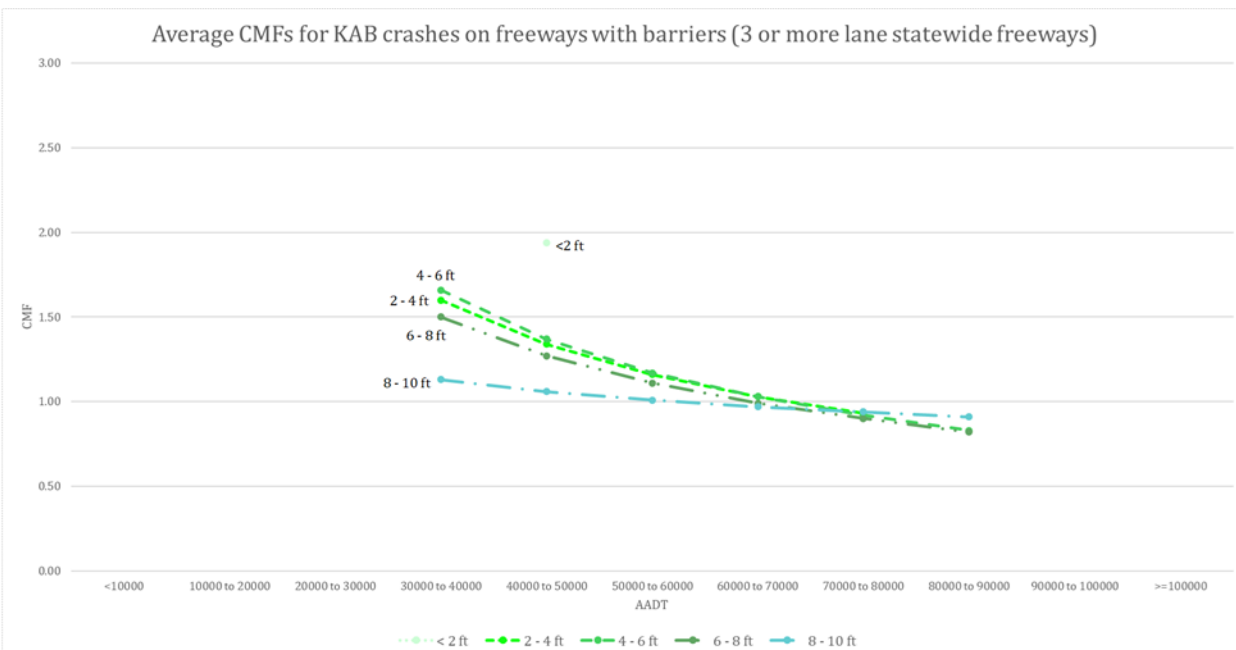

Figure 55. Graph. Average CMFs for KAB crashes on freeways with barrier (three-or-more–lane statewide).

Table presents the average CMFs for KAB crashes on Atlanta urban freeways with barrier under varying AADT levels and truck percentage ranges. The results demonstrate several clear patterns. First, across all truck percentage categories, the CMFs for left shoulders <6 ft are generally >1.0, especially at lower AADT ranges. This indicates a higher crash frequency compared to the baseline of ≥10 ft shoulders. Conversely, shoulders in the 6–10-ft range consistently show lower CMFs as AADT increases, often dropping below 1.0, suggesting enhanced safety performance in higher-volume contexts when moderate shoulder width is provided. A particularly notable trend is the effect of truck percentage. As truck percentage increases, CMFs for narrow shoulders (<2 ft and 2–4 ft) increase significantly—sometimes exceeding 3.0 or even 9.0 at low AADT values. This suggests that the presence of a high proportion of trucks exacerbates the likelihood of crashes associated with narrow left shoulders. For instance, at truck percentages >15 percent, CMFs for shoulders <2 ft exceed 2.0 even at AADT levels above 200,000, indicating a persistent elevated crash potential. In contrast, for shoulders in the 6–10-ft range, CMFs remain close to or below 1.0 in high-AADT and moderate-truck scenarios, showing the added benefit of sufficient shoulder width in mitigating crash severity. In addition, while the CMFs for the 4–6-ft shoulder category remain elevated—typically around 1.15 across truck and AADT combinations—they appear relatively stable, suggesting that they may not provide adequate safety improvement compared to wider shoulder widths. On the other hand, the 6–8-ft and 8–10-ft categories show progressive improvements in CMFs as both AADT and truck percentage increase, reflecting their effectiveness in accommodating higher traffic volumes and heavier vehicle mixes. Figure 56, figure 57, figure 58, and figure 59 show CMFs for Atlanta urban freeways with barrier under different ranges of truck percentages.

Table 37. Average CMFs for KAB crashes on freeways with barrier (Atlanta urban).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
Truck percentage: ≤5										
<25,000	2.50	0	1.30	0	1.26	0	0.59	0	0.33	0
25,000–50,000	1.68	0	1.06	0	1.21	0	0.66	0	0.41	0
50,000–75,000	1.34	0	0.93	0	1.19	0	0.70	0	0.47	0
75,000–100,000	1.16	2	0.87	0	1.19	0	0.74	0	0.52	0
100,000–125,000	1.04	6	0.81	3	1.18	17	0.76	3	0.56	2
125,000–150,000	0.95	12	0.78	12	1.17	51	0.78	19	0.59	3
150,000–175,000	0.88	6	0.74	19	1.17	23	0.80	15	0.62	4
175,000–200,000	0.83	11	0.72	28	1.16	15	0.82	49	0.65	13
200,000–225,000	0.78	16	0.70	43	1.16	23	0.83	50	0.67	9
225,000–250,000	0.75	1	0.68	13	1.15	18	0.84	14	0.69	1
250,000–275,000	0.71	0	0.66	2	1.15	2	0.85	16	0.71	1
275,000–300,000	0.68	0	0.65	0	1.15	2	0.86	15	0.73	0
≥300,000	0.66	0	0.64	0	1.15	22	0.87	92	0.75	0
Truck percentage: 5–10										
<25,000	3.62	3	1.09	0	3.64	0	0.57	0	1.27	0
25,000–50,000	2.11	9	1.12	4	2.25	0	0.72	0	1.08	0
50,000–75,000	1.59	7	1.13	0	1.73	29	0.82	1	0.99	3
75,000–100,000	1.31	34	1.14	17	1.46	33	0.90	23	0.93	9
100,000–125,000	1.14	19	1.15	5	1.29	18	0.96	22	0.89	16
125,000–150,000	1.02	13	1.15	7	1.16	28	1.02	51	0.86	16
150,000–175,000	0.93	41	1.16	18	1.06	75	1.06	54	0.83	14
175,000–200,000	0.86	2	1.16	6	0.99	47	1.11	31	0.81	6
200,000–225,000	0.80	13	1.16	17	0.93	69	1.14	29	0.79	12
225,000–250,000	0.75	16	1.17	6	0.88	39	1.18	11	0.78	0
250,000–275,000	0.71	1	1.17	0	0.83	3	1.21	3	0.76	0
275,000–300,000	0.67	0	1.18	2	0.80	0	1.24	0	0.75	0
≥300,000	0.64	0	1.18	1	0.76	2	1.27	0	0.74	0
Truck percentage: 10–15										
<25,000	5.53	0	0.89	0	13.29	6	0.54	0	5.71	0
25,000–50,000	2.65	6	1.17	0	4.18	0	0.77	5	2.86	0
50,000–75,000	1.87	4	1.36	0	2.51	4	0.96	1	2.06	5
75,000–100,000	1.49	8	1.50	7	1.80	32	1.10	16	1.66	19
100,000–125,000	1.25	2	1.61	1	1.40	3	1.22	4	1.41	0
125,000–150,000	1.09	21	1.71	12	1.15	47	1.32	15	1.24	10
150,000–175,000	0.98	13	1.80	20	0.97	91	1.41	33	1.11	15
175,000–200,000	0.88	4	1.87	5	0.84	53	1.50	43	1.02	54
200,000–225,000	0.81	4	1.94	4	0.74	32	1.58	19	0.94	19
225,000–250,000	0.75	4	2.01	10	0.67	33	1.66	13	0.87	15
250,000–275,000	0.70	7	2.07	13	0.60	8	1.73	0	0.82	2
275,000–300,000	0.66	10	2.13	8	0.55	2	1.79	0	0.77	0
≥300,000	0.62	11	2.18	4	0.51	7	1.85	0	0.73	0

Continued on next page.

Table 37. Average CMFs for KAB crashes on freeways with barrier (Atlanta urban). (Continued)

Truck percentage: >15

<25,000	9.11	0	0.72	0	16.78	0	0.50	0	8.01	0
25,000–50,000	3.34	0	1.23	0	7.98	0	0.84	0	7.76	0
50,000–75,000	2.21	0	1.64	1	3.68	4	1.11	9	4.35	1
75,000–100,000	1.69	6	1.97	1	2.23	8	1.33	6	2.98	0
100,000–125,000	1.38	0	2.27	1	1.53	22	1.53	1	2.25	3
125,000–150,000	1.17	6	2.54	12	1.14	69	1.71	28	1.80	15
150,000–175,000	1.03	6	2.79	4	0.89	41	1.88	15	1.50	12
175,000–200,000	0.91	0	3.03	0	0.72	0	2.04	3	1.28	7
200,000–225,000	0.83	0	3.25	0	0.60	0	2.18	0	1.11	0
225,000–250,000	0.76	0	3.46	0	0.51	0	2.32	0	0.98	0
250,000–275,000	0.70	0	3.65	0	0.44	0	2.45	0	0.88	0
275,000–300,000	0.65	0	3.85	0	0.38	0	2.58	0	0.79	0
≥300,000	0.61	0	4.03	0	0.34	0	2.70	0	0.72	0

Base condition: Atlanta urban freeways with barrier and left shoulder width ≥10 ft

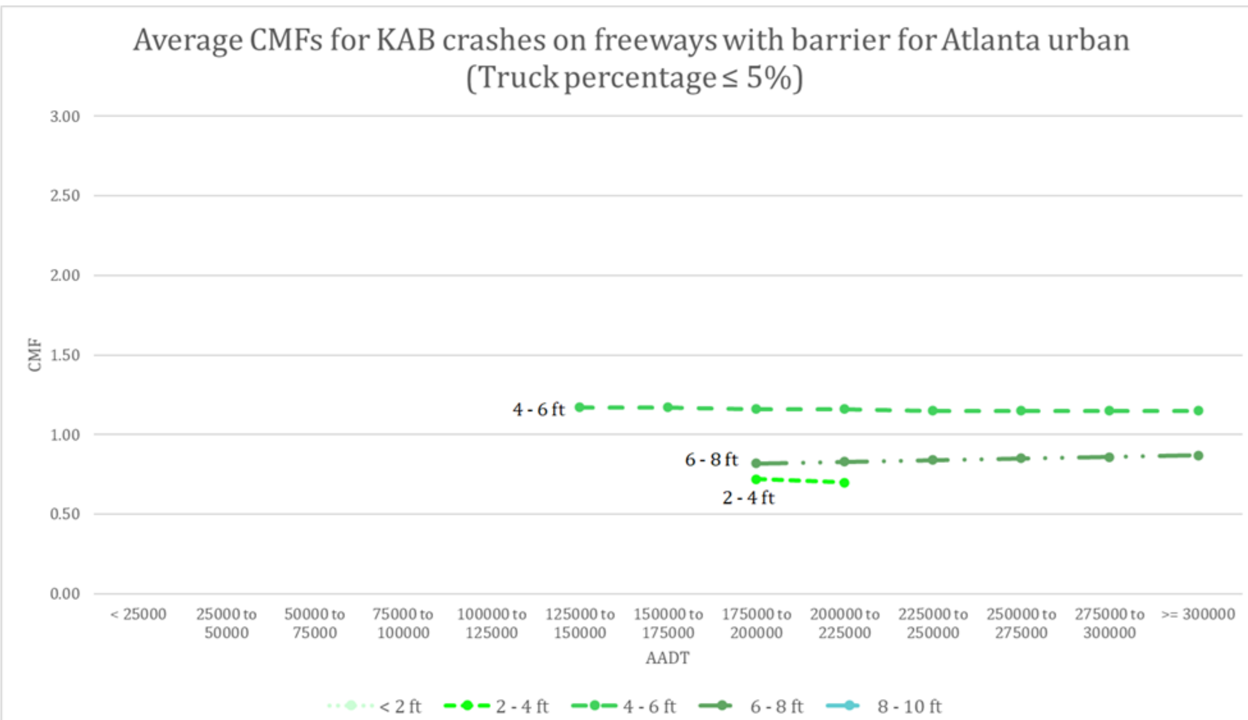

Figure 56. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: ≤5).

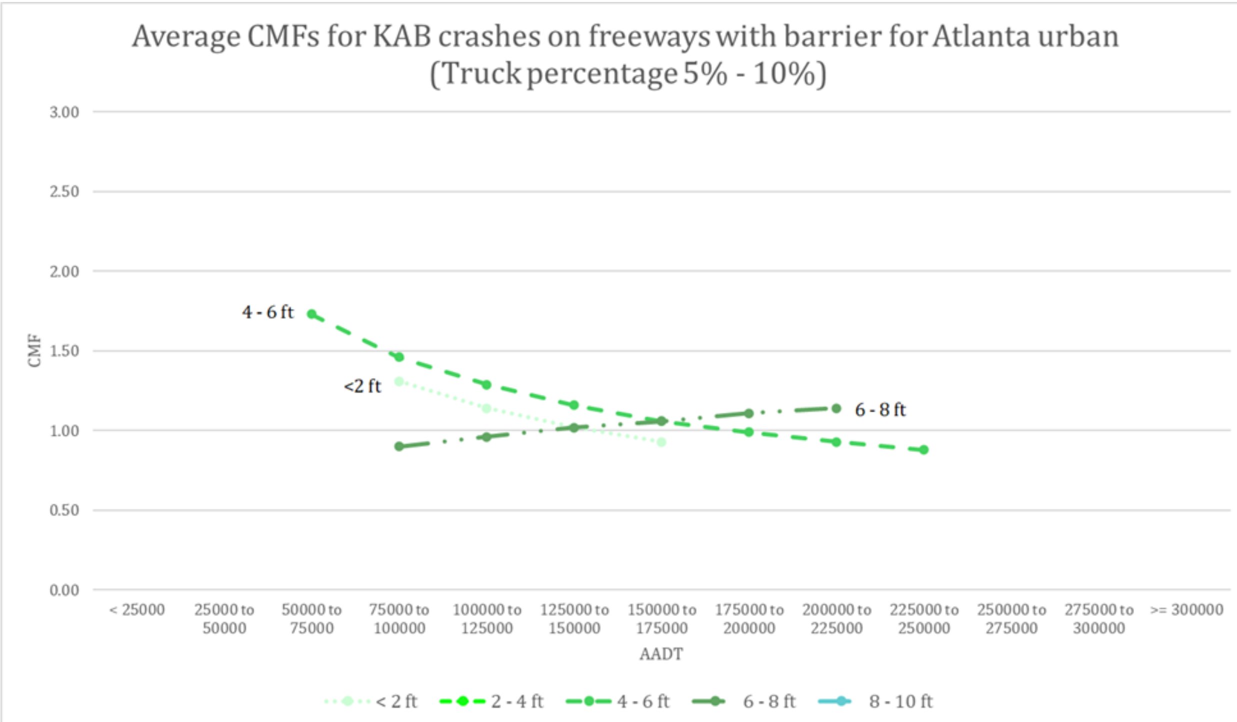

Figure 57. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10).

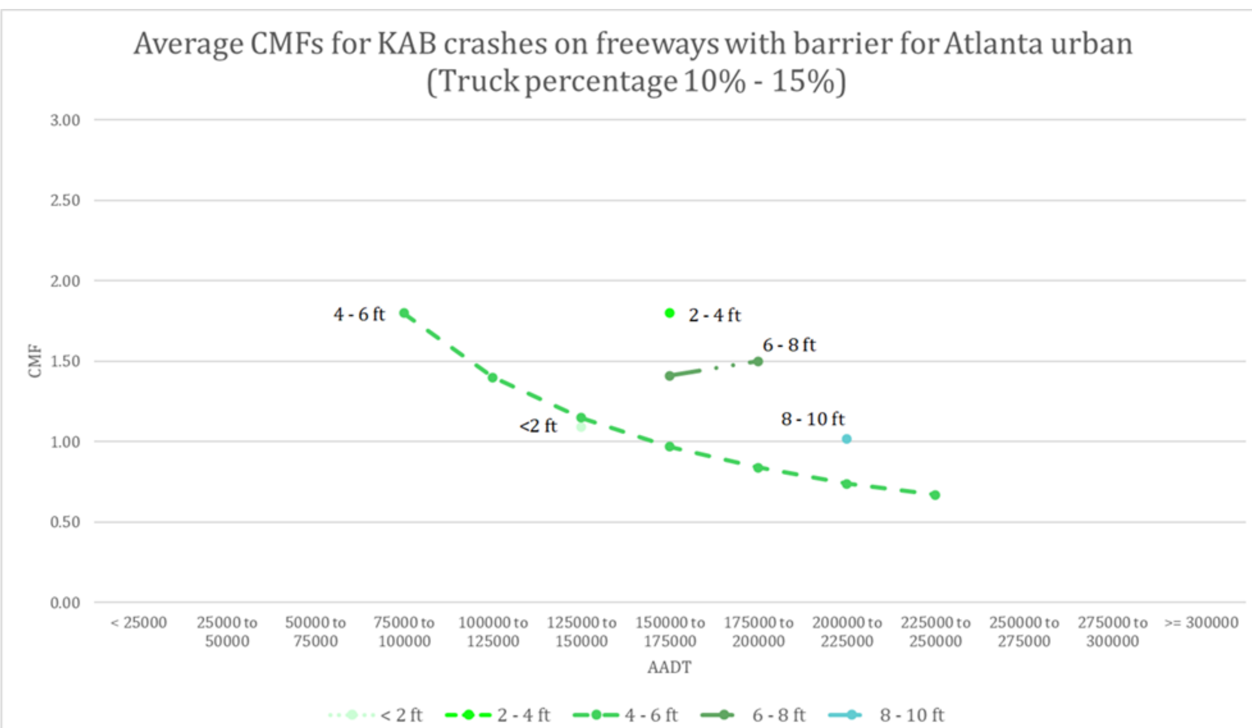

Figure 58. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15).

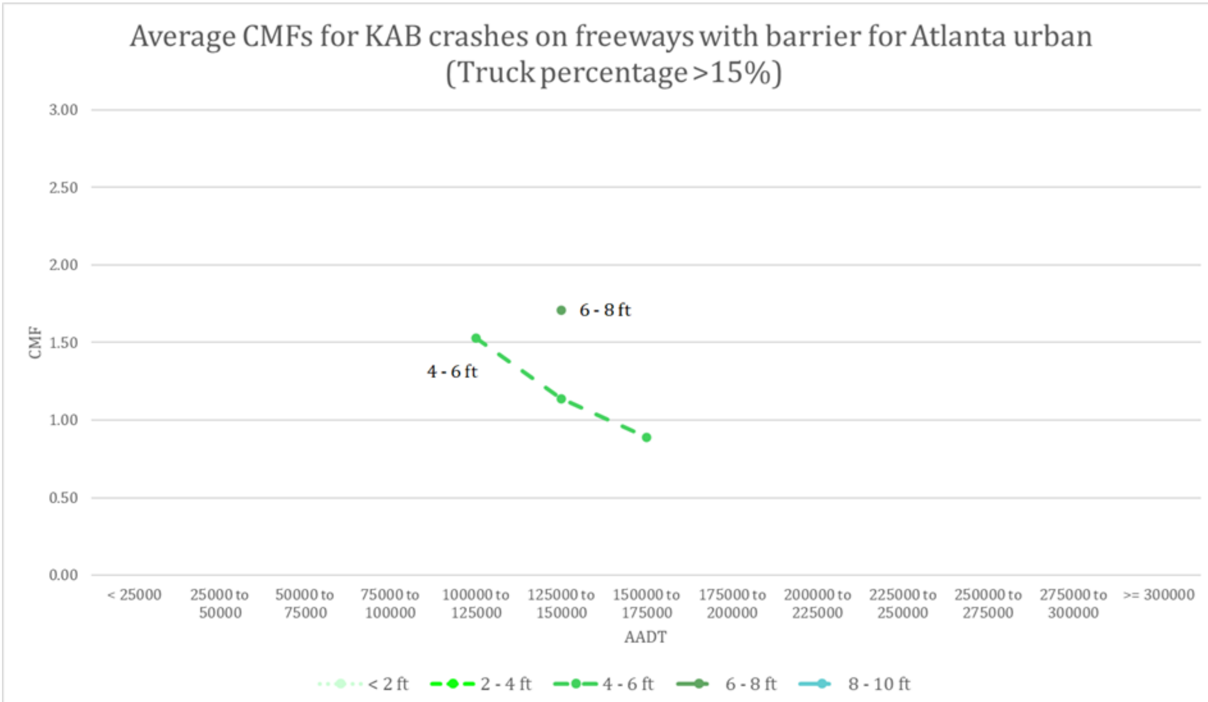

Figure 59. Graph. Average CMFs for KAB crashes on freeways with barrier for Atlanta urban (truck percentage: >15).

