GEORGIA DOT RESEARCH PROJECT 22-35

FINAL REPORT

DEVELOPMENT OF AREA-SPECIFIC LANE DISTRIBUTION FACTORS FOR PAVEMENT DESIGN

OFFICE OF PERFORMANCE-BASED MANAGEMENT AND RESEARCH

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16. Abstract

Lane Distribution Factor (LDF) is a critical input for pavement design, and the Georgia Department of Transportation (GDOT) is currently using outdated design LDF values based on old traffic data. To address this issue, a previous study (RP 21-11) was conducted to update statewide design LDF values. The study recommended the adoption of separate LDF tables for different area/facility types to support GDOT's pavement design practice. However, this finding raises the question of whether specific LDF values should be considered for freight-intensive areas, such as Savannah and Atlanta. Additionally, the previous study was based on four-year (2018-2021) data, which covers only pre-COVID and COVID periods. As COVID restrictions have been removed and life has returned to normal in 2022, this study also aims to evaluate whether there is any remaining COVID impact on LDFs using the latest 2022 data.

The results of this study show that LDF values vary significantly across different geographical areas characterized by different municipalities. Atlanta Metro and Macon share similar LDF values while Savannah maintains its own LDF values as compared to the rest of the State. Additionally, no COVID-related impact on LDF was found based on the 2022 data. To facilitate pavement design practice, three sets of LDF tables were developed for three sub-areas, including (1) Atlanta Metro/Macon region, (2) Savannah region, and (3) the rest of the State, referred to as the Statewide region.

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Lane Distribution Factor, Annual Average Daily Traffic, Continuous Count Station, Pavement Design, Weigh-in-Motion, Statistical Analysis, Logistic Regression	No Restrictions

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Final Report

DEVELOPMENT OF AREA-SPECIFIC LANE DISTRIBUTION FACTORS FOR PAVEMENT DESIGN

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DISCLAIMER STATEMENT

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

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EXECUTIVE SUMMARY

The Georgia Department of Transportation (GDOT) currently uses the Lane Distribution Factor (LDF) values that were last updated in 1983. Since then, traffic characteristics have changed dramatically due to significant economic growth, demographic changes, and expansion of the highway network in Georgia. This study serves as a continuation of the previous study (RP 21-11) that used four-year (2018-2021) data to update the LDF values. The previous study concluded that the area and facility type were both significant features underlying the variance of LDF and it was suggested that GDOT adopt different design tables for different area/facility types. This study aims to answer two questions that were not addressed in the previous study: (1) Should specific LDF values be considered for specific freight intensive areas (e.g., Savannah and Atlanta) in Georgia? (2) Are there any residual COVID impact on LDF in the post-pandemic era as reflected in the latest 2022 data? Based on the data analysis, it was discovered that there are significant variations in LDF values across different regions in Georgia. The Atlanta Metro and Macon exhibit similar LDF values, while Savannah maintains its own LDF values as compared to the rest of the state. Furthermore, the 2022 data did not reveal any COVID-related impact on LDFs. To facilitate pavement design practice, three sets of LDF tables were developed for each of the three subareas. These include (1) Atlanta Metro/Macon, (2) Savannah, and (3) the rest of the state.

INDEX WORDS: Lane Distribution Factor, Annual Average Daily Traffic, Continuous Count Station, Pavement Design, Weigh-in-Motion, Statistical Analysis, Logistic Regression.

CHAPTER 1. INTRODUCTION

BACKGROUND AND PROBLEM STATEMENT

The Lane Distribution Factor (LDF) is one of the key pavement design parameters for determining the amount of 18-kip ESALs (Equivalent Single-Axle Load) in the design lane. The LDF is defined as the percentage of truck traffic that is traveling in the outside lane (design lane) of a multi-lane highway. Due to the multiplicative effect of LDF on the design ESAL, the accuracy of LDF is crucial to pavement design. The Georgia Department of Transportation (GDOT) uses the Pavement Design Manual (GDOT, 2022) for designing pavements in the state of Georgia. In the previous study (RP 21-11), statewide LDF design values were developed for different area and facility types, including urban versus rural areas and interstate versus other facilities. However, freight-intensive areas such as Metro Atlanta and Savannah may have unique truck traffic lane distribution patterns that were not fully accounted for in the previous study. Furthermore, given the availability of new 2022 data, it is important to assess any lingering effects of COVID-19 on LDFs. To better support GDOT's pavement design practice, an updated statistical analysis is needed to address these concerns.

STUDY OBJECTIVES

The primary objectives of this study are:

1. To evaluate LDFs in the post-COVID era using the 2022 CCS data.
2. To assess the geospatial variation of LDFs and develop area-specific LDFs as necessary.

CHAPTER 2. LITERATURE REVIEW

LANE DISTRIBUTION FACTOR

The Lane Distribution Factor (LDF) is simply defined as the percentage of truck volumes traveling in the outermost lane, referred to as the design lane, to the total truck volumes of all lanes in one travel direction (Lu & Harvey 2006). LDF is one of the critical pavement design parameters, which determines the amount of 18-kip ESAL (Equivalent Single Axle Load) in the design lane. Equation 1 is typically used to estimate the design ESAL. Considering the multiplicative effect of LDF on the design ESAL, it is important to ensure the accuracy of LDF to avoid potential over- or under-design of pavement.

$$\mathrm{ESAL}_{\mathrm{Design}} = \left(\frac{\mathrm{ADT}_1 + \mathrm{ADT}_N}{2}\right) \times \sum_i (\mathrm{P}_i \times \mathrm{LEF}_i) \times 365 \times \mathrm{N} \times \mathrm{DDF} \times \mathrm{LDF} \qquad (1)$$

where,

P_i = percent of vehicles in each of the three categories: (1) passenger cars and pickup trucks, (2) single unit trucks, and (3) combination trucks.

LEF_i = load equivalency factor for each of the three vehicle categories above.

