

# Central District Freeway Frontage Road Traffic Control Study

## Working Paper #2: Frontage Road Traffic Control Guidelines



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## CHAPTER 5 RAMP AND FRONTAGE ROAD TRAFFIC CONTROL GUIDELINES

### Introduction

With the completion of Working Paper #1: Current and Future Conditions, and the Nationwide Best Practices survey findings, Working Paper #2 presents traffic control design guideline recommendations along ADOT's Freeway frontage roads in the Central District. Extensive inventory and analysis of the existing ramp and frontage road conditions, crash analysis, coordination and deliberation with the TAC and various ADOT staff members, the recommended traffic control guidelines are presented below. It is worth noting that an enhanced level of collaboration occurred with a separate ADOT study team on a somewhat similar and ongoing study in the ADOT Southcentral District. This study team was commissioned to partner with the other study team to examine and ensure consistency between the recommendations of two studies in their respective application of methodologies, assumptions and findings. The findings and recommendations presented below represent the culmination of these various efforts.

### Complaints

As described in the *Need and Purpose of the Study* section in Working Paper #1, ADOT has received numerous complaints from constituents regarding the use of "Stop" signs at certain locations where the frontage road merged with the exit ramp vs the use of "Yield" signs at other similar locations along the same corridor and complaints that the drivers on the frontage road are not yielding to the drivers exiting the Freeway. These inquiries and/or complaints reflect a general confusion or frustration with differences or variations in traffic control devices employed at different frontage road/mainline ramp convergence locations in the ADOT Central District. Often times these driver inquiries/complaints arise from witnessing other drivers' behaviors in these areas, and as a by-product, the evaluation of the variations in traffic control devices employed at different frontage road/ramp convergence areas that may influence driving behavior at these locations.

A complaint log for the entire study area for the years 2016 to 2018 was obtained from ADOT. A summary of the complaints is included in the **Attachments** section of this report.

There were eight (8) complaints regarding the traffic control signs where frontage road merges with the exit ramp from the years 2016 to 2018. The type of complaints included:

- "Yield to Ramp Traffic" signs are currently lacking, request sign installation,
- "YIELD" signs are placed too far prior to the merge point,
- Drivers on the frontage road often do not yield to the exit ramp traffic etc.

It is our understanding based on conversations with ADOT that there is the likelihood of additional complaints than what was currently provided for this study.

The *Central District Freeway Frontage Road Traffic Control Study* largely resulted from driver complaints within the study area. The data from the complaint log obtained from ADOT does not provide sufficient information to determine the best solution to the challenge. Therefore, the TAC determined that crash data within the study area should be analyzed to determine patterns/similarities in crashes relating to the

traffic control signs. This approach represents a subtle departure from initial observations made in the **Crash Analysis** section in Working Paper 1.

## Crash Analysis

As mentioned above, a detailed crash analysis was performed at various locations within the study area to determine patterns/similarities in crashes relating to the traffic control signs. Crash analysis was conducted to include locations with the following major elements that represent the freeway frontage road/ramp condition of the existing transportation system along the Central District Frontage Roads:

1. One lane and two-lane frontage roads,
2. STOP sign and YIELD sign locations,
3. YIELD sign locations with and without YIELD pavement marking,
4. Weave lengths less than 300 feet and greater than 300 feet,
5. Weave lengths greater than 1,000 feet, and
6. Locations with driveways existing between the physical gore where frontage road merges with exit ramp and the solid intersection striping.

The parameters that were used for the crash analysis are described below:

**Crash Data:** crash data for the five-year period from January 1, 2012 to December 31, 2016 obtained from the Arizona Department of Transportation (ADOT) Traffic Records Section was used for the analysis. Crashes that occurred between 300 feet upstream of the physical gore where frontage road merges with the exit ramp and the arterial street intersection are used for the analysis. Engineering judgement was used to determine the crashes that are closer to the arterial street intersection that could have been caused due to the weaving/merging maneuver to be used in the analysis.

**Segment Crash Rate:** segment crash rate is calculated using the following formula:

$$\text{Segment Crash Rate} = \frac{\text{Number of Crashes in the } n \text{ Year Period} * 1,000,000}{\text{AADT} * \text{segment length} * 365 * \text{number of years}}$$

Average annual daily traffic volume (AADT) for the study locations is obtained from the ADOT Transportation Data Management System (TDMS) website. A combined AADT on the exit ramp and on the frontage road approaching the merge point is used for the analysis.

Segment length is the length between the tip of the striped gore to the stop bar at the intersection.

**Weave Length:** weave length is the distance between the tip of the striped gore and the start of the solid white line approaching the intersection.

**Crash Rate (R) Factor:** crash rate (R) factor is calculated using the following formula:

$$R = \frac{\text{Segment Crash Rate} * \text{AADT}}{\text{Weave Length}}$$

**Ranking of Locations:** after calculating the crash rates and R factors at various study locations, the locations are ranked by various factors, i.e., number of crashes (by decreasing number of crashes), crash rate (by decreasing crash rate), weave length (by increasing weave length) and R-factor (by increasing R factor). Ranking of the study locations by various factors is shown in **Table 1**.

Based on the crash analysis shown in **Table 1**, 20 of the top 25 highest crash rate locations have a weave length of less than 300 feet and 23 of the top 25 highest crash rate locations have YIELD signs. In contrast to the top 25 highest crash rates, only 8 of the bottom 25 crash rate locations have a weave length of less than 300 feet and only 12 of the bottom 25 crash rate intersections have YIELD signs. This summary shows a distinct correlation between the weave length, traffic control and the crash rates.

Weighted Average: A further analysis was performed to determine the ranking of each location by comparing each individual ranking criteria, termed as “Weighted Average”. A point system was created for each ranking criterion, i.e., number of crashes, crash rates, weave length and R-factor. A total of eight points were allotted to each criterion, one for number of crashes, three for crash rate and two each for weave length and R-Factor. Weighted Average for each location is calculated as follows:

$$\text{Weighted Average} = \frac{(\# \text{ of crashes} * C) + (\text{Crash Rate} * CR) + (\text{Weave Length} * WL) + (\text{R Factor} * R)}{\text{Total Number of Points}}$$

Where,

- C = Points allotted to number of crashes, 1,
- CR = Points allotted to crash rate, 3,
- WL = Points allotted to weave length, 2,
- R = Points allotted to R-Factor, 2, and
- Total Number of Points = 8.

