# Design of Turn Lane Guidelines

Prepared By:

**Howard Preston, PE**

CH2MHILL

Minnesota Department of Transportation

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The guidance in MnDOT's Road Design Manual relative to the design of turn lanes is at least 35 years old and is reflective of a time when vehicle speed and volume were lower than they are today. In response to these current conditions, some designers have been providing longer turn lanes. However, this approach has resulted in inconsistent designs across MnDOT's system. In response to concerns about the dated guidance in the Road Design Manual, the inconsistent treatment across the system and the lack of a documented design process; MnDOT developed and documented a new turn lane design process.

The suggested design process is based on the notion that turn lanes should be designed to be long enough to accommodate deceleration from the prevailing highway speeds plus the storage needed for left or right turning vehicles. The new guidance provides a check list for designers that have links to look up tables for deceleration based on speed, storage based on volume of turning vehicles and type of intersection control and adjustments for grades and the fraction of heavy vehicles.

These guidelines provide a resource for designers that will allow greater consistency between the length of turn lanes and traffic and roadway characteristics.

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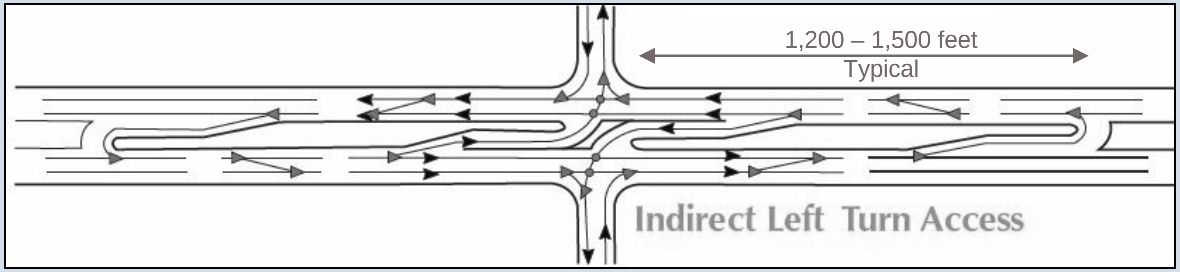
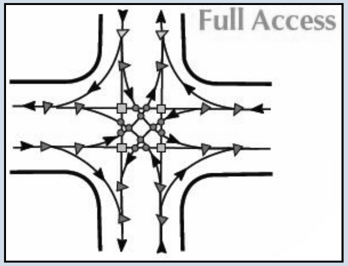
# Part A - Introduction

## Innovative Intersection Design Concept – *Indirect Left Turn*





- Recent safety research has identified indirect turns as an intersection design concept that:
  - Reduces or eliminates the high-risk crossing maneuvers.
  - Substitutes with low-risk turning, merging or diverging maneuvers.
- This concept is considered experimental because it has been deployed at approximately 20 locations, primarily in Maryland, North Carolina and Missouri. Initial evaluations have documented an 80% - 90% overall crash reduction and 100% reduction in the most severe angle crashes.
- A directional median was installed along TH 169 in Belle Plaine. A preliminary evaluation found crash reductions consistent with the national results.

# Factors that Affect Turn Lane Length

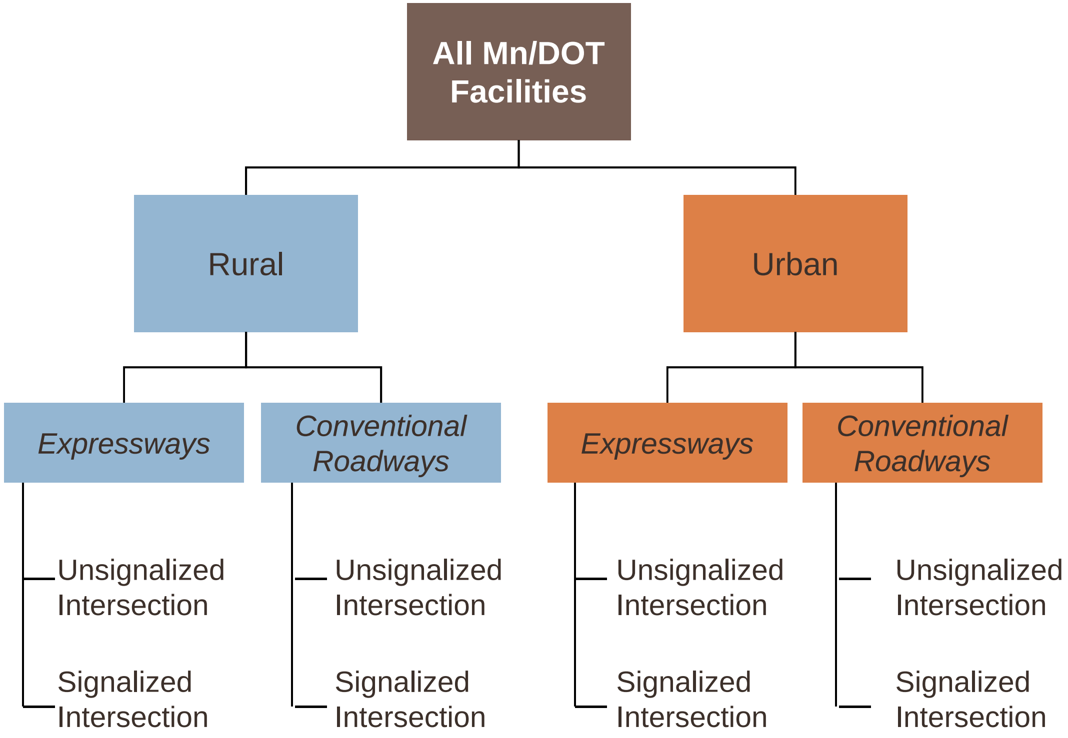


**Figure A-1 – Mn/DOT Facilities**

- These turn lane length guidelines document the primary factors that influence the suggested length of any particular turn lane and a best practices design process.
- These suggested turn lane lengths are considered to be ***reasonable default values*** that should be used when more precise output from computer modeling (SYNCHRO, SimTraffic, CORSIM, etc.) is not available.
- The primary factors affecting the suggested length of turn lanes along Mn/DOT facilities include:
  - Location: Rural vs. Urban
  - Facility Type: Expressway vs. Conventional
  - Intersection Type: Uncontrolled or Signalized
  - Speed: 30 mph to 65 mph
  - Traffic Volumes
- Other Factors Include:
  - Grade
  - Vehicle Mix: passenger vehicles or heavy commercial
  - Proximity to Horizontal Curves
  - Single vs. Dual Turn Lane operation
  - Consistency Along Corridor

# Facility Type Classification

**Rural Expressway**

Divided roadways with limited access and high speeds in rural area

**Rural Conventional**

Undivided two-lane roadway with multiple access locations and low to high speeds in rural area