CMFS FOR MEDIAN-RELATED CRASHES

Table shows the average CMFs for median-related crashes on statewide freeways without barrier. For two-lane freeways, the CMFs indicate a general trend of decreasing crash potential with increasing AADT for narrower shoulder widths. At lower AADT levels (e.g., <30,000 vpd), the CMFs are often >1.0 when the left shoulder width is very narrow (e.g., <2 ft), implying higher crash potential relative to the base condition. However, as traffic volumes increase beyond 30,000, CMFs for <2-ft shoulders begin to drop steadily and fall below 1.0, indicating improved safety performance relative to the base. In contrast, shoulder widths between 2 and 6 ft consistently show CMFs below 1.0 across most AADT ranges, especially in the 30,000–70,000 range. Interestingly, the 6–8-ft shoulder width category demonstrates the lowest CMFs among all groups at high AADT levels, particularly for AADT above 50,000. In several cases, CMFs drop significantly below 0.10, suggesting very strong safety benefits for median-related crashes in that shoulder width range.

For three-or-more–lane freeways, the CMFs are substantially higher at lower AADT levels across all shoulder widths, particularly for shoulder widths under 6 ft. For example, when AADT is below 30,000, CMFs are often well above 2.0 or even 5.0 for shoulder widths below 6 ft, indicating elevated crash potential compared to the base. However, with increasing AADT, especially above 60,000 vpd, CMFs steadily decrease across all shoulder width categories. The 6–8-ft shoulder widths again show the most consistent and significant reductions in CMFs, suggesting this width range offers the greatest safety effectiveness under higher traffic volumes. Figure 60 and figure 61 show the average CMFs for median-related crashes on statewide freeways without barrier, distinguishing between two-lane and three-or-more–lane segments.

Table 38. Average CMFs for median-related crashes on freeways without barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	2.91	0	1.30	0	0.11	0	9.19	0	0.52	0
10,000–20,000	1.68	19	1.02	12	0.24	6	3.14	1	0.77	2
20,000–30,000	1.27	138	0.90	90	0.38	16	0.87	40	0.96	38
30,000–40,000	1.06	155	0.83	109	0.52	47	0.38	22	1.12	12
40,000–50,000	0.92	68	0.78	125	0.65	34	0.21	8	1.25	12
50,000–60,000	0.83	18	0.74	35	0.78	28	0.13	0	1.37	3
60,000–70,000	0.75	20	0.71	0	0.91	6	0.09	0	1.47	1
70,000–80,000	0.70	1	0.68	0	1.03	0	0.06	0	1.57	1
80,000–90,000	0.65	0	0.66	0	1.16	0	0.04	0	1.67	4
90,000–100,000	0.61	0	0.64	0	1.28	0	0.03	0	1.75	1
≥100,000	0.58	0	0.63	0	1.41	0	0.03	0	1.83	0
3-or-more–lane statewide freeways										
<10,000	134.64	0	9.81	0	18.10	0	7.27	0	0.17	0
10,000–20,000	22.69	0	3.71	0	6.04	5	2.43	0	0.32	0
20,000–30,000	9.70	31	2.21	5	3.39	0	1.36	0	0.48	0
30,000–40,000	5.54	12	1.57	0	2.31	0	0.93	6	0.62	1
40,000–50,000	3.65	8	1.21	5	1.74	0	0.70	34	0.76	23
50,000–60,000	2.61	6	0.99	19	1.38	27	0.56	23	0.90	32
60,000–70,000	1.98	6	0.83	19	1.14	15	0.46	15	1.03	27
70,000–80,000	1.56	7	0.72	30	0.97	40	0.39	22	1.15	14
80,000–90,000	1.26	1	0.63	28	0.84	41	0.34	23	1.28	23
90,000–100,000	1.05	0	0.56	11	0.74	31	0.30	11	1.40	18
≥100,000	0.89	0	0.51	0	0.66	10	0.27	0	1.52	0

Base condition: Statewide freeways without barrier and left shoulder width ≥10 ft

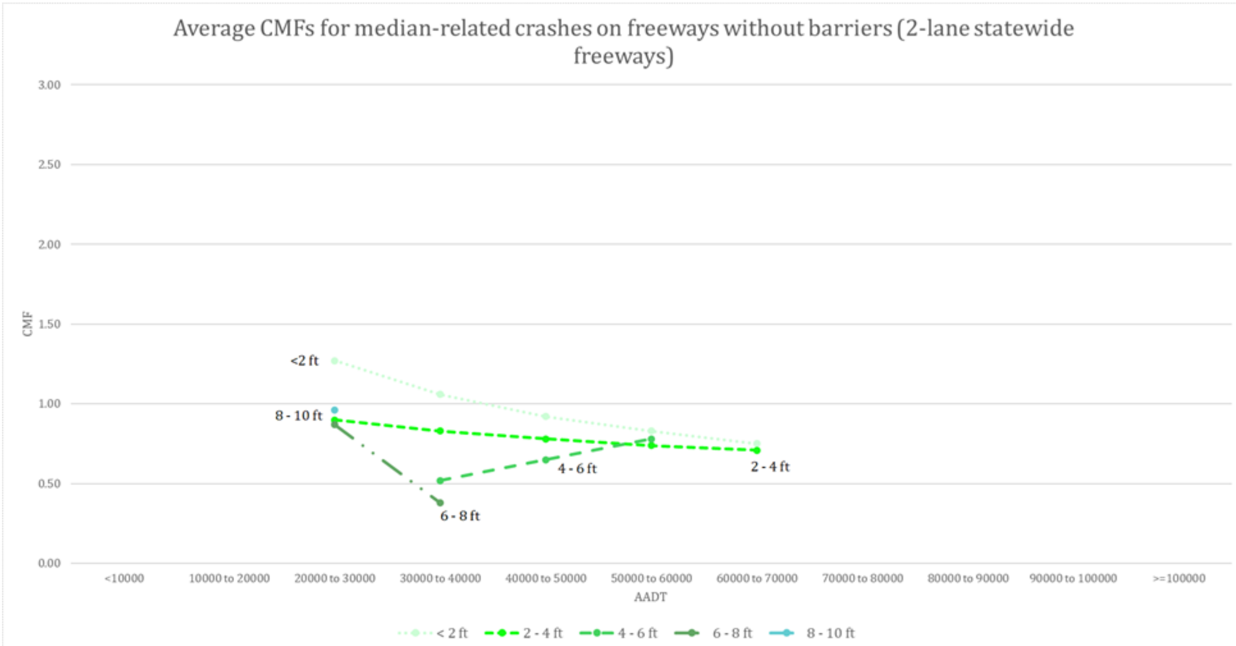

Figure 60. Graph. Average CMFs for median-related crashes on freeways without barrier (two-lane statewide).

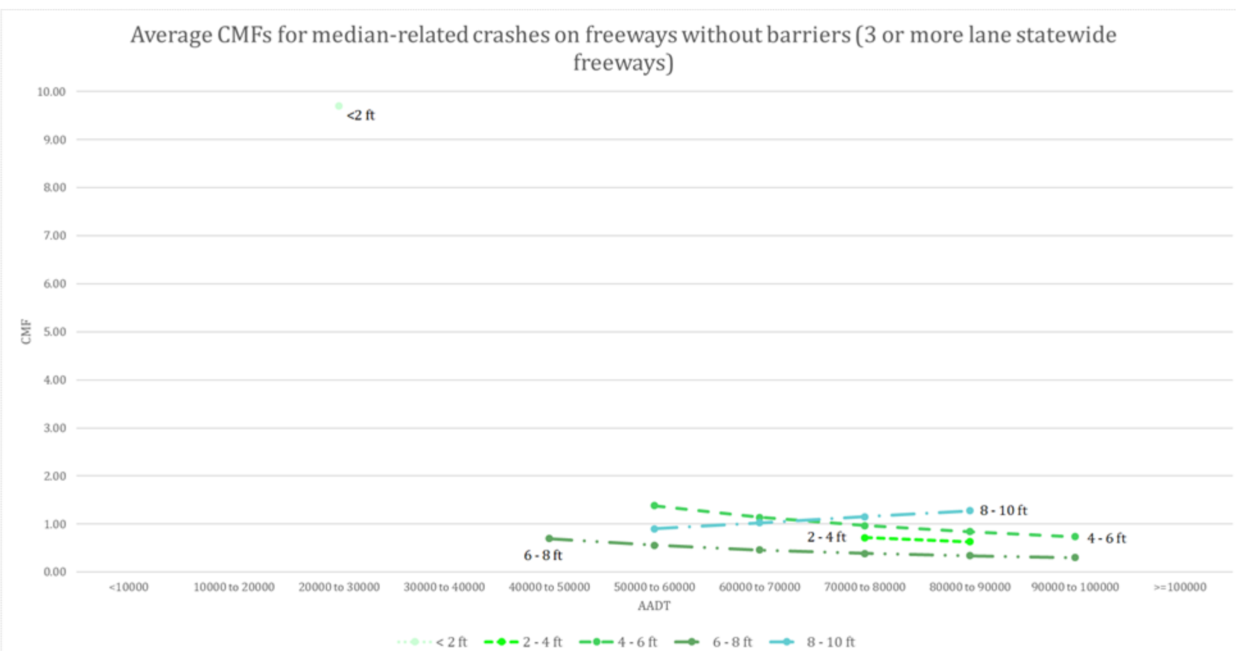

Figure 61. Graph. Average CMFs for median-related crashes on freeways without barrier (three-or-more–lane statewide).

Table displays the average CMFs for median-related crashes on statewide freeways with barrier. For two-lane freeways, CMFs are generally <1.0 across all shoulder widths and AADT levels, indicating a consistent safety benefit compared to the base condition. The lowest CMFs (e.g., 0.29 to 0.81) are observed for narrow shoulders (<2 ft and 2–4 ft) at lower AADT levels (<50,000 vpd), suggesting that in barrier-separated environments, narrower shoulders may be sufficient to mitigate median-related crashes when traffic volumes are low to moderate. However, as AADT increases beyond 50,000, CMFs begin to rise gradually across all shoulder width categories, although they still remain mostly below 1.0 for widths below 6 ft. This trend implies diminishing returns in safety benefits as volume increases unless shoulder widths are appropriately widened or other design considerations are implemented. Shoulder widths of 6–8 ft exhibit an inflection point: CMFs are lower than 1.0 at low AADT but rise above 1.0 for AADT beyond 60,000, indicating that this width may become less effective at higher volumes. Conversely, 8–10-ft shoulders remain relatively stable and hover near 0.90–0.95 across most AADT levels, offering moderate but consistent crash reduction benefits.

On three-or-more–lane freeways, the CMFs for median-related crashes vary dramatically based on shoulder width and AADT. For shoulder widths <6 ft, especially <2 ft, CMFs escalate rapidly with increasing AADT. For instance, CMFs for <2-ft shoulders jump from 0.03 at <10,000 AADT to over 7.0 for AADT ≥100,000, signaling a sharp increase in crash potential when shoulders are extremely narrow under high-volume conditions. This pattern highlights a serious safety concern for narrow shoulders on high-capacity roadways, even when barriers are present. On the other hand, shoulder widths between 4 and 6 ft show gradual increases in CMFs but remain below 1.0 for most AADT levels, indicating reasonable effectiveness. The 6–8-ft shoulders begin with very low CMFs (e.g., 0.01 to 0.33) at low AADT but also rise substantially at higher AADT levels, reaching values well above 1.0 (e.g., 2.37 at AADT ≥100,000), signaling that wider shoulders may be more critical as volume increases. Figure 62 and figure 63 show the corresponding trends for statewide freeways with barrier.

Table 39. Average CMFs for median-related crashes on freeways with barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	0.11	0	0.34	0	0.98	0	0.18	0	0.91	0
10,000–20,000	0.29	8	0.56	9	0.97	0	0.40	2	0.92	6
20,000–30,000	0.47	31	0.70	91	0.97	8	0.59	36	0.93	94
30,000–40,000	0.64	16	0.82	67	0.97	24	0.76	38	0.93	39
40,000–50,000	0.81	20	0.92	53	0.96	19	0.93	15	0.94	16
50,000–60,000	0.98	14	1.01	25	0.95	7	1.08	2	0.94	10
60,000–70,000	1.15	8	1.09	8	0.94	1	1.22	4	0.94	5
70,000–80,000	1.31	1	1.16	0	0.94	4	1.36	1	0.94	0
80,000–90,000	1.48	0	1.23	0	0.93	4	1.50	0	0.94	0
90,000–100,000	1.64	2	1.29	0	0.90	10	1.63	0	0.95	0
≥100,000	1.80	0	1.35	0	0.84	0	1.76	0	0.95	0
3-or-more–lane statewide freeways										
<10,000	0.03	0	1.13	2	0.23	0	0.01	0	0.01	0
10,000–20,000	0.19	0	1.08	0	0.42	6	0.07	0	0.07	0
20,000–30,000	0.50	3	1.06	6	0.54	2	0.18	12	0.17	2
30,000–40,000	0.94	11	1.05	30	0.64	123	0.33	33	0.31	130
40,000–50,000	1.52	34	1.04	34	0.73	153	0.52	113	0.47	208
50,000–60,000	2.23	5	1.03	39	0.80	156	0.74	100	0.67	37
60,000–70,000	3.07	1	1.03	23	0.87	129	1.00	93	0.90	38
70,000–80,000	4.03	4	1.02	36	0.93	62	1.29	82	1.15	33
80,000–90,000	5.12	1	1.02	14	0.99	29	1.62	29	1.43	29
90,000–100,000	6.33	0	1.01	0	1.05	3	1.98	0	1.73	9
≥100,000	7.66	0	1.01	2	1.10	0	2.37	0	2.06	0

Base condition: Statewide freeways with barrier and left shoulder width ≥10 ft

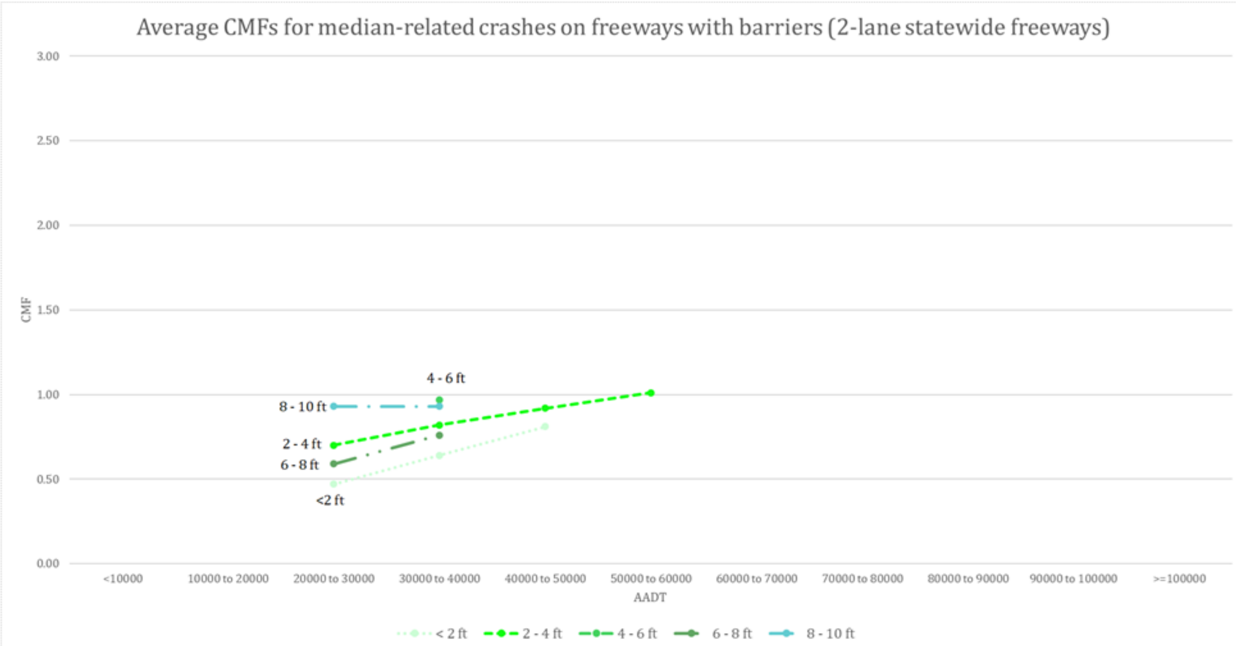

Figure 62. Graph. Average CMFs for median-related crashes on freeways with barrier (two-lane statewide).

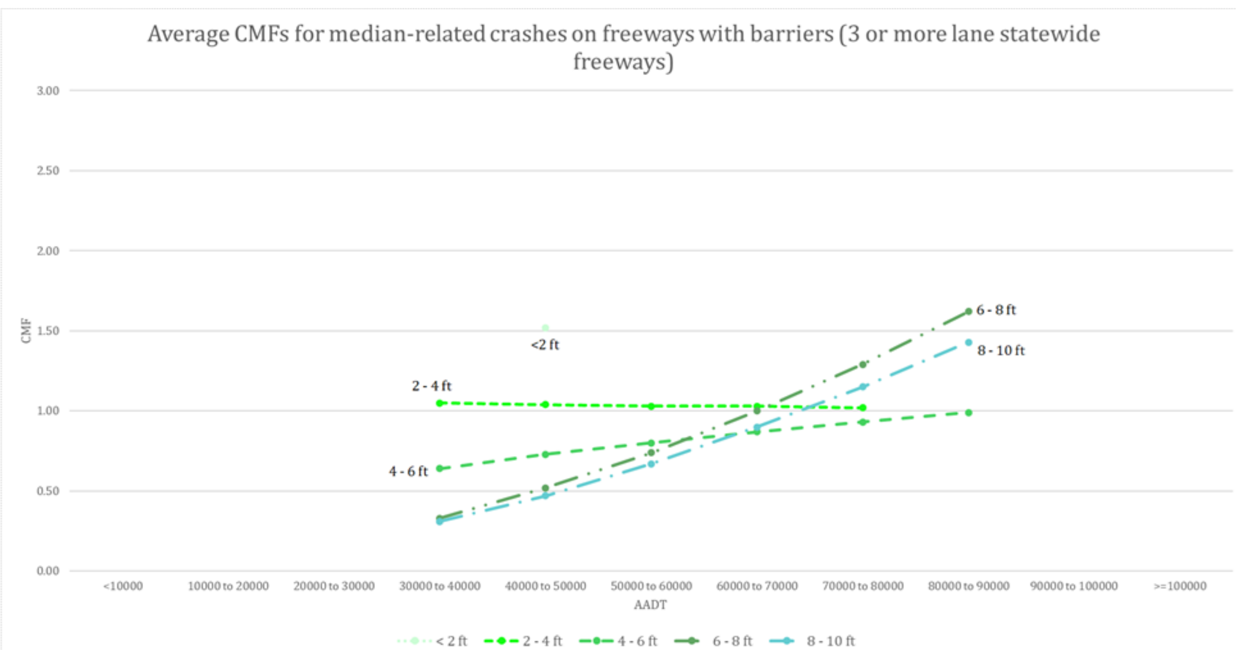

Figure 63. Graph. Average CMFs for median-related crashes on freeways with barrier (three-or-more–lane statewide).

Table presents the average CMFs for median-related crashes on Atlanta urban freeways with barrier. The results consistently show that narrower left shoulders are associated with increased crash frequency, especially on segments with lower AADT and higher truck percentages. For corridors with a low percentage of trucks (≤5 percent), CMFs tend to decrease as AADT increases, suggesting that wider shoulders become relatively more beneficial in higher-volume environments. Narrow shoulders, such as those under 4 or 6 ft, tend to perform worse in low-volume segments but offer marginal improvements in crash reduction as volume grows. As the percentage of trucks increases to between 5 and 10 percent, the benefits of wider shoulders become more apparent. Narrow shoulder widths continue to be linked with elevated crash frequencies, particularly on low-volume segments. Although some reductions in CMFs are observed as AADT increases, the presence of more trucks appears to dampen the positive effects of higher volume. In corridors with truck percentages between 10 and 15 percent, the crash potential associated with narrow shoulders intensify. The protective effect of wider shoulders remains evident, especially in higher-AADT segments. Nonetheless, the potential challenges are more pronounced in segments with a greater number of trucks, suggesting that the increased mass and size of trucks may amplify the issues related to shoulder width. The highest level of truck activity (>15 percent) shows the most pronounced safety concerns for narrow shoulders. In these environments, narrow left shoulders are consistently associated with higher crash frequency across nearly all AADT ranges. Even as AADT increases, the safety benefits from wider shoulders are not enough to fully offset the elevated crash frequency imposed by heavy truck volumes. Figure 64, figure 65, figure 66, and figure 67 show the CMFs for median-related crashes on Atlanta urban freeways with barrier under different truck percentages ranges (≤5, 5–10, 10–15, and >15 percent). As truck percentage increases, CMFs for narrower shoulders become significantly elevated, particularly at lower AADT levels.

