

# Auxiliary Turn Lanes at Intersections

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# PennDOT Policy

ONLY

# PennDOT Dist. 6-0 Previous Policy

- Left-turn lanes at unsignalized intersections - Highway Research Record 211, 1967
- Right-turn lanes at unsignalized intersections - Virginia and Colorado DOT guidelines
- Signalized intersections – based on capacity analysis (to achieve acceptable levels of service)

# New PennDOT Policy

- Per SOL 9/30/08 – revisions to Chapter 11 of *PennDOT Publication 46, Traffic Studies*, Chapter 11, Section 17, Turn Lane Guidelines
- Applies to all PennDOT projects, all Highway Occupancy Permit (HOP) projects, and all traffic signal projects
- PennDOT's practices are not a “one size fits all” solution, but rather must be applied on a case-by-case basis. Consult PennDOT with any questions as it relates to your project.

# Turn Lane Warrants

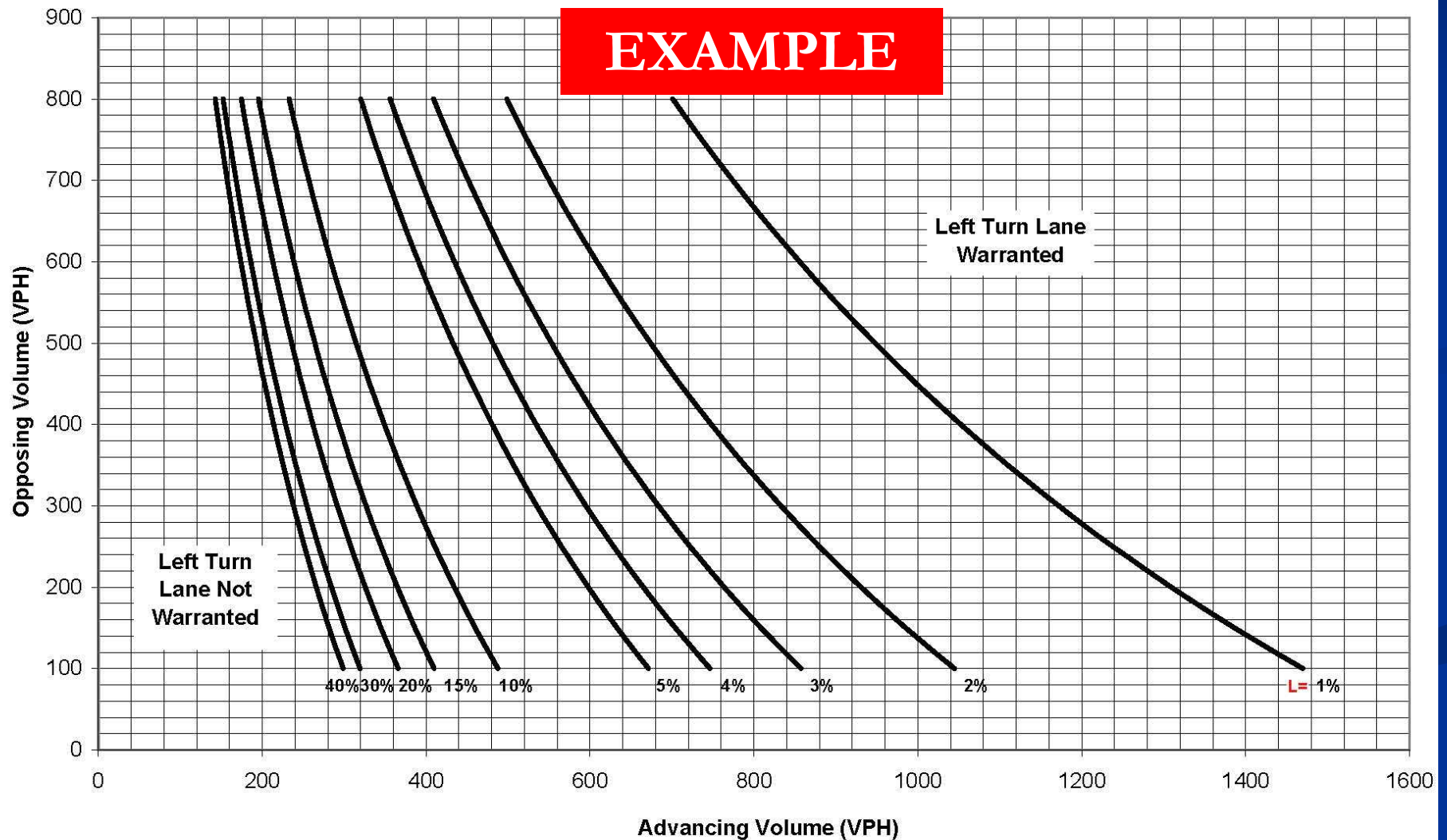


# Pub. 46 Turn Lane Warrants

- Warrants for both left- and right-turn lanes
- Same warrants for both signalized and unsignalized intersections
- Based on future design year peak hour traffic volumes (usually from TIS)
- Traffic volumes adjusted to reflect truck volumes
- Warrants satisfied when the turning traffic exceeds threshold limits
- Triggering threshold varies according to different nomographs based on speed & number of travel lanes