**Table 2** shows the summary of the overall ranking of all study area locations by weighted average.

Table 1: Ranking of Locations by Various Categories

Ranking by # of Crashes								Ranking by Rate							
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor	Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor
1	L101 & Broadway	SB	YIELD	47	11.32052	290	936.5583	1	L101 & Broadway	SB	YIELD	47	11.32052	290	936.5583
2	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863	2	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863
2	L101 & Broadway	NB	YIELD	20	5.387247	130	803.653	3	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906
4	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664	4	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382
5	L101 & 27th	EB	YIELD	13	4.758321	330	253.2725	5	L101 & Broadway	NB	YIELD	20	5.387247	130	803.653
6	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178	6	L101 & 67th	EB	YIELD	7	4.984925	150	321.4612
6	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382	7	L101 & 27th	EB	YIELD	13	4.758	330	253.27
8	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906	8	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178
8	L101 & Ray Rd	SB	YIELD	9	2.753485	280	189.7839	9	L101 & Elliot	NB	YIELD	6	3.643927	230	184.0817
10	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446	10	L101 & 51st	EB	YIELD	5	3.267	330	84.30
10	L101 & 67th	EB	YIELD	7	4.984925	150	321.4612	11	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446
10	L101 & Guadalupe	SB	YIELD	7	2.761784	220	191.7808	12	L101 & Guadalupe	SB	YIELD	7	2.761784	220	191.7808
13	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079	13	L101 & Ray Rd	SB	YIELD	9	2.753	280	189.78
13	L101 & Elliot	NB	YIELD	6	3.643927	230	184.0817	14	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353
15	L101 & 51st	EB	YIELD	5	3.26703	330	84.29926	15	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664
15	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353	16	L101 & Warner	NB	YIELD	4	2.35707	250	107.6521
17	I-17 & Thomas Rd	NB	None	4	0.49203	1,270	5.841209	17	L101 & 59th	EB	YIELD	4	2.219	180	146.12
17	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485	18	L101 & Ray Rd	NB	YIELD	4	2.088902	250	105.2055
17	L101 & 59th	EB	YIELD	4	2.218589	180	146.1187	19	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565
17	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565	20	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133
17	L101 & Ray Rd	NB	YIELD	4	2.088902	250	105.2055	21	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095
17	L101 & Warner	NB	YIELD	4	2.35707	250	107.6521	22	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494
17	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133	23	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317
24	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494	24	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869
24	I-17 and Indian School Road	SB	None	3	0.940	340	47.274	25	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079
24	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869	26	I-17 and Indian School Road	SB	None	3	0.94011	340	47.2737
24	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	1.972603	27	I-17 and 19th Avenue	WB	STOP	2	0.911	250	57.86
28	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095	28	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485
28	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215	29	I-17 & 7th St	NB	STOP	1	0.62991	100	93.32744
28	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	57.86301	30	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215
28	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591	31	L101 & 19th Ave	WB	YIELD	1	0.550014	350	16.20813
32	I-17 & 7th St	NB	STOP	1	0.62991	100	93.32744	32	L101 & 7th Ave	EB	YIELD	1	0.506111	300	17.85895
32	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912	33	I-17 & Thomas Rd	NB	None	4	0.492	1,270	5.84
32	I-17 & Dunlap Rd	SB	YIELD	1	0.154	1120	2.018	34	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912
32	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765	35	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591
32	I-17 & Northern Avenue	NB	None	1	0.296915	570	6.953018	36	I-17 and Glendale Avenue	SB	None	1	0.360841	490	9.840649
32	I-17 and Glendale Avenue	SB	None	1	0.360841	490	9.840649	37	I-17 & Northern Avenue	NB	None	1	0.297	570	6.953
32	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317	38	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765
32	L101 & 19th Ave	WB	YIELD	1	0.550014	350	16.20813	39	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	1.972603
32	L101 & 7th Ave	EB	YIELD	1	0.506111	300	17.85895	40	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1120	2.018102
41	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0	41	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0
41	I-10 and 99th Avenue	WB	None	0	0	160	0	41	I-10 and 99th Avenue	WB	None	0	0	160	0
41	I-17 & 16th St	EB	STOP	0	0	180	0	41	I-17 & 16th St	EB	STOP	0	0	180	0
41	I-17 & 7th Ave	EB	STOP	0	0	20	0	41	I-17 & 7th Ave	EB	STOP	0	0	20	0
41	I-17 & 7th Ave	WB	STOP	0	0	50	0	41	I-17 & 7th Ave	WB	STOP	0	0	50	0
41	I-17 & 7th St	SB	STOP	0	0	100	0	41	I-17 & 7th St	SB	STOP	0	0	100	0
41	I-17 & Buckeye Road	NB	None	0	0	720	0	41	I-17 & Buckeye Road	NB	None	0	0	720	0
41	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0	41	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0
41	I-17 & Deer Valley Rd	SB	YIELD	0	0	320	0	41	I-17 & Deer Valley Rd	SB	YIELD	0	0	320	0
41	I-17 & Dunlap Rd	NB	None	0	0	680	0	41	I-17 & Dunlap Rd	NB	None	0	0	680	0
41	I-17 & Grant Road	NB	YIELD	0	0	150	0	41	I-17 & Grant Road	NB	YIELD	0	0	150	0
41	I-17 & Northern Avenue	SB	None	0	0	910	0	41	I-17 & Northern Avenue	SB	None	0	0	910	0
41	I-17 & Union Hills	NB	YIELD	0	0	350	0	41	I-17 & Union Hills	NB	YIELD	0	0	350	0
41	I-17 & Utopia	NB	YIELD	0	0	430	0	41	I-17 & Utopia	NB	YIELD	0	0	430	0
41	I-17 and Bethany Home Road	NB	None	0	0	550	0	41	I-17 and Bethany Home Road	NB	None	0	0	550	0
41	I-17 and Bethany Home Road	SB	None	0	0	410	0	41	I-17 and Bethany Home Road	SB	None	0	0	410	0
41	I-17 and Glendale Avenue	NB	None	0	0	450	0	41	I-17 and Glendale Avenue	NB	None	0	0	450	0
41	I-17 and Indian School Road	NB	None	0	0	340	0	41	I-17 and Indian School Road	NB	None	0	0	340	0
41	I-17 and McDowell Road	SB	None	0	0	670	0	41	I-17 and McDowell Road	SB	None	0	0	670	0
41	I-17 and Thomas Rd	SB	YIELD	0	0	430	0	41	I-17 and Thomas Rd	SB	YIELD	0	0	430	0
41	L101 & 27th Ave	WB	YIELD	0	0	1,240	0	41	L101 & 27th Ave	WB	YIELD	0	0	1,240	0
41	L101 & 7th Ave	WB	YIELD	0	0	380	0	41	L101 & 7th Ave	WB	YIELD	0	0	380	0
41	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0	41	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0
41	L202 & Broadway Rd	SB	YIELD	0	0	190	0	41	L202 & Broadway Rd	SB	YIELD	0	0	190	0
41	SR 101 and 7th Street	WB	YIELD	0	0	470	0	41	SR 101 and 7th Street	WB	YIELD	0	0	470	0