Table 40. Average CMFs for median-related crashes on freeways with barrier (Atlanta urban).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
Truck percentage: ≤5										
<25,000	6.24	0	9.18	0	12.42	0	5.13	0	2.34	0
25,000–50,000	3.51	0	3.3	0	4.67	0	2.45	0	1.57	0
50,000–75,000	2.53	0	1.89	0	2.74	0	1.62	0	1.23	0
75,000–100,000	2.03	2	1.31	0	1.92	0	1.23	0	1.05	0
100,000–125,000	1.71	6	0.99	3	1.46	17	1.00	3	0.93	2
125,000–150,000	1.5	12	0.79	12	1.18	51	0.85	19	0.85	3
150,000–175,000	1.35	6	0.66	19	0.99	23	0.74	15	0.78	4
175,000–200,000	1.22	11	0.56	28	0.85	15	0.65	49	0.73	13
200,000–225,000	1.13	16	0.49	43	0.74	23	0.59	50	0.69	9
225,000–250,000	1.05	1	0.43	13	0.66	18	0.54	14	0.65	1
250,000–275,000	0.98	0	0.39	2	0.59	2	0.49	16	0.62	1
275,000–300,000	0.92	0	0.35	0	0.54	2	0.46	15	0.59	0
≥300,000	0.87	0	0.32	0	0.49	22	0.43	92	0.57	0
Truck percentage: 5–10										
<25,000	6.24	3	23.90	0	8.67	0	6.47	0	3.33	0
25,000–50,000	5.10	9	7.00	4	5.99	0	3.52	0	2.22	0
50,000–75,000	2.79	7	3.71	0	3.32	29	2.49	1	1.75	3
75,000–100,000	1.86	34	2.42	17	2.23	33	1.97	23	1.49	9
100,000–125,000	1.37	19	1.77	5	1.66	18	1.66	22	1.33	16
125,000–150,000	1.08	13	1.38	7	1.31	28	1.45	51	1.21	16
150,000–175,000	0.89	41	1.12	18	1.08	75	1.29	54	1.12	14
175,000–200,000	0.75	2	0.93	6	0.91	47	1.17	31	1.05	6
200,000–225,000	0.64	13	0.80	17	0.79	69	1.07	29	0.98	12
225,000–250,000	0.56	16	0.69	6	0.69	39	0.99	11	0.93	0
250,000–275,000	0.50	1	0.61	0	0.61	3	0.93	3	0.89	0
275,000–300,000	0.45	0	0.54	2	0.55	0	0.87	0	0.85	0
≥300,000	0.40	0	0.49	1	0.50	2	0.82	0	0.82	0
Truck percentage: 10–15										
<25,000	16.20	0	24.90	0	28.58	6	8.33	0	4.80	0
25,000–50,000	7.47	6	14.75	0	7.64	0	5.00	5	3.13	0
50,000–75,000	3.08	4	7.27	0	4.01	4	3.82	1	2.49	5
75,000–100,000	1.71	8	4.52	7	2.59	32	3.17	16	2.13	19
100,000–125,000	1.11	2	3.18	1	1.88	3	2.77	4	1.90	0
125,000–150,000	0.78	21	2.40	12	1.45	47	2.48	15	1.73	10
150,000–175,000	0.58	13	1.89	20	1.17	91	2.26	33	1.60	15
175,000–200,000	0.45	4	1.55	5	0.98	53	2.09	43	1.50	54
200,000–225,000	0.36	4	1.30	4	0.83	32	1.95	19	1.41	19
225,000–250,000	0.30	4	1.11	10	0.72	33	1.83	13	1.34	15

Continued on next page.

Table 40. Average CMFs for median-related crashes on freeways with barrier (Atlanta urban). (Continued)

250,000–275,000	0.25	7	0.96	13	0.63	8	1.73	0	1.28	2
275,000–300,000	0.22	10	0.85	8	0.56	2	1.65	0	1.23	0
≥300,000	0.19	11	0.75	4	0.50	7	1.58	0	1.18	0
Truck percentage: >15										
<25,000	24.04	0	0.07	0	24.97	0	10.51	0	6.87	0
25,000–50,000	7.39	0	0.24	0	9.88	0	7.21	0	4.46	0
50,000–75,000	3.51	0	0.46	1	4.84	4	5.86	9	3.54	1
75,000–100,000	2.16	6	0.73	1	3.02	8	5.10	6	3.03	0
100,000–125,000	1.50	0	1.03	1	2.13	22	4.61	1	2.71	3
125,000–150,000	1.13	6	1.35	12	1.61	69	4.24	28	2.47	15
150,000–175,000	0.89	6	1.70	4	1.27	41	3.96	15	2.29	12
175,000–200,000	0.72	0	2.07	0	1.04	0	3.73	3	2.14	7
200,000–225,000	0.60	0	2.46	0	0.88	0	3.54	0	2.02	0
225,000–250,000	0.51	0	2.86	0	0.75	0	3.38	0	1.92	0
250,000–275,000	0.44	0	3.28	0	0.65	0	3.25	0	1.83	0
275,000–300,000	0.39	0	3.72	0	0.57	0	3.13	0	1.76	0
≥300,000	0.35	0	4.17	0	0.51	0	3.02	0	1.69	0

Base condition: Atlanta urban freeways with barrier and left shoulder width ≥10 ft

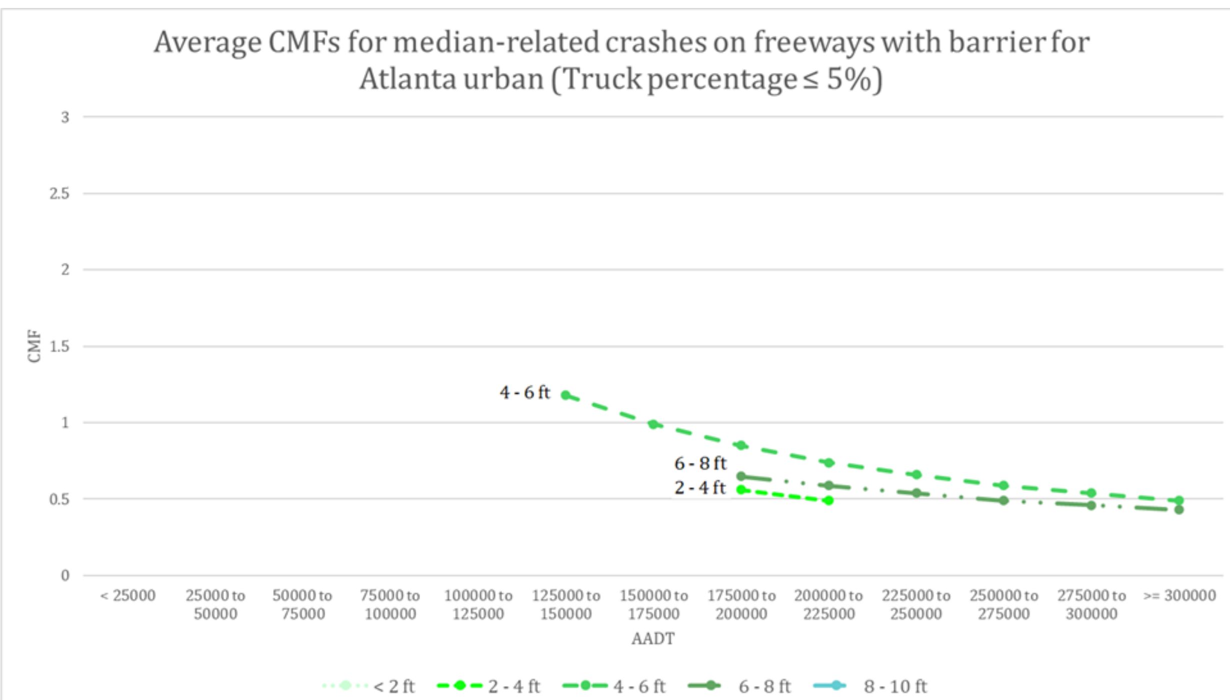

Figure 64. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: ≤5).

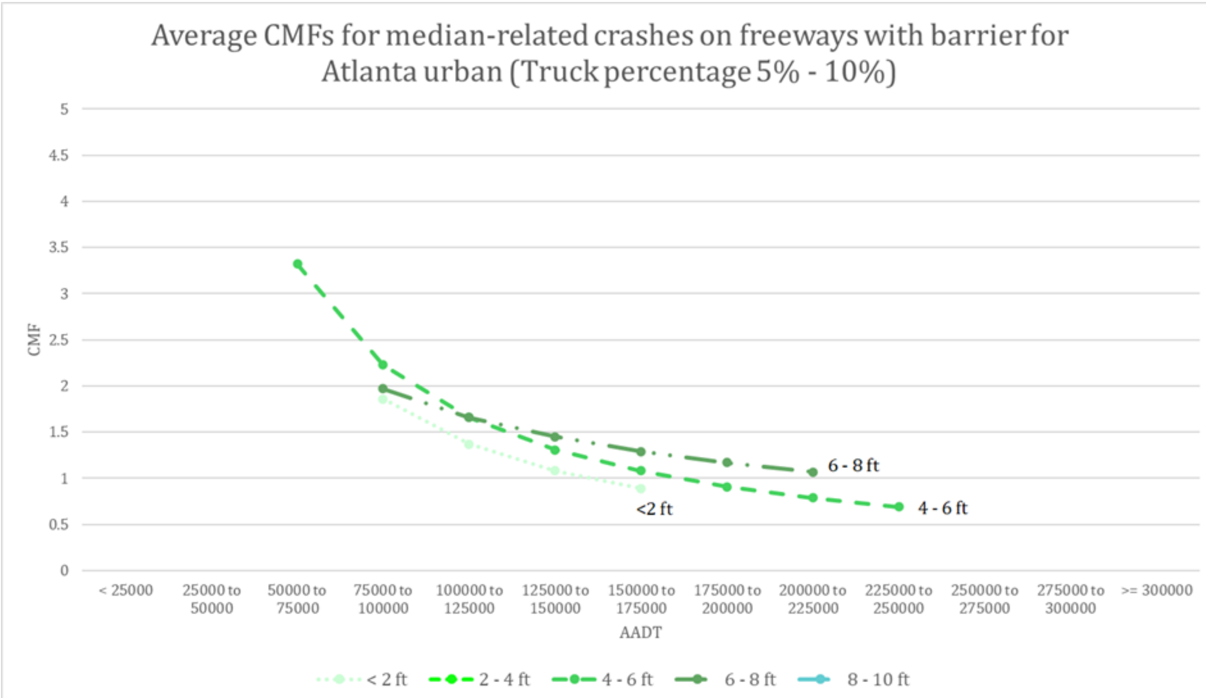

Figure 65. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10).

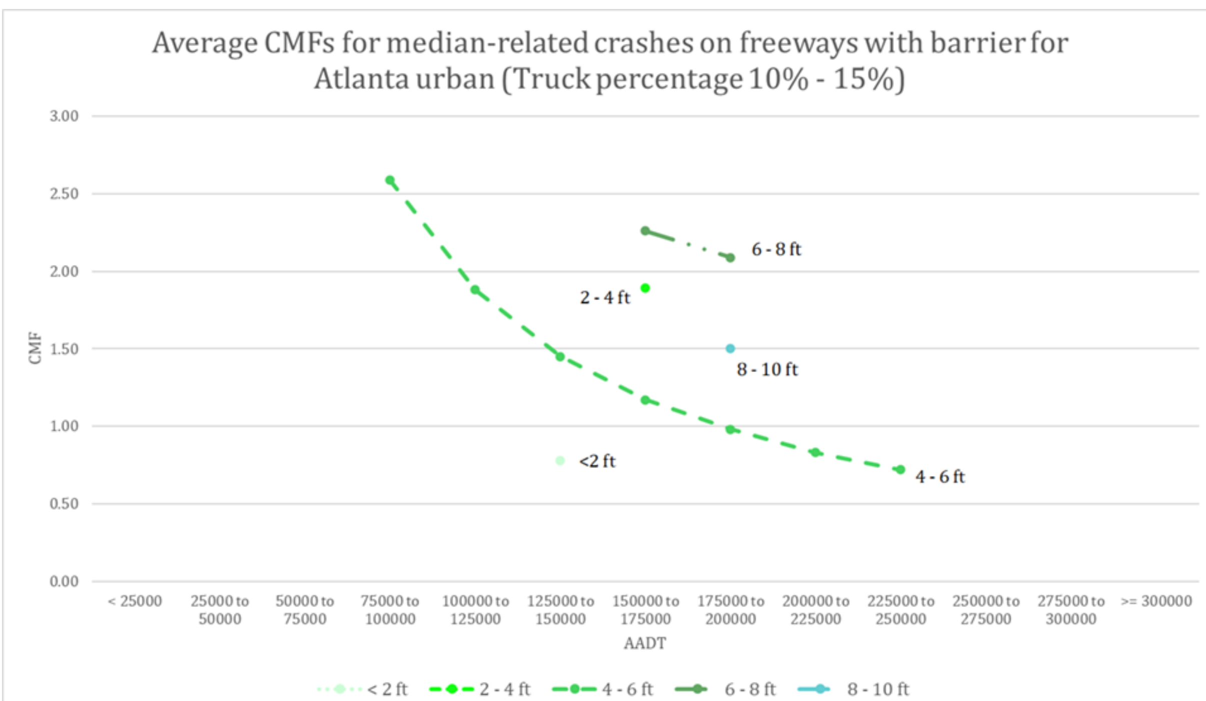

Figure 66. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15).

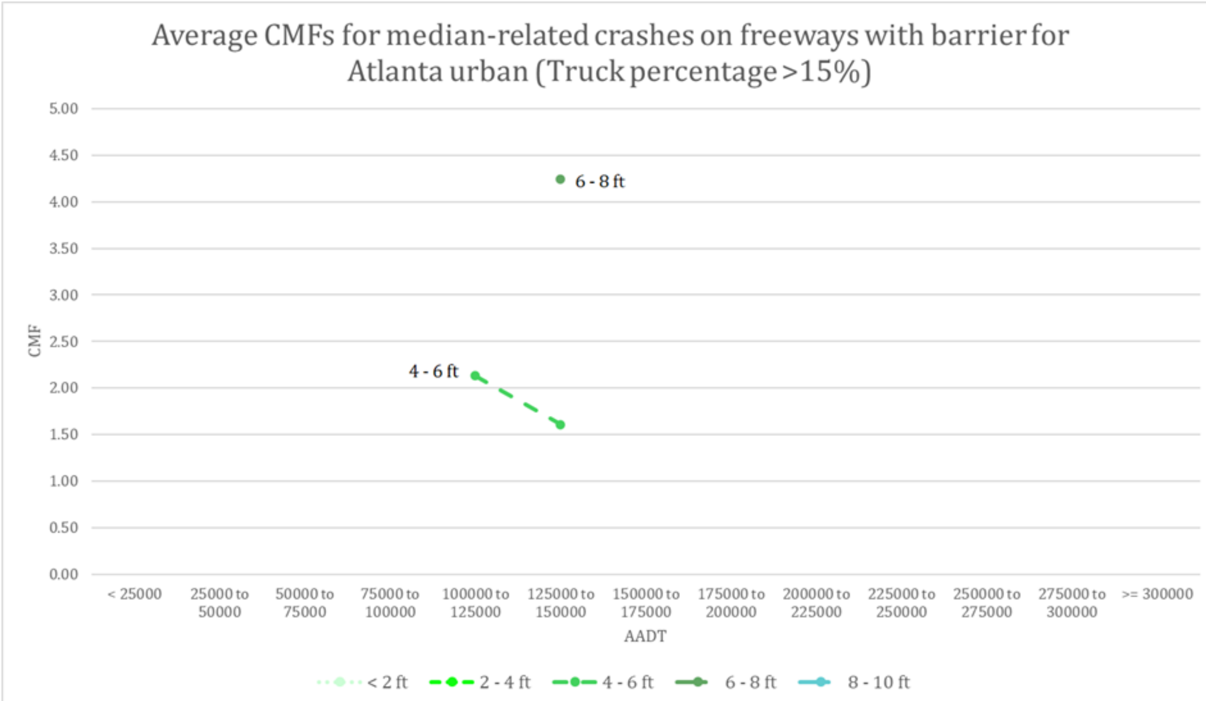

Figure 67. Graph. Average CMFs for median-related crashes on freeways with barrier for Atlanta urban (truck percentage: >15).

Table summarizes the average CMFs for median-related KAB crashes on statewide freeways without barrier. For two-lane freeways, the data reveal that extremely narrow shoulders (<2 ft) are consistently associated with significantly elevated crash occurrences as AADT increases. Notably, the CMFs for these narrow shoulders rise steadily with increasing traffic volume, underscoring the growing safety concern posed by insufficient shoulder width in high-traffic conditions. In contrast, left shoulders between 2 and 4 ft consistently yield much lower CMFs—substantially below 1—across all AADT ranges. This indicates strong safety benefits, even with minimal widening. Similarly, shoulders in the 6–8-ft range also demonstrate low CMFs across nearly all traffic volumes, suggesting they too are effective at mitigating crash potential. Interestingly, shoulder widths of 4–6 ft tend to show much higher CMFs than narrower (2–4 ft) or wider (6–8 ft) alternatives. This may suggest a transitional zone where the shoulder is wide enough to invite risky driver behavior (e.g., temporary stopping) but not wide enough to safely accommodate stopped vehicles or emergency maneuvers, highlighting a potential design pitfall.

For three-or-more–lane freeways, the trends are more stable and consistent across AADT levels. Again, the 2–4-ft shoulder width range shows the lowest CMFs across nearly all volumes, pointing to its consistent safety performance. CMFs for shoulder widths under 2 ft remain relatively low at low volumes but gradually increase with higher traffic, reinforcing concerns over insufficient lateral clearance in busier corridors. Shoulder widths of 6–8 ft begin to show some rise in CMFs at higher AADT levels but not as dramatically as narrower widths. Meanwhile, shoulder widths between 4 and 6 ft again reflect a relative safety disadvantage compared to narrower or wider alternatives. Figure 68 shows the trends of average CMFs for median-related KAB crashes on two-lane statewide freeways without barrier. Figure 69 presents the average CMFs for median-related KAB crashes on three-or-more–lane statewide freeways without barrier.

Table 41. Average CMFs for median-related KAB crashes on freeways without barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	0.60	0	0.03	0	0.01	0	0.39	0	0.01	0
10,000–20,000	1.50	19	0.02	12	0.10	6	0.63	1	0.07	2
20,000–30,000	2.38	138	0.03	90	0.42	16	0.04	40	0.32	38
30,000–40,000	3.21	155	0.06	109	1.10	47	0.01	22	0.87	12
40,000–50,000	4.04	68	0.08	125	2.27	34	0.03	8	1.86	12
50,000–60,000	4.84	18	0.11	35	4.04	28	0.01	0	3.42	3
60,000–70,000	5.63	20	0.15	0	6.56	6	0.04	0	5.69	1
70,000–80,000	6.41	1	0.18	0	9.90	0	0.02	0	8.79	1
80,000–90,000	7.17	0	0.22	0	14.24	0	0.01	0	12.88	4
90,000–100,000	7.94	0	0.26	0	19.66	0	0.06	0	15.06	1
≥100,000	8.68	0	0.31	0	20.29	0	0.05	0	24.56	0
3-or-more–lane statewide freeways										
<10,000	0.33	0	0.07	0	4.26	0	0.54	0	0.13	0
10,000–20,000	0.46	0	0.05	0	2.51	5	0.18	0	0.35	0
20,000–30,000	0.55	31	0.04	5	1.97	0	0.14	0	0.60	0
30,000–40,000	0.63	12	0.04	0	1.68	0	0.01	6	0.86	1
40,000–50,000	0.69	8	0.03	5	1.49	0	0.02	34	1.13	23
50,000–60,000	0.74	6	0.03	19	1.35	27	0.04	23	1.41	32
60,000–70,000	0.79	6	0.03	19	1.25	15	0.09	15	1.70	27
70,000–80,000	0.83	7	0.03	30	1.17	40	0.18	22	1.99	14
80,000–90,000	0.87	1	0.03	28	1.10	41	0.31	23	2.28	23
90,000–100,000	0.91	0	0.03	11	1.05	31	0.51	11	2.57	18
≥100,000	0.95	0	0.02	0	1.00	10	0.80	0	2.87	0

Base condition: Statewide freeways without barrier and left shoulder width ≥10 ft

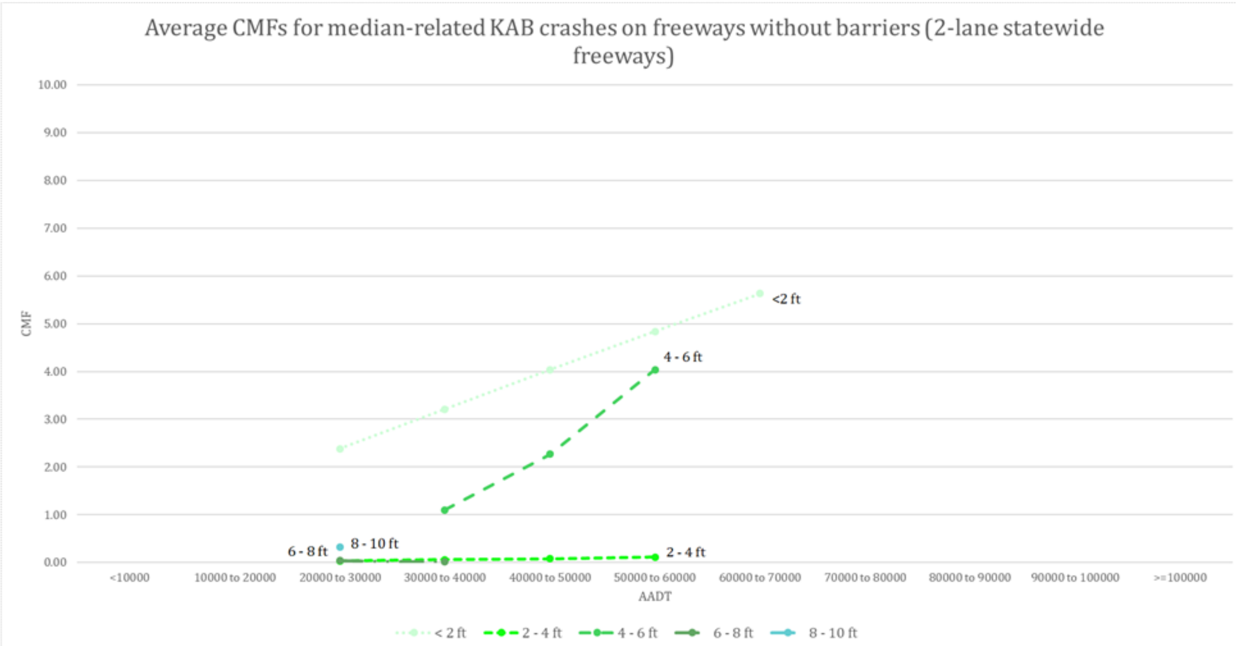

Figure 68. Graph. Average CMFs for median-related KAB crashes on freeways without barrier (two-lane statewide).