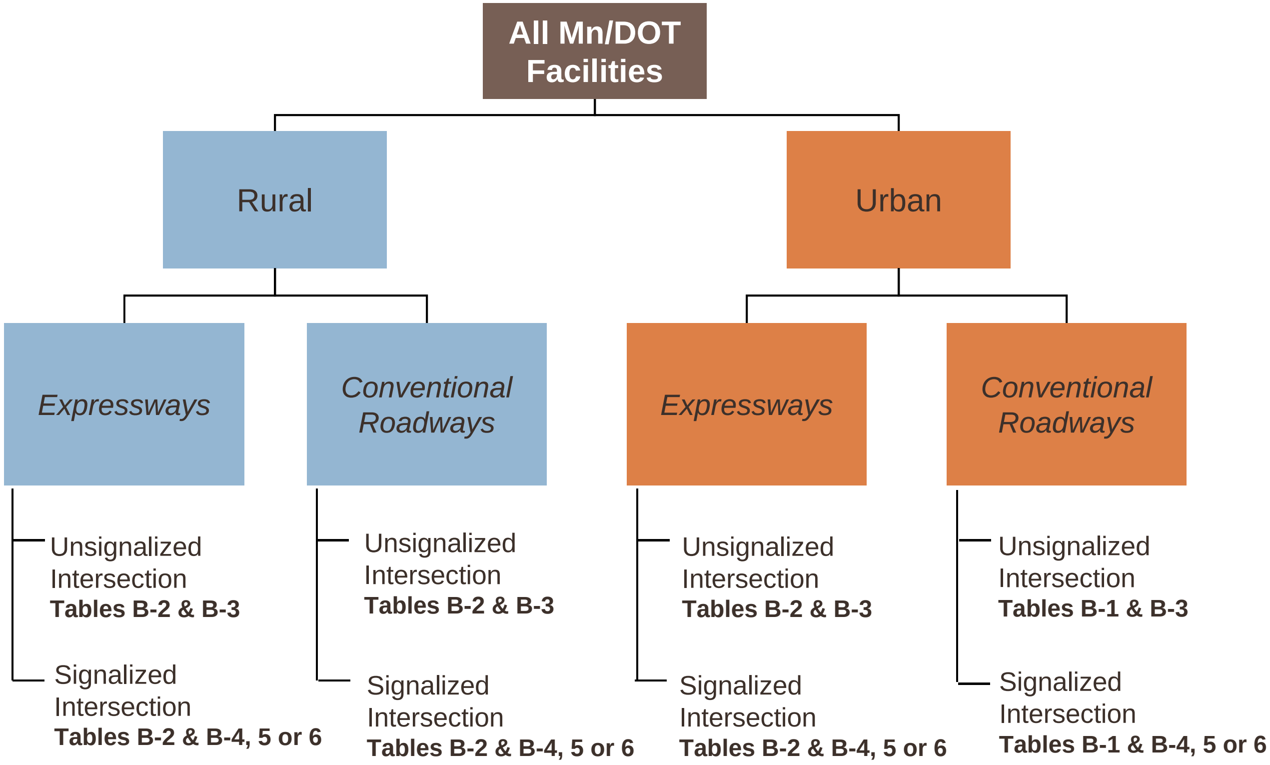
**Urban Expressway**

Divided roadway with limited signalized intersections and high speeds in urban area

**Urban Conventional**

Undivided two-lane or four-lane roadway with multiple access locations with low speeds in urban area

# List of Tables (1 of 2)



- **All Mn/DOT Facilities**
  - Rural
    - *Expressways*
      - Unsignalized Intersection **Tables B-2 & B-3**
      - Signalized Intersection **Tables B-2 & B-4, 5 or 6**
    - *Conventional Roadways*
      - Unsignalized Intersection **Tables B-2 & B-3**
      - Signalized Intersection **Tables B-2 & B-4, 5 or 6**
  - Urban
    - *Expressways*
      - Unsignalized Intersection **Tables B-2 & B-3**
      - Signalized Intersection **Tables B-2 & B-4, 5 or 6**
    - *Conventional Roadways*
      - Unsignalized Intersection **Tables B-1 & B-3**
      - Signalized Intersection **Tables B-1 & B-4, 5 or 6**

- Urban vs. Rural: Based on ***Access Management Category Assignments*** prepared by *Mn/DOT Office of Investment Management*

  www.dot.state.mn.us/accessmanagement/index.categoryassignments.html

- Conventional vs. Expressways: Based on segment determination completed by district staff and collected by the *Mn/DOT Office of Traffic, Safety, and Technology*

Figure A-2 – Mn/DOT Facilities and Tables

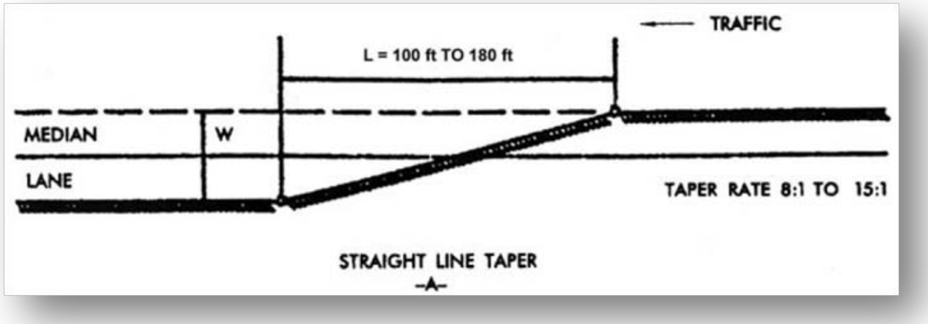
# List of Tables (2 of 2)

# Basic Objective

**Demand** Deceleration + Storage = ***Functional Turn Lane Length***

**Design** Taper + Full Width Turn Lane + Adjustments = ***Geometric Turn Lane Length***

*Example of Turn Lane Design*



*Source: AASHTO Green Book – Geometric Design of Highways and Streets, 2004*

- The basic objective of a turn lane is to reasonably accommodate deceleration plus storage.
- The design process involves first computing the expected DEMAND, which is based on vehicle speeds and volume and is considered to be the ***FUNCTIONAL TURN LANE LENGTH***.
- The next step in the design process involves determining the DESIGN side of the equation, how to distribute the available space in the corridor between the taper and the full width portion of the turn lane. The DESIGN is considered to be the ***GEOMETRIC TURN LANE LENGTH***.
- Adjustments may need to be applied to the design components of the turn lane length determination.

# Part B - Process

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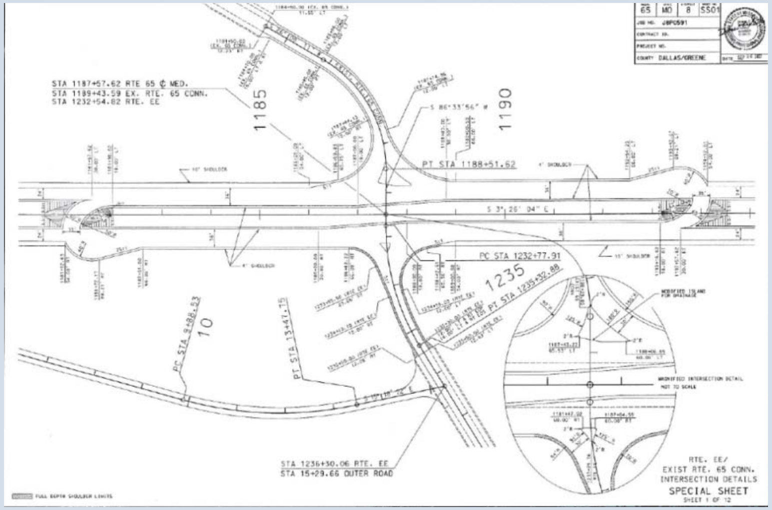
## Innovative Intersection Design Concept – *Indirect Left Turn*



*Source: Missouri Department of Transportation*

- A variation of the indirect turn intersection design concept is being used in Missouri. This design is more compact than the directional median version and prohibits all movements except the right turns at the minor road.
- The downstream u-turns which provide access between all legs, are located approximately 600 feet past the minor leg. The left turn lane for the u-turn extends all the way back to the minor roads to encourage drivers on the minor road to turn directly into the left turn lane (instead of into the through lanes on the major road and then weaving).

# Turn Lane Length Process

Step 1

**Collect Data**

***Demand Factors***

- Speed
- Forecast Volumes
- Seasonal Variations
- Grade
- Heavy Commercial %

***Design Factors***

- Distance to Adjacent Intersections
- Roadway Geometry (Horizontal Curve)

Step 2

**Determine Facility Type**

- Facility type in ***Figure B-1***
- Intersection control

Step 3

**Calculate Turn Lane Demand**

- Calculate deceleration based on ***Tables B-1 & B-2***
- Calculate storage needs based on ***Tables B-3 to B-6***
- Suggested signal cycle lengths on ***Table B-7***

Step 4

**Calculate Turn Lane Design**

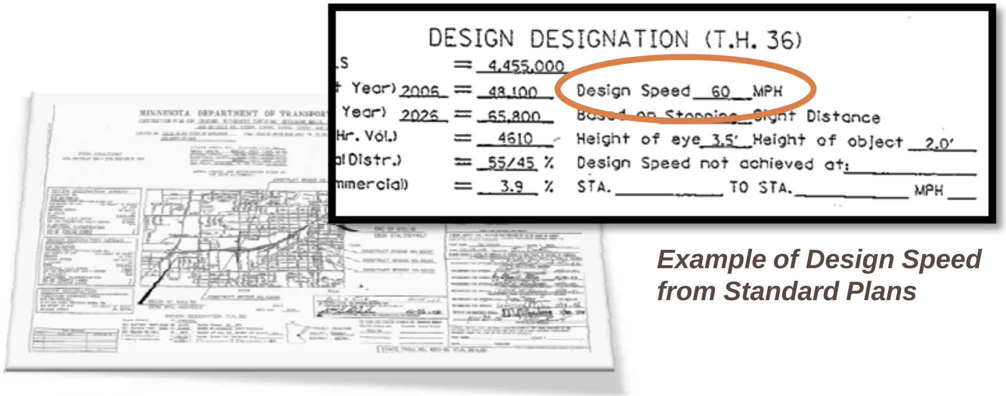
- Determine taper length based on ***Table B-8***
- Calculate turn lane design (turn lane demand length from Step 3 minus taper)
- Determine appropriate adjustments based on list.