Table 1: Ranking of Locations by Various Categories (Continued)

Ranking by Weave Length							
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor
1	I-17 & 7th Ave	EB	STOP	0	0	20	0
2	I-17 & 7th Ave	WB	STOP	0	0	50	0
3	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906
3	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317
5	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095
6	I-17 & 7th St	NB	STOP	1	0.62991	100	93.32744
6	I-17 & 7th St	SB	STOP	0	0	100	0
8	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863
8	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565
10	L101 & Broadway	NB	YIELD	20	5.387247	130	803.653
11	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133
12	L101 & 67th	EB	YIELD	7	4.984925	150	321.4612
12	I-17 & Grant Road	NB	YIELD	0	0	150	0
14	I-10 and 99th Avenue	WB	None	0	0	160	0
15	L101 & 59th	EB	YIELD	4	2.218589	180	146.1187
15	I-17 & 16th St	EB	STOP	0	0	180	0
17	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353
17	L202 & Broadway Rd	SB	YIELD	0	0	190	0
19	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494
20	L101 & Guadalupe	SB	YIELD	7	2.762	220	191.78
21	L101 & Elliot	NB	YIELD	6	3.643927	230	184.0817
21	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215
21	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0
24	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178
25	L101 & Ray Rd	NB	YIELD	4	2.088902	250	105.2055
25	L101 & Warner	NB	YIELD	4	2.35707	250	107.6521
25	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	57.86301
28	L101 & Ray Rd	SB	YIELD	9	2.753485	280	189.7839
29	L101 & Broadway	SB	YIELD	47	11.32052	290	936.5583
29	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912
31	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382
31	L101 & 7th Ave	EB	YIELD	1	0.506	300	17.86
33	I-17 & Deer Valley Rd	SB	YIELD	0	0	320	0
34	L101 & 27th	EB	YIELD	13	4.758321	330	253.2725
34	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446
34	L101 & 51st	EB	YIELD	5	3.26703	330	84.29926
37	I-17 and Indian School Road	SB	None	3	0.94011	340	47.2737
37	I-17 and Indian School Road	NB	None	0	0	340	0
39	L101 & 19th Ave	WB	YIELD	1	0.550014	350	16.20813
39	I-17 & Union Hills	NB	YIELD	0	0	350	0
41	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079
41	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869
41	L101 & 7th Ave	WB	YIELD	0	0	380	0
44	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765
44	I-17 and Bethany Home Road	SB	None	0	0	410	0
46	I-17 & Utopia	NB	YIELD	0	0	430	0
46	I-17 and Thomas Rd	SB	YIELD	0	0	430	0
48	I-17 and Glendale Avenue	NB	None	0	0	450	0
49	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485
49	SR 101 and 7th Street	WB	YIELD	0	0	470	0
51	I-17 and Glendale Avenue	SB	None	1	0.360841	490	9.840649
52	I-17 and Bethany Home Road	NB	None	0	0	550	0
53	I-17 & Northern Avenue	NB	None	1	0.297	570	6.95
54	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591
55	I-17 and McDowell Road	SB	None	0	0	670	0
56	I-17 & Dunlap Rd	NB	None	0	0	680	0
57	I-17 & Buckeye Road	NB	None	0	0	720	0
58	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664
59	I-17 & Northern Avenue	SB	None	0	0	910	0
60	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1,120	2.018102
61	L101 & 27th Ave	WB	YIELD	0	0	1,240	0
62	I-17 & Thomas Rd	NB	None	4	0.49203	1,270	5.841209
63	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	1.972603
64	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0
65	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0

Ranking by R-Factor							
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor
1	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863
2	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906
3	L101 & Broadway	SB	YIELD	47	11.32052	290	936.5583
4	L101 & Broadway	NB	YIELD	20	5.387247	130	803.653
5	L101 & 67th	EB	YIELD	7	4.984925	150	321.4612
6	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565
7	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178
8	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317
9	L101 & 27th	EB	YIELD	13	4.758321	330	253.2725
10	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095
11	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382
12	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133
13	L101 & Guadalupe	SB	YIELD	7	2.761784	220	191.7808
14	L101 & Ray Rd	SB	YIELD	9	2.753	280	189.78
15	L101 & Elliot	NB	YIELD	6	3.643927	230	184.0817
16	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353
17	L101 & 59th	EB	YIELD	4	2.218589	180	146.1187
18	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446
19	L101 & Warner	NB	YIELD	4	2.357	250	107.65
20	L101 & Ray Rd	NB	YIELD	4	2.089	250	105.21
21	I-17 & 7th St	NB	STOP	1	0.62991	100	93.32744
22	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494
23	L101 & 51st	EB	YIELD	5	3.26703	330	84.29926
24	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079
25	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	57.86301
26	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215
27	I-17 and Indian School Road	SB	None	3	0.940	340	47.27
28	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664
29	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869
30	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485
31	L101 & 7th Ave	EB	YIELD	1	0.506111	300	17.85895
32	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912
33	L101 & 19th Ave	WB	YIELD	1	0.550	350	16.21
34	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591
35	I-17 and Glendale Avenue	SB	None	1	0.360841	490	9.840649
36	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765
37	I-17 & Northern Avenue	NB	None	1	0.296915	570	6.95
38	I-17 & Thomas Rd	NB	None	4	0.492	1,270	5.84
39	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1,120	2.018102
40	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	1.972603
41	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0
41	I-10 and 99th Avenue	WB	None	0	0	160	0
41	I-17 & 16th St	EB	STOP	0	0	180	0
41	I-17 & 7th Ave	EB	STOP	0	0	20	0
41	I-17 & 7th Ave	WB	STOP	0	0	50	0
41	I-17 & 7th St	SB	STOP	0	0	100	0
41	I-17 & Buckeye Road	NB	None	0	0	720	0
41	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0
41	I-17 & Deer Valley Rd	SB	YIELD	0	0	320	0
41	I-17 & Dunlap Rd	NB	None	0	0	680	0
41	I-17 & Grant Road	NB	YIELD	0	0	150	0
41	I-17 & Northern Avenue	SB	None	0	0	910	0
41	I-17 & Union Hills	NB	YIELD	0	0	350	0
41	I-17 & Utopia	NB	YIELD	0	0	430	0
41	I-17 and Bethany Home Road	NB	None	0	0	550	0
41	I-17 and Bethany Home Road	SB	None	0	0	410	0
41	I-17 and Glendale Avenue	NB	None	0	0	450	0
41	I-17 and Indian School Road	NB	None	0	0	340	0
41	I-17 and McDowell Road	SB	None	0	0	670	0
41	I-17 and Thomas Rd	SB	YIELD	0	0	430	0
41	L101 & 27th Ave	WB	YIELD	0	0	1,240	0
41	L101 & 7th Ave	WB	YIELD	0	0	380	0
41	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0
41	L202 & Broadway Rd	SB	YIELD	0	0	190	0
41	SR 101 and 7th Street	WB	YIELD	0	0	470	0