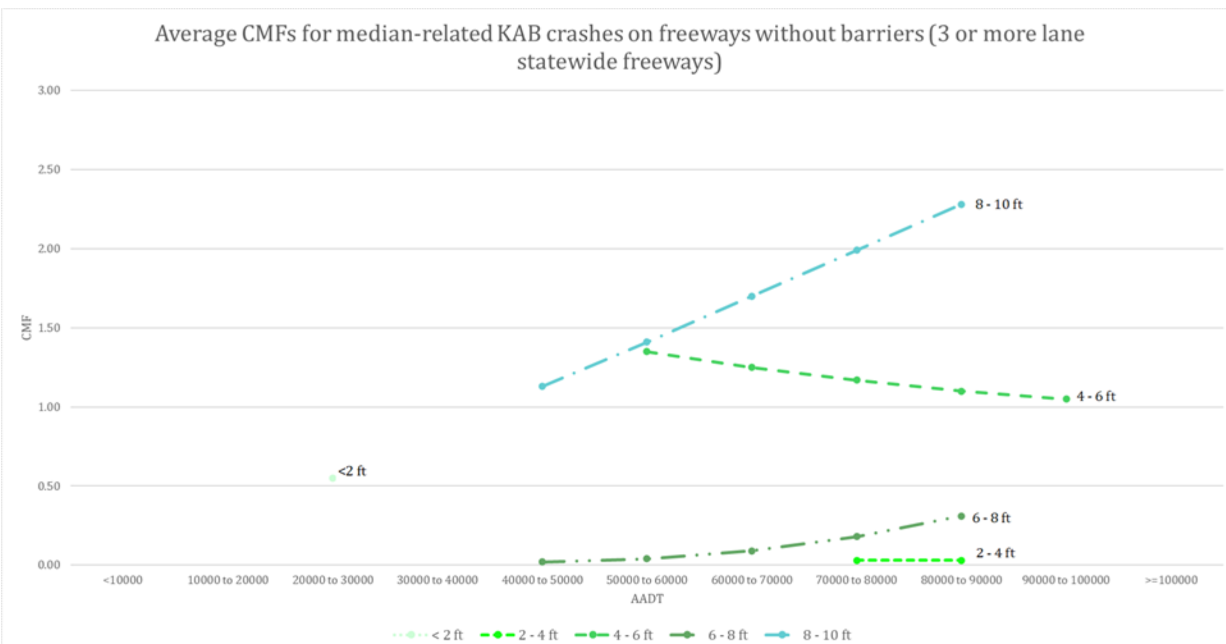

Figure 69. Graph. Average CMFs for median-related KAB crashes on freeways without barrier (three-or-more–lane statewide).

Table presents the average CMFs for median-related KAB on statewide freeways with barrier. For two-lane freeways, the results show a consistent and meaningful trend: very narrow shoulders (<2 ft) are associated with substantially higher CMFs, indicating increased crash potential, especially at lower AADT levels. As AADT increases, the CMFs gradually decline but still remain higher than for wider shoulders, suggesting persistent safety concerns. In contrast, left shoulder widths of 2–4 ft and especially 4–6 ft are associated with significantly lower CMFs, particularly at moderate to high AADT levels. These ranges consistently offer improved safety performance over narrower shoulders. Interestingly, shoulders of 6–8 ft show mixed outcomes—low CMFs in some traffic volumes but slightly elevated values in others—suggesting diminishing safety returns or behavioral factors at play. Shoulder widths >8 ft show consistently low CMFs, reinforcing the benefits of providing generous lateral clearance.

For freeways with three or more lanes, the pattern is similar but with some added nuance. Left shoulders narrower than 2 ft yield dramatically elevated CMFs, particularly as traffic volume increases. This suggests that insufficient shoulder width in high-speed, high-volume environments contributes significantly to safety degradation. Once again, 2–4-ft and 4–6-ft shoulders offer better safety outcomes, with CMFs generally declining with higher AADT. Notably, 6–8-ft shoulders consistently yield the lowest CMFs across all AADT levels, indicating the highest safety effectiveness in these multi-lane barrier-separated corridors. Figure 70 illustrates the average CMFs for median-related KAB crashes on two-lane statewide freeways with median barriers. Figure 71 presents the CMFs for median-related KAB crashes on three-or-more–lane statewide freeways with median barriers.

Table 42. Average CMFs for median-related KAB crashes on freeways with barrier (statewide).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
2-lane statewide freeways										
<10,000	7.34	0	1.38	0	2.17	0	0.31	0	0.39	0
10,000–20,000	3.04	8	0.99	9	0.72	0	0.48	2	0.33	6
20,000–30,000	1.91	31	0.83	91	0.41	8	0.64	36	0.30	94
30,000–40,000	1.39	16	0.73	67	0.28	24	0.76	38	0.38	39
40,000–50,000	1.10	20	0.66	53	0.21	19	0.87	15	0.37	16
50,000–60,000	0.91	14	0.61	25	0.17	7	0.97	2	0.37	10
60,000–70,000	0.78	8	0.58	8	0.14	1	1.07	4	0.37	5
70,000–80,000	0.68	1	0.54	0	0.12	4	1.15	1	0.38	0
80,000–90,000	0.60	0	0.52	0	0.10	4	1.24	0	0.37	0
90,000–100,000	0.54	2	0.50	0	0.09	10	1.31	0	0.32	0
≥100,000	0.49	0	0.48	0	0.08	0	1.39	0	0.31	0
3-or-more–lane statewide freeways										
<10,000	0.53	0	1.50	2	4.27	0	0.05	0	2.15	0
10,000–20,000	1.23	0	1.04	0	2.37	6	0.07	0	1.54	0
20,000–30,000	1.95	3	0.88	6	1.81	2	0.08	12	1.32	2
30,000–40,000	2.64	11	0.79	30	1.52	123	0.09	33	1.19	130
40,000–50,000	3.33	34	0.72	34	1.32	153	0.10	113	1.10	208
50,000–60,000	4.00	5	0.67	39	1.19	156	0.11	100	1.03	37
60,000–70,000	4.66	1	0.64	23	1.09	129	0.12	93	0.98	38
70,000–80,000	5.32	4	0.61	36	1.01	62	0.12	82	0.94	33
80,000–90,000	5.98	1	0.58	14	0.95	29	0.13	29	0.90	29
90,000–100,000	6.63	0	0.56	0	0.89	3	0.14	0	0.87	9
≥100,000	7.26	0	0.54	2	0.85	0	0.14	0	0.85	0

Base condition: Statewide freeways with barrier and left shoulder width ≥10 ft

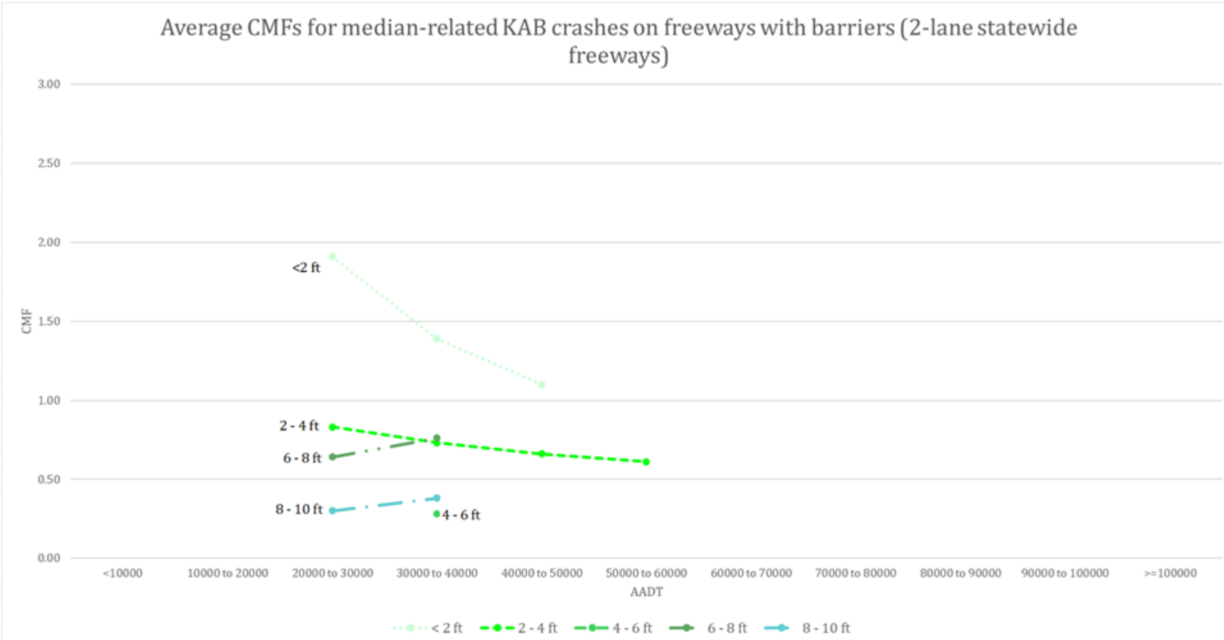

Figure 70. Graph. Average CMFs for median-related KAB crashes on freeways with barrier (two-lane statewide).

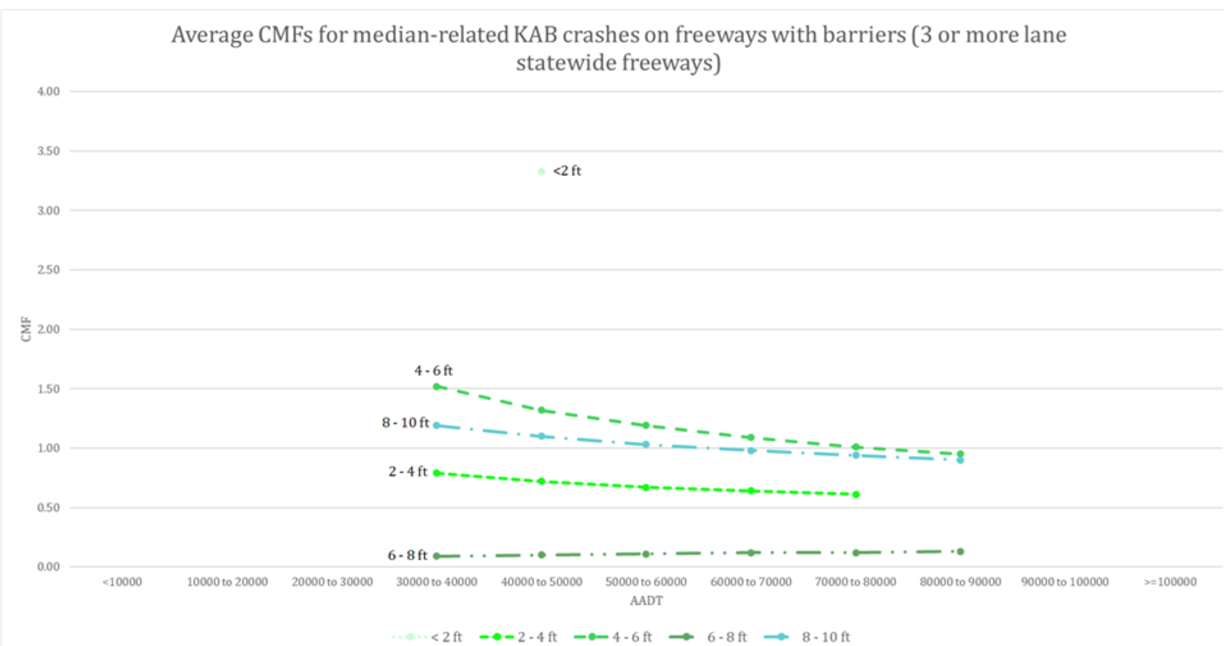

Figure 71. Graph. Average CMFs for median-related KAB crashes on freeways with barrier (three-or-more–lane statewide).

Table presents the average CMFs for median-related KAB crashes (fatal and injury crashes) on Atlanta urban freeways with barrier, stratified by left shoulder width, AADT, and truck percentage. The base condition is a left shoulder width of 10 ft or more. Across all truck percentage categories, very narrow left shoulders (<2 ft) consistently exhibit the highest CMFs, particularly at lower AADT levels, indicating a substantial increase in crash frequency compared to the base condition. As AADT increases, the CMFs for narrow shoulders generally decline but still remain higher than for wider shoulder widths. This trend is observed even when truck percentages rise, emphasizing the safety disadvantage of very narrow shoulders regardless of traffic composition. Shoulder widths between 2 and 4 ft show a moderate improvement in CMFs compared to <2 ft, especially under low to moderate truck volumes. However, as truck percentage increases (above 10 percent), the CMFs for this shoulder width often remain above 1.0 and in some cases escalate significantly with increasing AADT, highlighting potential safety concerns for narrow shoulders in truck-heavy corridors. For 4–6-ft shoulder widths, the results are mixed. Under lower truck volumes (≤5 percent), CMFs are generally near or slightly above 1.0. However, with increasing truck percentages, the CMFs for this shoulder width tend to increase, particularly in high AADT scenarios, suggesting that although better than narrower shoulders, this width may not consistently provide sufficient buffer in freight-intensive environments. The most consistently favorable results are observed for shoulders 6–8 ft wide. This category yields the lowest CMFs across nearly all AADT levels and truck percentages, especially when AADT exceeds 75,000 vpd. Even in high truck percentage ranges (>10 percent), CMFs remain closer to 1.0 or slightly below for this shoulder width, suggesting its effectiveness in mitigating crash severity under demanding conditions. Left shoulder widths of 8–10 ft generally maintain low CMFs, though they are not always lower than the 6–8-ft category. In some cases, CMFs in this wider range begin to rise under very high truck percentages and AADT levels, potentially reflecting diminishing returns beyond 6–8 ft or geometric tradeoffs not captured in the table. Figure 72, figure 73, figure 74, and figure 75 illustrate the trends of CMFs for median-related KAB crashes on Atlanta urban freeways with barrier under varying truck percentages (≤5, 5–10, 10–15, and >15 percent).

Table 43. Average CMFs for median-related KAB crashes on freeways with barrier (Atlanta urban).

	<2 ft		2–4 ft		4–6 ft		6–8 ft		8–10 ft	
AADT	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**	**CMF**	**Count**
Truck percentage: ≤5										
<25,000	5.47	0	4.89	0	1.59	0	1.59	0	4.37	0
25,000–50,000	2.89	0	2.64	0	1.53	0	1.30	0	2.27	0
50,000–75,000	2.00	0	1.83	0	1.46	0	1.15	0	1.55	0
75,000–100,000	1.56	2	1.43	0	1.44	0	1.06	0	1.20	0
100,000–125,000	1.28	6	1.19	3	1.41	17	0.99	3	0.99	2
125,000–150,000	1.10	12	1.02	12	1.39	51	0.95	19	0.84	3
150,000–175,000	0.97	6	0.90	19	1.36	23	0.91	15	0.74	4
175,000–200,000	0.87	11	0.81	28	1.35	15	0.87	49	0.66	13
200,000–225,000	0.79	16	0.74	43	1.34	23	0.85	50	0.60	9
225,000–250,000	0.73	1	0.68	13	1.33	18	0.82	14	0.55	1
250,000–275,000	0.67	0	0.63	2	1.32	2	0.80	16	0.51	1
275,000–300,000	0.63	0	0.59	0	1.31	2	0.78	15	0.47	0
≥300,000	0.59	0	0.56	0	1.30	22	0.77	92	0.44	0
Truck percentage: 5–10										
<25,000	9.74	3	1.21	0	7.15	0	2.00	0	1.25	0
25,000–50,000	3.93	9	1.18	4	3.53	0	1.59	0	1.13	0
50,000–75,000	2.41	7	1.16	0	2.37	29	1.40	1	1.04	3
75,000–100,000	1.73	34	1.14	17	1.82	33	1.27	23	0.99	9
100,000–125,000	1.35	19	1.13	5	1.49	18	1.19	22	0.96	16
125,000–150,000	1.11	13	1.12	7	1.27	28	1.13	51	0.93	16
150,000–175,000	0.94	41	1.12	18	1.11	75	1.08	54	0.91	14
175,000–200,000	0.82	2	1.11	6	0.99	47	1.04	31	0.89	6
200,000–225,000	0.72	13	1.11	17	0.90	69	1.00	29	0.87	12
225,000–250,000	0.65	16	1.10	6	0.82	39	0.97	11	0.86	0
250,000–275,000	0.59	1	1.09	0	0.76	3	0.95	3	0.84	0
275,000–300,000	0.54	0	1.09	2	0.71	0	0.93	0	0.83	0
≥300,000	0.49	0	1.09	1	0.66	2	0.90	0	0.82	0

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Table 44. Average CMFs for median-related KAB crashes on freeways with barrier (Atlanta urban). (Continued)

Truck percentage: 10–15										
<25,000	19.27	0	0.30	0	18.82	6	2.52	0	0.37	0
25,000–50,000	5.38	6	0.53	0	8.49	0	1.94	5	0.56	0
50,000–75,000	2.91	4	0.73	0	3.90	4	1.69	1	0.70	5
75,000–100,000	1.94	8	0.92	7	2.34	32	1.54	16	0.83	19
100,000–125,000	1.42	2	1.08	1	1.59	3	1.43	4	0.93	0
125,000–150,000	1.12	21	1.23	12	1.17	47	1.35	15	1.02	10

150,000–175,000	0.91	13	1.38	20	0.91	91	1.29	33	1.11	15
175,000–200,000	0.77	4	1.51	5	0.73	53	1.23	43	1.19	54
200,000–225,000	0.66	4	1.65	4	0.60	32	1.19	19	1.27	19
225,000–250,000	0.58	4	1.77	10	0.51	33	1.16	13	1.34	15
250,000–275,000	0.51	7	1.90	13	0.44	8	1.12	0	1.40	2
275,000–300,000	0.46	10	2.01	8	0.38	2	1.09	0	1.47	0
≥300,000	0.41	11	2.13	4	0.34	7	1.07	0	1.53	0
Truck percentage: >15										
<25,000	13.01	0	0.07	0	12.90	0	3.20	0	0.10	0
25,000–50,000	7.40	0	0.24	0	9.06	0	2.37	0	0.27	0
50,000–75,000	3.51	0	0.46	1	4.38	4	2.04	9	0.47	1
75,000–100,000	2.16	6	0.73	1	2.69	8	1.84	6	0.68	0
100,000–125,000	1.50	0	1.03	1	1.87	22	1.71	1	0.90	3
125,000–150,000	1.13	6	1.35	12	1.41	69	1.61	28	1.13	15
150,000–175,000	0.88	6	1.70	4	1.10	41	1.53	15	1.36	12
175,000–200,000	0.72	0	2.07	0	0.90	0	1.47	3	1.60	7
200,000–225,000	0.60	0	2.45	0	0.75	0	1.42	0	1.84	0
225,000–250,000	0.51	0	2.86	0	0.64	0	1.37	0	2.08	0
250,000–275,000	0.44	0	3.28	0	0.55	0	1.33	0	2.33	0
275,000–300,000	0.39	0	3.72	0	0.49	0	1.29	0	2.58	0
≥300,000	0.35	0	4.18	0	0.43	0	1.26	0	2.83	0

Base condition: Atlanta urban freeways with barrier and left shoulder width ≥10 ft

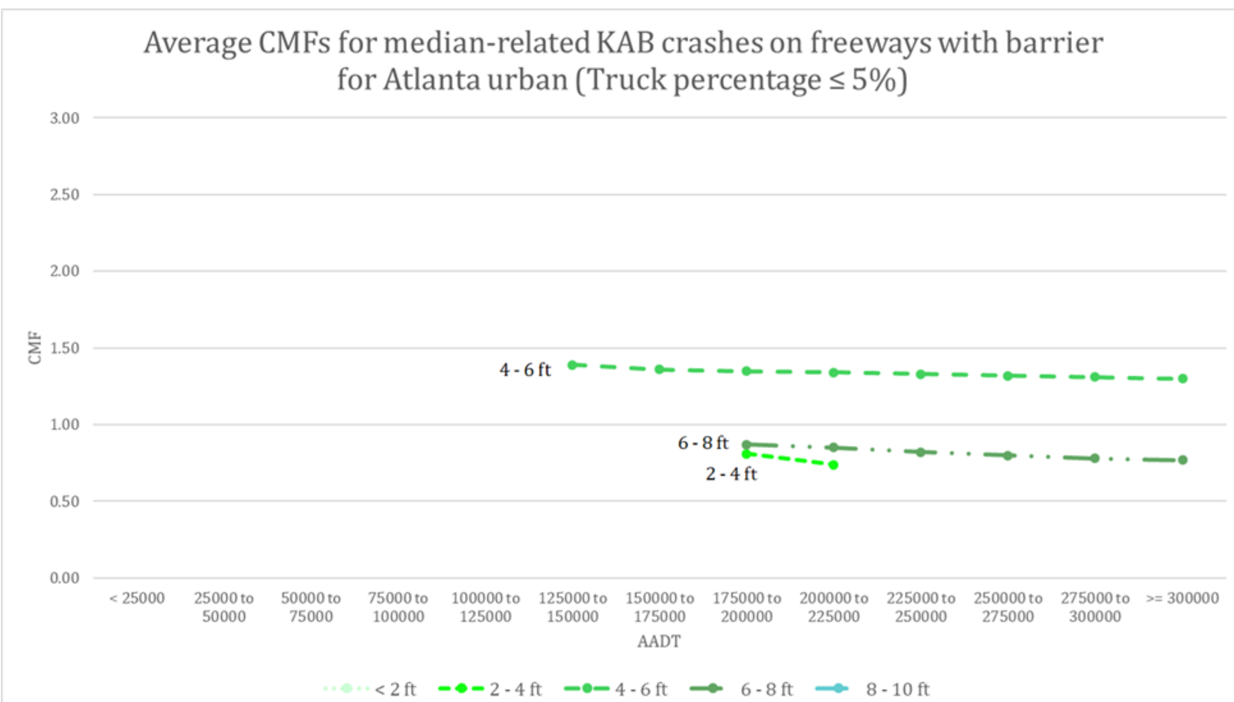

Figure 72. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: ≤5).