N = design period in years (e.g., 20 years)

DDF = directional distribution factor

LDF = lane distribution factor

Generally, LDF varies by area/facility type, the number of lanes, and traffic volume. For two-lane highways, (one lane in each direction), the LDF is 1.0, where drivers have no choice but to use the only lane available. For facilities of more than one lane in each direction, LDF varies by other factors, such as AADT, geometric, and site-specific conditions (Haider et al. 2018). Typically, LDF decreases with the increase in the number of lanes as more lane options are available to drivers. Based on field observations, the outermost lane usually carries the highest percentage of truck traffic, referred to as the design lane for the purpose of pavement design.

The LDF values currently adopted in the Pavement Design Manual (GDOT, 2022) are shown in Table 1 with recommended values by the number of lanes in one direction.

Table 1. Lane Distribution Factors by Facility Type (GDOT Pavement Design Manual 2022)

# of Lanes in one direction	LDF (%)
1	100
2	90
3	80
4+	70

The AADT-specific LDF values adopted in the previous Pavement Design Manual (GDOT, 2019) are shown in Table 2.

Table 2. Lane Distribution Factors for Multilane Highways
(GDOT Pavement Design Manual 2019)

One Way ADT	2 Lanes (one Direction)		3+ Lanes (one-Direction)		
	Inner	Outer	Inner*	Center	Outer
2,000	6**	94	6	12	82
4,000	12	88	6	18	76
6,000	15	85	7	21	72
8,000	18	82	7	23	70
10,000	19	81	7	25	68
15,000	23	77	7	28	65
20,000	25	75	7	30	63
25,000	27	73	7	32	61
30,000	28	72	8	33	59
35,000	30	70	8	34	58
40,000	31	69	8	35	57
50,000	33	67	8	37	55
60,000	34	66	8	39	53
70,000	--	--	8	40	52
80,000	--	--	8	41	51
100,000	--	--	9	42	49

* Combined inner one or more lanes.
** Percent of all trucks in one direction (note that the proportion of trucks in one direction sums to 100 percent).

It is important to note that the LDF values presented in Table 2 are based on a study conducted back in 1982-1983. Since then, Georgia's traffic patterns have undergone significant changes, particularly in the last decade, as the state's economy and population have grown, and demographics have shifted. The current LDFs may not accurately reflect the actual truck traffic lane distributions, given that they are outdated. Therefore, a new study is needed that relies on the latest lane-specific vehicle counts and classification data to verify and, if necessary, update the LDF values. This would better support GDOT's pavement design practice.

REVIEW OF PREVOUS STUDIES

The literature review reveals limited research on estimating LDFs. The most relevant studies are summarized in this section. Albright and Blewett (1988) conducted a study in which a model was developed to estimate LDF values on tangent sections of the New Mexico rural interstates. Based on the study, the total vehicle volume and truck percentage are statistically significant in terms of truck lane use and should be considered as explanatory variables. Another study (Fwa and Li, 1995) was conducted in Singapore to evaluate the effects of certain factors on the lane distribution of trucks. These factors include the functional class of roads, the number of travel lanes, the total directional traffic volume, and the volume of truck traffic. Statistical regression models were developed to estimate truck volume in the critical lane. The study indicated that changes in land-use development, economic, and social structures are effective on travel characteristics, traffic flow composition, and hence lane distribution factors. Thus, it is necessary for highway agencies to develop their own regression models and update them periodically to reflect such changes and provide more accurate LDF for pavement design.

Besides the regression approach, machine learning approach (e.g., clustering) was attempted as well. Lu and Harvey (2006) utilized WIM data to characterize truck traffic to assist with mechanistic–

empirical pavement design in California. Kernel density estimation was performed to estimate the density function of LDF for highways with different numbers of lanes. The analysis showed that when there are two lanes in one travel direction, more than 90% of the truck traffic will use the outside lane, and when there are three or more lanes in one travel direction, more than 90% of the truck traffic will use the outermost two lanes.

CHAPTER 3. RESEARCH APPROACH

This research project involves collecting and processing the latest (year 2022) lane-based vehicle count and classification data from all active CCS sites throughout the state of Georgia. This latest data, combined with the data obtained through the previous study (RP21-11), is utilized to estimate area-specific LDFs to support GDOT's pavement design practice.

TRAFFIC DATA COLLECTION

The GDOT's Office of Transportation Data (OTD) has a comprehensive traffic count program. Traffic data is collected by permanent continuous count stations (CCS), portable count stations, continuous weigh-in-motion (permanent WIM) sites, and temporary weigh-in-motion sites (Wiegand 2018). Besides the four-year (2018-2021) CCS data obtained in the previous project (RP 21-11), the lane-specific vehicle count and classification data for the most recent year (2022) were obtained from all active CCS in Georgia. The WIM data from 29 active WIM sites in 2021, collected as part of another study (Chorzepa et al., 2022), was utilized as well. The locations of these CCS and WIM sites are depicted in Figure 1, where the CCS are denoted by blue circles and the WIM sites are denoted by red circles.