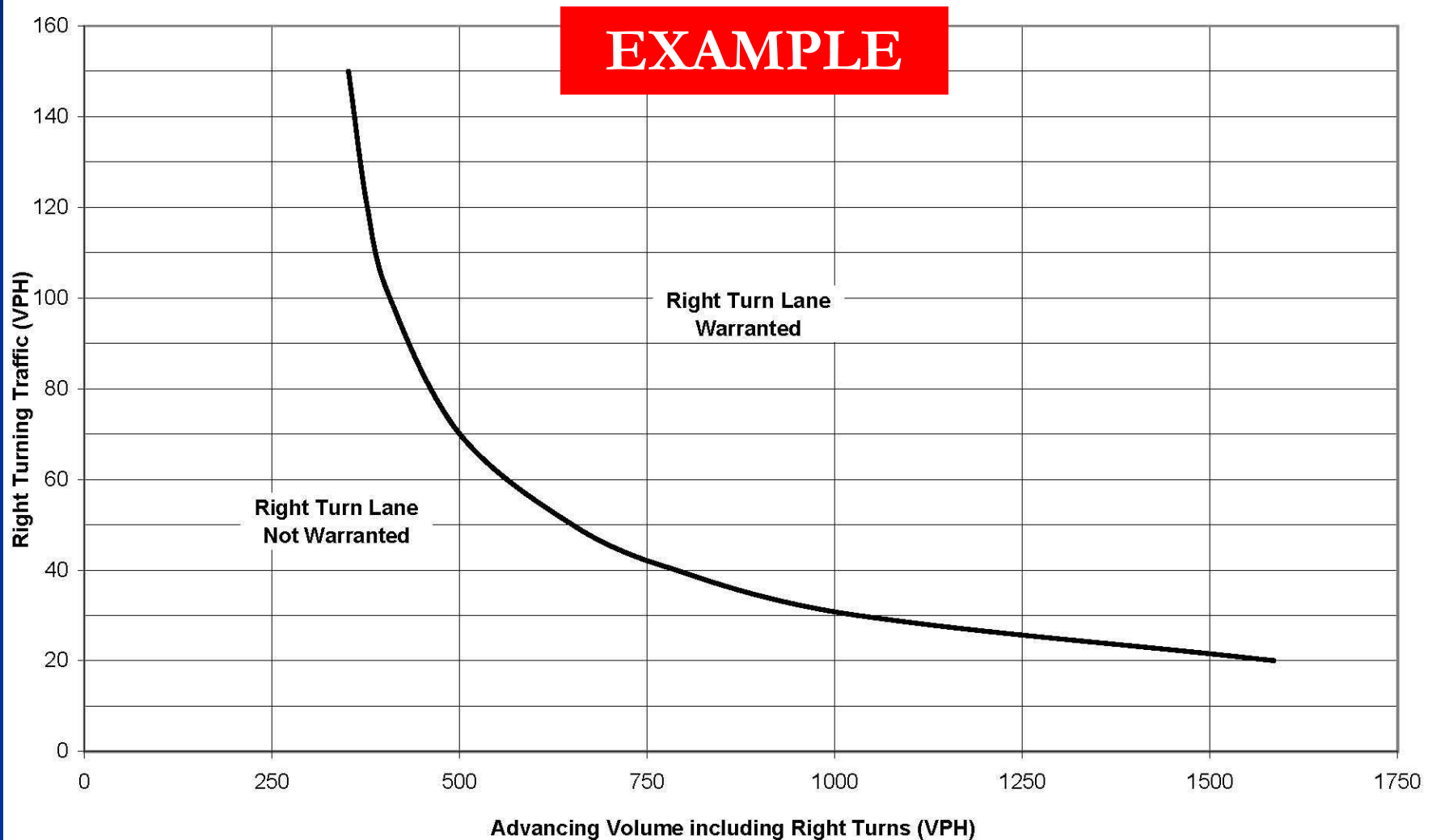
# Pub. 46 Left-Turn Lane Warrants

**Figure 3. Warrant for left turn lanes on two-lane highways (45 mph speed, unsignalized and signalized intersections)**  
(L = % Left Turns in Advancing Volume)



# Pub. 46 Right-Turn Lane Warrants

Figure 12. Warrant for right turn lanes on four-lane roadways (45 mph or greater speeds, unsignalized and signalized intersections)



# Turn Lane Warrants

In District 6-0, turn lane warrants are satisfied when:

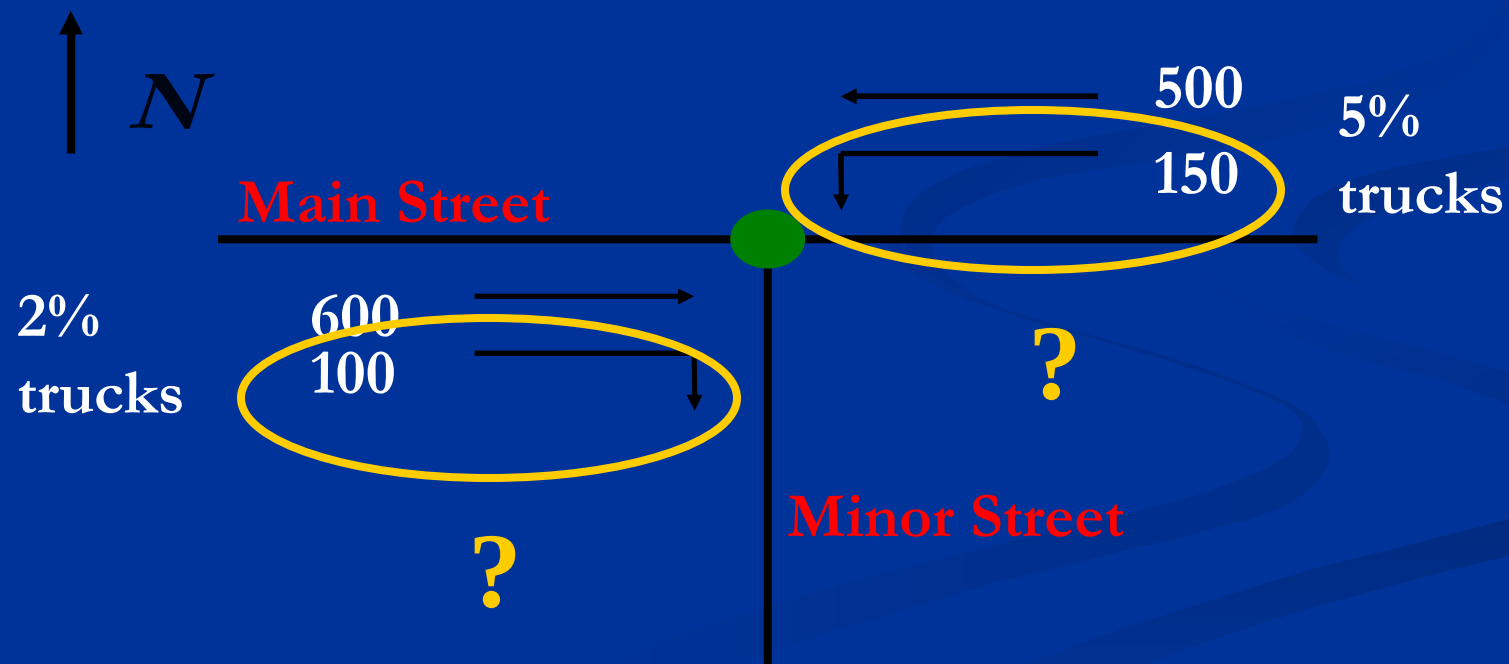
- When indicated by Pub. 46, Chapter 11 nomographs
- When determined necessary for traffic operations – usually based on level-of-service and 95<sup>th</sup> percentile queue analysis from the TIS – referenced in Pub. 46
- At accesses to schools or age-qualified facilities
- At high volume driveways (greater than 1500 vehicles per day or 3000 trips per day)
- When necessary for safety based on engineering judgment

# Turn Lane Warrants - Sample Problem

Signalized intersection; level terrain

Main Street – 1 lane in each direction; 45 miles per hour

Are turn lanes warranted on Main Street?



# Turn Lane Warrants – Sample Problem

Step 1 – Calculate the truck adjustment factor

$$T = 1 + P_T (E_T - 1)$$

T = truck adjustment factor

$P_T$  = proportion of trucks in traffic stream (as a decimal fraction)

$E_T$  = passenger car equivalent for trucks

(Pub. 46, page 11.17-2 – see below)

| Type of Terrain |         |             |
|-----------------|---------|-------------|
| Level           | Rolling | Mountainous |
| 1.5             | 2.5     | 4.5         |