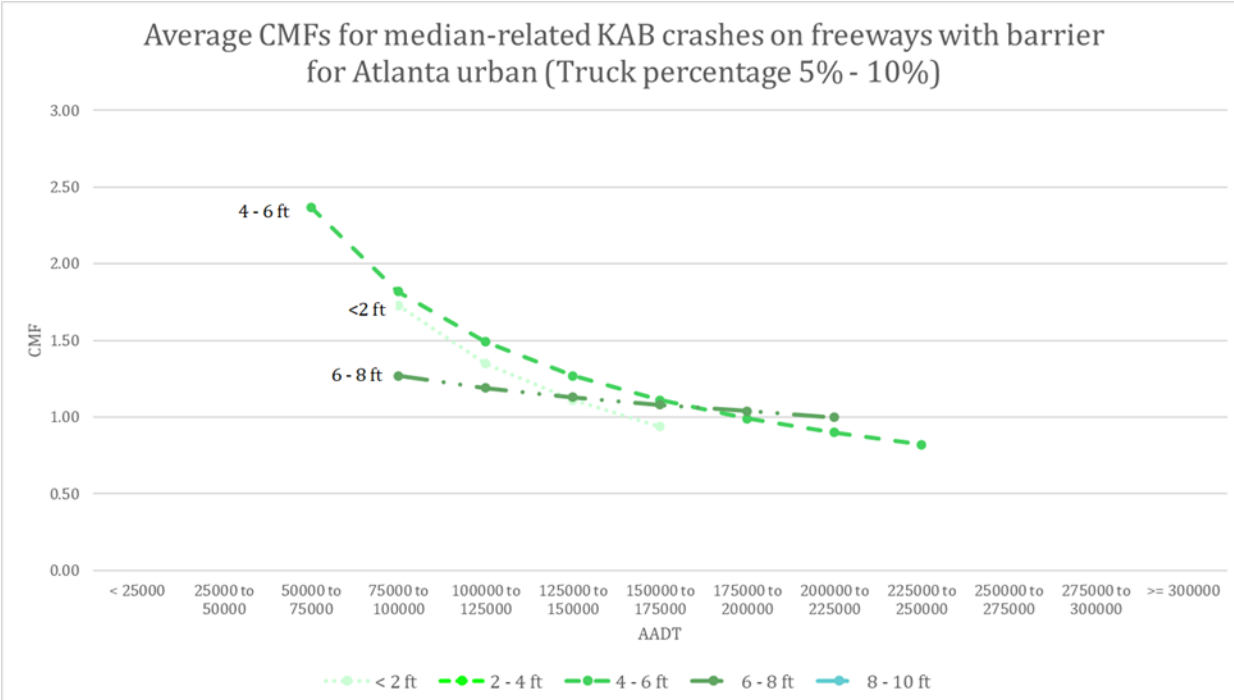

Figure 73. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 5–10).

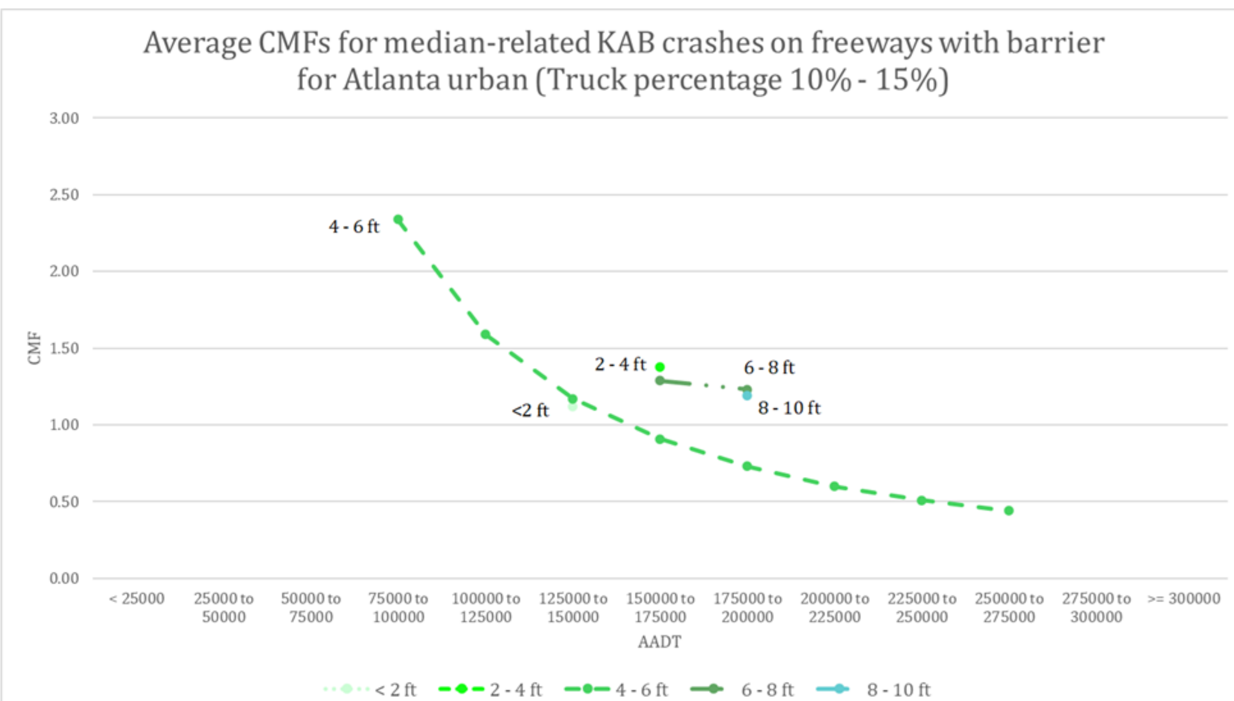

Figure 74. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: 10–15).

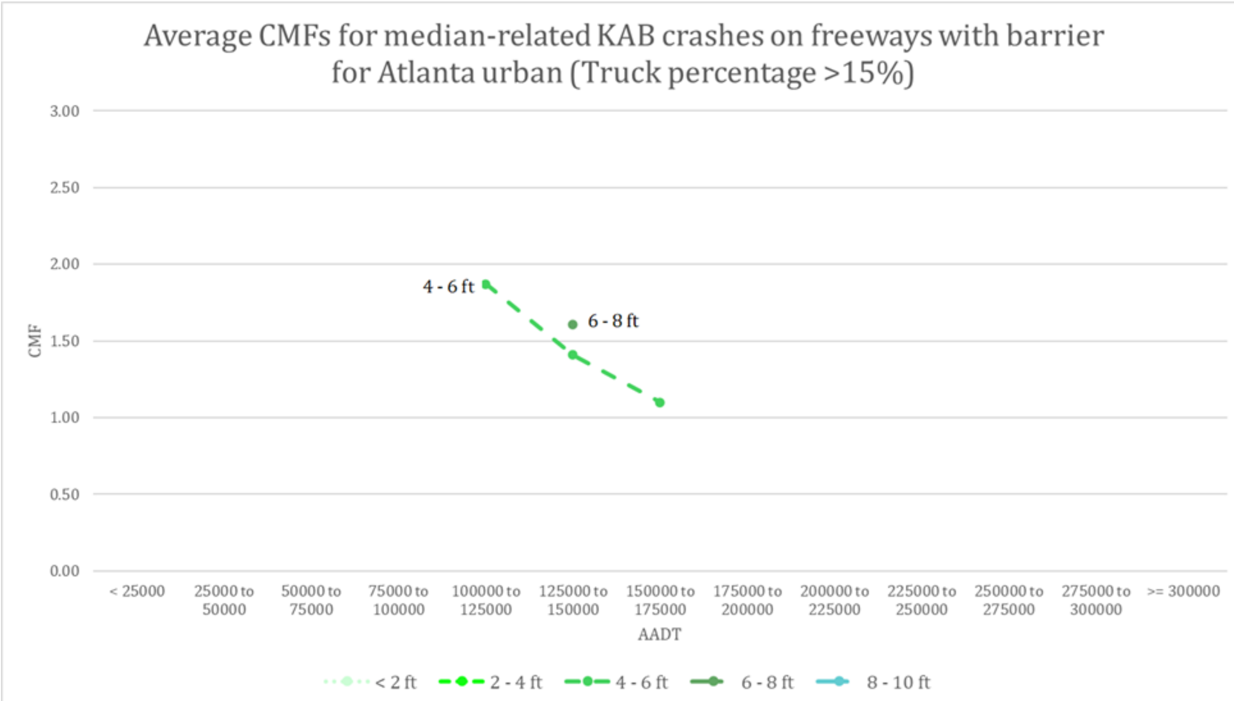

Figure 75. Graph. Average CMFs for median-related KAB crashes on freeways with barrier for Atlanta urban (truck percentage: >15).

TAKEAWAYS OF CMF RESULTS

When considering all freeway crashes, wider left shoulders—particularly those between 6 and 10 ft—consistently enhance safety across a range of conditions. Their benefits are most pronounced on high-volume roadways (AADT >40,000), urban and high-speed segments, and barrier-separated corridors where lateral clearance is constrained. Narrow shoulders (<4 ft), on the other hand, are consistently associated with elevated crash potential. This crash potential intensifies as AADT and truck percentages increase, with CMFs often well above 1.0 when truck percentages exceed 10–15 percent. Moderate shoulder widths (4–6 ft) offer limited and inconsistent safety benefits, tending to lose effectiveness as volume and truck presence grow. Among all categories, left shoulders in the 6–8-ft range stand out for their strong and reliable performance—CMFs generally remain below 1.0, especially for KAB crashes.

Focusing specifically on median-related crashes (those occurring on or attributed to medians), similar patterns emerge. Wider left shoulders—again, especially 6–8 ft—consistently yield lower CMFs, particularly in high-volume, high-speed, and barrier-separated environments. In contrast, very narrow shoulders (<2 ft) show sharply elevated crash potential, especially under low AADT or high truck percentage conditions. Interestingly, shoulder widths of 4–6 ft often underperform compared to both 2–4-ft and 6–8-ft shoulders, possibly due to insufficient space for emergency maneuvers or stopping behavior. Overall, these findings reinforce the importance of designing freeway shoulders—particularly in median areas—with adequate width (ideally 6–8 ft) to reduce crash frequency and improve safety performance under demanding traffic conditions.

CHAPTER 7. POLICY IMPLICATIONS

This study aimed to provide evidence-based guidance on inside (left) shoulder widths for Georgia freeways, based on a comprehensive analysis of six years of crash, traffic, and roadway inventory data. The study identified conditions where narrower shoulders may be acceptable (e.g., as design exceptions) and highlight situations where wider shoulders are critical to maintaining safe operations. These recommendations are intended to help GDOT make context-sensitive design decisions, particularly in cases where findings differ from existing AASHTO and FHWA standards or prior HSM-based research.

STATEWIDE FREEWAYS WITHOUT BARRIERS

For two-lane freeways:

- Low AADT (<30,000 vpd): 4–6 ft recommended; 2–4 ft acceptable.
- Moderate AADT (30,000–50,000 vpd): Transition to 6–8 ft to reducing crash potential; 4–6 ft acceptable.
- High AADT (50,000+ vpd): 8–10 ft recommended; 6–8 ft acceptable.

For three-plus–lane freeways:

- Low AADT (<40,000 vpd): 2–4 ft recommended for low-traffic contexts.
- Moderate AADT (40,000–60,000 vpd): Shift to 6–8 ft; narrow widths (2–4 ft) suggests safety justification.
- High AADT (60,000+ vpd): 6–8 ft minimum; 4–6 ft reserved for safety justification.

Table summarizes these recommended shoulder widths for statewide freeways without barriers.

Table 45. Statewide freeways without barrier.

Lane Type	AADT Range	Recommended Width (ft)	Constrained Width Option (ft)
2 lanes	<30,000	4–6	2–4
	30,000–50,000	6–8	4–6
	50,000+	8–10	6–8
3+ lanes	<40,000	2–4	<2
	40,000–60,000	6–8	2–4
	60,000+	6–8	4–6

STATEWIDE FREEWAYS WITH BARRIERS

For statewide freeways with barriers:

- Low AADT (<30,000 vpd): 8–10 ft recommended to create a safety buffer around barriers, reducing vehicle strikes.
- Moderate AADT (30,000–60,000 vpd): 4–6 ft practical for urban retrofits, but 6–8 ft remains acceptable below 40,000 vpd.
- High AADT (60,000+ vpd): 6–8 ft baseline; <6 ft acceptable only in constrained urban upgrades with existing barrier systems.

Table summarizes these recommended shoulder widths for statewide freeways with barriers.

Table 46. Statewide freeways with barrier.

Lane Type	AADT Range	Recommended Width (ft)	Constrained Width Option (ft)
2 lanes	<30,000	8-10	6-8
	30,000–40,000	4–6	N/A
	40,000+	6–8	4–6
3+ lanes	<30,000	8-10	6-8
	30,000–60,000	8–10	4–6
	60,000+	6–8	<6 (retrofits)

Note: N/A – not applicable.

ATLANTA URBAN FREEWAYS

For truck percentage ≤5 percent:

- Low AADT (<100,000 vpd): ≥10 ft ideal for traffic in urban cores.
- High AADT (100,000+ vpd): 8–10 ft recommended; <4 ft acceptable in retrofits but suggests safety impact assessments.

For truck percentage 5–15 percent:

- Moderate AADT (75,000–150,000 vpd): 8–10 ft recommended; 6 ft acceptable in low-AADT truck routes.
- High AADT (150,000+ vpd): 4–6 ft practical in dense corridors; <2 ft common in legacy lanes but suggests safety enhancements.

For truck percentage >15 percent:

- All AADT: 8–10 ft prioritized for truck maneuvering below 150,000 vpd; narrow shoulders (<2 ft) for new truck lanes in high-density areas.

Table summarizes these recommended shoulder widths for Atlanta urban freeways with barriers.

Table 47. Atlanta urban freeways with barrier.

Truck Percentage	AADT Range	Recommended Width (ft)	Constrained Width Option (ft)
≤5	<100,000	≥10	8–10
	100,000+	8–10	<4 (retrofits)
5–10	<75,000	≥10	8–10
	75,000–150,000	8–10	6–8
	150,000+	4–6	<2 (retrofits)
10–15	<50,000	8–10	<4 (retrofits)
	50,000–150,000	8–10	<4 (retrofits)
	150,000+	4–6	<2 (retrofits)
>15	<75,000	8–10	<4 (retrofits)
	75,000–150,000	8–10	<4 (retrofits)
	150,000+	4–6	<2 (retrofits)

SOME INSIGHTS

Narrow shoulders measuring <4 ft are considered exceptions to the standard recommendations. They may only be used in specific contexts: low-AADT rural areas where traffic volume is minimal, dense urban retrofits where space constraints are severe, or projects with documented safety mitigation plans. Such plans may include enhanced lighting, shoulder edge markings, or other measures to compensate for reduced shoulder width and maintain safety.

Design approaches should vary based on regional characteristics. Rural districts may prioritize cost-effective narrow shoulder designs due to lower traffic volumes and budget considerations, while urban corridors should balance safety with limited right-of-way. In urban areas, new constructions should favor wider shoulders to enhance safety, whereas retrofits may suggest more flexible solutions that accommodate existing infrastructure.

Post-construction monitoring is essential to validate the effectiveness of shoulder width designs. Agencies should implement systematic crash data analysis, particularly in high-AADT corridors or areas with high truck percentages, to assess whether shoulder widths are reducing crash severity and improving operational safety. This feedback loop will enable ongoing refinement of design standards to meet evolving traffic needs. The recommendations will interpret in the context of AADT and truck percentage, as these factors most strongly influence when deviations from standard shoulder widths can be considered. Narrower shoulders may only be justified under constrained conditions where these factors indicate lower crash potential and where appropriate safety mitigations are applied.

This report provides a data-driven framework to enhance freeway safety across Georgia. By aligning designs with traffic volume, barrier presence, and truck dynamics, the guidelines strike a balance between safety optimization and contextual constraints in rural, suburban, and urban environments. Implementation can prioritize wider shoulders in elevated crash frequency scenarios, such as high-AADT corridors, barrier-separated freeways, or truck-heavy routes, while suggesting rigorous justification for narrow widths. This approach ensures long-term operational safety and supports GDOT's mission to deliver efficient, secure transportation infrastructure.

CHAPTER 8. CONSLUSIONS AND RECOMMENDATIONS

The objective of this study was to evaluate the linkage between inside shoulder width and crash history, which could help support use of a narrower shoulder width where the corridor is tightly constrained but is not meant to change shoulder width policy defined by AASHTO and FHWA. In line with this objective, the project conducted a comprehensive statewide analysis of the safety impact of inside (left) shoulder widths on Georgia freeways, integrating six years of traffic crash data (2018–2023), traffic volume data, and roadway inventory data. The research team developed Safety Performance Functions (SPFs) and Crash Modification Factors (CMFs) to quantify the relationship between left shoulder width and crash outcomes, including total crashes (KABCO), fatal and injury crashes (KAB), median-related crashes, and median-related KAB crashes across diverse freeway configurations.

The study demonstrated that wider inside shoulders improve safety outcomes, with effects varying by facility type, traffic volume, and crash severity. Wider inside shoulders (6–8 ft) were most effective across all facility types, particularly reducing the frequency of fatal/injury (KAB) and median-related crashes. This width range showed the strongest and most reliable safety benefits, with CMFs consistently below 1.0 relative to the baseline (≥10-ft shoulders). Narrow shoulders (<4 ft) were associated with elevated crash potential, especially at high AADT (>60,000 vpd) and high truck percentages (>10 percent), where CMFs often exceeded 1.0, indicating higher crash potential than the baseline. Median-related crashes revealed a unique pattern: shoulders 4–6 ft wide frequently underperformed compared to both narrower (2–4 ft) and wider (6–8 ft) alternatives, likely due to insufficient space for emergency maneuvers. Atlanta urban freeways with high truck percentages (>15 percent) suggests 8–10-ft shoulders to reduce crash potential, even at moderate AADT, highlighting the need for wider buffers in truck-heavy environments. Notably, safety benefits were more pronounced for severe crashes (KAB) and on barrier-separated freeways, where wider shoulders (8–10 ft) were critical for reducing vehicle-barrier impacts and enabling safe recovery.

The project's findings translate to evidence-based policy recommendations for left shoulder widths, tailored to Georgia's diverse freeway network, as follows:

- Statewide freeways without barriers: For two-lane segments, 4–6 ft may be considered for low AADT (<30,000 vpd), transitioning to 6–8 ft for moderate volumes (30,000–50,000 vpd) and 8–10 ft for high AADT (>50,000 vpd). For three-plus–lane segments, 2–4 ft suffices for low volumes (<40,000 vpd), but 6–8 ft is suggested for higher traffic, with narrower widths permitted with safety justification.
- Statewide freeways with barriers: Wider shoulders are prioritized to offset barrier proximity, with 8–10 ft recommended at low AADT (<30,000 vpd), 4–6 ft permitted for constrained urban retrofits at moderate volumes (30,000–60,000 vpd), and 6–8 ft suggested for higher AADT (>60,000 vpd).
- Atlanta urban freeways: Recommendations vary by truck percentage. For low-truck routes (<100,000 vpd), ≥10 ft is suggested. For moderate truck volumes (5–15%) and AADT of 75,000–150,000 vpd, 8–10 ft is recommended. In very high AADT corridors (>150,000 vpd), 4–6 ft may be acceptable in constrained areas. However, for high-truck corridors (>15%), 8–10 ft is suggested at AADT levels below 150,000 vpd, with narrower widths (<2 ft) permitted only in dense urban conditions and with safety justification.

The study faced limitations. First, some CMF trends appeared counter to past research directly on the topic of inside shoulder width and safety. These results should be interpreted with caution, as they may simply reflect artifacts of the dataset, such as corridor-specific characteristics and conditions rather than a true effect of shoulder width, insufficient sample sizes for rare configurations (e.g., very wide shoulders or specific lane-barrier-truck combinations), or crash histories dominated by events not directly linked to inside shoulders. In some cases, the degree of scatter in the data may also limit the reliability of apparent trends. Second, the reliance on observational crash data means that unmeasured factors (e.g., driver behavior, weather conditions) are not fully captured, while geolocation constraints make it difficult to definitively attribute crashes to the left shoulder. Given these uncertainties, conclusions should be validated against past research and treated as indicative rather than definitive. Future research should explore long-term impacts of shoulder width adjustments, particularly in high-growth urban areas like Atlanta, and validate findings with real-world implementation data. Expanding data collection to include more granular driver behavior metrics (e.g., lane departure events) could further refine CMFs and SPFs.