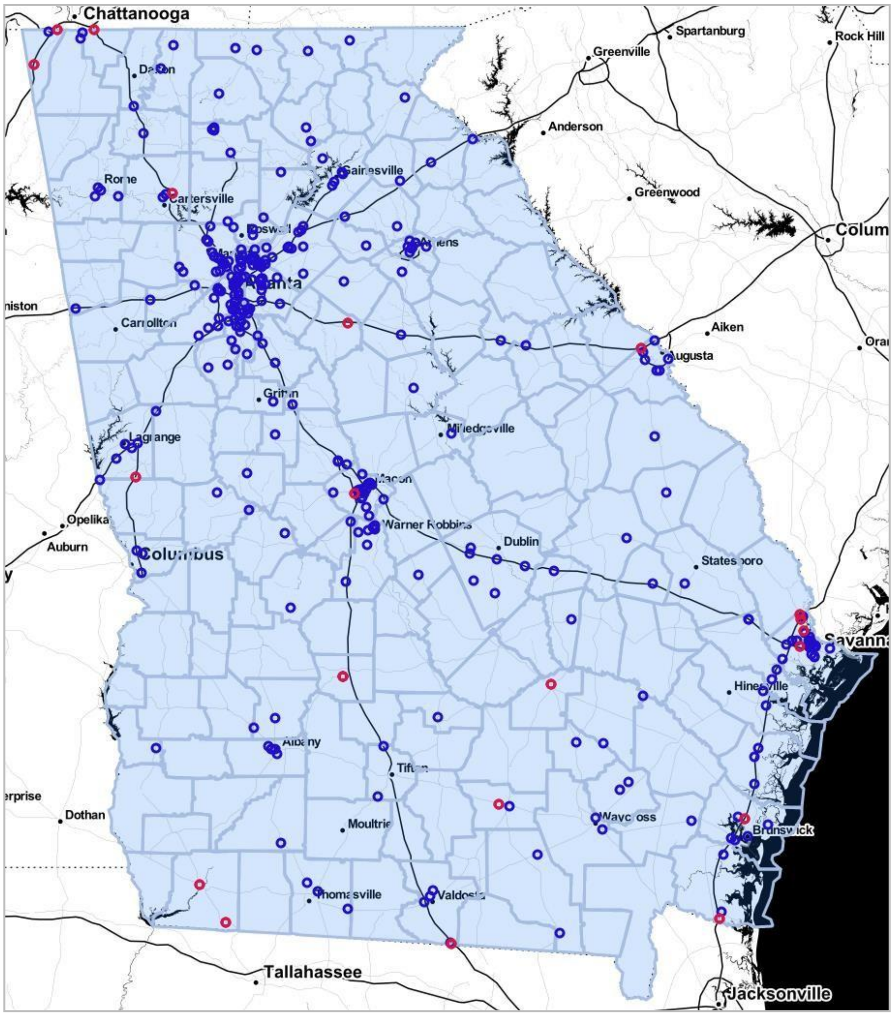


Figure 1. Locations of active CCS and WIM sites in Georgia.

DATA ANALYSIS

The data were processed to compute LDFs together with other related features, including directional AADT, the number of lanes, truck volumes and percentages, metropolitan regions, area (urban versus rural) and facility types. FHWA defined 13 vehicle classes, ranging from motorcycles/passenger cars to multi-trailer trucks, as depicted in Figure 2. Classes 5-13 are considered as trucks, which are considered for pavement design. The LDFs are computed by considering these truck classes.

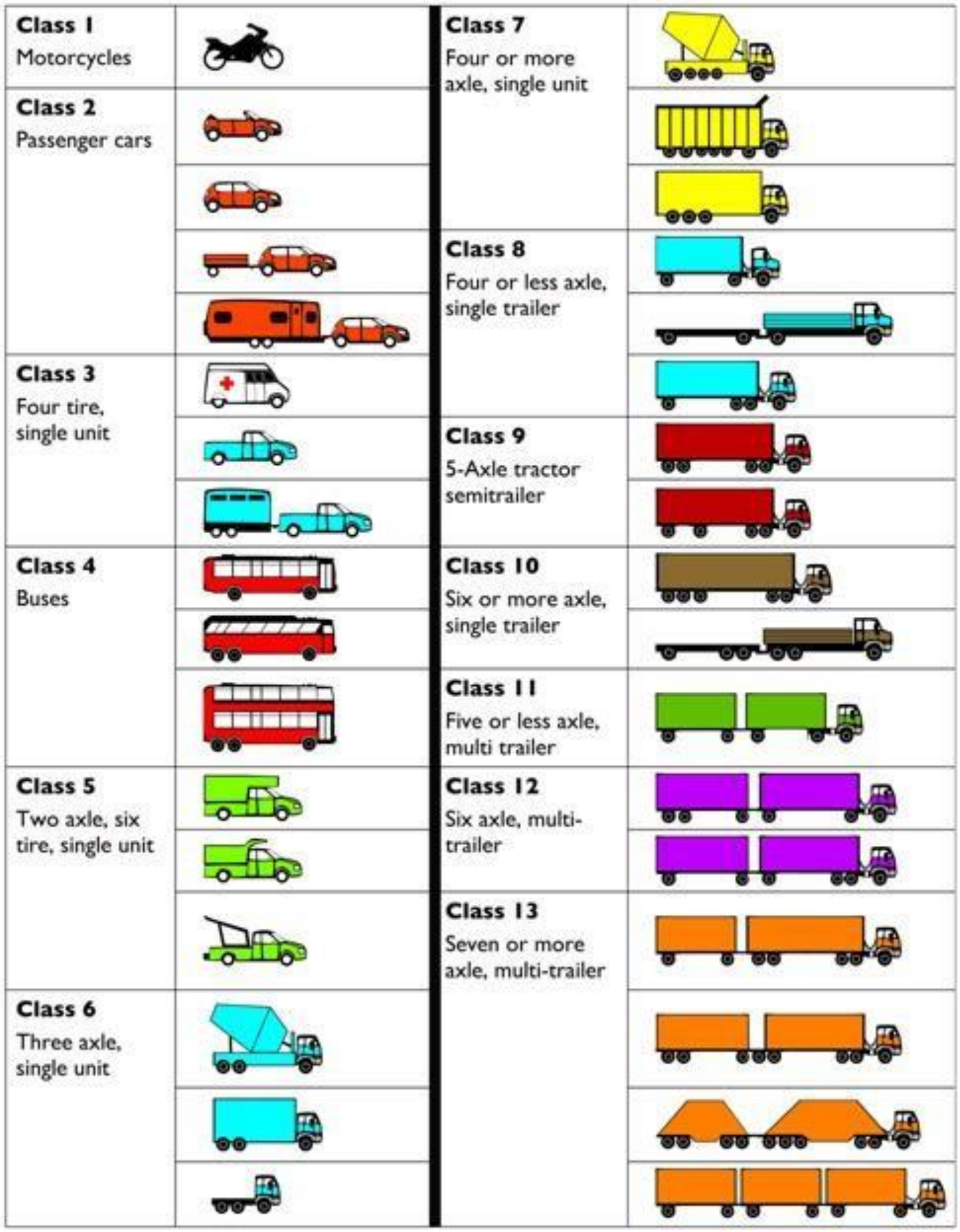


Figure 2. FHWA vehicle classification system.