Step 5

**Document Turn Lane Length**

- Depending on constraints of the area, characteristics of the intersection and their applicability to the stated assumptions, and engineering judgment, determine final length of turn lane.

# *Vehicle Speed*



DESIGN DESIGNATION (T.H. 36)

S = 4,455,000

Year) 2006 = 48,100    Design Speed 60 MPH

Year) 2026 = 65,800    Based on Stopping Sight Distance

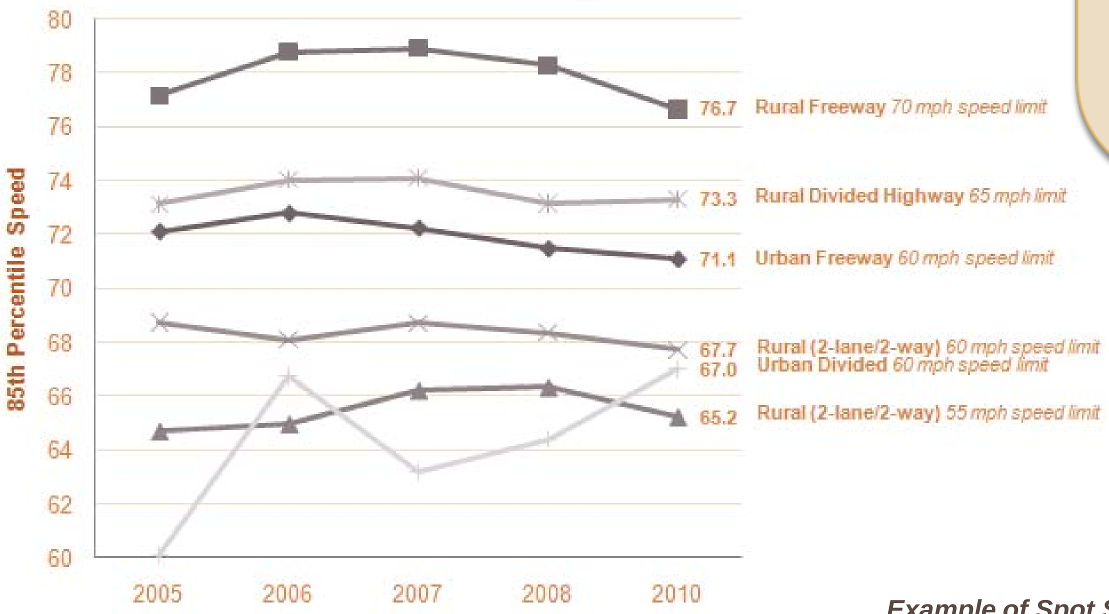
Hr. Vol.) = 4610    Height of eye 3.5' Height of object 2.0'

l Distr.) = 55/45 %    Design Speed not achieved at:

mercial) = 3.9 %    STA. ______ TO STA. ______ MPH ___

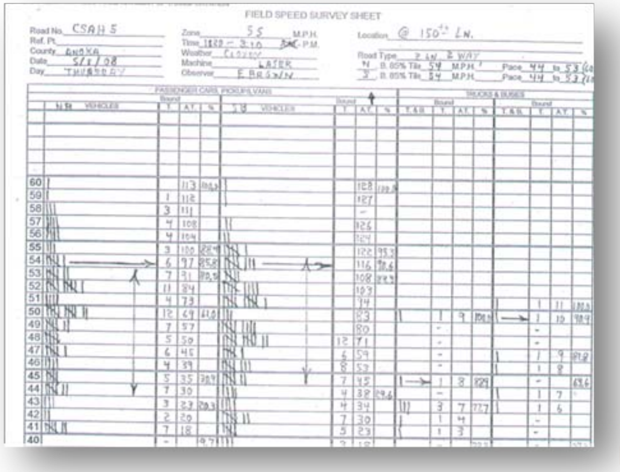
***Example of Design Speed from Standard Plans***

- Understanding vehicle speeds along a segment of highway is a key factor affecting the recommended deceleration component of the ultimate turn lane length.
- There are a variety of measures of related vehicle speed. For determining turn lane lengths, the suggested order of preference is:
  - 1. Design Speed of the facility
  - 2. 85th percentile Speed of facility
  - 3. Statewide Average 85th percentile for Facility Type (*see Figure B-1*)
- In no case should the posted speed limit be used in determining the estimated deceleration length.



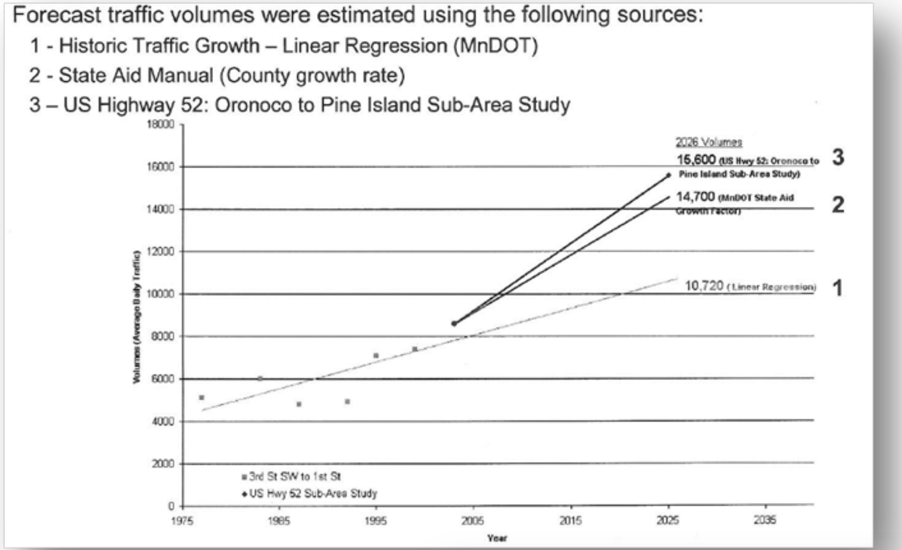
*Source: Minnesota Department of Transportation*

**Figure B-1 - Statewide Average Speed Trends**



***Example of Spot Speed (85th Percentile) Study***

# Forecast Traffic Volumes



Forecast traffic volumes were estimated using the following sources:

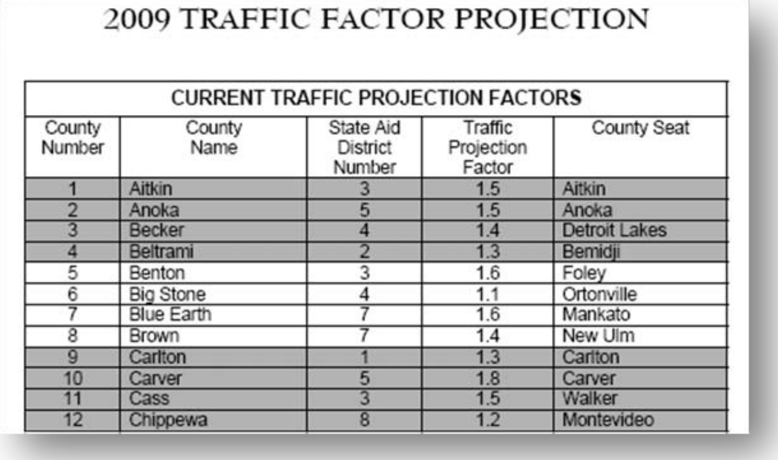
1 - Historic Traffic Growth – Linear Regression (MnDOT)

2 - State Aid Manual (County growth rate)