In summary, this project provides a data-driven framework for understanding the safety impact of left shoulder widths on Georgia freeways. By aligning designs with traffic volume, barrier presence, and truck dynamics, the recommendations balance safety and contextual constraints, prioritizing wider shoulders in elevated crash frequency scenarios (e.g., high AADT, barrier-separated corridors, truck-heavy routes) while allowing flexibility for low-traffic or constrained environments. These guidelines empower GDOT to enhance freeway safety, support efficient operations, and adapt to evolving transportation needs, ultimately advancing the mission of delivering secure, reliable infrastructure for all road users.

APPENDIX. SUMMARY OF SCHOLARLY RESEARCH ON THE SAFETY IMPACT OF LEFT (INSIDE) SHOULDER WIDTHS.

Table 48. Summary of scholar research on the safety impact of left (inside) shoulder widths.

Author(s)	Year	Study Region	Roadway Type	Inside Shoulder Type	Inside Shoulder Width	Data	Study Focus	SPF	CMF	Modeling Method	Safety Impact from Inside Shoulder
Zhao et al.	2015	China	Eight-lane, two-way divided freeway	Inside shoulders	0, 0.5, 0.75, 1.5, and 2.5 m, respectively	Driving simulation	Optimal width	No	No	ANOVA and the contrast analysis	Freeways with 0-ft shoulder width were the farthest from the center of the lane
Zhong et al.	2014	China	Six-lane, two-way divided freeway	Inside shoulders	0.75 m	Driving simulation	Recommended design width	No	No	Linear regression	Speed in the innermost lane increases as inner lateral clearance increases
Haleem et al.	2013	Florida	4- and ≥6-lane two-way urban freeways in interchange influence areas	Inside shoulders	4, 10, 11, and 12 ft	Crash data (2007–2010)	Inside shoulder, outside shoulder, and median width CMFs	No	Yes	Multivariate adaptive regression splines (MARS) and CMFs	Reduction in fatal and injury crashes—see build CMFs
Bauer et al.	2004	California	4- to 5-lane and 5- to 6-lane one-way divided urban freeways	Inside shoulders	2 ft, except for one instance each of 1 and 3 ft	Crash data (1991–2000)	Crash frequency before and after shoulder conversion to additional lane	No	No	EB technique to test for significant difference	Converting from 4 to 5 lanes results in an average of a statistically significant ~11% increase in total accidents and for fatal and injury accidents; accident increases resulting from the 5 to 6 lanes conversion were not statistically significant
Dixon et al.	2016	Dallas, Houston, and San Antonio, Texas	2- to 5-lane one-way divided urban freeway	Inside shoulders	Range of 1.5–11 ft	Crash data (2010–2013)	Prediction of freeway operational speeds and crash frequencies based on roadway characteristics	No	No	Stepwise regression	When all other variables are unchanged, a 1-ft increase in left shoulder width results in a 5% decrease in crashes
Dong et al.	2018	I-25 in Colorado	3- to 5- lane one-way freeway	Inside shoulders	Range of 5–15 ft	Crash data (unknown year)	Different probabilities and influences on single-vehicle and multi-vehicle crashes	No	No	Mixed logit model	Wider inside shoulders have different impacts on multi-vehicle crashes across road segments; on 75% of segments, they increase motor vehicle (MV) crash probability; on 25%, they decrease MV crash probability
Fitzpatrick et al.	2010	Rural Texas	Divided and undivided 4-lane two-way rural freeway	Inside shoulders as part of medians	Range of 0–10 ft	Crash data (1997–2001)	Horizontal curve AMFs (CMFs)	No	Yes	NB regression	Median width (including inside shoulder) has more of an impact on crashes on horizontal curves than tangents; wider medians generally result in fewer crashes

Liu et al.	2016	China	Underground 3-lane one-way urban expressway	Inside shoulders	0.5, 0.75, and 1 m	Driving simulation	Effects of lane and shoulder width on speed and lane deviation	No	No	ANOVA	Average speed in left lane increases as shoulder width increases; effect of left shoulder width has significant effect on lane deviation in left lane
Ni et al.	2023	China	Ten-lane two-way highways	Inside shoulders	2.5, 3, and 3.5 m	Driving simulation	Optimal left hard shoulder width	No	No	ANOVA with Bonferroni multiple comparison test	Drivers were closer to the center of the lane when the shoulder width was 3 m in both scenarios; speed was highest when shoulder was 3 m (still within safe range); stability was optimal when shoulder width was 3 m; yaw velocity is most stable for the 3 m shoulder
Zhao et al.	2022	China	Two-way six lane divided highway	Inside hard shoulders	2.5 m initially; range of 0–4 m	Traffic simulation (VISSIM) with crash data	Impact of left hard shoulder presence and width	No	Yes	Safety Surrogate Assessment Model (SSAM), multi-lane highway accident prediction model based on SPF	Accident rates decrease by ~1.5% for each additional 0.5 m of left hard shoulder (between 0 and 4 m); having a left hard shoulder decreases accidents by ~2.9% compared to not having one
Jafari Anarkooli et al.	2021	Ontario, Canada	Divided two-way freeway	Medians (inside shoulder included)	Range of 0–6 m	Crash data (2015–2017)	CMFs for median width with exploration of other cross-sectional factors	Yes	No	Full Bayesian Markov Chain Monte Carlo model and NB model	In all models, increasing left shoulder width decreases expected crashes; model parameters show left shoulder width has the largest influence on FI and total median-related crashes and the smallest influence on MV FI crashes
Fitzpatrick et al.	2008	Texas	Multilane urban divided and undivided freeways, multilane rural undivided highways	Inside shoulders	Range of 0–10 ft; 10 ft most common	Crash data (1997–2001)	Safety impacts of medians	No	Yes	NB regression	1.6% decrease in median-related crash frequency on freeways with barriers for 1-ft increase in total barrier offset (including shoulder width)
Hadi et al.	1995	Florida	Various; of interest, four-lane two-way and six-lane two-way urban freeways and rural freeways	Inside shoulders	4–6 ft	Crash data (1988–1991)	Optimal cross-sectional design	No	No	NB regression	4–6-ft inside shoulders effectively reduce crashes on rural freeways; 6-ft shoulders can reduce crash rate by 15.7%
Noland and Oh	2004	Illinois	urban and rural divided and undivided freeways, <4 lanes and multilane	Inside shoulders	Values not given	Crash data (1987–1990)	Significance of infrastructure changes on safety improvements	No	No	NB regression	Increasing inside shoulder width has no significant benefits for safety, though increases in outside shoulder width are associated with reduced crashes

Kitali et al.	2020	California	Four-lane, two-way divided express lanes	Inside hard shoulders	6 ft	Crash data (2012–2014)	Contributing factors to crash severity on express lanes	No	No	Support vector machines with Firefly optimization	The probability of injury/fatal crashes is 2.87% lower when inside shoulder widths are >6 ft as opposed to <6 ft
Chen et al.	2019	Unknown	Three classes of highway sections	Inside shoulders	Interstates: 4.562 ft (Mean), 1.765 ft (SD), 3 ft (Max), 8 ft (Min) State Roads: 0.647 ft (Mean), 1.614 ft (SD), 0 ft (Max), 6.21 ft (Min) US Roads: 1.337 ft (Mean), 2.061 ft (SD), 0 ft (Max), 6.85 ft (Min)	Crash data (unknown year)	Accident risk factors associated with highway traffic and roadway design (including inside shoulder design)	No	No	A bivariate modeling framework involving two levels of accident severity	Inside shoulder is the most sensitive compared to all other design features; for Interstate roads, a 1% increase in the inside shoulder width is associated with a 1.7248% decrease in casualty accidents and a 2.9666% decrease in no-casualty accidents
Chimba et al.	2017	Tennessee	highways	Inside shoulders	Not available	Crash data (2013–2016)	Median cable barrier safety effectiveness	Yes	No	Descriptive statistics and parametric tests; Empirical Bayes evaluation	Segments with wider shoulder widths experienced fewer number of crashes compared to narrow shoulder width segments as revealed by the negative coefficient in the model; inside shoulder width is a significant factor for after cable barrier model; however, the impact of the inside shoulder widths is highly correlated with that of cable offset
Guo et al.	2021	Texas	Texas roadways from RHiNO database	Inside shoulders	Inside shoulder width: 0 ft (Min), 25 ft (Max), 4.92 ft (Mean), 4.16 ft (SD)	Crash data, Phone use event data (2017–2019)	If phone use data can be used to predict distracted-affected crashes	Yes	No	Random Forest (RF) SPFs for distraction-affected crashes with and without the phone use data, separately	Four variables (i.e., number of lanes, peak hour factor, outside shoulder width, and inside shoulder width) are not significant at the 95% level, but they are still kept in the model as the primary purpose of the distraction-affected crash SPFs in this study is not for prediction; some variables, such as inside shoulder width and outside shoulder width, may be correlated, making the parameter estimates relatively unstable

Bisht and Tiwari	2022	Punjab, state of India	two-way four-lane highway	Inside shoulder	0,0–1.5,1.5–2.0, and 2.0–2.5 m	Crash data (2016–2018)	Impact of paved shoulder width on the frequency of fatal crashes in case of heterogeneous traffic on a rural four-lane divided highway	No	No	Case-control (C-C) method	The paved shoulder has safety benefits for all road users up to 1.5 m shoulder width; the provision of paved shoulders reduced the risk of all fatal crashes and improved the safety of pedestrians and slow-moving vehicles; however, the safety of motorized two-wheel (MTW) users reduced on segments having paved shoulder width more than 2 m; also, segments with a paved shoulder width of more than 1.5 m have a higher risk of rear-end fatal crashes than no shoulder segments
Mallipaddi and Anderson	2020	Huntsville, Alabama	Freeway weaving	Inside shoulders	1 ft (Min), 6 ft (Max), 3.05 ft (Mean), 1.39 ft (SD)	Crash data (2010–2017)	Impact of geometric design factors (including inside shoulder) and operational factors on total crashes and four crash types	No	Yes	Traditional NB approach and develop CMFs	Total crashes CMFs gradually decrease as inside shoulder width increases; this implies that widening shoulder width has positive effects on weaving section safety; meanwhile, total crashes CMFs gradually increase as outside shoulder width increases in type-A weaving sections indicating that wider outside shoulder widths have negative impacts on weaving section safety
Zhao et al.	2022	China`	One way of three, four , five lanes	Inside shoulders	0–4 m	Road and conflict simulation	Influence of the left hard shoulder on the safety of vehicles traveling on multi-lane highways	Yes	Yes	SPF in multi-lane highway accident prediction model derived from HSM; the model first introduces the CMF for different traffic and road conditions and then determines the correction factors based on the differences between the prediction models in space and time to predict future accidents	A single vehicle changing lanes continuously can have an impact on the speed of other vehicles and lead to an increased potential risk of collisions, thus illustrating the need for a left hard shoulder to reduce lane changes on multi-lane freeways; installing a hard left shoulder for a one-way five-lane highway can significantly reduce the number of accidents that occur

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the Georgia Department of Transportation (GDOT) for providing financial support, which was crucial to the successful implementation of this project. Special thanks are extended to Daniel Pass, Michelle Pate, Marcus Givens, Douglas Preece, Hoke Ward, and MD Sabbir Ahmed of GDOT for their exceptional support, insightful guidance, and valuable contributions that played a key role in the project's completion. In addition, the dedicated work of undergraduate students Joan White and Brandon Madden at the University of Alabama (UA) is deeply appreciated. The administrative support provided by Eileen Carroll at the University of Georgia and Sherri Mink at UA was equally invaluable, and their contributions are warmly recognized.

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APPENDIX A

CMF Plots by Truck Percentage and AADT

A 1-1: Average CMFs for KAB crashes – Atlanta Urban with barrier

A 1-2: Average CMFs for median-related KAB crashes – Atlanta Urban with barrier

A 1-3: Average CMFs for all crashes – Atlanta Urban with barrier

A 1-4: Average CMFs for median-related crashes – Atlanta Urban with barrier

A 2-1: Average CMFs for KAB crashes – Statewide with barrier

A 2-2: Average CMFs for median-related KAB crashes – Statewide with barrier

A 2-3: Average CMFs for all crashes – Statewide with barrier

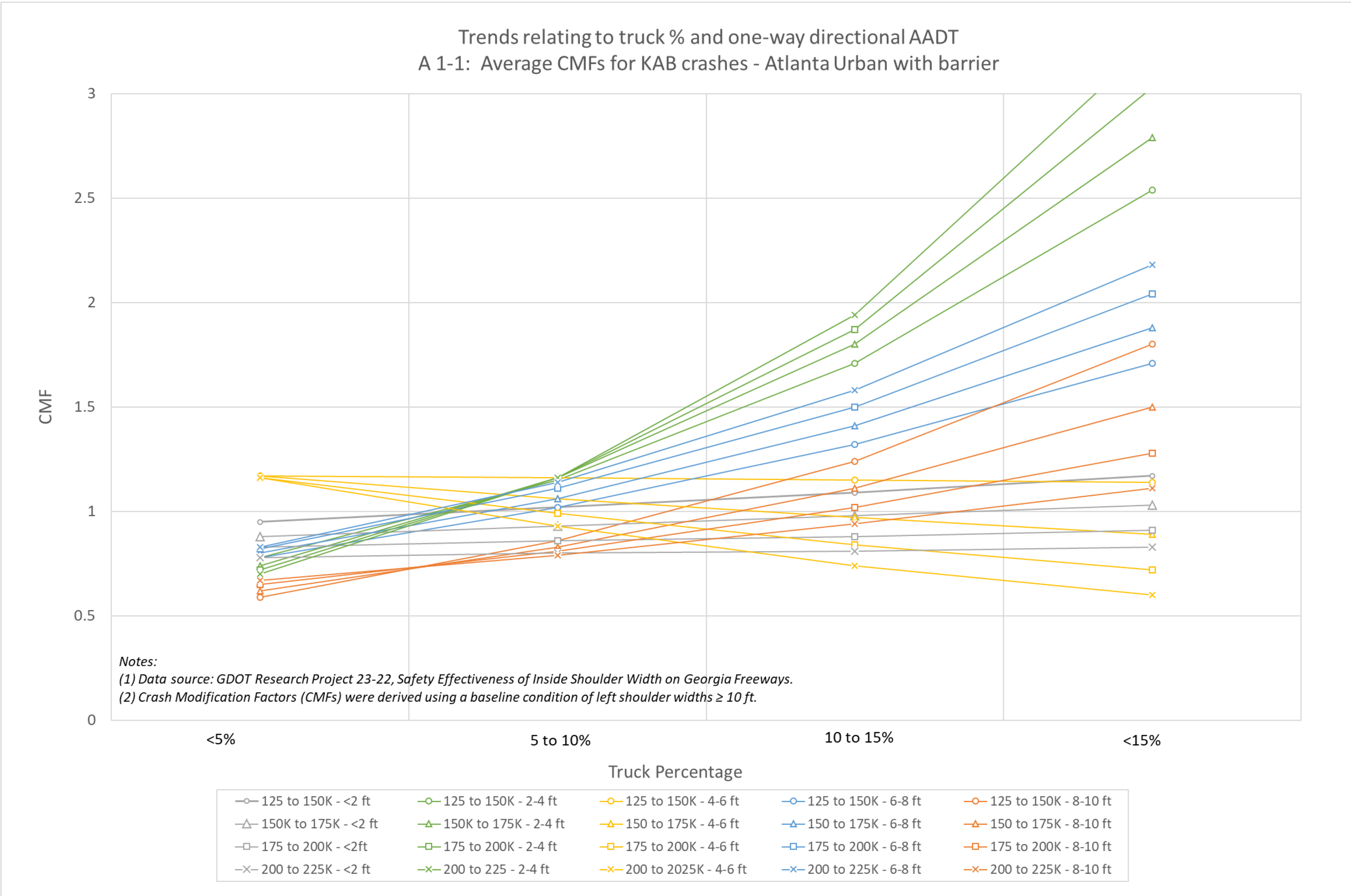
A 2-4: Average CMFs for median-related crashes – Statewide with barrier

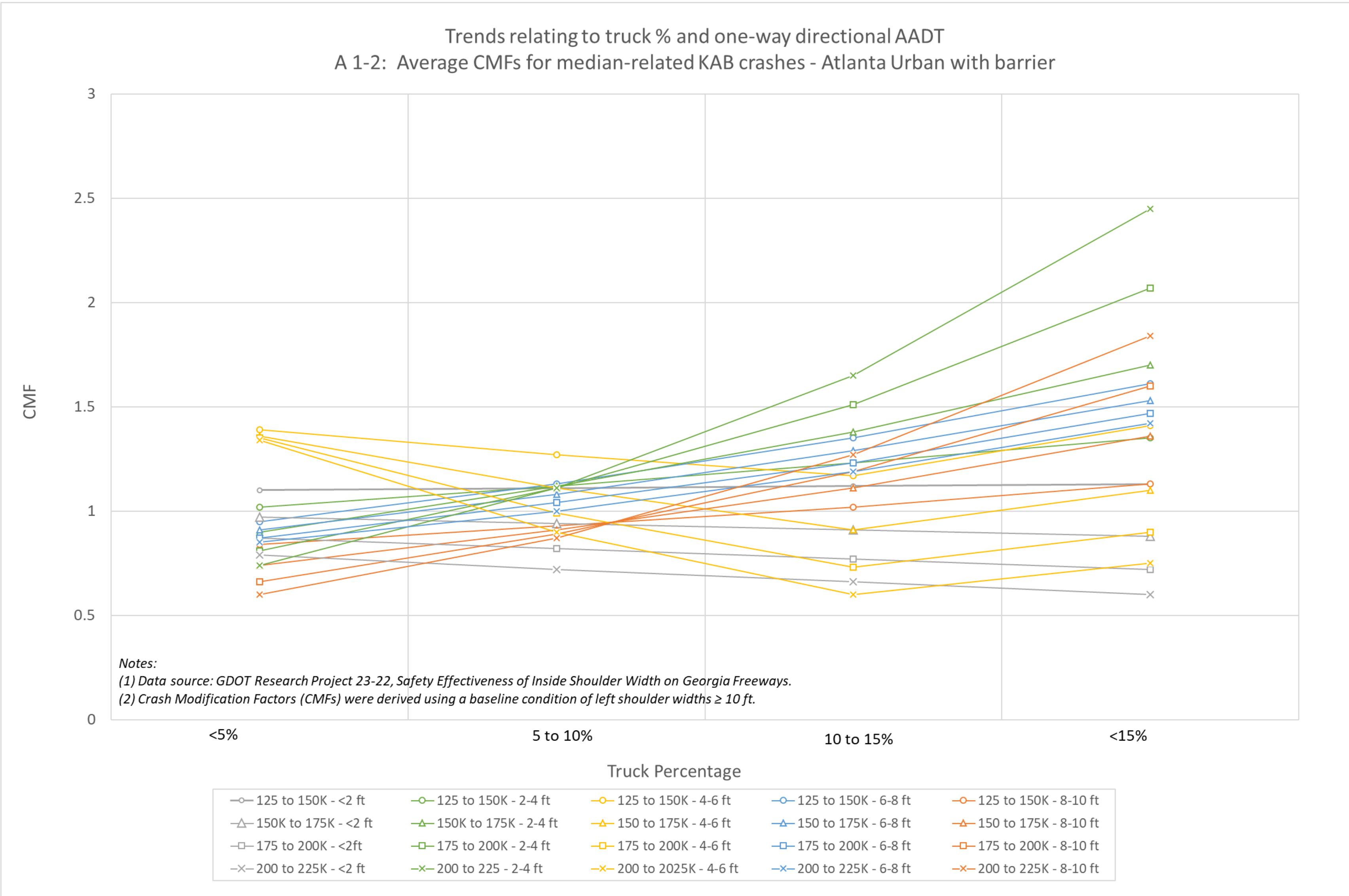
A 3-1: Average CMFs for KAB crashes – Statewide without barrier