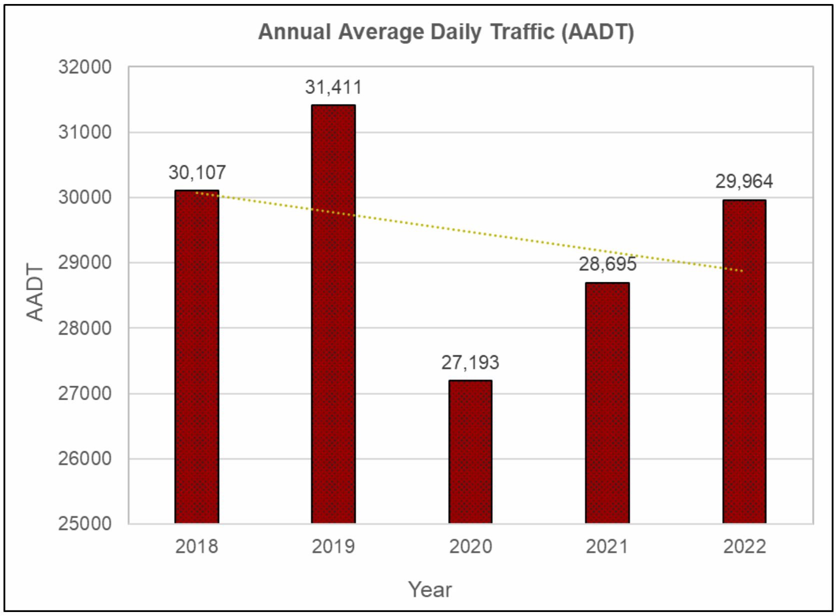
Given the definition of LDF, yearly traffic data is first compiled for each lane in each travel direction, resulting in AADT and AADTT by lane and by direction. Then, the corresponding LDF values are computed for each direction. For each of the 2-lane (one travel direction) facilities, two LDF values are computed, one for the inner lane (denoted as LDF_inner) and one for the outer lane (denoted as LDF_outer). For each of facilities with three or more lanes (one travel direction), three LDF values are computed, including one for the outermost lane (LDF_outer), one for the second outmost lane (denoted as LDF_center), and one for the remaining lane(s) combined (denoted as LDF_inner). Besides the LDF values, explanatory variables (features) are compiled from the CCS and WIM data as well and are summarized in Table 3. It should be noted that regrouping of the original functional classes of facilities into two categories (i.e., Interstate and Others) was based on statistical analysis of the data.

Table 3. Description of Variables

Variable	Description	Statistics of Dataset
AADT	Annual Average Daily Traffic	Mean: 29,470 Min: 1,207 Max: 161,449
LnAADT	Natural logarithm of AADT	Mean: 9.777 Min: 7.096 Max: 11.992
Urban	Dummy variable to indicate whether the facility is in an urban or rural setting.	1 – Urban (count: 1233) 0 – Rural (count: 371)
Interstate	Dummy variable to indicate whether the facility is Interstate, other Freeways or Expressways.	1 – Interstate (count: 908) * 0 – Others (count: 696)
3+ln	Dummy variable to indicate if the facility has 3 or more lanes (one travel direction).	1 – 3 or more lanes (count: 599) 0 – 2 lanes (count: 1,005)
Lanes	Number of lanes (one travel direction)	Min: 2, Max: 7, Mean: 2.76
Truck percentage	Percent of trucks in the traffic (one travel direction)	Mean: 12.15% Min: 0.71%, Max: 81.75%
Covid	Indicates whether data is from pre-covid, covid, or post-covid year.	Pre-Covid – 2018 & 2019 (count: 643) Covid – 2020 & 2021 (count: 655) Post-Covid – 2022 (count: 306)
Region	Variable indicating if the facility is in a specific metro-area.	Metro Atlanta + Macon – count: 711 Savannah – count: 120 Statewide – count: 773

* Includes other Freeways and Expressways.

Additionally, to assess the effect of COVID-19 on statewide traffic characteristics, the statewide mean AADT, AADTT were computed and are presented in Figure 3. Similarly, the statewide mean LDF values were computed and are presented in Figure 4. As seen in Figure 3, a significant traffic drop is observed in 2020 due to the COVID-19. However, traffic for 2022 returns to what it previously was in 2018, prior to the COVID-19. The statewide truck traffic also increased steadily throughout COVID-19 and has continued to do so consistently since 2020. However. as shown in Figure 4, the LDF values remained relatively constant before, during and after the COVID-19.