3 – US Highway 52: Oronoco to Pine Island Sub-Area Study

*Example of Different Forecast Methods*

*Source: CH2M HILL*



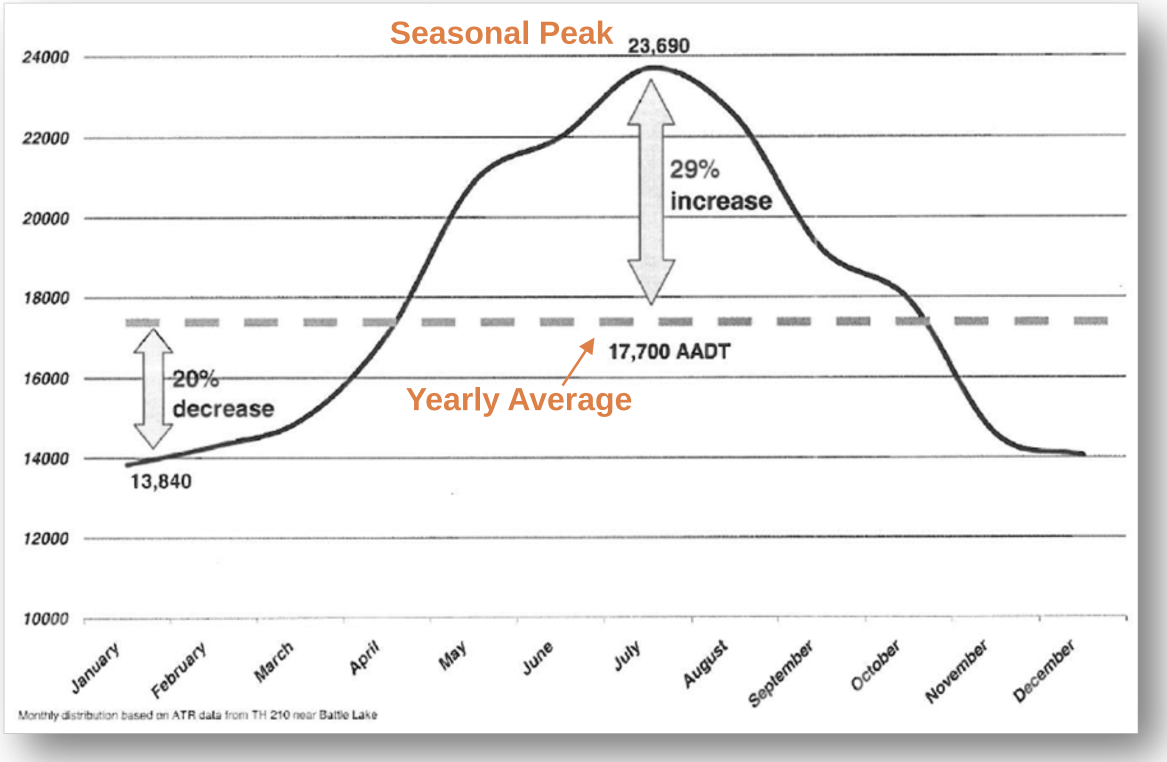
2009 TRAFFIC FACTOR PROJECTION

| CURRENT TRAFFIC PROJECTION FACTORS | | | | |
|---|---|---|---|---|
| County Number | County Name | State Aid District Number | Traffic Projection Factor | County Seat |
| 1 | Aitkin | 3 | 1.5 | Aitkin |
| 2 | Anoka | 5 | 1.5 | Anoka |
| 3 | Becker | 4 | 1.4 | Detroit Lakes |
| 4 | Beltrami | 2 | 1.3 | Bemidji |
| 5 | Benton | 3 | 1.6 | Foley |
| 6 | Big Stone | 4 | 1.1 | Ortonville |
| 7 | Blue Earth | 7 | 1.6 | Mankato |
| 8 | Brown | 7 | 1.4 | New Ulm |
| 9 | Carlton | 1 | 1.3 | Carlton |
| 10 | Carver | 5 | 1.8 | Carver |
| 11 | Cass | 3 | 1.5 | Walker |
| 12 | Chippewa | 8 | 1.2 | Montevideo |

*Source: Mn/DOT State Aid, 20-Year Traffic Projection Factors*

- Forecast Traffic Volumes (both turning and mainline volumes) should be calculated by one of the following methods (in order of preference):
  1. Design Year Volumes (provided by District/Central Office Planning Staff)
  2. Historic Volumes extrapolated to estimate 20 Year forecast volumes
  3. 20-Year Multiplier as documented by State Aid and found at the following website under County Reference Data: www.dot.state.mn.us/stateaid/sa_csah.html
- In ***no case*** should existing volumes be used in computing the estimated future demand.

# Seasonal Variations



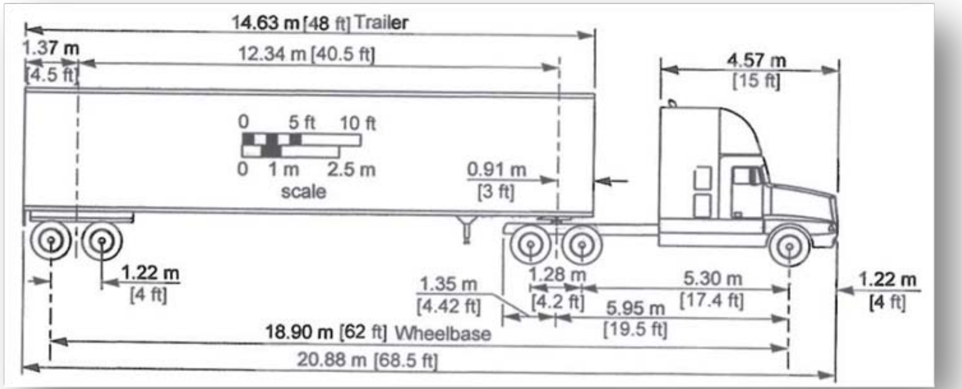
*Example of Seasonal Variation*

- If the segment of highway is subject to large seasonal variations (recreational routes, primary farm to market routes, etc.), the designer should make a decision – is the turn lane going to be designed to accommodate the seasonal peak or the yearly average?
- There is no correct answer to this question, but the answer may impact construction costs (designing for the seasonal peak will likely result in the need for longer turn lanes) and public perception (the road was just reconstructed – why are queues of vehicles backing out of the brand new left turn lane?).

# Grade and Heavy Commercial

*Example of Intersection on Grade*

*Heavy Commercial Size Example*

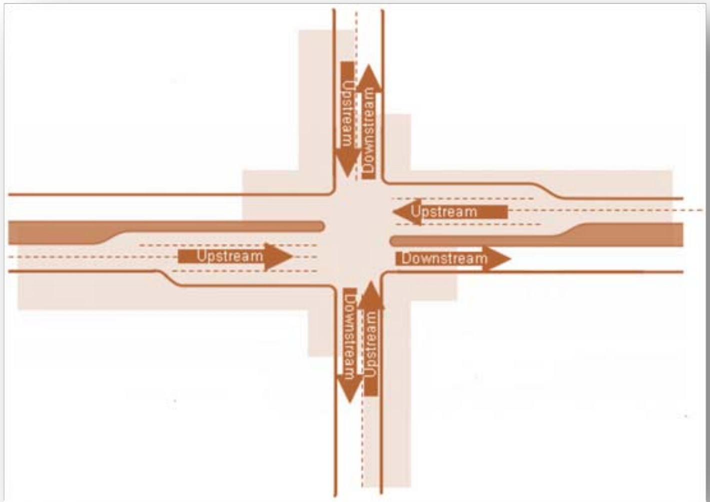


*Source: AASHTO Green Book, WB-19 [WB-62] Design Vehicle*

- **Grade at Intersection –** what is the roadway grade at the intersection? Downhill grades in excess of 3% increase deceleration distances by 20% to as much as 35%. Uphill grades in excess of 3% shorten deceleration distances by 10% to 20%.
- **Heavy Commercial -** what is the fraction of heavy commercial in the traffic stream? Determining a storage length requires an understanding of the composition of the traffic stream. The distance required to store a platoon of passenger cars (at 20 feet/vehicle) is much less than for commercial vehicles – single unit trucks (30 feet), buses (up to 45 feet) and interstate semi trailers (75 feet).

# Roadway Geometry & Adjacent Intersections

*Example of Turn Lane on Horizontal Curve*



*Intersection Influence Areas*

- **Roadway Geometry –** Is the intersection located near or in a horizontal curve? The use of 15:1 tapers to transition into turn lanes has been observed to result in erratic maneuvers on the part of some drivers when the beginning of the turn lanes is located near or on the outside of a horizontal curve.
- The 15:1 taper can look very much like the tangent extended and the entrance to the turn lane is, therefore, not well define. In this case, the designer is encouraged to use a sharper taper to better identify the entrance to the turn lane.
- **Distance to Adjacent Intersections –** How constrained are the conditions in terms of distances to adjacent intersections and driveways? The distance to adjacent intersections can have a significant effect on the recommended turn lane length. Intersections have influence areas both upstream and down and basic access management principles suggest that to optimize safety these influence areas should not overlap. In addition, an effort should be made to avoid the placement of private driveways anywhere along the length of either the full width turn lane or taper.