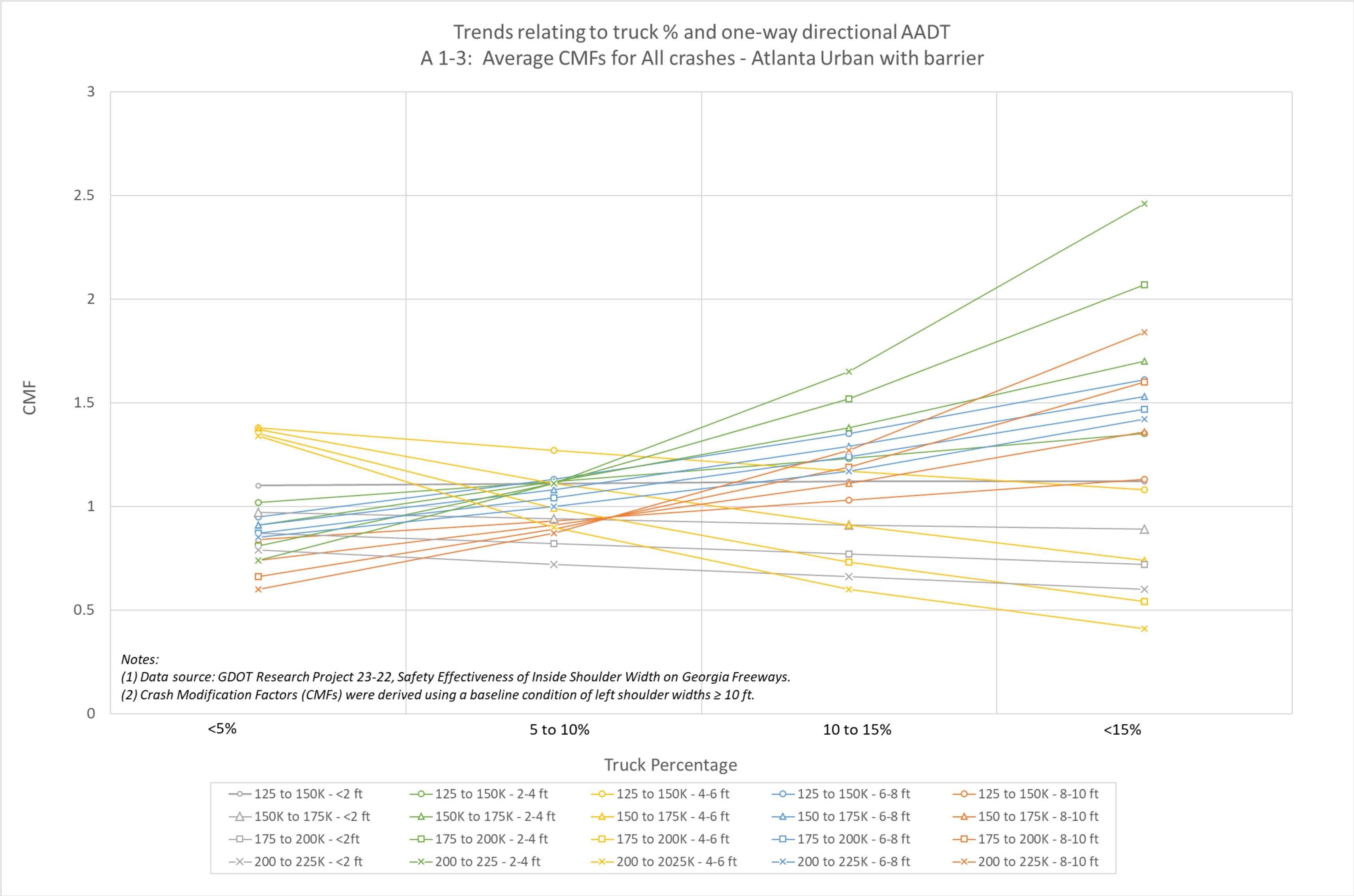
A 3-2: Average CMFs for median-related KAB crashes – Statewide without barrier

A 3-3: Average CMFs for all crashes – Statewide without barrier

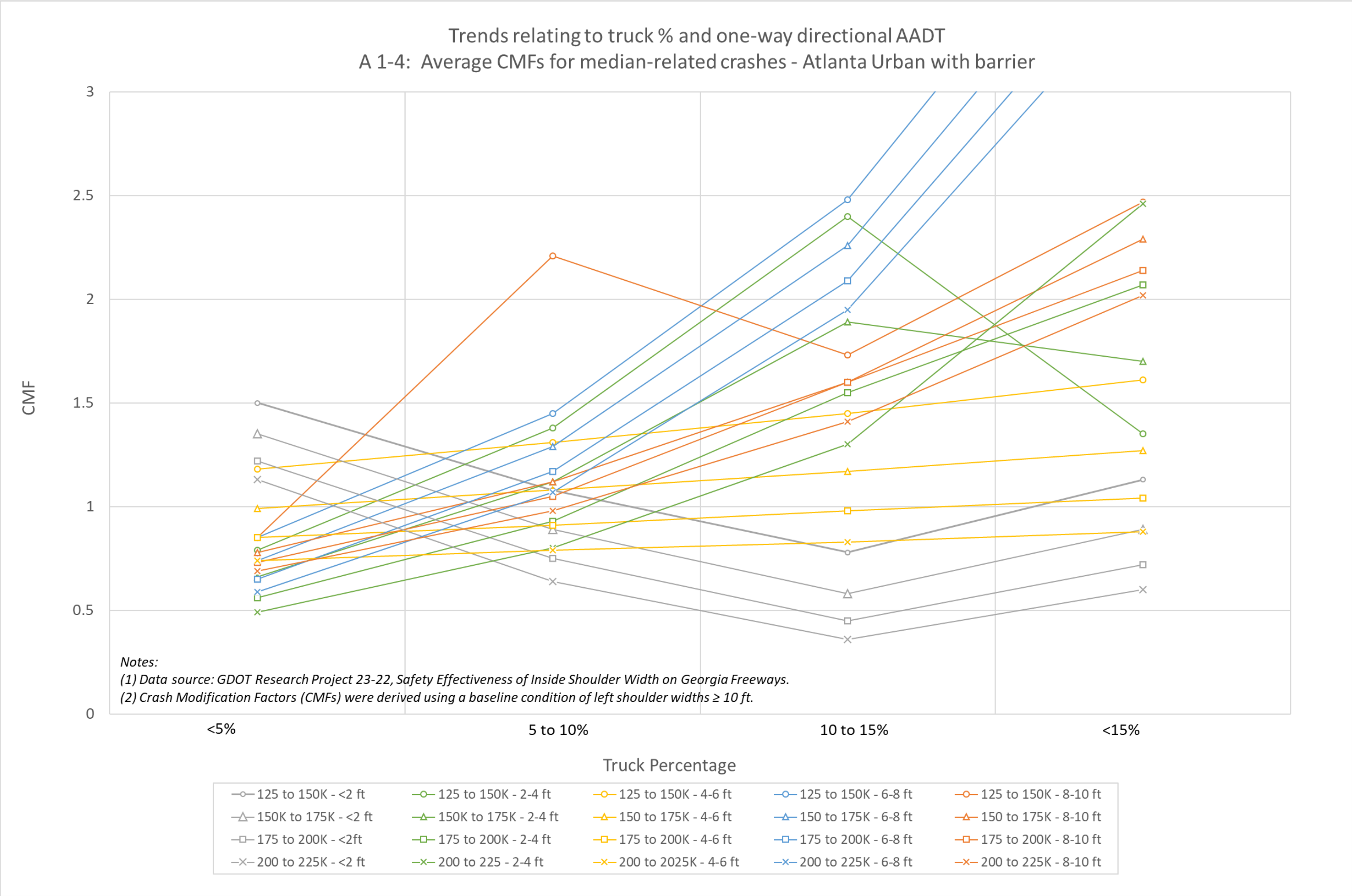
A 4-4: Average CMFs for median-related crashes – Statewide without barrier

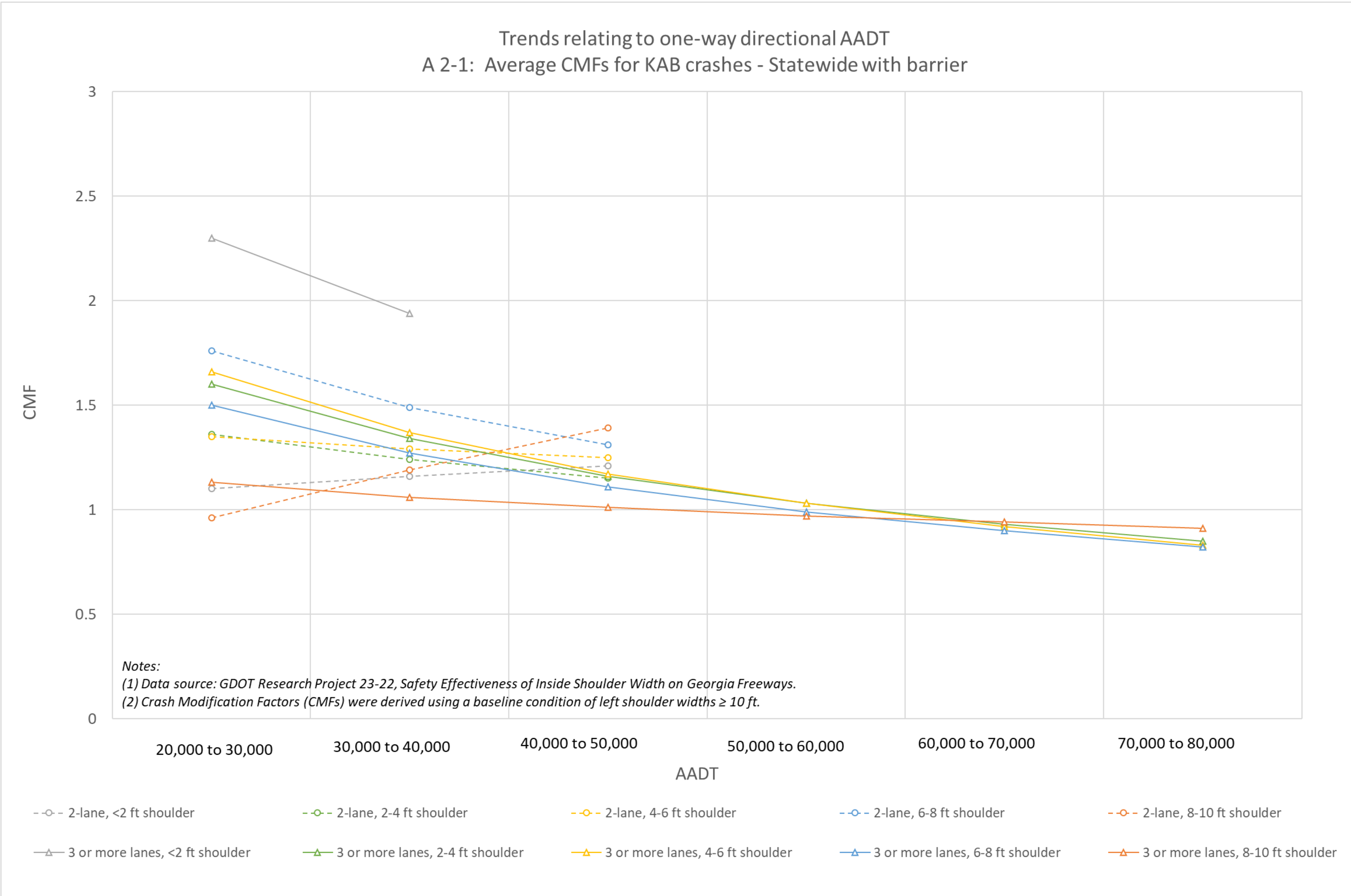

Trends relating to truck % and one-way directional AADT
A 1-1: Average CMFs for KAB crashes - Atlanta Urban with barrier
CMF
3
2.5
2
1.5
1
0.5
0
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
<5%
5 to 10%
10 to 15%
<15%
Truck Percentage
125 to 150K - <2 ft
125 to 150K - 2-4 ft
125 to 150K - 4-6 ft
125 to 150K - 6-8 ft
125 to 150K - 8-10 ft
150K to 175K - <2 ft
150K to 175K - 2-4 ft
150 to 175K - 4-6 ft
150 to 175K - 6-8 ft
150 to 175K - 8-10 ft
175 to 200K - <2ft
175 to 200K - 2-4 ft
175 to 200K - 4-6 ft
175 to 200K - 6-8 ft
175 to 200K - 8-10 ft
200 to 225K - <2 ft
200 to 225 - 2-4 ft
200 to 2025K - 4-6 ft
200 to 225K - 6-8 ft
200 to 225K - 8-10 ft

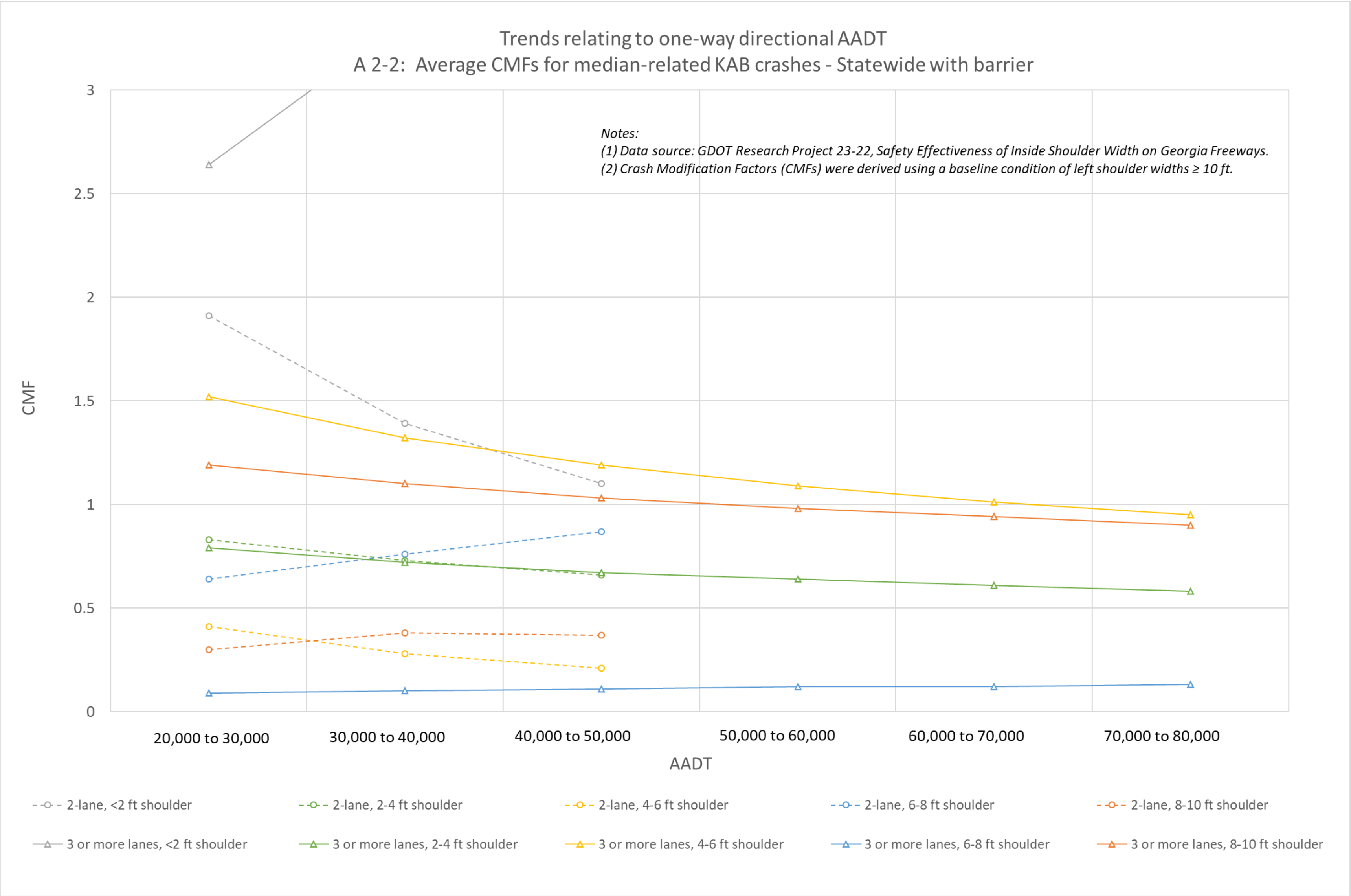

Trends relating to truck % and one-way directional AADT
A 1-2: Average CMFs for median-related KAB crashes - Atlanta Urban with barrier
CMF
3
2.5
2
1.5
1
0.5
0
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
<5%
5 to 10%
10 to 15%
<15%
Truck Percentage
125 to 150K - <2 ft
125 to 150K - 2-4 ft
125 to 150K - 4-6 ft
125 to 150K - 6-8 ft
125 to 150K - 8-10 ft
150K to 175K - <2 ft
150K to 175K - 2-4 ft
150 to 175K - 4-6 ft
150 to 175K - 6-8 ft
150 to 175K - 8-10 ft
175 to 200K - <2ft
175 to 200K - 2-4 ft
175 to 200K - 4-6 ft
175 to 200K - 6-8 ft
175 to 200K - 8-10 ft
200 to 225K - <2 ft
200 to 225 - 2-4 ft
200 to 2025K - 4-6 ft
200 to 225K - 6-8 ft
200 to 225K - 8-10 ft



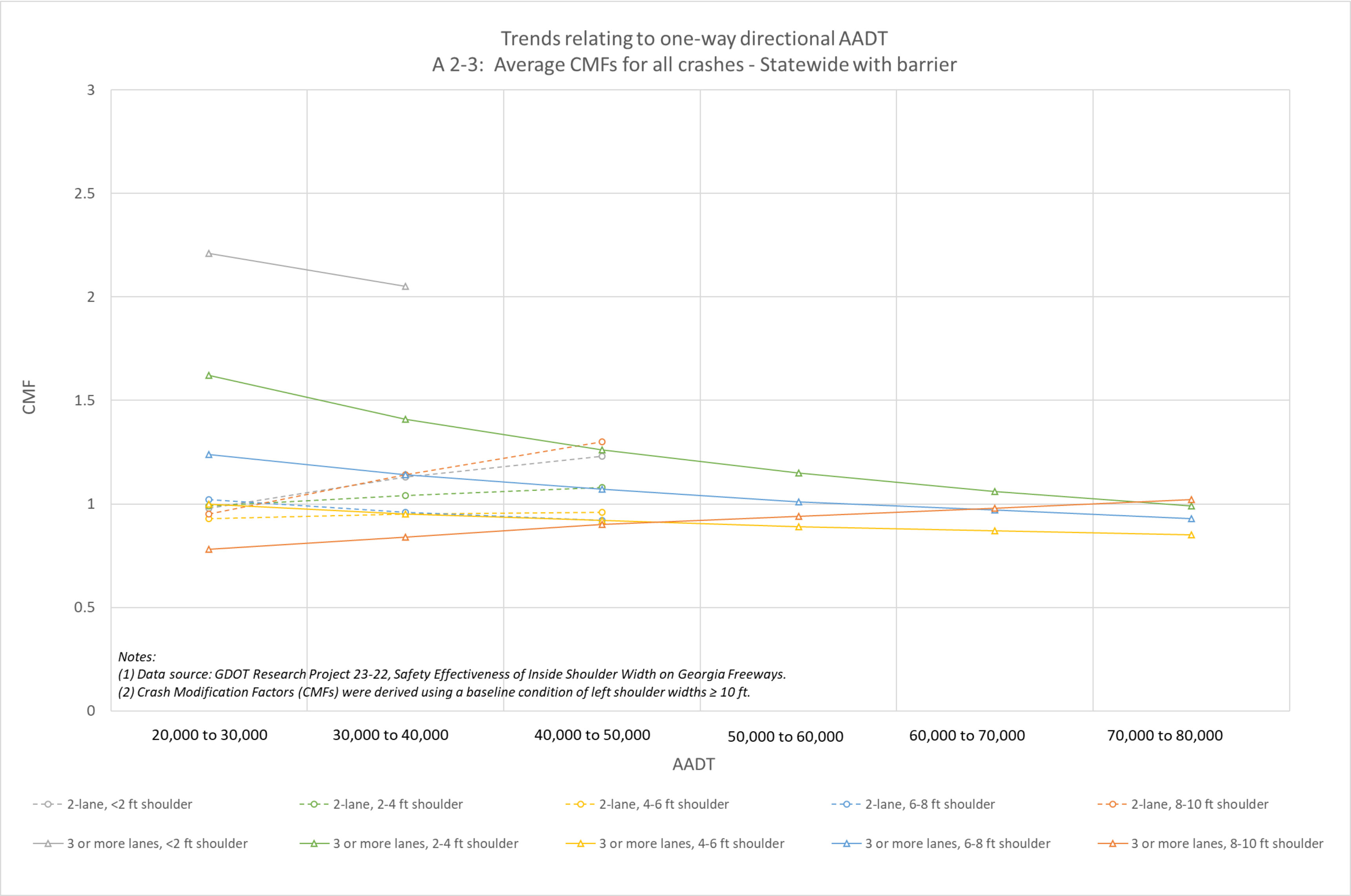
Trends relating to truck % and one-way directional AADT
A 1-3: Average CMFs for All crashes - Atlanta Urban with barrier
CMF
3
2.5
2
1.5
1
0.5
0
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
<5%
5 to 10%
10 to 15%
<15%
Truck Percentage
125 to 150K - <2 ft
125 to 150K - 2-4 ft
125 to 150K - 4-6 ft
125 to 150K - 6-8 ft
125 to 150K - 8-10 ft
150K to 175K - <2 ft
150K to 175K - 2-4 ft
150 to 175K - 4-6 ft
150 to 175K - 6-8 ft
150 to 175K - 8-10 ft
175 to 200K - <2ft
175 to 200K - 2-4 ft
175 to 200K - 4-6 ft
175 to 200K - 6-8 ft
175 to 200K - 8-10 ft
200 to 225K - <2 ft
200 to 225 - 2-4 ft
200 to 2025K - 4-6 ft
200 to 225K - 6-8 ft
200 to 225K - 8-10 ft