Table 2: Overall Ranking of Locations by Weighted Average

Overall Ranking by Weighted Average								
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor	Wt Avg Rank
1	SR 101 and University Drive	NB	YIELD	2	2	8	1	3.3
2	I-17 & Grant	SB	YIELD	8	3	3	2	3.4
3	L101 & Broadway	NB	YIELD	2	5	10	4	5.6
4	L101 & 67th	EB	YIELD	10	6	12	5	7.8
5	L101 & Broadway	SB	YIELD	1	1	29	3	8.5
6	L101 & 67th Ave	WB	YIELD	6	8	24	7	11.5
7	L101 & Southern Ave	SB	YIELD	6	4	31	11	12.8
7	L101 & Elliot Rd	SB	YIELD	17	19	8	6	12.8
9	L101 & 27th	EB	YIELD	5	7	34	9	14.0
9	L101 & Guadalupe	SB	YIELD	10	12	20	13	14.0
9	L101 & Elliot	NB	YIELD	13	9	21	15	14.0
12	I-10 & Jefferson	NB	STOP	28	21	5	10	15.1
13	L101 & 59th Ave	WB	YIELD	15	14	17	16	15.4
13	SR 101 and Warner	SB	YIELD	17	20	11	12	15.4
13	I-17 and Jefferson	SB	STOP	32	23	3	8	15.4
16	L101 & Ray Rd	SB	YIELD	8	13	28	14	16.4
17	L101 & 59th	EB	YIELD	17	17	15	17	16.5
18	L101 & 35th	EB	YIELD	10	11	34	18	18.4
19	L101 & Warner	NB	YIELD	17	16	25	19	19.1
20	L101 & 51st	EB	YIELD	15	10	34	23	19.9
21	L101 & Ray Rd	NB	YIELD	17	18	25	20	20.1
22	I-17 & Pinnacle Peak Rd	NB	YIELD	24	22	19	22	21.5
23	I-17 & 7th St	NB	STOP	32	29	6	21	21.6
24	I-17 and 19th Avenue	WB	STOP	28	27	25	25	26.1
25	I-17 & Thunderbird	SB	YIELD	28	30	21	26	26.5
26	I-17 and Durango Street	SB	STOP	13	25	41	24	27.3
27	I-17 and Peoria Road	SB	YIELD	4	15	58	28	27.6
28	I-17 and Indian School Road	SB	None	24	26	37	27	28.8
29	L101 & 7th St	EB	YIELD	24	24	41	29	29.5
30	I-17 & 7th Ave	EB	STOP	41	41	1	41	31.0
31	I-17 & 7th Ave	WB	STOP	41	41	2	41	31.3
32	L101 & 7th Ave	EB	YIELD	32	32	31	31	31.5
33	I-17 & Cactus	SB	YIELD	32	34	29	32	32.0
34	I-17 & 7th St	SB	STOP	41	41	6	41	32.3
35	I-17 and Camelback Road	SB	None	17	28	49	30	32.4
36	L101 & 19th Ave	WB	YIELD	32	31	39	33	33.6
37	I-17 & Grant Road	NB	YIELD	41	41	12	41	33.8
38	I-10 and 99th Avenue	WB	None	41	41	14	41	34.3
39	I-17 & 16th St	EB	STOP	41	41	15	41	34.5
40	L202 & Broadway Rd	SB	YIELD	41	41	17	41	35.0
41	I-17 & Deer Valley Rd	NB	YIELD	41	41	21	41	36.0
42	I-17 & Greenway Road	NB	YIELD	32	38	44	36	38.3
43	L101 & Frank Lloyd Wright	SB	YIELD	28	35	54	34	38.6
44	I-17 and Glendale Avenue	SB	None	32	36	51	35	39.0
44	I-17 & Deer Valley Rd	SB	YIELD	41	41	33	41	39.0
46	I-17 & Thomas Rd	NB	None	17	33	62	38	39.5
47	I-17 and Indian School Road	NB	None	41	41	37	41	40.0
48	I-17 & Northern Avenue	NB	None	32	37	53	37	40.4
49	I-17 & Union Hills	NB	YIELD	41	41	39	41	40.5
50	L101 & 7th Ave	WB	YIELD	41	41	41	41	41.0
51	I-17 and Bethany Home Road	SB	None	41	41	44	41	41.8
52	I-17 & Utopia	NB	YIELD	41	41	46	41	42.3
52	I-17 and Thomas Rd	SB	YIELD	41	41	46	41	42.3
54	I-17 and Glendale Avenue	NB	None	41	41	48	41	42.8
55	SR 101 and 7th Street	WB	YIELD	41	41	49	41	43.0
56	L101 & Ranitree Dr	SB	YIELD	24	39	63	40	43.4
57	I-17 & Dunlap Rd	SB	YIELD	32	40	60	39	43.8
57	I-17 and Bethany Home Road	NB	None	41	41	52	41	43.8
59	I-17 and McDowell Road	SB	None	41	41	55	41	44.5
60	I-17 & Dunlap Rd	NB	None	41	41	56	41	44.8
61	I-17 & Buckeye Road	NB	None	41	41	57	41	45.0
62	I-17 & Northern Avenue	SB	None	41	41	59	41	45.5
63	L101 & 27th Ave	WB	YIELD	41	41	61	41	46.0
64	L101 & Frank Lloyd Wright	NB	YIELD	41	41	64	41	46.8
65	I-10 & 99th Ave	EB	YIELD	41	41	65	41	47.0

## Summary and Results of the Crash Analysis

Shown below is a brief summary of the crash analysis included in **Table 1** and **Table 2**.