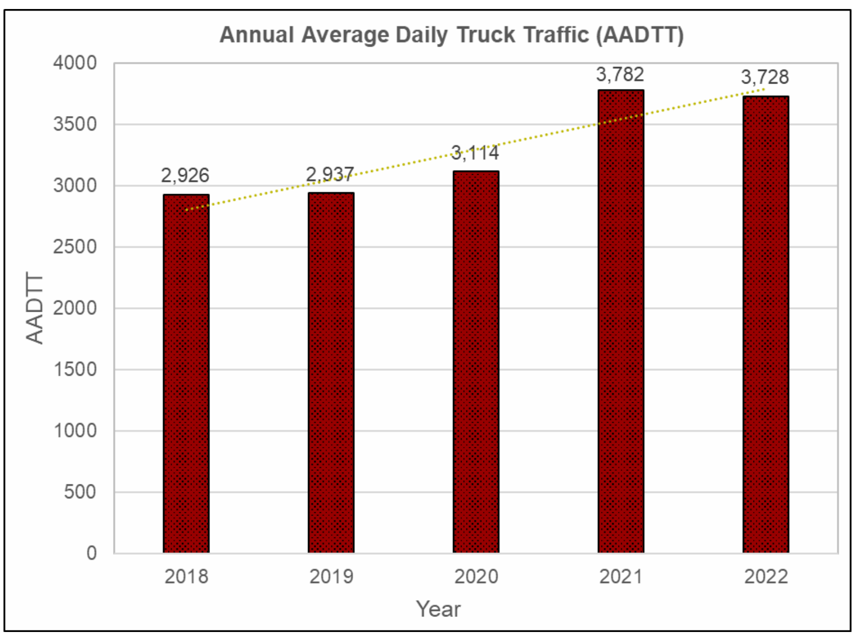
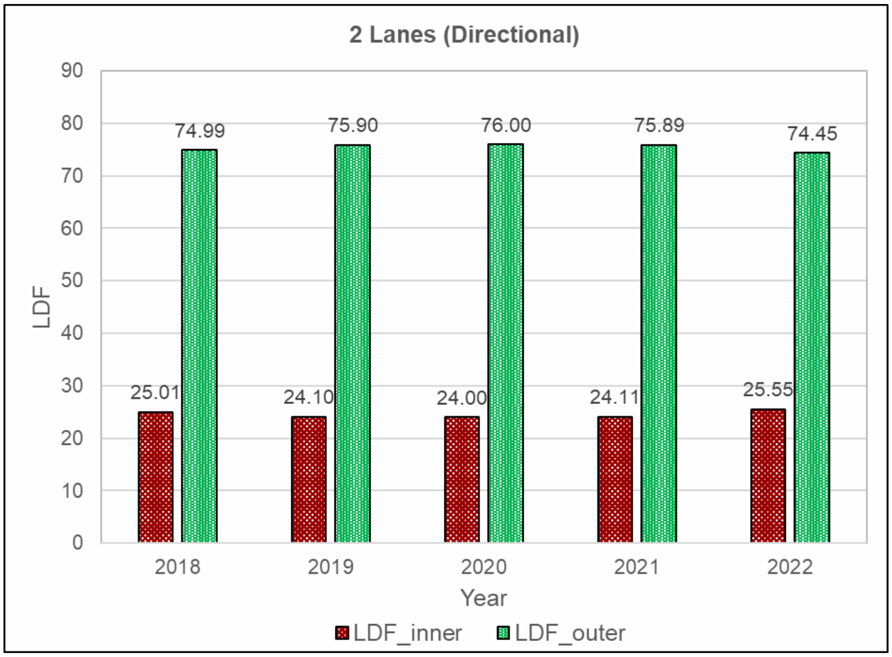


Figure 3. Statewide traffic by year.



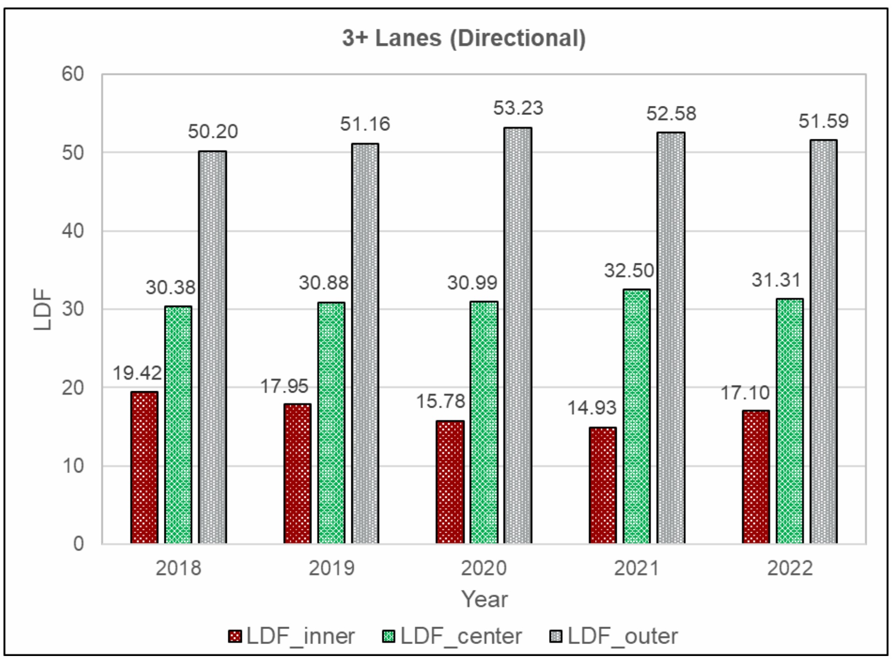


Figure 4. Statewide LDFs by year.

ESTIMATING LANE DISTRIBUTION FACTOR

LDF typically varies by area/facility type, the number of lanes, AADT, and truck traffic (truck percentage). Since LDF is defined as the percentage of directional truck traffic traveling in the outermost lane (the lane with the highest percentage of truck volume, referred to as the design lane), it is natural to model LDFs as probability distribution across lanes. To capture the effect of the number of lanes (one travel direction), a hierarchical modeling framework is adopted with a higher-level logistic model (referred to as Model A) to estimate LDF_outer (i.e., LDF for the outermost lane) and a lower-level logistic model (referred to as Model B) to estimate LDF_center (i.e., LDF for the second outmost lane) for facilities with three or more lanes in one travel direction. In this study, Model B is specified as such to estimate the "relative" LDF for the second outermost lane by disregarding the outmost lane. The hierarchical modeling framework is illustrated in Figure 5.