# Turn Lane Length Process

Step 1

**Collect Data**

*Demand Factors*
- Speed
- Forecast Volumes
- Seasonal Variations
- Grade
- Heavy Commercial %

*Design Factors*
- Distance to Adjacent Intersections
- Roadway Geometry (Horizontal Curve)

Step 2

**Determine Facility Type**

- Facility type in ***Figure B-1***
- Intersection control

Step 3

**Calculate Turn Lane Demand**

- Calculate deceleration based on ***Tables B-1 & B-2***
- Calculate storage needs based on ***Tables B-3 to B-6***
- Suggested signal cycle lengths on ***Table B-7***

Step 4

**Calculate Turn Lane Design**

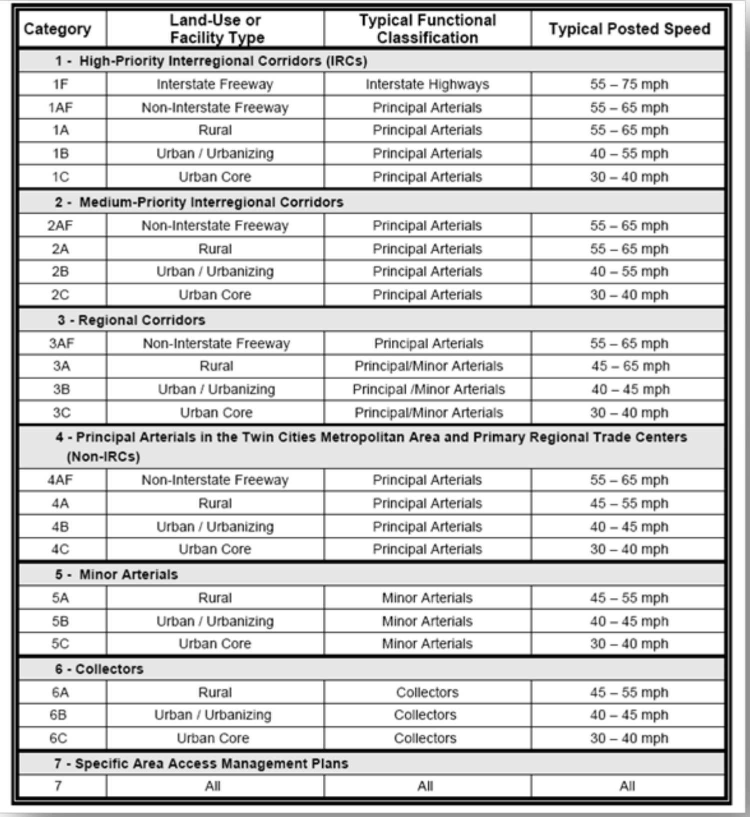
- Determine taper length based on ***Table B-8***
- Calculate turn lane design (turn lane demand length from Step 3 minus taper)
- Determine appropriate adjustments based on list.

Step 5

**Document Turn Lane Length**

- Depending on constraints of the area, characteristics of the intersection and their applicability to the stated assumptions, and engineering judgment, determine final length of turn lane.

# *Functional Classification*



| Category | Land-Use or Facility Type | Typical Functional Classification | Typical Posted Speed |
|---|---|---|---|
| **1 - High-Priority Interregional Corridors (IRCs)** | | | |
| 1F | Interstate Freeway | Interstate Highways | 55 – 75 mph |
| 1AF | Non-Interstate Freeway | Principal Arterials | 55 – 65 mph |
| 1A | Rural | Principal Arterials | 55 – 65 mph |
| 1B | Urban / Urbanizing | Principal Arterials | 40 – 55 mph |
| 1C | Urban Core | Principal Arterials | 30 – 40 mph |
| **2 - Medium-Priority Interregional Corridors** | | | |
| 2AF | Non-Interstate Freeway | Principal Arterials | 55 – 65 mph |
| 2A | Rural | Principal Arterials | 55 – 65 mph |
| 2B | Urban / Urbanizing | Principal Arterials | 40 – 55 mph |
| 2C | Urban Core | Principal Arterials | 30 – 40 mph |
| **3 - Regional Corridors** | | | |
| 3AF | Non-Interstate Freeway | Principal Arterials | 55 – 65 mph |
| 3A | Rural | Principal/Minor Arterials | 45 – 65 mph |
| 3B | Urban / Urbanizing | Principal /Minor Arterials | 40 – 45 mph |
| 3C | Urban Core | Principal/Minor Arterials | 30 – 40 mph |
| **4 - Principal Arterials in the Twin Cities Metropolitan Area and Primary Regional Trade Centers (Non-IRCs)** | | | |
| 4AF | Non-Interstate Freeway | Principal Arterials | 55 – 65 mph |
| 4A | Rural | Principal Arterials | 45 – 55 mph |
| 4B | Urban / Urbanizing | Principal Arterials | 40 – 45 mph |
| 4C | Urban Core | Principal Arterials | 30 – 40 mph |
| **5 - Minor Arterials** | | | |
| 5A | Rural | Minor Arterials | 45 – 55 mph |
| 5B | Urban / Urbanizing | Minor Arterials | 40 – 45 mph |
| 5C | Urban Core | Minor Arterials | 30 – 40 mph |
| **6 - Collectors** | | | |
| 6A | Rural | Collectors | 45 – 55 mph |
| 6B | Urban / Urbanizing | Collectors | 40 – 45 mph |
| 6C | Urban Core | Collectors | 30 – 40 mph |
| **7 - Specific Area Access Management Plans** | | | |
| 7 | All | All | All |

*Source: Mn/DOT Access Management Manual*

**Figure B-2 - Mn/DOT Access Categories**

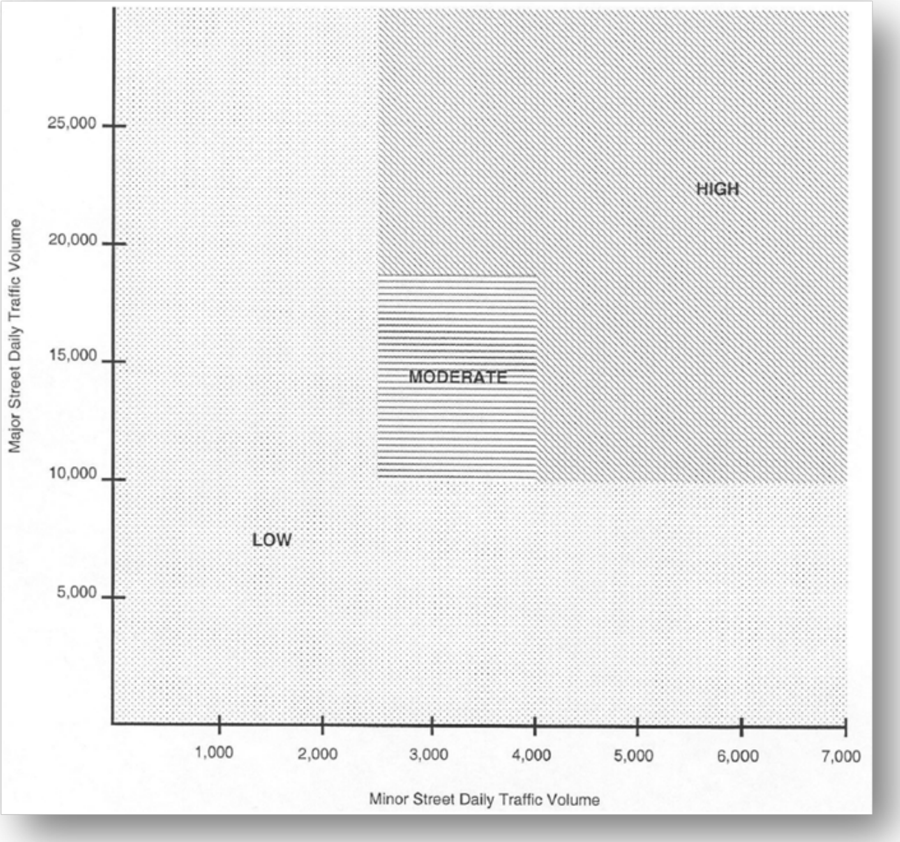
***Example Rural Conventional Roadway***

***Example Rural Expressway Roadway***

| ***Examples:*** | Location | Category | Facility Type | Functional Classification |
|---|---|---|---|---|
| US Highway 10 | Anoka Co | 1A-F | Non-Interstate Freeway | Principal Arterial |
| US Highway 10 | Washington Co | 5A | Rural Conventional | Minor Arterial |

- Selecting a facility type is an important step because the facility type suggests a speed, which influences deceleration distances, and it suggests a design priority.
- On high speed (rural and urban) arterials it is suggested that ***ALL*** deceleration take place in the turn lane but on low speed urban roadways a fraction of the deceleration can take place in the through lane.
- Determination of rural or urban category is based on ***Access Management Category Assignments*** prepared by the *Mn/DOT Office of Investment Management*
  Access Management Website:
  www.dot.state.mn.us/accessmanagement/index. categoryassignments.html
- The roadway is categorized as expressway or conventional roadway based on segment determinations completed by district staff and collected by the ***Mn/DOT Office of Traffic, Safety, and Technology***.