### Overall Summary

- A total of 65 locations are included in the analysis,
- Nine of the 65 locations are STOP controlled, 42 are YIELD controlled and 14 have no traffic control signs,
- The average weave length of all the locations analyzed is 462 feet,
- Average weave length of the top 10 locations based on weighted average is 202 feet,
- Average weave length of the bottom 10 locations based on weighted average is 1,273 feet,
- 75<sup>th</sup> percentile crash rate is 2.377215,
- Average weave length above the 75<sup>th</sup> percentile crash rate is 272 feet,
- 20 of the top 25 locations based on the crash rate have weave lengths less than 300 feet,
- 23 of the top 25 locations based on the crash rate are YIELD controlled,
- Eight of the bottom 25 locations based on the crash rate have weave lengths less than 300 feet,
- 12 of the bottom 25 locations based on the crash rate are YIELD controlled,
- 22 of the top 25 locations based on the weighted average have weave lengths less than 300 feet,
- 21 of the top 25 locations based on the weighted average are YIELD controlled,
- 14 of the bottom 25 locations based on the weighted average are YIELD controlled, and
- Two of the bottom 25 locations based on the weighted average have weave lengths less than 300 feet.

### STOP Controlled Locations Summary

- Average weave length of the STOP controlled locations is 137 feet,
- 75<sup>th</sup> percentile crash rate at the STOP controlled locations is 1.26, and
- Average weave length above the 75<sup>th</sup> percentile crash rate at the STOP controlled locations is 75 feet.

### YIELD Controlled Locations Summary

- Average weave length of the YIELD controlled locations is 494 feet,
- Average weave length of the top 10 YIELD controlled locations by weighted average is 192 feet,
- Average weave length of the bottom 10 YIELD controlled locations by weighted average is 1,207 feet,
- 75<sup>th</sup> percentile crash rate of the YIELD controlled locations is 3.361254, and
- Average weave length above the 75<sup>th</sup> percentile crash rate at the YIELD controlled locations is 214 feet.

### NO Traffic Control Locations Summary

- Average weave length of the locations with NO traffic control is 574 feet,
- 75<sup>th</sup> percentile crash rate of the NO traffic control locations is 0.393638, and
- Average weave length above the 75<sup>th</sup> percentile crash rate at the NO traffic control locations is 693 feet.

Based on the crash analysis and the summary described above, it can be concluded that the locations with YIELD signs and weave lengths less than 300 feet have the highest ranking. Locations with YIELD signs and weave lengths greater than 1,000 feet ranked the lowest for crash rates.

According to the Manual on Uniform Traffic Control Devices (MUTCD) Table 2C-4 and the American Association of State Highway and Transportation Officials (AASHTO) Policy on Geometric Design, vehicle drivers need approximately 4.5 seconds of time for making vehicle maneuvers in addition to the perception-reaction time to adjust speed and lane changes in heavy traffic, which would include performing weaving maneuvers. Assuming the typical frontage road posted speed limit of 45 mph, this 4.5 second time demand results in a distance of 300 feet required for a driver in an ideal setting free from any side friction to perform a weave maneuver. Assuming the perception-reaction time occurs before approaching the striped gore, an additional 300 feet is needed from the tip of the striped gore to the solid white intersection striping for a driver to be able to perform the weaving maneuver. These important factors and assumptions, together with the crash analysis findings, are important in influencing the recommended traffic control.

## Recommended Traffic Control

Based on the conclusions from the crash analysis and the MUTCD/AASHTO suggestions, the following standards/guidelines are recommended for the frontage road traffic control:

1. If STOP (R1-1) signs are recommended on a two lane frontage road, then, STOP signs shall be installed on both sides of the frontage road in which case the sign located in the gore area on the left side of the frontage road will be visible to the exit ramp traffic causing confusion. Therefore, a STOP (R1-1) sign should not be recommended on multi-lane frontage roads.
2. If the weaving distance (distance between tip of striped gore to the beginning of the solid white stripe at the arterial street intersection) is less than 300 feet, consider restriping the striped gore, where physically possible, to provide a weaving distance of 300 feet or more.
3. For single lane frontage roads with a weaving distance of less than 300 feet, and after confirmation of STEP 2, a STOP sign shall be installed.
4. For two lane frontage roads with a weaving distance of less than 300 feet, and after confirmation of STEP 2, a traffic volume analysis shall be completed to determine if the two lanes should be merged into one lane based on the following criteria, then, install a STOP sign.
  - Number of lanes and traffic volumes upstream and downstream of the striped gore where frontage road merges with the exit ramp,
  - Signal timing at the arterial street intersection to determine if any existing traffic volume backups can/cannot be mitigated by adjusting the signal timing,
  - Crashes associated with weaving vehicles between the physical gore and arterial street intersection to ensure number of crashes at the study location are not increasing by eliminating one lane,
  - Presence of driveways between the physical gore and the arterial street intersection ensure that there are no driveway conflicts,
  - To ensure that sight visibility is adequate and not compromised by eliminating one lane, etc.
5. If the weaving distance for a two-lane frontage road cannot be increased/expanded to 300 feet per STEP 2, and if the traffic analysis determines that the two-lane frontage roads cannot be merged into one lane, then a YIELD (R1-2) sign shall be installed.

6. If the weaving distance is between 300 feet and 700 feet for both one lane and two-lane frontage roads, install YIELD signs.
7. If the weaving distance is between 750 feet and 1,000 feet and there are no sight restrictions for both one lane and two-lane frontage roads, further crash analysis shall be performed to determine if a YIELD sign is warranted or if no traffic control sign shall be recommended.
8. If the weaving distance is greater than 1,000 feet for both one lane and two-lane frontage roads, no traffic control sign is recommended.

**Figure 1** is a flowchart illustrating the sequencing of steps/considerations in determining the recommended traffic control for one lane and two-lane frontage roads.