Eastbound

$$T = 1 + 0.02 (1.5 - 1) = 1.01$$

Westbound

$$T = 1 + 0.05 (1.5 - 1) = 1.025$$

# Turn Lane Warrants - Sample Problem

## Step 2 – Apply truck adjustment factors

### Eastbound Approach

$$T = 1.01$$

$$\text{Through Volume} = 606$$

$$\text{Right-turn Volume} = \mathbf{101}$$

$$\text{Advancing Volume} = \mathbf{707}$$

### Westbound Approach

$$T = 1.025$$

$$\text{Through Volume} = 513$$

$$\text{Left-turn Volume} = 154$$

$$\text{Advancing Volume} = \mathbf{667}$$

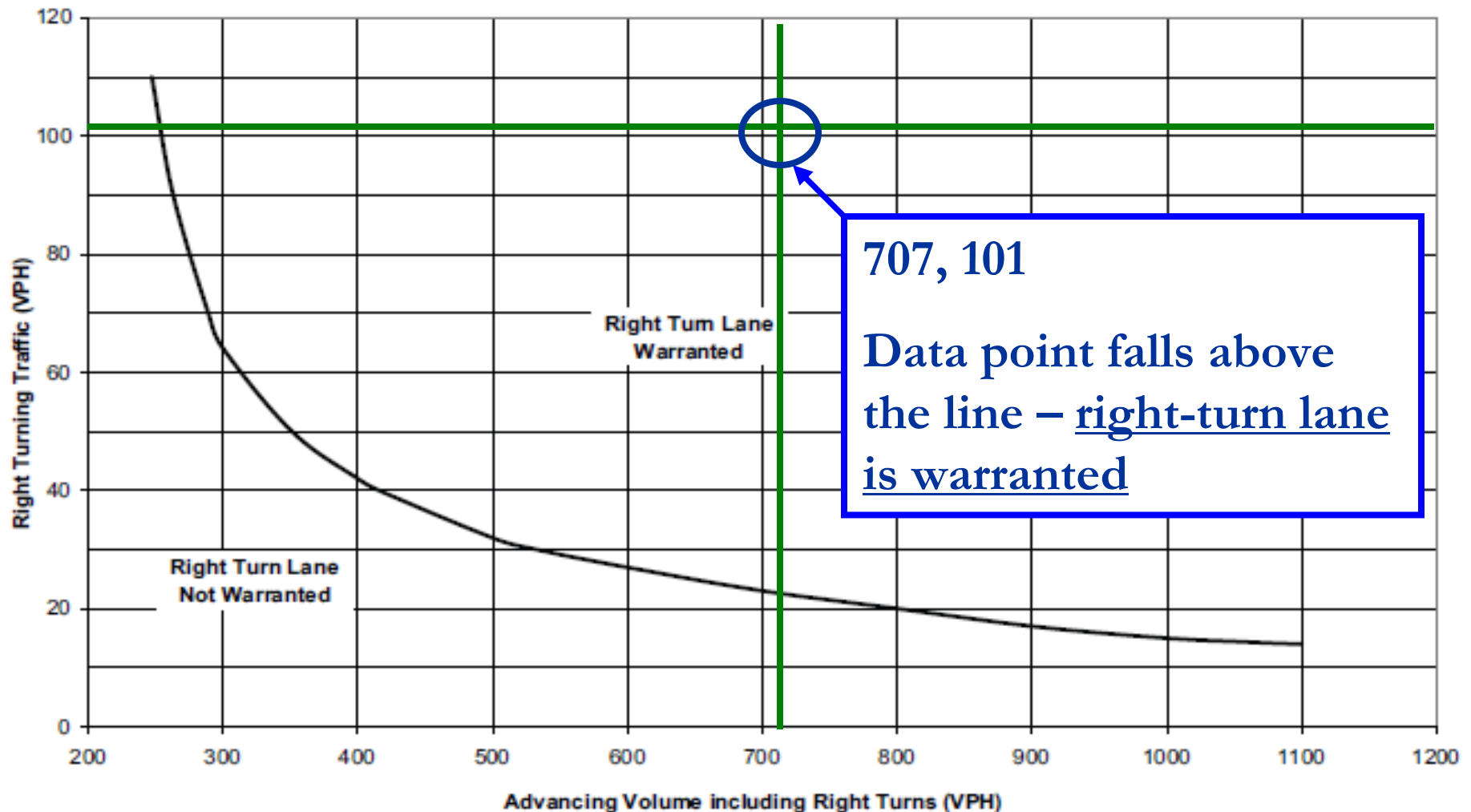
$$\text{Percentage Left Turns} =$$

$$154/667 = \mathbf{23\%}$$

# Turn Lane Warrants - Sample Problem

## Is an eastbound right-turn lane warranted?

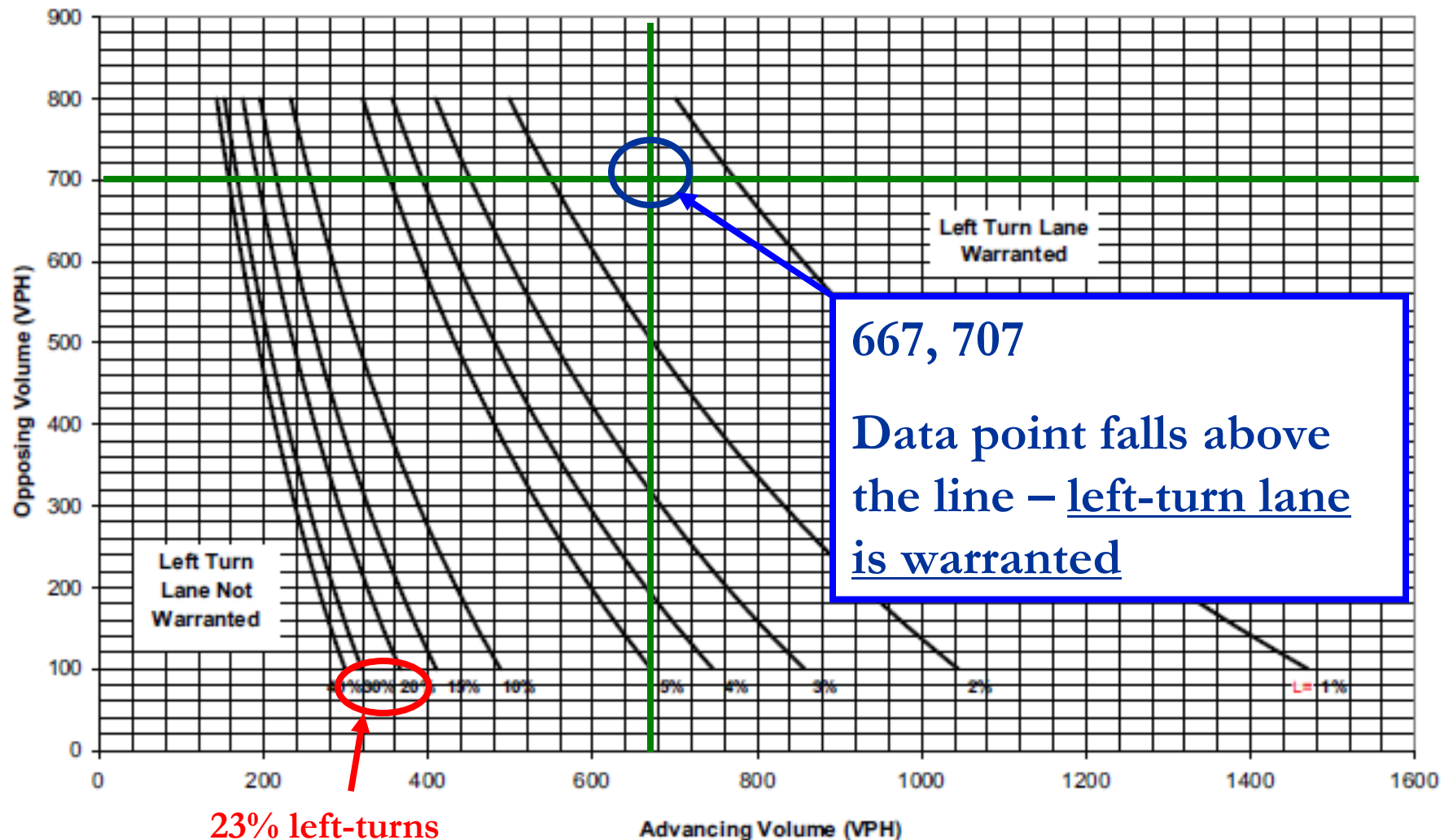
Figure 10. Warrant for right turn lanes on two-lane roadways (45 mph or greater speeds, unsignalized and signalized intersections)



# Turn Lane Warrants - Sample Problem

## Is a westbound left-turn lane warranted?

Figure 3. Warrant for left turn lanes on two-lane highways (45 mph speed, unsignalized and signalized intersections)  
(L = % Left Turns in Advancing Volume)



# Turn Lane Storage Requirements



# Pub. 46 Turn Lane Storage Requirements

- Applies to both left- and right-turn lanes
- Calculation process applies to both signalized and unsignalized intersections
- Storage length adjusted for speed limit and percentage of turning traffic (high or low demand)
- Storage length determined for three conditions
- Derived from Ohio DOT criteria
- Minimum recommended storage is 75', and round to next highest 25' increment

# Pub. 46 Turn Lane Storage Requirements

- Condition A – For low speed design (signalized & unsignalized)
- Conditions B and C – For higher speed design (above 40 miles per hour)
- Different criteria for low or high demand turn volume (low demand is 10% or less of the approach volume)
- Use the higher calculated value when Conditions B and C apply (Pub. 46, Table 1, page 11.17-3)

TABLE 1

