DelDOT – Development Coordination
AUXILIARY AND BYPASS LANE WARRANTS

DelDOT has updated the low volume left-turn lane warrant criteria contained in the *Development Coordination Manual* (Section 5.2.9.3.C). The previous criteria were based on guidelines for rural roadways within the *NCHRP Report 745: Left-Turn Accommodations at Unsignalized Intersections* published by the Transportation Research Board (TRB) in 2013. The criteria contained in *NCHRP Report 745* for rural roadways was compared to the criteria in the report for urban roadways as well as other published warrant criteria, such as the *Maryland State Highway Access Manual* and the *DelDOT Road Design Manual,* and it was acknowledged that *NCHRP Report 745* has stricter standards for rural roadways compared to other guidelines. Effort was made to change the very low volume left-turn warrant criteria comparable to other standards. Therefore, the low volume left-turn lane warrant criteria have been modified to be consistent with *NCHRP Report 745* for urban roadways and *Maryland State Highway Access Manual* standards.

To ensure consistency between the left-turn lane and the bypass lane warrants, the bypass lane criteria has also been updated. The previous bypass lane criteria were based on roadway and left-turn AADT. However, the criteria has been updated to be based on left-turn vph, similar to the left-turn lane warrants. Additionally, the storage lengths presented in the bypass lane warrants table has also been updated to be consistent with the storage length methodology for left-turn lanes, which is based on *Transportation Research Record (TRR) 1500: Lengths of Left-Turn Lanes at Unsignalized Intersections*. Furthermore, the bypass lane taper lengths have also been updated to be consistent with driver behavior for utilizing bypass lanes as well as with left-turn lane taper length methodology which is adopted from the *AASHTO Green Book*, 6th Edition, 2011.

If you choose to use this design for the Left-Turn, you must also use it for the Bypass Lane.

Bypass Lane

Listed below are notes related to the warrants and bypass lane lengths:

A. Bypass lanes will not be permitted in the following locations:
   1. On roads with a projected 10-year roadway ADT ≥ 4,000 vpd and a projected left-turn volume ≥ 15 vph.
   2. Where an existing entrance or street lies within the limits of the proposed bypass lane, including at intersections where the proposed entrance creates the fourth leg. Separate worksheets shall be completed and submitted for review of both the proposed entrance and the existing entrance or street to determine if either entrance would meet the bypass lane warrants and thereby trigger the need for left-turn lane(s).
   3. Signalized intersections. The table provided in Figure 1 is for unsignalized intersections only, coordinate with the DelDOT Traffic Impact Studies Group to determine left-turn lane warrants and required lengths at signalized intersections, (see the "Signalized Intersection-Tab 6", of the Auxiliary Lane Worksheet for additional guidance).
   4. On roads where physical characteristics limit the ability to provide adequate sight distance meeting DelDOT's requirements. Inadequate intersection sight distance would trigger the need for left-turn lane(s).

B. If any of the conditions listed in Section A exist, then the left-turn lane warrants will be evaluated in accordance with Section 5.2.9.3.

C. At age-restricted communities where there is a need to accommodate older drivers and drivers wait for longer gaps to make left-turns, DelDOT Subdivision Engineer may require a bypass lane.

D. For any special cases with very low opposing volumes, DelDOT's Subdivision Engineer may waive the requirement of a bypass lane.

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Figure 1- Bypass Lane Warrants

Projected 10-year Roadway AADT	Projected 10-Year Opposing Volume (vph)	Left-Turning Vehicles (vph)						
		Less than 5	5- 9	10-14	15-20	21-30	31-40	Over 40
		Storage Length (feet)						
Less than 2,000 Vehicles	0 - 200	-	-	50	50	50	50	Separate Left-Turn Lane
2,000 to 4,000 Vehicles	0 - 100	-	-	50	50	50	50	
	101 - 200	-	-	50	50	50	50	
	201 - 300	-	-	50	50	50		
	301 – 400	-	-	50	50	50		
	Over 400	-	-	75	75			
Over 4,000 Vehicles	Over 100	-	75	75				

Posted Speed (mph)	Approach Taper Length (feet)
25	Bypass Lane Not Warranted
30	125
35	155
40	155
45	180
50	215
55	250

Posted Speed (mph)	Departure Taper Length (feet)
25	Bypass Lane Not Warranted
30	65
35	80
40	80
45	90
50	110
55	125

Assumptions:

1. *Vehicle Length (ft): 25*
2. *Brake Reaction time, t (sec): 2.5*
3. *Assumes the following speed reduction from posted speed limit in through lane:*
   a. *0 mph for 25 - 35 mph posted speed*
   b. *5 mph for 40 - 55 mph posted speed*
4. *Stopping Sight Distance adopted from Table 3-1 form AASHTO Green Book*
   a. *AASHTO equation and exhibit references design speed which DelDOT defines as posted speed + 5 mph.*
   b. *Approach Taper Length = Stopping Sight Distance/2.0*
   c. *Departure Taper Length = Stopping Sight Distance/4.0*
5. *Queue Storage and Taper Lengths listed in chart are rounded up to the nearest 5'.*
6. *Queue Storage length calculated as per Transportation Research Record (TRR) 1500, Lengths of Left-Turn Lanes at Unsignalized Intersections, p.193.*
   a. *The required space for the first vehicle in the queue is 15 ft because no buffer zone is needed between the first car and the stop line.*
   b. *Proportion of Heavy Vehicles (%) = 5%*
   c. *Left-Turn from Major Road on a Two or Four-Lane Roadway*
   d. *Critical Headway (sec) = 4.2 (in this case, based on the assumptions listed above)*
      i. *Per the HCM 2010, Equation 19-30, Critical Headway = Base critical headway + (adjustment factor for heavy vehicles * % of HV). For example, using 5% of Heavy Vehicles; Critical Headway = 4.1 + (2 * 0.05) = 4.2*
      ii. *The values on the critical headway tables from TRR 1500, pages 197-198, have been adapted to always include a minimum of one vehicle storage or 15'.*
      iii. *Based on the Proportion of Heavy Vehicles (truck %) selected, critical headway values 4.1-4.9, 5.1 and 5.5 are used*
   e. *Threshold Probability of Overflow = 0.015; From TRR 1500, p. 194*
   f. *Storage Length = (Lane Length in Number of Vehicles * Vehicle Length) + 25 ft*
   g. *25 ft length represents 25 ft on departure side of the entrance*

Left-Turn Lane

Listed below are notes related to the warrants and left-turn-lane lengths:

A. The table provided in Figure 2 is based on the following criteria:
   1. Roadway grades are between -3% and +3%.
   2. Left-turn movements from major 2 or 4-lane roadway. Contact DelDOT Development Coordination Section when the left-turn movements are from a roadway having more than 4 travel lanes.
   3. Left-turn movement volume with Heavy Vehicles (HV) ≤ 5%.
   4. Opposing volumes are less than 1200 vph OR left-turning vehicles per hour are less than 400 vph. If volumes are greater than specified limits, then the engineer shall submit an intersection and traffic signal analysis to the Development Coordination Section for review.

B. Opposing Volume (vph) is the total volume of vehicles on the approach across from (and heading in the opposite direction of) the left-turn movement under analysis. The opposing volumes shall be calculated by adding any known committed development traffic volumes (including traffic generated from secondary entrances of the site under analysis) to the Projected 10-year roadway ADT.

C. If an entrance is proposed across from an existing entrance or street to create a four-legged intersection, then separate worksheets shall be completed and submitted for review of both the proposed entrance and the existing entrance or street. For any four-legged intersection, the need for a left-turn lane on one approach to the intersection will trigger DelDOT's determination of the need to create of a reciprocal "shadowed" left-turn lane on the opposing approach.

D. Left-turn lanes may be required when physical characteristics limit the ability to provide adequate sight distance meeting DelDOT's requirements for intersection sight distance, (such as those adopted from AASHTO's standards or other Nationally Accepted Standards (NAS).

E. At age-restricted communities where there is a need to accommodate older drivers and drivers wait for longer gaps to make left-turns, DelDOT Subdivision Engineer may require a left-turn lane.

F. Queue storage length may need to be greater, (depending on the design vehicle or proposed use), than the length given by the design methodology and demonstrated through the completion of the Auxiliary Lane Worksheet.

G. The following conditions apply for left-turning vehicle (vph) volumes less than 50 vph:
   1. Left-turn lanes will not be required along roadways with 10-year Projected AADT under 1,500 vpd.
   2. Left-turn lane (having the recommended queue storage length shown in the table for 50 vph), will be warranted on roadways for any combination of conditions that include; left-turning vehicle volumes between 30 to 50 vph, a highway posted speed between 35 MPH and 50 MPH, and a projected 10 year roadway AADT between 1,500 and 2,000.
   3. Left-turn lane, (having the recommended queue storage length shown in the table for 50 vph), will be warranted on roadways for any combination of conditions that include; left-turning vehicle volumes between 20 to 50 vph and a projected 10 year roadway AADT between 2,000 and 4,000.
   4. Left-turn lane, (having the recommended queue storage length shown in the table for 50 vph),

will be warranted on roadways for any combination of conditions that include; left-turning vehicle volumes between 15 to 50 vph and a projected 10 year roadway AADT over 4,000.

5. For any special cases with very low opposing volumes, DelDOT's Subdivision Engineer may waive the requirement of a left-turn lane.
6. For any intersection/corridor with a high crash history, DelDOT's Subdivision Engineer may require a left-turn lane.

H. The table is for unsignalized intersections only. For signalized intersections, coordinate with the DelDOT Traffic Impact Studies Group to determine left-turn lane warrants and required lengths at signalized intersections, (see the "Signalized Intersection-Tab 6" tab of the Auxiliary Lane Worksheet for additional guidance).