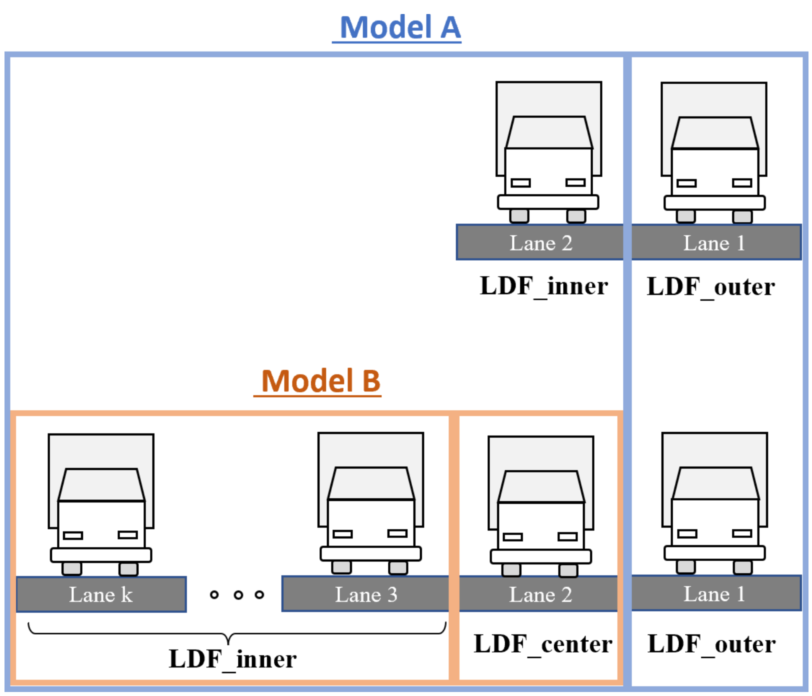


Figure 5. Illustration of the hierarchical modeling framework.

Model A is fit by considering all relevant features. Model B is fit only for facilities with 3+ lanes by simply disregarding the outermost lane and treating the second outermost lane as the “outmost lane”. Our analysis indicates that grouping the number of lanes into two categories (i.e., 2 lanes and 3+ lanes) does improve model fitting as compared to using the number of lanes directly as ordinal features, which substantiates the original design of the LDF table in the GDOT’s pavement design manual. On the other hand, by closely examining the LDF values with respect to AADTs in the currently adopted design table, it becomes apparent that LDF is logarithmically related to AADT. Based on our data analysis, the logarithm transformation of AADT dramatically improves model fitting, thus it was adopted. Additionally, COVID-19 was also considered as a feature by coding it as a dummy variable. It turns out that the effect of COVID-19 on the LDF is not significant, which concurs with the stable LDF values before and after the COVID-19 in Figure 4.

This study also aimed to analyze the impact of different metropolitan regions on the LDFs. When looking at the CCS and WIM sites on a map there are various geographical clusters of sites throughout the state. Based on the number of sites that are available in each metropolitan area, three major metropolitan regions are targeted for this study, including Metro-Atlanta Area, Macon, and Savannah. These regions were coded as dummy variables for analyzing their impacts on LDF. The CCS or WIM sites, which were not located in any of these metropolitan regions, were classified as being part of the “Statewide” region. Figure 6 shows a map of the state of Georgia with the metropolitan regions identified. The CCS and WIM sites located in the gray shaded area fall in the “statewide” region, while sites within the yellow shaded areas fall in respective metropolitan regions. Based on detailed analyses, the Metro-Atlanta and Macon have almost equivalent impacts on LDF, thus these two metropolitan regions are combined as a single region in our final model, named “Atlanta+Macon”.

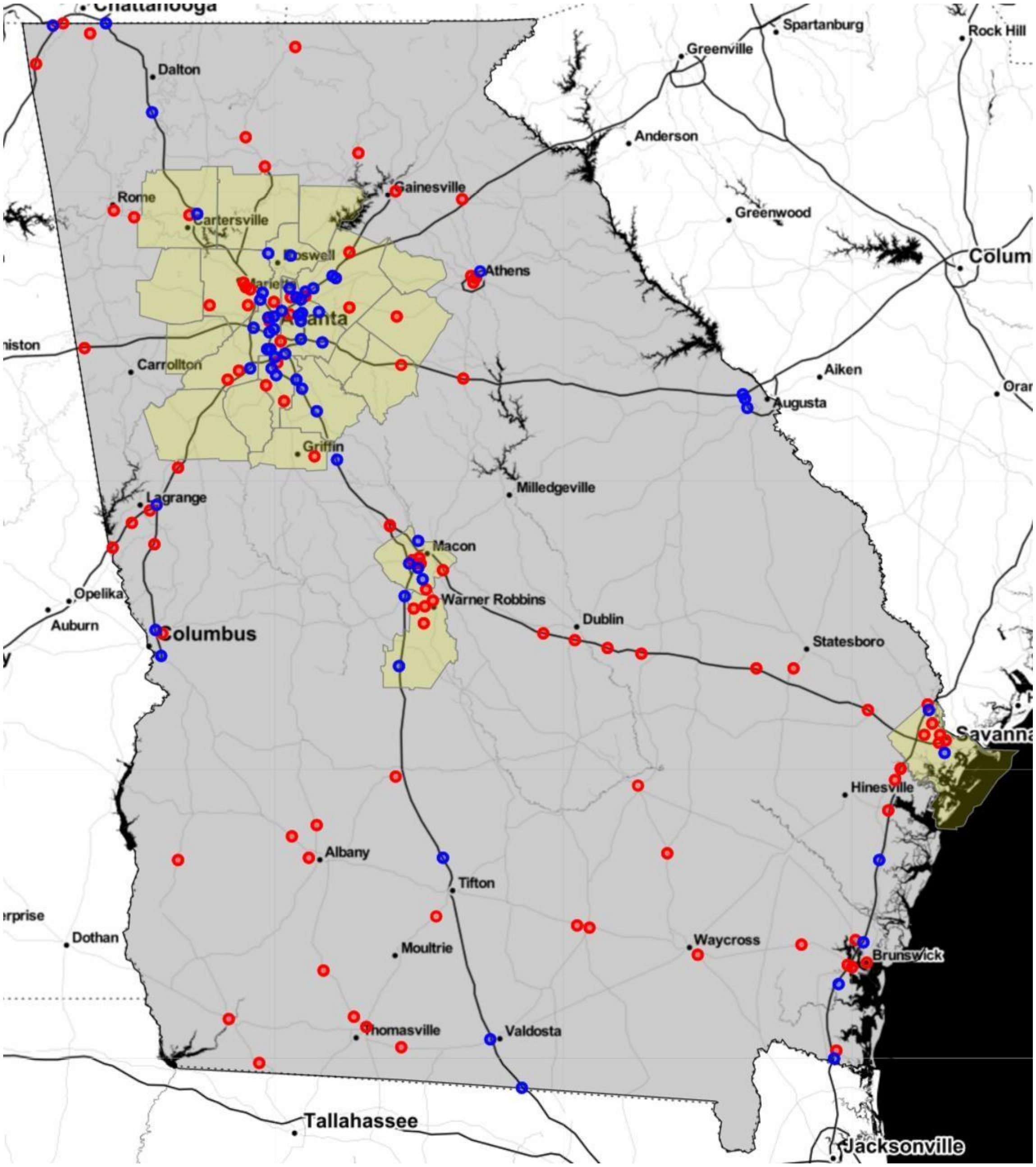


Figure 6: Map of CCS sites (Red indicates 2-lane sites and Blue indicates 3+ lane sites) and Target Metropolitan Regions (Yellow Areas).