| TYPE OF<br>TRAFFIC<br>CONTROL | SPEED (MPH)        |       |          |          |          |          |
|-------------------------------|--------------------|-------|----------|----------|----------|----------|
|                               | 25 – 35            |       | 40 – 45  |          | 50 - 60  |          |
|                               | TURN DEMAND VOLUME |       |          |          |          |          |
|                               | HIGH               | LOW * | HIGH     | LOW*     | HIGH     | LOW *    |
| SIGNALIZED                    | A                  | A     | B or C** | B or C** | B or C** | B or C** |
| UNSIGNALIZED                  | A                  | A     | C        | B        | B or C** | B        |

\* LOW is considered 10% or less of approach traffic volume

\*\* Whichever is greater

# Pub. 46 Turn Lane Storage Requirements

**TABLE 2**

| <b>CONDITION A</b> |                                       |
|--------------------|---------------------------------------|
| <b>SPEED (MPH)</b> | <b>STORAGE LENGTH</b>                 |
| Any speed          | Length from Table 3                   |
| <b>CONDITION B</b> |                                       |
| <b>SPEED (MPH)</b> | <b>STORAGE LENGTH</b>                 |
| 40                 | 75'                                   |
| 45                 | 125'                                  |
| 50                 | 175'                                  |
| 55                 | 235'                                  |
| 60                 | 295'                                  |
| <b>CONDITION C</b> |                                       |
| <b>SPEED (MPH)</b> | <b>STORAGE LENGTH</b>                 |
| 40                 | 61' + Additional length from Table 3  |
| 45                 | 75' + Additional length from Table 3  |
| 50                 | 93' + Additional length from Table 3  |
| 55                 | 114' + Additional length from Table 3 |
| 60                 | 131' + Additional length from Table 3 |