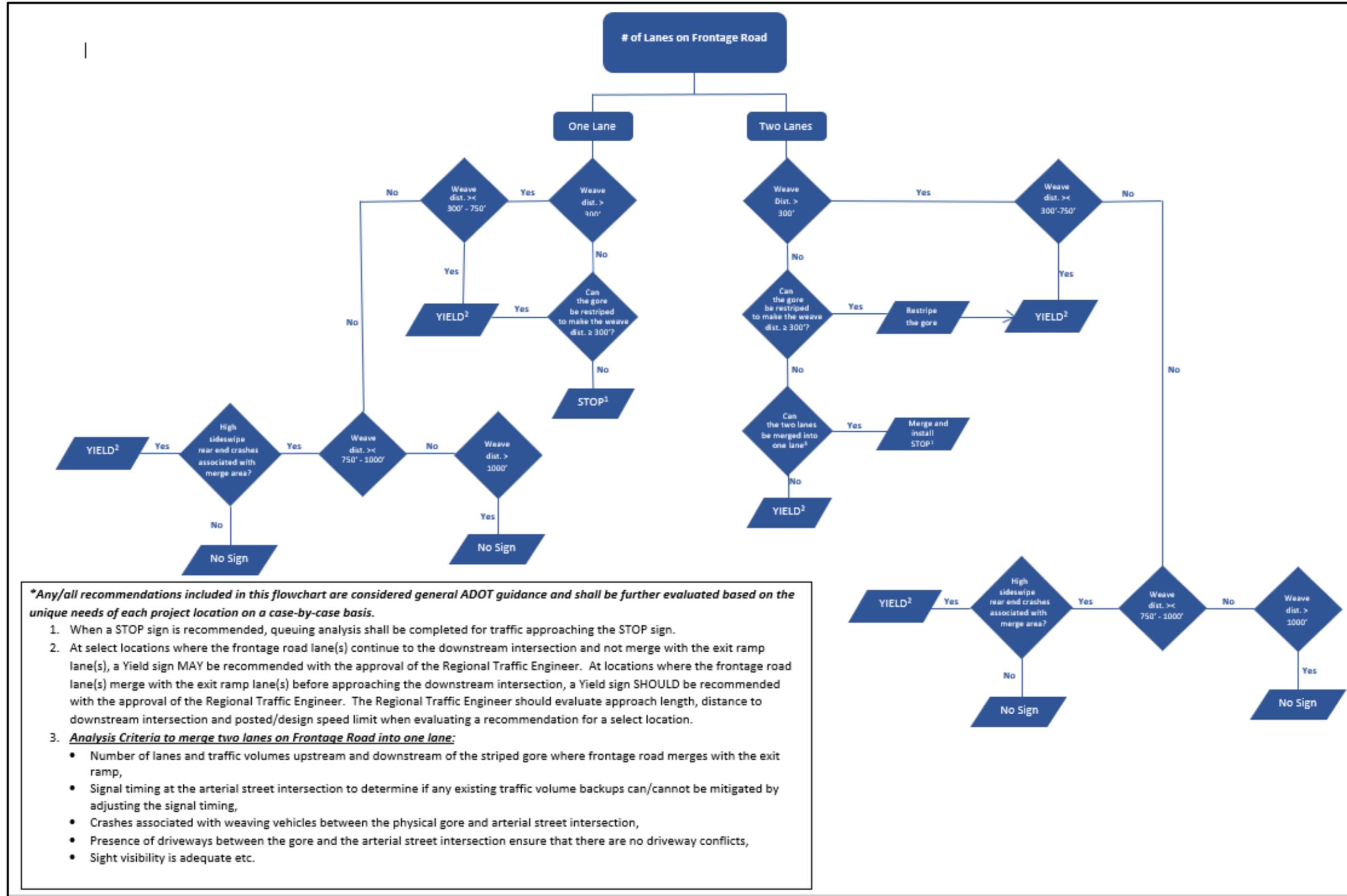


Figure 1: Flowchart of the Traffic Control Recommendations Along Frontage Roads

## Sign Size Recommendations

Recommended sign sizes along the frontage roads where they merge with the exit ramps within the Central District are as follows:

1. STOP (R1-1) signs shall be 36" x 36" (per MUTCD Section 2B.03)
2. YIELD (R1-2) signs shall be 36" x 36" x 36" for one lane frontage road and 48" x 48" x 48" for two lane frontage roads (per MUTCD Table 2B.1)
3. STOP AHEAD (W3-1) and YIELD AHEAD (W3-2) signs shall be 36" x 36".
4. TO RAMP TRAFFIC (R1-2rP) supplemental plaque shall be 30" x 18" (ADOT Manual of Approved Signs).
5. Larger signs may be considered to bring attention to sign if deemed necessary by the Regional Traffic Engineer (RTE).

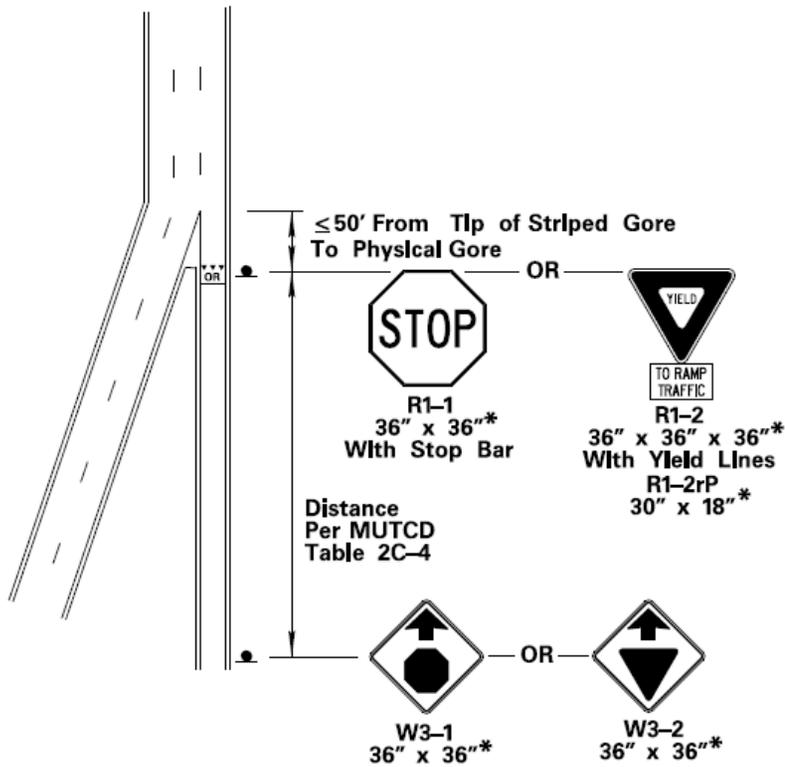
## Placement of Signs and Pavement Marking Recommendations

Locations of the sign placements along the frontage roads where they merge with the exit ramps within the Central District are as follows:

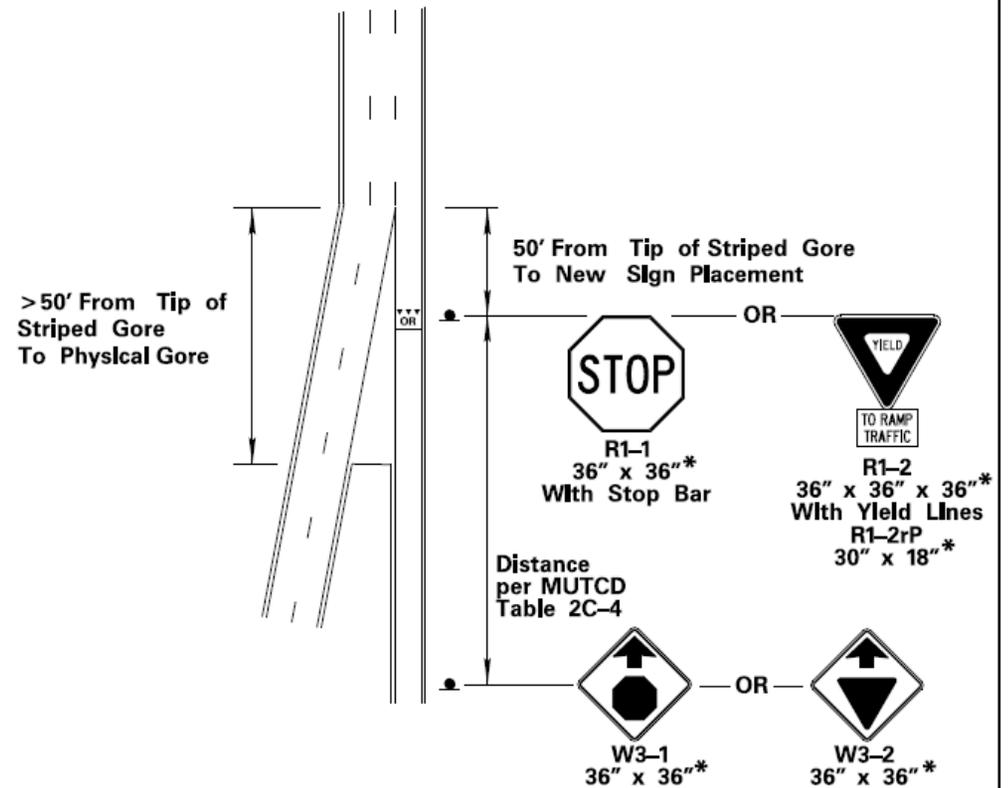
1. For single lane frontage roads with no sight visibility constraints (such as landscaping, noise reduction walls etc.) between the frontage road and exit ramp, a STOP sign or Yield sign (as recommended per the **Recommended Traffic Control** section) shall be placed 50 feet from the tip of the striped gore on the right-hand side of the approach. If the distance between physical gore and striped gore is less than 50 feet with no sight visibility issues between the frontage road and exit ramp, STOP sign or YIELD sign (as recommended per the **Recommended Traffic Control** section) shall be placed at the physical gore on the right-hand side of the approach.
2. For two-lane frontage roads with no sight visibility constraints between the frontage road and exit ramp and the distance between striped gore and physical gore is greater than 50 feet, a YIELD sign shall be placed at 50 feet from the tip of striped gore on the right-hand side of the frontage road approach. YIELD pavement marking shall be installed with the YIELD sign to improve visibility and right-of-way control.
3. For two-lane frontage roads with no sight visibility constraints between the frontage road and exit ramp and the distance between the striped gore and physical gore is less than 50 feet, a YIELD sign shall be placed at the physical gore on the right-hand side of the approach. YIELD pavement marking shall be installed with the YIELD sign to improve visibility and right-of-way control. An additional YIELD sign may be installed on the left-hand side of the frontage road if sight visibility is not obstructed. If a YIELD sign is placed on the left-hand side of the frontage road, it should be angled towards the frontage road and shielded from the exit ramp traffic.
4. If there are sight visibility constraints between the frontage road and exit ramp, the STOP sign or YIELD sign (as recommended per the **Recommended Traffic Control** section) shall be placed at 10 feet from the tip of the striped gore for both one lane and two-lane frontage roads, assuming that there are no more sight visibility restrictions at this location.
5. A "To Ramp Traffic" plaque shall be installed under all YIELD signs as discussed above.
6. "Stop Ahead" and "Yield Ahead" signs shall be installed in accordance with MUTCD Table 2C-4: Placement of Advance Warning Signs.

Figure 2 and Figure 3 shows a schematic of sign placement and sign sizes along one lane and two-lane frontage roads respectively.

**One Lane Frontage Rd With Distance Between Physical Gore and Tip of Striped Gore  $\leq 50$  ft.**



**One Lane Frontage Rd With Distance Between Physical Gore and Tip of Striped Gore  $> 50$  ft.**



\* Larger Signs May Be Considered Depending on Operations and Location, As Determined By The RTE.