Figure 2 - Left-Turn Lane Warrants at Unsignalized Intersections

QUEUE STORAGE (Feet)												
Left-Turning Vehicles (vph)	Projected 10-Year Opposing Volume (vph)											
	100	200	300	400	500	**600**	700	800	900	1000	1100	1200
50	15	15	15	40	40	40	40	40	40	65	65	65
100	15	15	40	40	40	65	65	65	65	65	90	90
150	15	40	40	40	65	**65**	65	90	90	90	115	115
200	15	40	40	65	65	90	90	90	115	115	140	140
250	40	40	65	65	90	90	90	115	115	140	165	190
300	40	40	65	65	90	90	115	140	140	165	190	240
350	40	40	65	90	90	115	140	140	165	190	240	290
400	40	65	65	90	115	115	140	165	190	240	290	365

Posted Speed (mph)	**DECELERATION (Feet)***
25	135
35	180
40	180
45	**220**
50	270
55	325

** Includes a 100-foot taper length*

LEFT-TURN LANE LENGTH (Feet) = QUEUE STORAGE + DECELERATION			
Input Data		**Sample**	
		Input Data	Length from Table
Queue Storage	Left-turning vehicles in vph →	**150**	65
	Opposing Volume in vph →	**600**	
Deceleration	Posted Speed in mph →	**45**	220
		Total Left-Turn Lane Length (feet)	285

Assumptions

1. *Vehicle Length (ft): 25*
2. *Brake Reaction time, t (sec): 1*
3. *Deceleration length includes 100' opening taper to left-turn lane*
4. *Full deceleration to 0 mph (stop condition)*

5. *Braking reaction distance assumes the following speed reduction from posted speed limit in through lane:*
   a. *0 mph for 25 - 35 mph posted speed*
   b. *5 mph for 40 - 55 mph posted speed*
6. *Braking distance assumes the following speed reduction from posted speed limit in through lane:*
   a. *0 mph for 25 mph posted speed*
   b. *5 mph for 35 mph posted speed*
7. *Lengths determined, using methodology adopted from AASHTO Green Book, as follows:*
   a. *Per Eq. 3-2, Brake reaction distance, d = 1.47*Vdesign speed*t*
   b. *Per Eq. 3-1, Braking distance on level, d = 1.075*((Vdesign speed)2/a), a = 11.2 ft/s (-3% < Grade < 3%)*
   c. *Per Eq. 3-3, Braking distance on grade, d = [(Vdesign speed)2/(30*(a/32.2)±G)], a = 11.2 ft/s, -3% ≥ G ≥ 3%*
   d. *AASHTO equation and exhibit references design speed which DelDOT defines as posted speed + 5 mph.*

Deceleration Length (ft) = Brake Reaction (ft) + Braking on Level (ft)	Posted Speed (mph)					
	25	35	40	45	50	55
Brake reaction distance	44.1	58.8	58.8	66.2	73.5	80.9
Braking distance on level	86.4	117.6	117.6	153.6	194.4	240
Stopping Sight Distance	131	177	177	220	268	321

8. *Queue Storage and Deceleration Lengths listed in chart are rounded up to the nearest 5'.*
9. *Queue Storage length calculated as per Transportation Research Record (TRR) 1500, Lengths of Left-Turn Lanes at Unsignalized Intersections, p.193.*
   a. *The required space for the first vehicle in the queue is 15 ft because no buffer zone is needed between the first car and the stop line.*
   b. *Proportion of Heavy Vehicles (%) = 5%*
   c. *Left-Turn from Major Road on a Two or Four-Lane Roadway*
   d. *Critical Headway (sec) = 4.2 (in this case, based on the assumptions listed above)*
      i. *Per the HCM 2010, Equation 19-30, Critical Headway = Base critical headway + (adjustment factor for heavy vehicles * % of HV). For example, using 5% of Heavy Vehicles; Critical Headway = 4.1 + (2 * 0.05) = 4.2*
      ii. *The values on the critical headway tables from TRR 1500, pages 197-198, have been adapted to always include a minimum of one vehicle storage or 15'.*
      iii. *Based on the Proportion of Heavy Vehicles (truck %) selected, critical headway values 4.1-4.9, 5.1 and 5.5 are used*
   e. *Threshold Probability of Overflow = 0.015; From TRR 1500, p. 194*
   f. *Storage Length = (Lane Length in Number of Vehicles * Vehicle Length) - 10*
10. *Projected 10-Year Opposing Volume in vph = AADT * K * D * 10-Year Growth Factor*
    a. *AADT - From the DelDOT 2010 Traffic Summary Book*
    b. *K and D factors from the TPG (Traffic Pattern Group) included in the most recent DelDOT Traffic Summary Reports*
    c. *10-Year Growth Factor = 1.16 (Assuming 1.5% annual growth)*