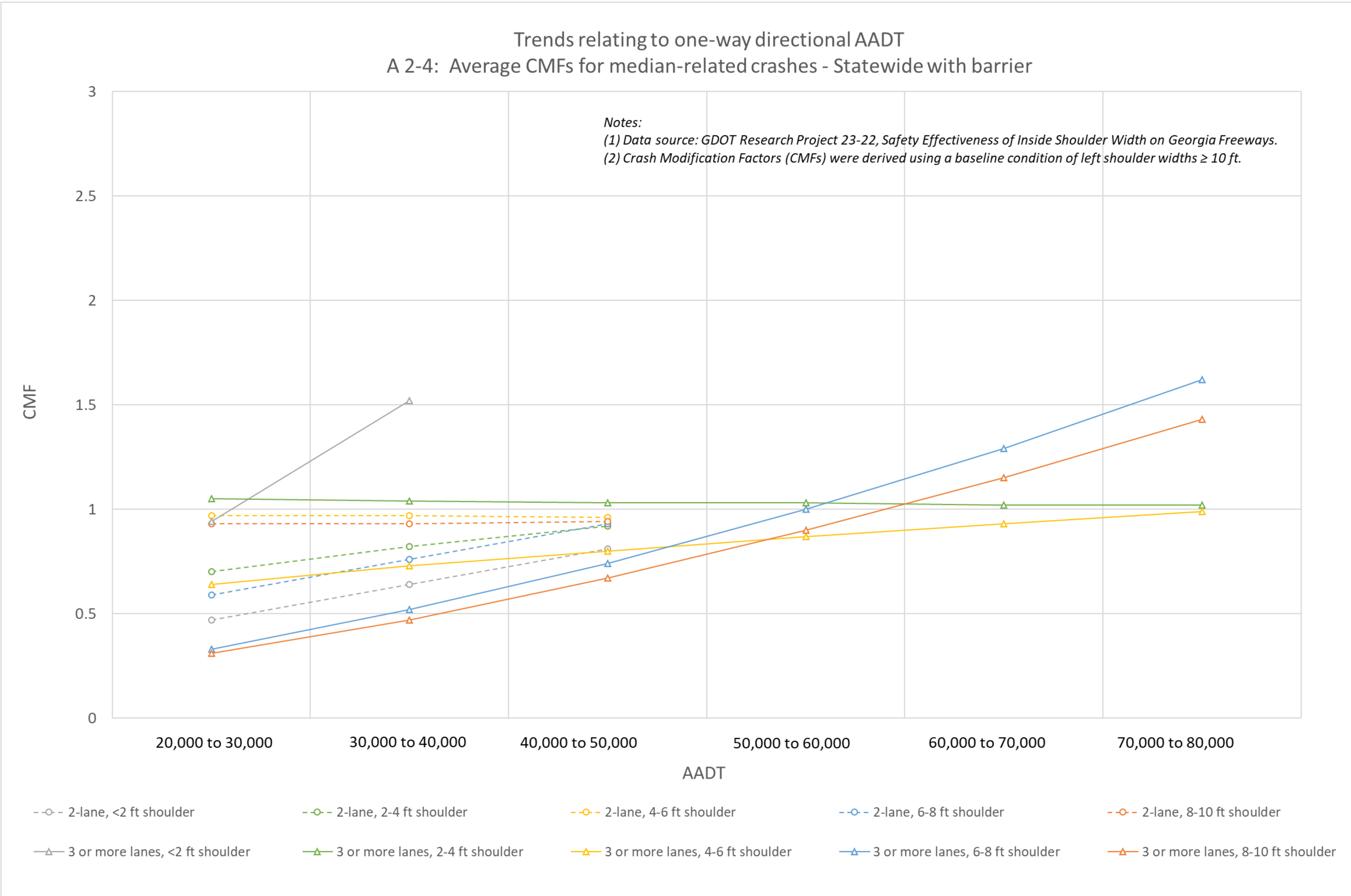

Trends relating to truck % and one-way directional AADT
A 1-4: Average CMFs for median-related crashes - Atlanta Urban with barrier
CMF
3
2.5
2
1.5
1
0.5
0
<5%
5 to 10%
10 to 15%
<15%
Truck Percentage
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
125 to 150K - <2 ft
125 to 150K - 2-4 ft
125 to 150K - 4-6 ft
125 to 150K - 6-8 ft
125 to 150K - 8-10 ft
150K to 175K - <2 ft
150K to 175K - 2-4 ft
150 to 175K - 4-6 ft
150 to 175K - 6-8 ft
150 to 175K - 8-10 ft
175 to 200K - <2ft
175 to 200K - 2-4 ft
175 to 200K - 4-6 ft
175 to 200K - 6-8 ft
175 to 200K - 8-10 ft
200 to 225K - <2 ft
200 to 225 - 2-4 ft
200 to 2025K - 4-6 ft
200 to 225K - 6-8 ft
200 to 225K - 8-10 ft

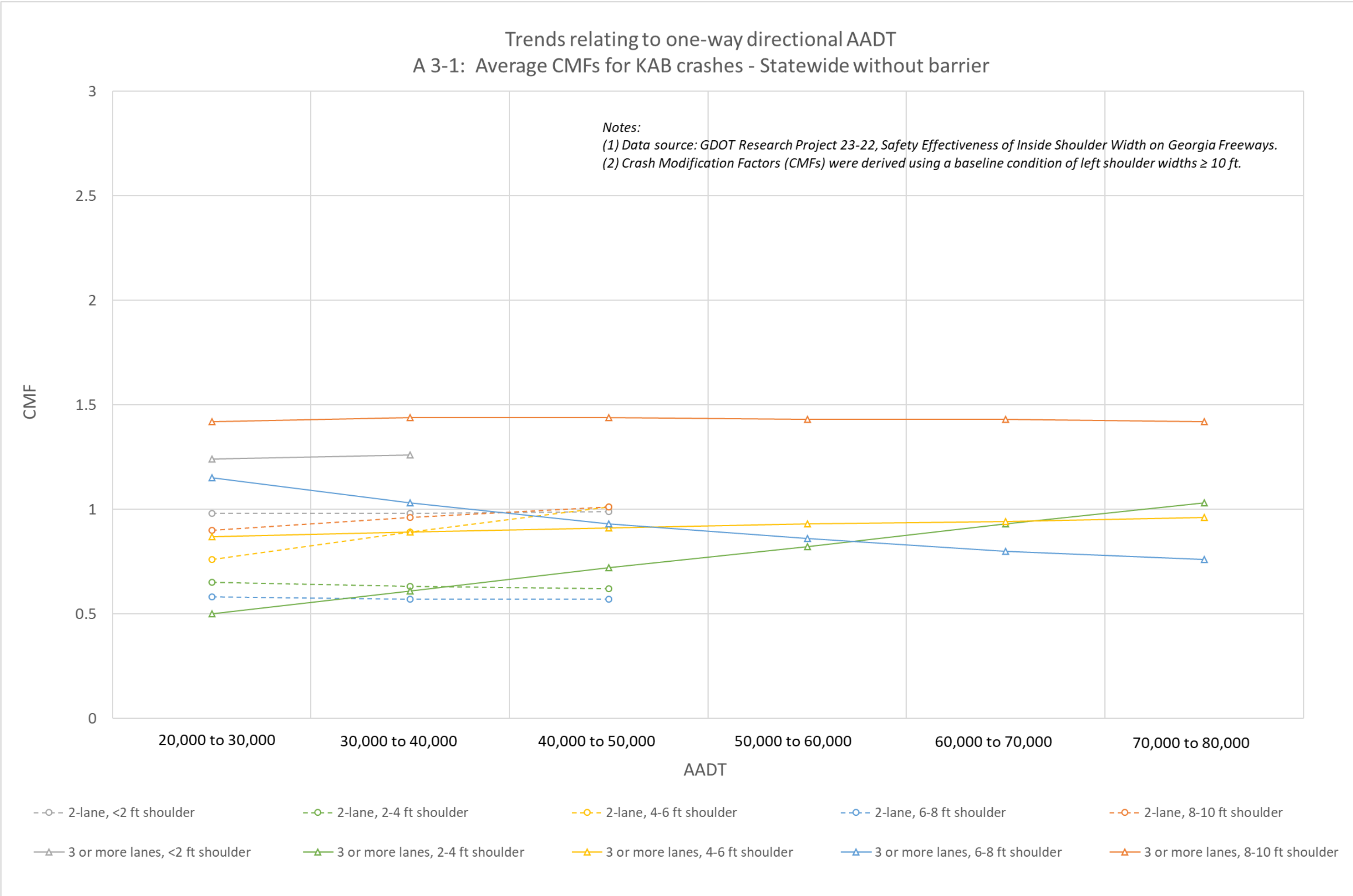

Trends relating to one-way directional AADT
A 2-1: Average CMFs for KAB crashes - Statewide with barrier
CMF
3
2.5
2
1.5
1
0.5
0
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder

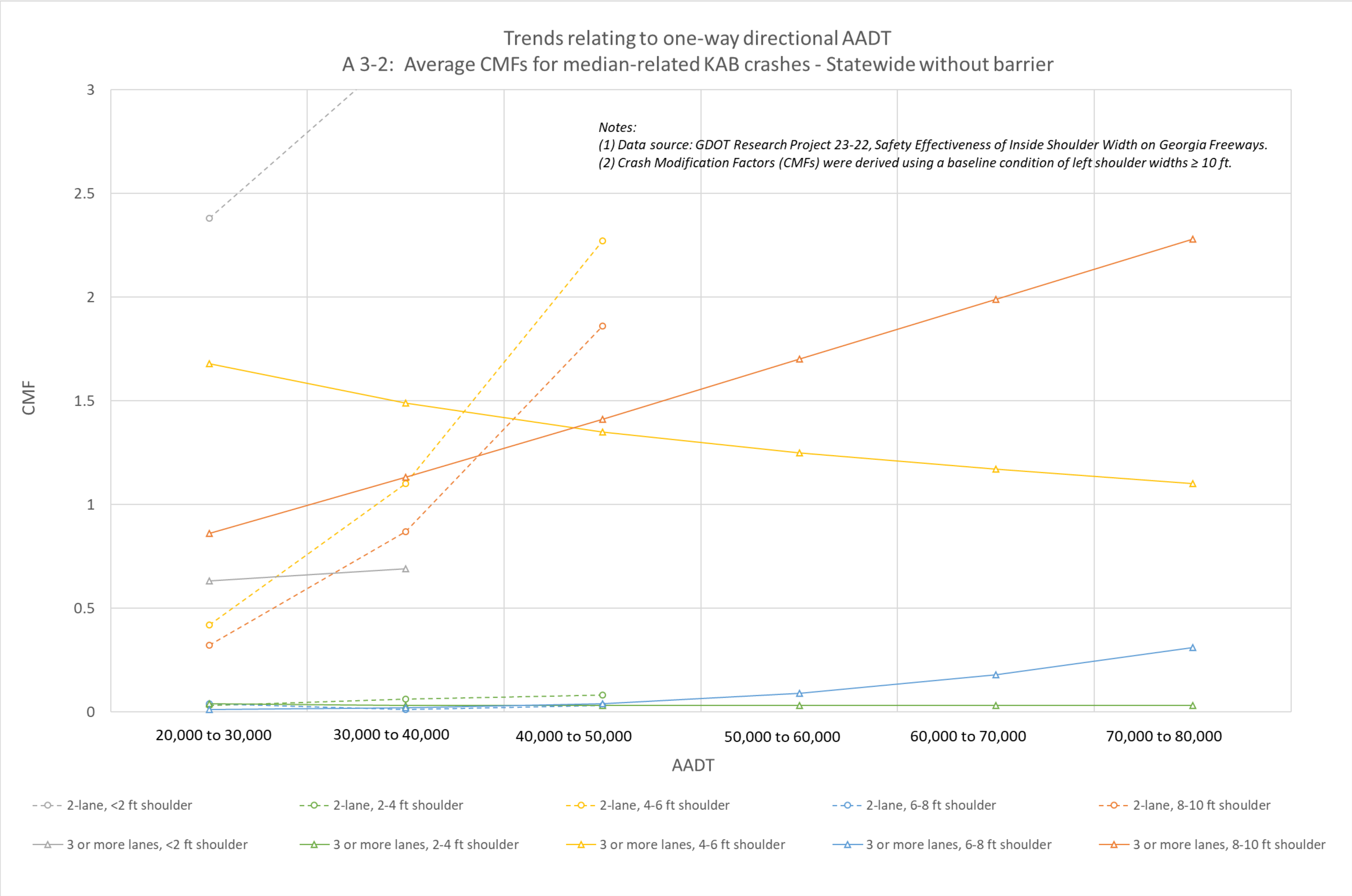


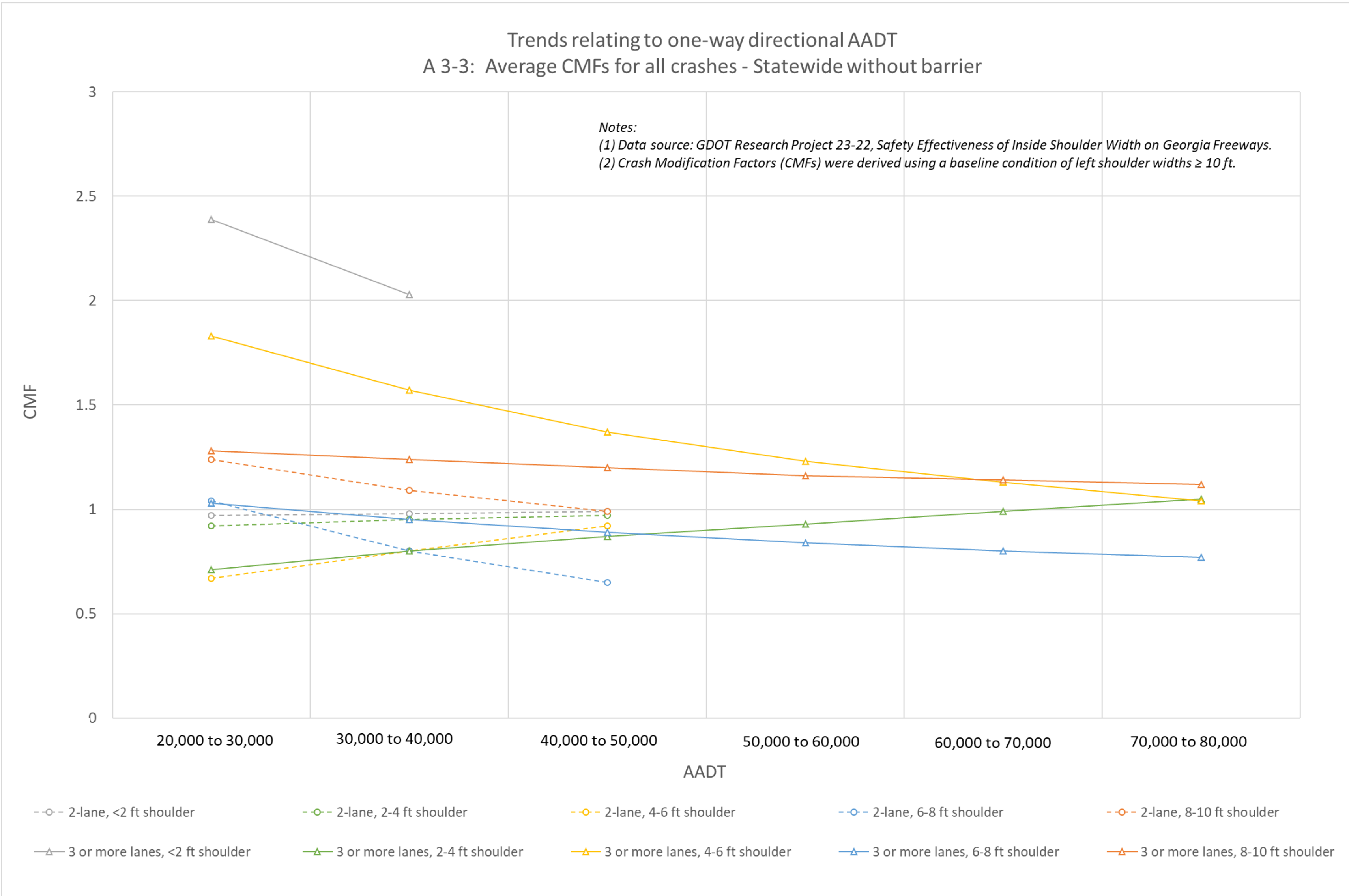
Trends relating to one-way directional AADT
A 2-2: Average CMFs for median-related KAB crashes - Statewide with barrier
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
CMF
3
2.5
2
1.5
1
0.5
0
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder

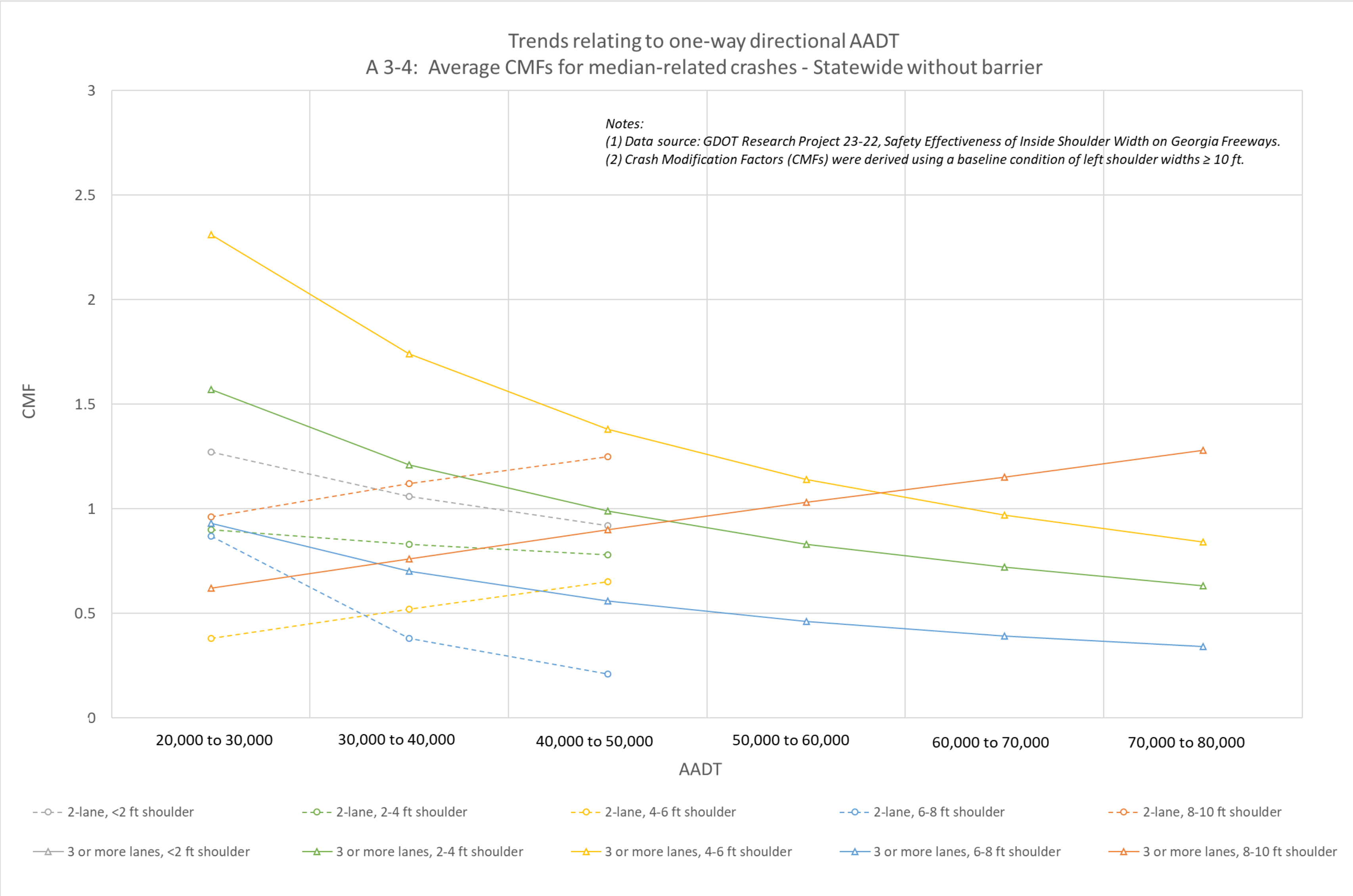

Trends relating to one-way directional AADT
A 2-3: Average CMFs for all crashes - Statewide with barrier
CMF
3
2.5
2
1.5
1
0.5
0
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder


Trends relating to one-way directional AADT
A 2-4: Average CMFs for median-related crashes - Statewide with barrier
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
CMF
3
2.5
2
1.5
1
0.5
0
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder


Trends relating to one-way directional AADT
A 3-1: Average CMFs for KAB crashes - Statewide without barrier
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
CMF
3
2.5
2
1.5
1
0.5
0
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder


Trends relating to one-way directional AADT
A 3-2: Average CMFs for median-related KAB crashes - Statewide without barrier
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
CMF
3
2.5
2
1.5
1
0.5
0
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder


Trends relating to one-way directional AADT
A 3-3: Average CMFs for all crashes - Statewide without barrier
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
CMF
3
2.5
2
1.5
1
0.5
0
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder


Trends relating to one-way directional AADT
A 3-4: Average CMFs for median-related crashes - Statewide without barrier
Notes:
(1) Data source: GDOT Research Project 23-22, Safety Effectiveness of Inside Shoulder Width on Georgia Freeways.
(2) Crash Modification Factors (CMFs) were derived using a baseline condition of left shoulder widths ≥ 10 ft.
CMF
3
2.5
2
1.5
1
0.5
0
20,000 to 30,000
30,000 to 40,000
40,000 to 50,000
50,000 to 60,000
60,000 to 70,000
70,000 to 80,000
AADT
2-lane, <2 ft shoulder
2-lane, 2-4 ft shoulder
2-lane, 4-6 ft shoulder
2-lane, 6-8 ft shoulder
2-lane, 8-10 ft shoulder
3 or more lanes, <2 ft shoulder
3 or more lanes, 2-4 ft shoulder
3 or more lanes, 4-6 ft shoulder
3 or more lanes, 6-8 ft shoulder
3 or more lanes, 8-10 ft shoulder