# Pub. 46 Turn Lane Storage Requirements

TABLE 3

| Average no. of vehicles/cycle* | Length (feet) | Average no. of vehicles/cycle* | Length (feet) |
|--------------------------------|---------------|--------------------------------|---------------|
| 1                              | 75            | 17                             | 600           |
| 2                              | 100           | 18                             | 625           |
| 3                              | 150           | 19                             | 650           |
| 4                              | 175           | 20                             | 675           |
| 5                              | 200           | 21                             | 725           |
| 6                              | 250           | 22                             | 750           |
| 7                              | 275           | 23                             | 775           |
| 8                              | 325           | 24                             | 800           |
| 9                              | 350           | 25                             | 825           |
| 10                             | 375           | 30                             | 975           |
| 11                             | 400           | 35                             | 1125          |
| 12                             | 450           | 40                             | 1250          |
| 13                             | 475           | 45                             | 1400          |
| 14                             | 500           | 50                             | 1550          |
| 15                             | 525           | 55                             | 1700          |
| 16                             | 550           | 60                             | 1850          |

\* Average no. of vehicles/cycle = design hour volume of turning lane/cycles per hour

If cycles per hour are unknown, assume:

Unsignalized or 2 phase – 60 cycles per hour

3 phase – 40 cycles per hour

4 phase or more – 30 cycles per hour



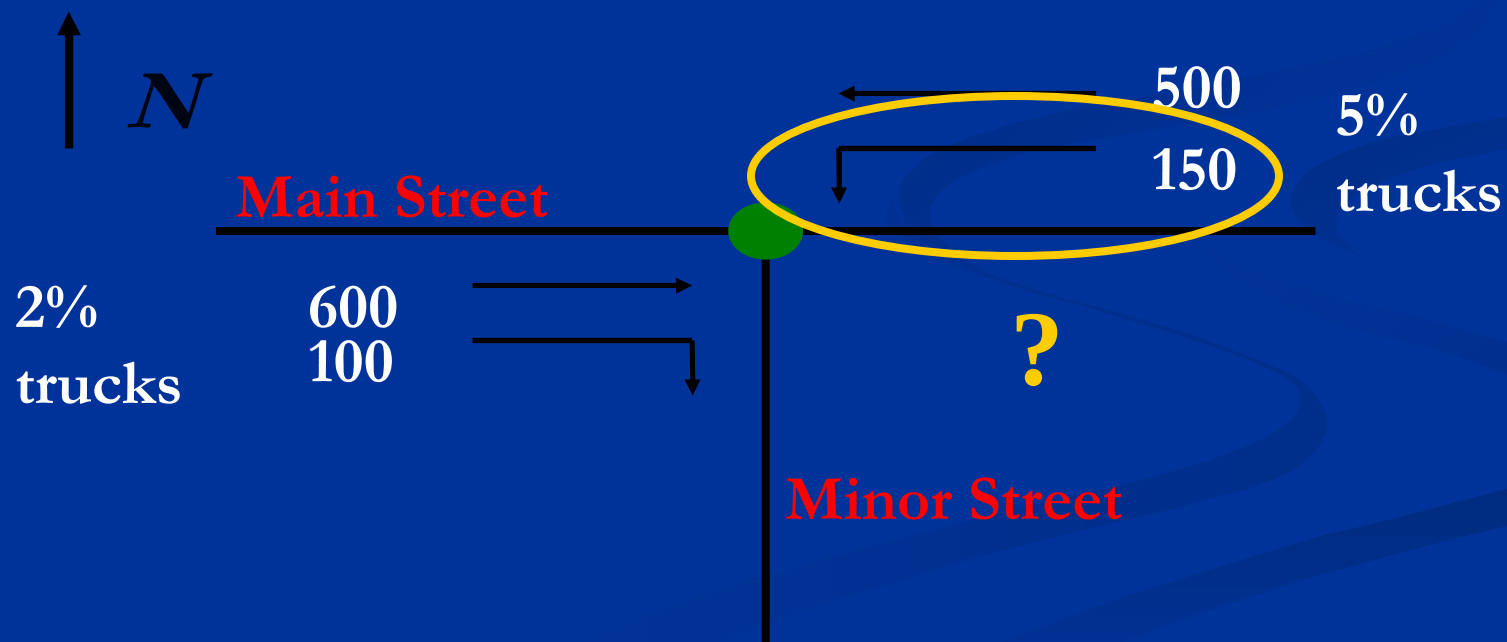
At signalized intersections, consider dual left turn lanes and operational analysis.