# Intersection Control



*Source: CH2M HILL*

**Figure B-3 - Estimated Probability of Meeting the Volume Warrant for Traffic Signal Installation**

- Assigning a type of intersection control (Thru/STOP, All-Way STOP or Traffic Signal) has a significant effect on the determination of turn lane lengths.
- Controlled intersections which require vehicles to stop, increase storage lengths while vehicles wait for their turn to enter the intersection.
- It is important to remember that turn lanes are designed for a point in time 20 years in the future. As a result, it is ***NOT*** sufficient to document the existing intersection control. An effort should be made to estimate the type of control that would likely be in place in the design year. Discussion with District Traffic Engineering staff can provide insight.
- In addition, plotting the forecast traffic volumes on the adjacent graph results in an estimate of the probability of the combination of major and minor road forecast volumes exceeding the warrants for signalization in the *Minnesota Manual on Uniform Traffic Control Devices (MNMUTCD).*

# Turn Lane Length Process

Step 1 **Collect Data**

***Demand Factors***
- Speed
- Forecast Volumes
- Seasonal Variations
- Grade
- Heavy Commercial %

***Design Factors***
- Distance to Adjacent Intersections
- Roadway Geometry (Horizontal Curve)

Step 2 **Determine Facility Type**

- Facility type in ***Figure B-1***
- Intersection control

Step 3 **Calculate Turn Lane Demand**

- Calculate deceleration based on ***Tables B-1 & B-2***
- Calculate storage needs based on ***Tables B-3 to B-6***
- Suggested signal cycle lengths on ***Table B-7***

Step 4 **Calculate Turn Lane Design**

- Determine taper length based on ***Table B-8***
- Calculate turn lane design (turn lane demand length from Step 3 minus taper)
- Determine appropriate adjustments based on list.

Step 5 **Document Turn Lane Length**

- Depending on constraints of the area, characteristics of the intersection and their applicability to the stated assumptions, and engineering judgment, determine final length of turn lane.

# Deceleration Length

**Table B-1** Deceleration Distances for Lower Speed Urban Conventional Roadways

| | **(No Deceleration in Through Lane)** | | **(10 mph Deceleration in Through Lane)** | |
|---|---|---|---|---|
| Design Speed (mph) | Stop Condition (feet) | To 15 mph (feet) | Stop Condition (feet) | To 15 mph (feet) |
| 20 | 70 | *35* | 20 | - |
| 25 | *110* | *75* | *40* | *5* |
| 30 | 160 | *125* | 70 | *35* |
| 35 | *215* | *180* | *110* | *75* |
| 40 | 275 | *240* | 160 | *125* |
| 45 | *350* | *215* | *215* | *180* |
| 50 | 425 | *390* | 275 | *240* |

**Table B-2** Deceleration Distances for High Speed Urban & Rural Roadways

| | **(No Deceleration in Through Lane)** | | **(10 mph Deceleration in Through Lane)** | |
|---|---|---|---|---|
| Design Speed (mph) | Stop Condition (feet) | To 15 mph (feet) | Stop Condition (feet) | To 15 mph (feet) |
| 45 | *350* | *315* | *215* | *180* |
| 50 | 425 | *390* | 275 | *240* |
| 55 | *515* | *480* | 350 | *315* |
| 60 | 605 | *570* | 425 | *390* |
| 65 | *715* | *680* | *515* | *480* |
| 70 | 820 | *785* | 605 | *570* |
| 75 | *940* | *905* | *715* | *680* |

- The deceleration component of the turn lane length is a function of the design speed of the facility and the amount of deceleration that is allowed in the through lanes.
- Deceleration lengths are provided for both a stop condition that would apply to left turn lanes and to 15 mph that would apply to right turn lanes.
  - ***Table B-1*** – Urban Conventional Roadway – assumes 10 mph deceleration in through lane
  - ***Table B-2*** – Urban/Rural Expressway Roadway – assumes no deceleration in through lane
- *Italicized* values within the tables are interpolated. The 15 mph values were calculated by subtracting 35 feet from the stop condition column.

Table Source: ITE Traffic Engineering Handbook (2009), Table 10-2, Page 172

# *Storage Length – Unsignalized Intersection*

**Table B-3**

Storage Length for Unsignalized Intersections

| Left-Turning Volume | Storage Length (feet) | | |
|---|---|---|---|
| | 0 – 5% Heavy Commercial | >5 – 10% Heavy Commercial | >10 – 15% Heavy Commercial |
| **50** | 50 | 50 | 60 |
| **60** | 55 | 60 | 70 |
| **70** | 65 | 70 | 80 |
| **80** | 75 | 80 | 90 |
| **90** | 85 | 90 | 100 |
| **100** | 95 | 100 | 115 |
| **110** | 105 | 110 | 125 |
| **120** | 110 | 120 | 135 |
| **130** | 120 | 130 | 150 |
| **140** | 130 | 140 | 160 |
| **150** | 145 | 150 | 170 |
| **160** | 150 | 160 | 180 |
| **170** | 160 | 170 | 190 |
| **180** | 165 | 180 | 205 |
| **190** | 175 | 190 | 215 |
| **200** | 185 | 200 | 225 |

- The storage length computation for left turn lanes at unsignalized intersections is based on accommodating the average number of arrivals in the turn lane during a two-minute period. The two minute period represents the upper range of the typical delay incurred by a left turning vehicle waiting for opposing vehicles to clear the intersection.
- The recommended practice assumes a minimum storage length for 2 vehicles equals 50 feet.
- The storage length requirements for right turn lanes at unsignalized intersections is assumed to be zero since, in virtually all cases, these vehicles would have the right-of-way entering the intersection and would incur no delay.

***Storage Length*** = ((Turn Lane Peak Hour Volume / 60)*2) * ((% Passenger Vehicles * 25 feet) + (% HC * 75 feet))

**Average number of cars in 2-minute arrival period**

**Weighted average between passenger cars and heavy commercial**

# Storage Length – Signalized Intersection (1 of 3)

## Method 1 – Basic Equation

- ***Note:*** The following method for estimating the storage length requirements at signalized intersections should only be used when the output from computer models (Synchro, VISSM, etc.) are not available.
- The storage length requirements for both right and left turn lanes at signalized intersections are based on the premise that vehicles only need to be stored during the red portion of the signal cycle. As a result, the basic equation includes the following mathematical operations:
  - Dividing the design hour approach volume by the number of signal cycles/hour.
  - Multiplying the vehicles per signal cycle by the fraction of the cycle that is red for that movement.
  - Multiplying by the average of 25 feet per vehicle and adjusting for the fraction of heavy commercial and the number of turning lanes.
  - Multiplying the results by 2 to account for the random arrival of vehicles.

**DHV** = Design Hourly Volume for turn lane

Adjustment to hourly volume to account for heavy commercial traffic.

Average storage length for a passenger vehicle

Randomness factor that converts the average storage length to a 95th percentile storage length

**1-G/C =** Identifies the fraction of the signal cycle that is red for a particular movement. Two key points – the formula assumes that vehicles only need to be stored during the red portion of the signal phase and that **<u>ALL</u>** vehicles in that arrival on red clear the intersection on the following green phase.

$$\text{Storage Length (ft)} = \frac{(1\text{-}G/C)(DHV)\left(1+\frac{\%\ \text{Heavy Commercial}}{100}\right)(25 \times 2)}{(\#\ \text{cycles per hour})(\#\ \text{traffic lanes})}$$

60 sec cycle length = 60 cycles per hour
90 sec cycle length = 40 cycles per hour
120 sec cycle length = 30 cycles per hour

# of Turn lanes (single or dual turn lanes)

# Storage Length – Signalized Intersection (2 of 3)

**Method 2 – Look Up Tables**

- A second method for determining the storage length at a signalized intersection involves using *Tables B-4, B-5* and *B-6*. The storage lengths in these tables are the output from the basic equation and represent the recommended left turn storage lengths in a single left turn lane for three common cycle lengths. The tables assume 5% heavy commercial and one turn lane.
- Storage Length Determination - Use of the tables require estimation of cycle length and the percent of left turn green time. Designers are encouraged to coordinate with District traffic signal operations staff for assistance. If signal operations staff are not available, *Mn/DOT's Traffic Signal Timing and Coordination Manual*, Section 3.7 Critical Lane Analysis, should be reviewed to estimate cycle length and percent of green time for left turn movements. See *Page B-15* for the Sum of Critical Movement approach for determining cycle length and percent of left turn green time.