The model estimation results are summarized in Table 4 and Table 5 for Model A and Model B, respectively.

Table 4. Model A - Estimating LDF for the Outermost Lane (LDF_outer)

Variable	Coef	Std Err	t statistic	p value	95% CI	
Const	4.811	0.224	21.453	0.000	4.371	5.250
Truck_percentage	0.504	0.173	2.918	0.004	0.165	0.842
LnAADT	-0.401	0.025	-15.972	0.000	-0.450	-0.352
Urban	-0.205	0.037	-5.472	0.000	-0.278	-0.131
Atlanta+Macon	-0.224	0.034	-6.623	0.000	-0.291	-0.158
Savannah	0.118	0.050	2.329	0.020	0.019	0.216
Interstate	0.685	0.043	15.988	0.000	0.601	0.769
3+ln	-0.771	0.039	-19.723	0.000	-0.847	-0.694
F statistic:	496.8	p value:	0.000			
R_squared:	0.685					
No. of obs:	1604					

Table 5. Model B - Estimating LDF for the Second Outermost Lane (LDF_center)

Variable	Coef	Std Err	t statistic	p value	95% CI	
Const	14.205	0.702	20.229	0.000	12.826	15.584
Truck_percentage	3.676	0.400	9.180	0.000	2.889	4.462
LnAADT	-1.349	0.074	-18.354	0.000	-1.494	-1.205
Atlanta+Macon	-0.170	0.094	-1.815	0.070	-0.353	0.014
Savannah	-0.265	0.213	-1.242	0.215	-0.684	0.154
Interstate	1.183	0.162	7.294	0.000	0.865	1.502
F statistic:	197.9	p value:	0.000			
R_squared:	0.625					
No. of obs:	599					

As shown in Table 4, increase of LnAADT will decrease LDF_outer as indicated by the negative coefficient for LnAADT. Conversely, an increase in Truck_percentage will increase LDF_outer indicated by the positive coefficient. Facilities in urban areas have a lower LDF_outer as compared to those in rural areas (reference base). Interstates and other Freeways/Expressways have a higher LDF_outer than the facilities of lower functional classes (reference base). The negative sign of "3+ln" reveals that facilities with three or more lanes (one travel direction) have a lower LDF_outer than facilities with two lanes (one travel direction). The metropolitan regions have differing impacts on the LDF_outer. As compared to the “Statewide” region (reference base), Metro-Atlanta and Macon (Atlanta+Macon) share a lower LDF_outer (indicated by the negative coefficient), while Savannah reveals a slightly higher LDF_outer (indicated by the positive coefficient).

Similar feature effects were noticed in Model B, as presented in Table 5, with respect to truck percentage, AADT, Metro-Atlanta region, and facility type. However, there were some notable differences as compared to Model A. The variable "Urban" was removed as it was found to be insignificant since a majority of facilities with 3+ lanes per direction are located in urban areas. Additionally, the region "Savannah" was observed to have a lower LDF_center, as indicated by the negative coefficient.

Both Models A and B show good overall fitting, as evidenced by their F statistics with lower p-values, and respective R-squares of 0.685 and 0.625. It is worth noting, though, that the "Savannah" region is not as significant as the other variables in Model B. Despite this, it is still retained in consideration of its relative significance, which is close to 20%.

CHAPTER 4. APPLICATION

To implement the study results, the LDF values were estimated by utilizing the models presented in Chapter 3. The significance of area/facility types and metropolitan regions in the variation of LDFs was taken into account, and as a result, three sets of design LDF tables were developed for the three target regions. Tables 6-9 are designed for the "Statewide" region, Tables 10-11 for the "Atlanta/Macon" region, and Tables 12-13 for the "Savannah" region.

Table 6. Statewide Region LDF (Urban Interstate/Freeways/Expressways)

One Way ADT	2 Lanes (one direction)		3+ Lanes (one direction)		
	Inner	Outer	Inner*	Center	Ou
2,000	9	91	0	17	
4,000	11	89	0	21	
6,000	13	87	0		
8,000	15	85	0		
10,000	16	84	1		
15,000	18	82			
20,000	20	80			
25,000	22	78			
30,000	23				
35,000	24				
40,000	25				
50,000	27				
60,000					
70,000					
80,000					
100					

*

Table 7. Statewide Region LDF (Rural Interstate/Freeways/Expressways)

Table 8. Statewide Region LDF (Urban Others)

One Way ADT	2 Lane s (one dire ction)		3+ Lane s (one dire ction)		
	Inne r	Oute r	Inne r*	Ce nte r	Oute r
2,000	17	83	0	30	70
4,000	21	79	1	35	64
6,000	24	76	2	38	60
8,000	26	74	4	40	57
10,000	28	72	5	40	54
15,000	32	68	9	40	50
20,000	34	66	14	39	47
25,000	36	64	18	37	45
30,000	38	62	22	35	43
35,000	39	61	25	33	42
40,000	41	59	29	31	40
50,000	43	57	35	27	38
60,000	45	55	40	24	36
70,000	46	54	44	21	35
80,000	48	52	47	19	34
100,000	50	50	53	16	32

* Combined inner one or more lanes

Table 9. Statewide Region LDF (Rural Others)