# Turn Lane Storage - Sample Problem

Signalized intersection; 90 second cycle length

Main Street – 1 lane in each direction; 45 miles per hour

What is the storage for the westbound Main Street left-turn lane?



# Turn Lane Storage - Sample Problem

## Step 1 – Determine the appropriate condition

- Speed = 45 miles per hour
- 23% left turns > 10 % turns = high demand
- Signalized intersection

TABLE 1

| TYPE OF<br>TRAFFIC<br>CONTROL | SPEED (MPH)        |      |          |          |          |          |
|-------------------------------|--------------------|------|----------|----------|----------|----------|
|                               | 25 – 35            |      | 40 – 45  |          | 50 - 60  |          |
|                               | TURN DEMAND VOLUME |      |          |          |          |          |
|                               | HIGH               | LOW* | HIGH     | LOW*     | HIGH     | LOW*     |
| SIGNALIZED                    | A                  | A    | B or C** | B or C** | B or C** | B or C** |
| UNSIGNALIZED                  | A                  | A    | C        | B        | B or C** | B        |

\* LOW is considered 10% or less of approach traffic volume

\*\* Whichever is greater

# Turn Lane Storage - Sample Problem

## Step 2 – Determine storage for Condition B

- Based on speed only = 125 feet

| CONDITION B |                |
|-------------|----------------|
| SPEED (MPH) | STORAGE LENGTH |
| 40          | 75'            |
| 45          | 125'           |
| 50          | 175'           |
| 55          | 235'           |
| 60          | 295'           |

# Turn Lane Storage - Sample Problem

## Step 3 – Determine storage for Condition C

- Calculate average number of vehicles using the left-turn lane per traffic signal cycle:
  - $3,600 \text{ sec per hour} / 90 \text{ sec cycle length} = 40 \text{ cycles/hour}$
  - $154 \text{ left-turns (adjusted for trucks)} / 40 \text{ cycles per hour} = 3.85 \text{ vehicle per cycle (round to 4 vehicles per cycle)}$

# Turn Lane Storage - Sample Problem

## Step 3 – Determine storage for Condition C

| CONDITION C |                                       |
|-------------|---------------------------------------|
| SPEED (MPH) | STORAGE LENGTH                        |
| 40          | 61' + Additional length from Table 3  |
| 45          | 75' + Additional length from Table 3  |
| 50          | 93' + Additional length from Table 3  |
| 55          | 114' + Additional length from Table 3 |
| 60          | 131' + Additional length from Table 3 |

Additional distance for deceleration

# Turn Lane Storage - Sample Problem

## Step 3 – Determine storage for Condition C

TABLE 3

| Average no. of vehicles/cycle* | Length (feet) | Average no. of vehicles/cycle* | Length (feet) |
|--------------------------------|---------------|--------------------------------|---------------|
| 1                              | 75            | 17                             | 600           |
| 2                              | 100           | 18                             | 625           |
| 3                              | 150           | 19                             | 650           |
| 4                              | 175           | 20                             | 675           |
| 5                              | 200           | 21                             | 725           |
| 6                              | 250           | 22                             | 750           |
| 7                              | 275           | 23                             | 775           |
| 8                              | 325           | 24                             | 800           |
| 9                              | 350           | 25                             | 825           |
| 10                             | 375           | 30                             | 975           |
| 11                             | 400           | 35                             | 1125          |
| 12                             | 450           | 40                             | 1250          |
| 13                             | 475           | 45                             | 1400          |
| 14                             | 500           | 50                             | 1550          |
| 15                             | 525           | 55                             | 1700          |
| 16                             | 550           | 60                             | 1850          |

\* Average no. of vehicles/cycle = design hour volume of turning lane/cycles per hour

If cycles per hour are unknown, assume:

Unsignalized or 2 phase – 60 cycles per hour

3 phase – 40 cycles per hour

4 phase or more – 30 cycles per hour



At signalized intersections, consider dual left turn lanes and operational analysis.

# Turn Lane Storage - Sample Problem

## Step 3 – Determine storage for Condition C

| CONDITION C |                                                 |
|-------------|-------------------------------------------------|
| SPEED (MPH) | STORAGE LENGTH                                  |
| 40          | 61' + Additional length from Table 3            |
| 45          | 75' + Additional length from Table 3 = 250 feet |
| 50          | 93' + Additional length from Table 3            |
| 55          | 114' + Additional length from Table 3           |
| 60          | 131' + Additional length from Table 3           |

## Step 4 – Compare Condition B and C results

Condition C: Total Storage = 75 feet + 175 feet = 250 feet

Condition B: Total Storage = 125 feet

Use Condition C since higher = 250 feet

# Other Turn Lane Storage Considerations

- Pub. 46 storage calculations should be used as a starting point.
- PennDOT may be willing to compromise if desired length is not feasible; if reasonable options have been explored; and if it is still safe based on engineering judgment.
- Consider 95<sup>th</sup> percentile queue results using approved traffic analysis software.