Figure 2: Sign Placement Schematic along One Lane Frontage Roads

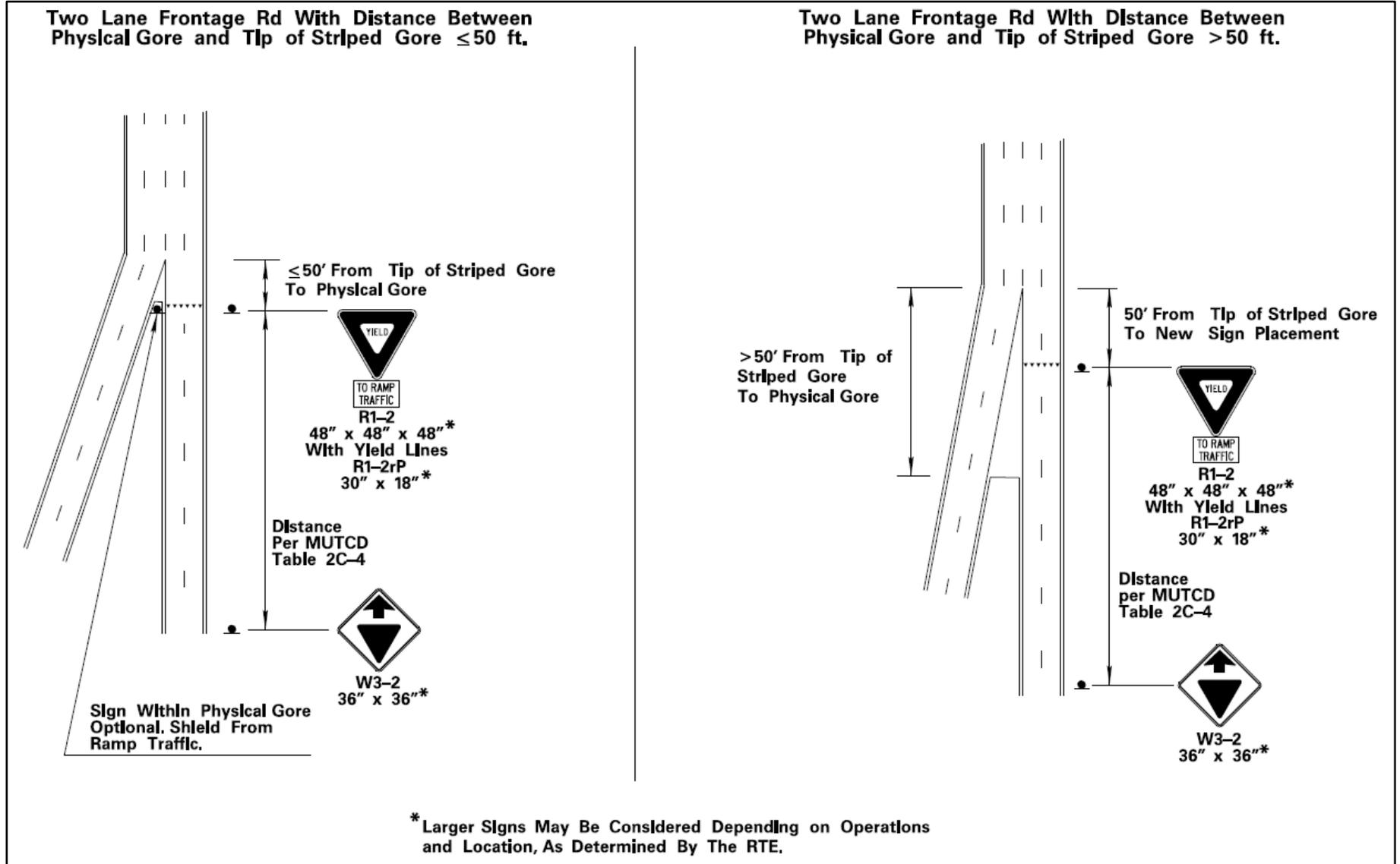


Figure 3: Sign Placement Schematic along Two Lane Frontage Roads

# **ATTACHMENT A**

## **COMPLAINTS LOG**

Date	Complaint #	Freeway	Cross Street	Complaint	Action	Action Result		Applicable to this project
						Disposition	Date	
3/23/2016		SR 101	Broadway Road	DPS and Tempe PD, with neither willing to enforce the "YIELD TO RAMP TRAFFIC" signage - concerned about the merging/gore area of SB Price and SB Loop 101 Frontage Rd at Broadway Rd in Tempe	Provided signing and striping improvements (Go to work order for details)	Completed	6/26/2016	Yes
11/15/2016		SR 101	Pima	As cars come fast down the north 101 off-ramp heading toward the traffic light at the intersection with Pima. Unfortunately, the traffic heading north on the Frontage Road (which crosses into the off-ramp) are often (may be even more often) not yielding until the last section, if at all (maybe because of bad sight lines). to avoid a big accident (if one hasn't happened already), Scottsdale and/or the State needs to do more! Should we be enlarging the yield sign or placing a blinking yellow light to warn the side-road's drivers of the need for caution as they head across/into the off-ramp?	Move the Yield sign close to the tip of the gore. We will also be moving the shark teeth to line up with the new Yield location.	Completed	12/13/2016	Yes
1/12/2017	1701281262	SR 101	Exit 36 - Pima Road NB	Every day I travel along the northbound 101 freeway, sometimes several times in one day, and exit at #36 to head north on Pima Road. As the time of the year gets busier, this exit ramp is so dangerous. The lower traffic is to YIELD to the exiting ramp traffic. THIS NEVER HAPPENS! Its's as if the YIELD sign does not exist. Any chance this is going to become at least a FLASHING yield sign or even a stop sign. We have a newer driver at our home and this intersection is terrifying!				Yes
1/12/2017	1701281262	SR 101	Frank Lloyd Wright NB	The second one in the area that is horrible also is as you are heading south on the 101 and exit Frank Lloyd Wright. If you want to head West on Frank Lloyd Wright, you need to cut over three lanes of traffic, which once again are supposed to YIELD to ramp traffic. Same problem here.				Yes
8/9/2017		SR 101	Warner Road NB	On NB 101 Warner Rd exit, there used to be a 'yield to ramp traffic' sign that was located on the left side of frontage road. Was it damaged and removed? Are there plans to reinstall it? How about merging the frontage road to one lane (similar to SB 202 at Elliott) to help prevent the off ramp traffic from getting backed up and having to cross to lanes of traffic to turn right?				Yes
10/27/2017	1730065877	SR 101	Ray Road SB	I have a concern as a driver. When exiting the 101 Loop South in Chandler, AZ to take Exit 59 at Ray Road, drivers that are approaching Ray Road from Price Road are supposed to yield to drivers taking the ramp off the 101. However, drivers on Price Road rarely do yield properly and often make a dangerous driving situation. I think putting a STOP sign instead of a YIELD sign for those traveling south on Price Road towards Ray Road would make for a better.	<a href="https://www.google.com/maps/@33.3221296,-111.8945761,3a,75y,191.31h,84.43t/data=!3m6!1e1!3m4!1svot-GyV8xF5lz1rReueqWg!2e0!7i13312!8i6656">https://www.google.com/maps/@33.3221296,-111.8945761,3a,75y,191.31h,84.43t/data=!3m6!1e1!3m4!1svot-GyV8xF5lz1rReueqWg!2e0!7i13312!8i6656</a>			Yes
11/14/2017	1731730208			Sure, that is what you and I would do if we were on the access road, yield to freeway traffic. But that becomes challenging for them too because both access road lanes get backed up from the light by 6-8 cars which is past the merge lines, so when the light turns green they would have to stay stationary in order to let anyone merge. However we have been driving this route for almost a year now, and unfortunately we have found that not many people will actually yield, and what seems to make it more difficult at this location is that the actual merge lines (where the solid white shoulder line changes to white dashed) are only a few short car lengths from the light, so when the access road traffic is full, as it often is around 8:10am, merging when you are almost at the light makes it extra challenging. I'm sure it's been this way forever, I just can't understand why the solid white shoulder line goes on for so long. Probably because it may be hard to see around the Great Wall if it was shorter. Some will even cut through the shoulder to try to ensure they will get over far enough to turn right which only further complicates things for those attempting to merge farther up at the dashed lines. Thanks for listening anyway. Have a good day.				Not sure of the location
11/17/2017	1732132524		Ray Road, Chandler Blvd	Yield Sign at Ray Road / Chandler Blvd is not visible for drivers to convey - heading EAST - and drivers coming from Ray rd are subject to collisions *** "Yield Sign" is NOT visible — It is posted on PASSENGER SIDE OF ROAD & POSTED TOO FAR AFTER THE TURN for vehicles to slow down and yield to oncoming traffic				Not sure of the location
1/19/2018	1801971588	SR 101	59th Avenue EB	The way this exit is designed makes it almost impossible for the freeway traffic to exit south. The gore point funnels all highway traffic into the left turn only lane. It directs traffic from the access road to the 3 right lanes. Many people live just south of the freeway. Tonight, like most evenings, there was a 1/4 mile backup onto the freeway because of this problem. People coming off the access road DO NOT yield. Freeway traffic is forced to drive across the gore point in order to get to any of the right 3 lanes. I see near misses every day. Very poor design, very unsafe. Please look at the design here.				Yes