One Way ADT	2 Lane s (one dire ction)		3+ Lane s (one dire ction)		
	Inne r	Oute r	Inne r*	Ce nte r	Oute r
2,000	14	86	0	25	75
4,000	17	83	1	30	69
6,000	20	80	2	33	65
8,000	22	78	3	35	62
10,000	24	76	4	36	60
15,000	27	73	7	37	56
20,000	29	71	11	36	53
25,000	31	69	14	35	51
30,000	33	67	18	34	49
35,000	34	66	21	32	47
40,000	36	64	24	30	46
50,000	38	62	30	27	44
60,000	39	61	34	24	42
70,000	41	59	38	21	40
80,000	42	58	42	19	39
100,000	45	55	47	16	37

* Combined inner one or more lanes

Table 10. Atlanta/Macon Region LDF (Interstate/Freeways/Expressways)

One Way ADT	2 Lane s (one dire ction)		3+ Lane s (one dire ction)		
	Inne r	Oute r	Inne r*	Ce nte r	Oute r
2,000	11	89	0	20	80
4,000	14	86	0	25	75
6,000	16	84	0	28	71
8,000	18	82	1	31	69
10,000	19	81	1	32	66
15,000	22	78	2	35	62
20,000	24	76	4	37	60
25,000	26	74	5	38	57
30,000	27	73	7	38	55
35,000	29	71	8	38	54
40,000	30	70	10	37	52
50,000	32	68	14	36	50
60,000	33	67	17	35	48
70,000	35	65	20	33	47
80,000	36	64	24	31	45
100,000	38	62	29	28	43

* Combined inner one or more lanes

Table 11. Atlanta/Macon Region LDF (Others)

One Way ADT	2 Lane s (one dire ction)		3+ Lane s (one dire ction)		
	Inne r	Oute r	Inne r*	Ce nte r	Oute r
2,000	20	80	1	35	65
4,000	25	75	2	40	58
6,000	28	72	3	43	54
8,000	31	69	5	44	51
10,000	33	67	7	44	49
15,000	37	63	12	43	45
20,000	39	61	18	41	42
25,000	42	58	22	38	39
30,000	43	57	27	35	38
35,000	45	55	31	33	36
40,000	46	54	35	30	35
50,000	49	51	41	26	33
60,000	50	50	46	23	31
70,000	52	48	50	20	30
80,000	53	47	53	18	29
100,000	56	44	59	14	27

* Combined inner one or more lanes

Table 12. Savannah Region LDF (Interstate/Freeways/Expressways)

One Way ADT	2 Lane s (one dire ction)		3+ Lane s (one dire ction)		
	Inne r	Oute r	Inne r*	Ce nte r	Oute r
2,000	8	92	0	15	85
4,000	10	90	0	19	81
6,000	12	88	0	22	78
8,000	13	87	1	24	76
10,000	14	86	1	25	74
15,000	17	83	2	28	70
20,000	18	82	3	29	68
25,000	20	80	4	30	66
30,000	21	79	6	31	64
35,000	22	78	7	31	62
40,000	23	77	9	30	61
50,000	25	75	12	30	59
60,000	26	74	15	28	57
70,000	27	73	18	27	55
80,000	29	71	20	26	54
100,000	30	70	25	23	52

* Combined inner one or more lanes

Table 13. Savannah Region LDF (Others)

One Way ADT	2 Lane s (one dire ction)		3+ Lane s (one dire ction)		
	Inne r	Oute r	Inne r*	Ce nte r	Oute r
2,000	17	83	0	27	72
4,000	21	79	1	32	66
6,000	24	76	3	35	62
8,000	26	74	4	36	60
10,000	28	72	6	36	57
15,000	32	68	11	36	53
20,000	34	66	16	34	50
25,000	36	64	20	32	48
30,000	38	62	24	30	46
35,000	39	61	28	28	45
40,000	41	59	31	26	43
50,000	43	57	37	22	41
60,000	45	55	42	19	39
70,000	46	54	45	17	38
80,000	48	52	48	15	36
100,000	50	50	53	12	34

* Combined inner one or more lanes

Upon comparing Tables 6-13 with Table 2, it can be concluded that the current design LDF values, if utilized, would generally result in under-design of Rural Interstate/Freeways/Expressways and over-design of other facilities. To simplify the design process, a web application has been developed to display the computed LDF values based on the user's design inputs. The user interface of this application is presented in Figure 7.

Figure 7. Web application interface.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

In this study, year 2022 lane-specific vehicle count/classification data are obtained from all active CCS stations in Georgia. In conjunction with the previous 4-year data from the previous study (RP 21-11), LDF values are computed for each CCS and WIM site and correlated with relevant features, including AADT, area type, facility type, the number of lanes, truck percentage, and freight intensive metropolitan regions, as well as considering the effect of COVID-19. A hierarchical modeling framework is developed, consisting of (1) a higher-level model for estimating LDF for the outmost lane (LDF_outer) for all facilities, and (2) a lower-level model for estimating LDF for the second outmost lane (LDF_center) for facilities with 3 or more lanes (one travel direction). The feature analysis reveals that grouping the number of lanes into two categories (i.e., 2 lanes and 3+ lanes) improves model fitting than treating the actual number of lanes as an ordinal feature. Following similar analysis, the facility types are regrouped into two categories: Interstate (including other Freeways and Expressways) and others. The existing area types (Urban versus Rural) are retained. Consistent with current practice, logarithm transformation of AADT is applied, resulting in improved model fitting. Additionally, three freight intensive metropolitan regions (i.e., Atlanta Metro, Macon, and Savannah) are studied with respect to the rest of the State, referred to as the "Statewide" region.

Based on the study, the effect of COVID-19 on the LDF is found to be nonsignificant. It is highly recommended that area specific LDF tables (Tables 6-13) be adopted for pavement design in light of the significant roles that the area, facility type and metropolitan region plays in LDF estimation. Given the anticipated economic growth and evolving socioeconomic characteristics of the state of Georgia as well as continuous adoption of new or emerging technologies (e.g., E-mobility, statewide deployment of charging stations, semi-autonomous or autonomous truck platooning, emerging connected and autonomous vehicles, etc.), regularly updating the LDF values (e.g., every 3 years) is recommended to capture the changes in traffic characteristics over time.

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