**Table B-4** – 60 Second Signal Cycle Length

**Storage Length in Feet** *(60 second cycle)*

| Left-Turning Volume | Percent Left-Turn Green Time | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% |
| **100** | 80 | 70 | 70 | 60 | 50 | 40 | 30 | 20 |
| **125** | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 |
| **150** | 120 | 110 | 100 | 80 | 70 | 60 | 40 | 30 |
| **175** | 140 | 130 | 110 | 100 | 80 | 70 | 50 | 40 |
| **200** | 160 | 140 | 130 | 110 | 90 | 70 | 60 | 40 |
| **225** | 180 | 160 | 140 | 120 | 100 | 80 | 60 | 40 |
| **250** | 20 | 180 | 160 | 140 | 110 | 90 | 70 | 50 |
| **275** | 220 | 200 | 170 | 150 | 120 | 100 | 80 | 50 |
| **300** | 240 | 210 | 190 | 160 | 140 | 110 | 80 | 60 |
| **325** | 260 | 230 | 200 | 180 | 150 | 120 | 90 | 60 |
| **350** | 280 | 250 | 220 | 190 | 160 | 130 | 100 | 70 |
| **375** | 300 | 270 | 230 | 200 | 170 | 140 | 100 | 70 |
| **400** | 320 | 280 | 250 | 210 | 180 | 140 | 110 | 70 |

**Table B-5** – 90 Second Signal Cycle Length

**Storage Length in Feet** *(90 second cycle)*

| Left-Turning Volume | Percent Left-Turn Green Time | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% |
| **100** | 120 | 110 | 100 | 80 | 70 | 60 | 40 | 30 |
| **125** | 150 | 140 | 120 | 100 | 90 | 70 | 50 | 40 |
| **150** | 180 | 160 | 140 | 120 | 100 | 80 | 60 | 40 |
| **175** | 210 | 190 | 170 | 140 | 120 | 100 | 70 | 50 |
| **200** | 240 | 210 | 190 | 160 | 140 | 110 | 80 | 60 |
| **225** | 270 | 240 | 210 | 180 | 150 | 120 | 90 | 60 |
| **250** | 300 | 270 | 230 | 200 | 170 | 140 | 100 | 70 |
| **275** | 330 | 290 | 260 | 220 | 180 | 150 | 110 | 80 |
| **300** | 360 | 320 | 280 | 240 | 200 | 160 | 120 | 80 |
| **325** | 390 | 350 | 300 | 260 | 220 | 180 | 130 | 90 |
| **350** | 420 | 370 | 330 | 280 | 230 | 190 | 140 | 100 |
| **375** | 450 | 400 | 350 | 300 | 250 | 200 | 150 | 100 |
| **400** | 480 | 420 | 370 | 320 | 270 | 210 | 160 | 110 |

**Table B-6** – 120 Second Signal Cycle Length

**Storage Length in Feet** *(120 second cycle)*

| Left-Turning Volume | Percent Left-Turn Green Time | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% |
| **100** | 160 | 140 | 130 | 110 | 90 | 70 | 60 | 40 |
| **125** | 200 | 180 | 160 | 140 | 110 | 90 | 70 | 50 |
| **150** | 240 | 210 | 190 | 160 | 140 | 110 | 80 | 60 |
| **175** | 280 | 250 | 220 | 190 | 160 | 130 | 100 | 70 |
| **200** | 320 | 280 | 250 | 210 | 180 | 140 | 110 | 70 |
| **225** | 360 | 320 | 280 | 240 | 200 | 160 | 120 | 80 |
| **250** | 400 | 350 | 310 | 270 | 220 | 180 | 140 | 90 |
| **275** | 440 | 390 | 340 | 290 | 250 | 200 | 150 | 100 |
| **300** | 480 | 420 | 370 | 320 | 270 | 210 | 160 | 110 |
| **325** | 520 | 460 | 400 | 350 | 290 | 230 | 180 | 120 |
| **350** | 560 | 490 | 430 | 370 | 310 | 250 | 190 | 130 |
| **375** | 600 | 530 | 460 | 400 | 330 | 270 | 200 | 140 |
| **400** | 630 | 560 | 490 | 420 | 350 | 280 | 210 | 140 |

# Storage Length – Signalized Intersection (3 of 3)

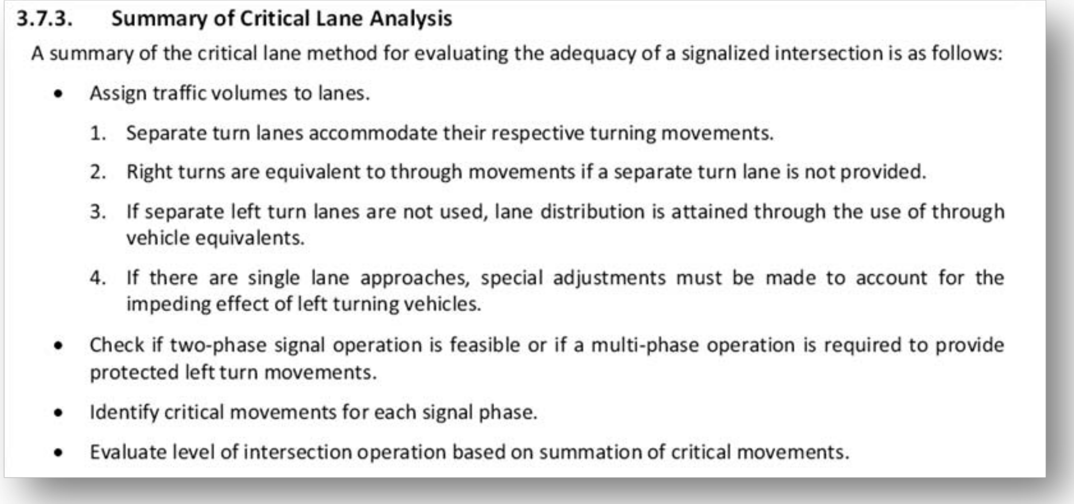
**Sum of Critical Movements** – Estimating Cycle Lengths and Percent Left Turning Green Time

- The process of summing critical movements at a signalized intersection (basically the addition of the left turn and opposing through volume on the N/S and E/W legs of intersections) provides a reasonable estimate of signal cycle lengths and the percent of left turn green time.
- The estimated cycle lengths are obtained from *Table B-7* and the percent of left turn green time is computed by dividing the left turn volume on any given approach by the total sum of the critical movements

**Table B-7**

Suggested Signal Cycle Lengths

| Sum of Critical Volume | 2 Phase Signal | 5 Phase Signal | 8 Phase Signal |
|---|---|---|---|
| 700 | 45 | 60 | 90 |
| 800 | 60 | 75 | 105 |
| 900 | 60 | 75 | 105 |
| 1000 | 75 | 90 | 105 |
| 1100 | 75 | 90 | 105 |
| 1200 | 90 | 105 | 120 |
| 1300 | 105 | 120 | 135 |
| 1400 | 120 | 135 | 150 |
| 1500 | 135 | 150 | 165 |
| 1600 | 150 | 165 | 180 |
| 1700 | 165 | 180 | 180 |
| 1800 | 180 | 180 | 180 |



**3.7.3. Summary of Critical Lane Analysis**

A summary of the critical lane method for evaluating the adequacy of a signalized intersection is as follows:

- Assign traffic volumes to lanes.
  1. Separate turn lanes accommodate their respective turning movements.
  2. Right turns are equivalent to through movements if a separate turn lane is not provided.
  3. If separate left turn lanes are not used, lane distribution is attained through the use of through vehicle equivalents.
  4. If there are single lane approaches, special adjustments must be made to account for the impeding effect of left turning vehicles.
- Check if two-phase signal operation is feasible or if a multi-phase operation is required to provide protected left turn movements.
- Identify critical movements for each signal phase.
- Evaluate level of intersection operation based on summation of critical movements.

*Source: Mn/DOT Traffic Signal Timing and Coordination Manual*

# Turn Lane Length Process

Step 1

**Collect Data**

*Demand Factors*

- Speed
- Forecast Volumes
- Seasonal Variations
- Grade
- Heavy Commercial %

*Design Factors*

- Distance to Adjacent Intersections
- Roadway Geometry (Horizontal Curve)

Step 2

**Determine Facility Type**

- Facility type in ***Figure B-1***
- Intersection control

Step 3

**Calculate Turn Lane Demand**

- Calculate deceleration based on ***Tables B-1 & B-2***
- Calculate storage needs based on ***Tables B-3 to B-6***
- Suggested signal cycle lengths on ***Table B-7***

Step 4

**Calculate Turn Lane Design**

- Determine taper length based on ***Table B-8***
- Calculate turn lane design (turn lane demand length from Step 3 minus taper)
- Determine appropriate adjustments based on list.

Step 5

**Document Turn Lane Length**

- Depending on constraints of the area, characteristics of the intersection and their applicability to the stated assumptions, and engineering judgment, determine final length of turn lane.