# Turn Lane Geometric Design Considerations



# Dist. 6-0 Left-Turn Lane Geometric Design Considerations

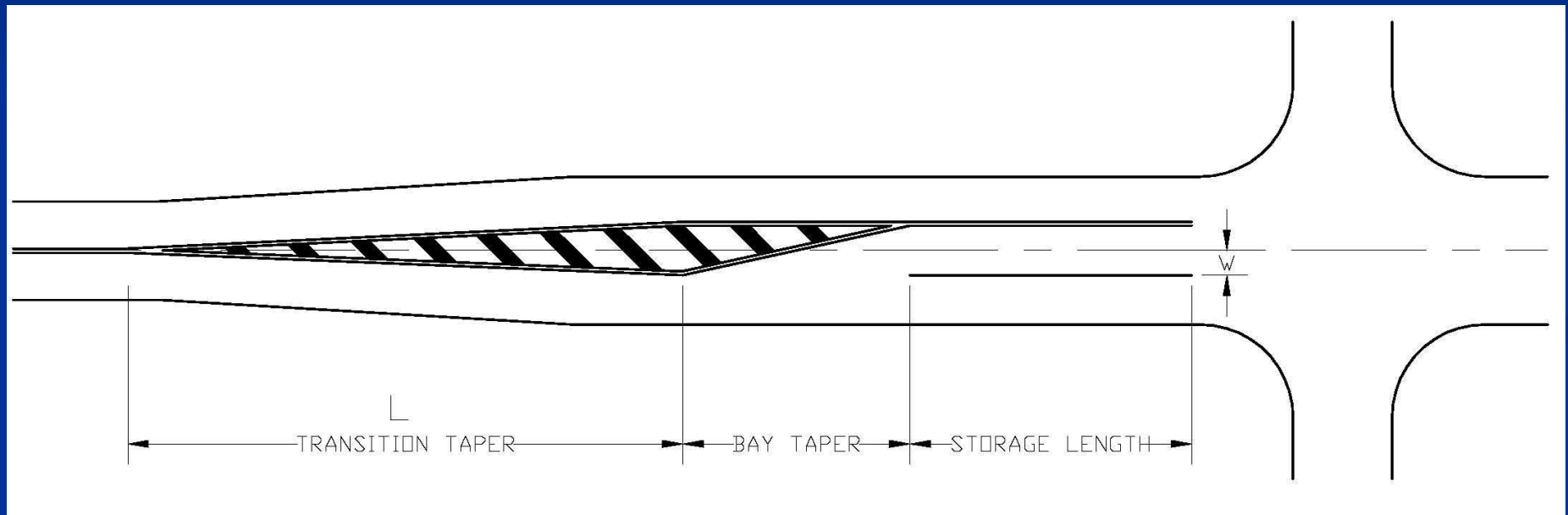
- Symmetrical widening on roadway centerline is preferred; however, consider design of adjacent intersections
- Avoid “hourglass” effect between intersections
- Full-width overlay within limits of widening
- Maintain shoulder or provide new shoulder within limits of widening
- 12 feet desirable lane width; typical minimum lane width is 11 feet; 10 feet permitted in special cases
- 85th percentile speed should be used for design if known and if greater than the posted speed limit.

# Dist. 6-0 Left-Turn Lane Geometric Design Considerations

- Bay Taper Design
  - 40 mph or less = 75 feet
  - greater than 40 mph = 100 feet
- Lane Shift Transition Taper Design
  - $L = W * S$ , where
    - $L$  = Transition taper length
    - $W$  = Lateral shift for through traffic
    - $S$  = Posted speed or 85th % speed of approach traffic in mph (whichever is greater)
  - In low speed urban areas where speeds are less than or equal to 40 miles per hour,  $L = W * S^2 / 60$  can be used

# Left-Turn Lane Geometric Design

## Lane Shift Transition Taper Design



$$L = W * S \text{ or } W * S^2 / 60$$

$S$  = Speed (mph)

# Dist. 6-0 Right-Turn Lane

## Geometric Design Considerations

- 14 feet desirable width for curbed lanes; 12 feet with shoulder for uncurbed lanes; lesser lane widths may be acceptable in special cases
- Overlay to the roadway centerline within limits of widening
- Bay Taper Design
  - 75 feet for speeds of 40 mph or less
  - 100 feet for speeds of 45 mph
  - 125 feet for speeds of 50 mph
  - Also, new Pub. 46 guidelines – 10:1 taper up to 50 mph and 15:1 if greater than 50 mph – consult PennDOT for guidance.
- 85th percentile speed should be used for design if known and if greater than posted speed limit

# Other Design Considerations

- Right-of-way acquisition for road widening
- Approval from adjacent property owners if located along the length of the auxiliary lane
- For two exit lanes on a side street approach, District 6-0 prefers a channelization island to separate the lanes for better operations/sight distance

A photograph of a paved road with double yellow lines, curving through a forest. The trees are covered in vibrant yellow autumn leaves, and fallen leaves are scattered on the road and the grassy shoulder. The scene is captured from a low angle, looking down the road.

Questions?