# Taper Lengths

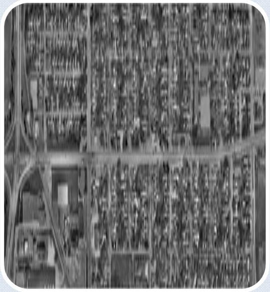
| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

*Example of Constrained Urban Environment*

- Tapers are the transition from the through lanes to the full width portion of the left or right turn lane. The basic taper length that should be used in most cases is 1:15 or 180 feet for a twelve foot wide turn lane.
- The two most common cases where consideration should be given to reducing the length of the taper include:
  - **Beginning turn lanes near or in horizontal curves.** At many curves, the 1:15 taper does not provide enough of a visual cue to drivers and they may end up following the taper because it can appear to be the tangent extended. If a shorter taper is used it is the recommended practice to add the difference to the full width portion so that the overall turn lane length remains sufficient to accommodate both deceleration and storage.
  - In **constrained urban environments** where the distance between adjacent intersections is insufficient to provide both the recommended taper and full width storage distances. In these constrained conditions, the recommended practice is to provide as much of the full width storage as possible and to sacrifice taper lengths to the extent necessary to make the design fit the available space. **However, in all cases the length of the full width turn lane should exceed the taper length.**

# Adjustments - Summary (1 of 7)

| Grade | Heavy Commercial | Horizontal Curves | Dual Left Turn Lanes | Location Constraints | Corridor Consistency |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| **Is the grade greater than 3%?** | **Is there more than 10% heavy commercial?** | **Is the intersection located in or near a horizontal curve?** | **Is there a need for dual left turn lanes (more than 300 turning vehicles in the peak hour)?** | **Is there existing constraints and not enough space to provide the recommended turn lane lengths?** | **Is this design consistent with adjacent intersection turn lanes?** |
| **See Page B-19** | **See Page B-20** | **See Page B-21** | **See Page B-22** | **See Page B-23** | **See Page B-24** |
| Adjust deceleration based on Table B-9. | Adjust deceleration based on Tables B-1 and B-2.<br>Adjust Storage lengths based on Tables B-3 through B-6. | Adjust taper to 1:8 to better delineate the entrance to the turn lane, adding the difference back to the full width length. | Adjust storage based on Tables B-4 through B-6. | Adjust taper, storage and deceleration based on operations, safety and cost. | Adjust taper, storage and deceleration based on operations, safety and cost. |

# Adjustments - Grades (2 of 7)

**Table B-9**
*Grade Adjustment*

| Grade | Upgrade Adjustment | Downgrade Adjustment |
|---|---|---|
| 3% to 4% | 0.9 | 1.2 |
| 5% to 6% | 0.8 | 1.35 |

- Grades in excess of 3% significantly effect vehicle speeds and, therefore, deceleration distances. It is the recommended practice to apply the adjustment factors in *Table B-9* in order to shorten deceleration distances on uphill grades and to lengthen deceleration distances on downhill grades.

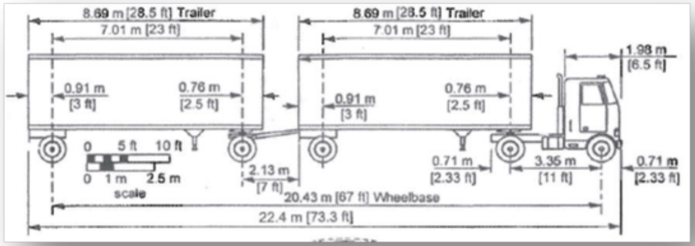
*Example of Intersection On a Grade*

# Adjustments – Heavy Commercial (3 of 7)

**Table B-10**
*Average % Heavy Vehicle Based on Facility Type*

| Facility Type | Sample Size | Average % Heavy Commercial |
|---|---|---|
| Rural Conventional | 11 | 14% |
| Rural Expressway | 7 | 9% |
| Urban Conventional | 1 | 7% |
| Urban Expressway | 2 | 4% |

*Source: Heavy Commercial Volumes at Selected Piezo and Wim Sites (2004 – 2009), Office of Transportation Data and Analysis, March 2010.*



**Example of Heavy Commercial Vehicle Dimensions from Green Book**

*Source: AASHTO Green Book, WB-20D [WB-67D] Design Vehicle*

**Example of Heavy Commercial Vehicle**

- **Adjustments to Storage based on Higher Heavy Commercial %** *:*
  - Synchro Method - In the Synchro computer model the default value for heavy commercial is 2% and the analyst needs to replace the default volume with the actual value.
  - Method 1 – Basic Equation – use the actual % heavy commercial in the equation to account for the higher truck volume.
  - Method 2 –*Tables B-4* through *B-6* – if the % heavy commercial is greater than 15%, use Method 1 to determine storage needs.
- **Adjust Deceleration Lengths** - Consider providing more deceleration length than shown in *Tables B-1 and B-2* to accommodate heavy commercial deceleration characteristics if the % heavy commercial is higher than the averages shown in *Table B-10*. The suggested increase is 30% to the deceleration length. (Source: Current practice of Illinois DOT)

# Adjustments – Horizontal Curves (4 of 7)

**Example of Intersection Located on a Horizontal Curve**

- The recommended practice for designing turn lanes that begin near or in the outside of a horizontal curve is to shorten the taper from the typical 1:15 (180 feet) to 1:8 (100 feet) in order to better delineate the entrance to the turn lane. The recommended practice also includes adding the difference (80 feet) back to the full width portion.
- An example of this adjustment on a rural two-lane highway with a design speed of 60 mph, the design of a right turn lane that begins near the start of a horizontal curve is shown to the left.

**Example of Horizontal Curve Adjustment to Taper Length**

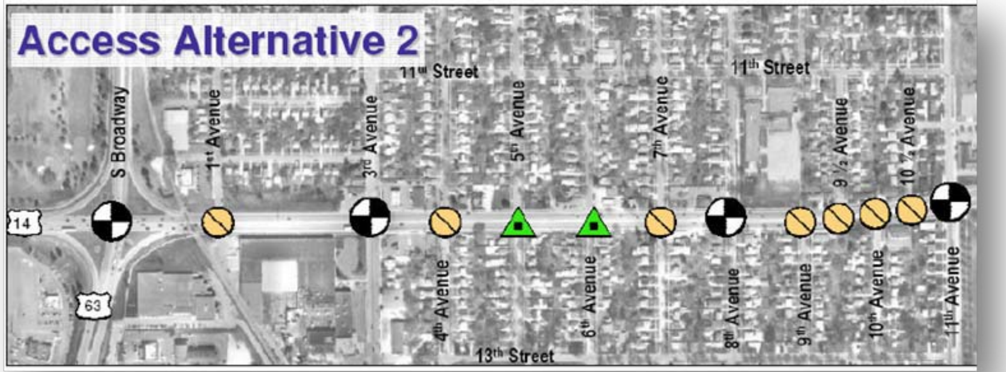
| | |
|---|---|
| Full Width Turn Lane Length = | **Deceleration + Storage** |
| | 570 feet + 0 = 570 feet |
| Turn Lane Design = | **Taper + Full Width** |
| | 180 feet + 390 feet = 570 feet |
| Adjusted Design = | **Taper + Full Width** |
| | 180 feet + 390 feet = 570 feet |
| | <u>-80 feet</u> + <u>80 feet</u> |
| | 100 feet + 470 feet = 570 feet |

# Adjustments – Dual Left Turn Lanes (5 of 7)

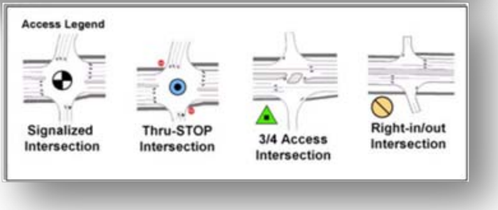
**Example Dual Left Turn Lane Design**

- It is recommended practice to consider providing two left turn lanes at signalized intersections whenever the following conditions are present:
  - The design year peak hour left turn volume approaches 300 vehicles per hour.
  - On divided roadways where the median is wide enough such that dual turn lanes can be provided without having to realign the opposing roadway.
- The primary advantage associated with the use of dual left turn lanes is improved traffic operations due to the shorter queue of vehicles in each of the two left turn lanes. The shorter queue requires less green time to clear, allowing the cycle length to be shorter, which reduces the average vehicle delay, the established performance measure for signalized intersection operations.
- If dual left turn lanes are provided, the receiving leg of the intersection also needs to provide two departing lanes for a minimum distance of 500 feet (distance to allow the two lanes of vehicles to merge back to a single lane).

# *Adjustments – Location Constraints (6 of 7)*



*Source: CH2M HILL, TH 14 in Rochester*



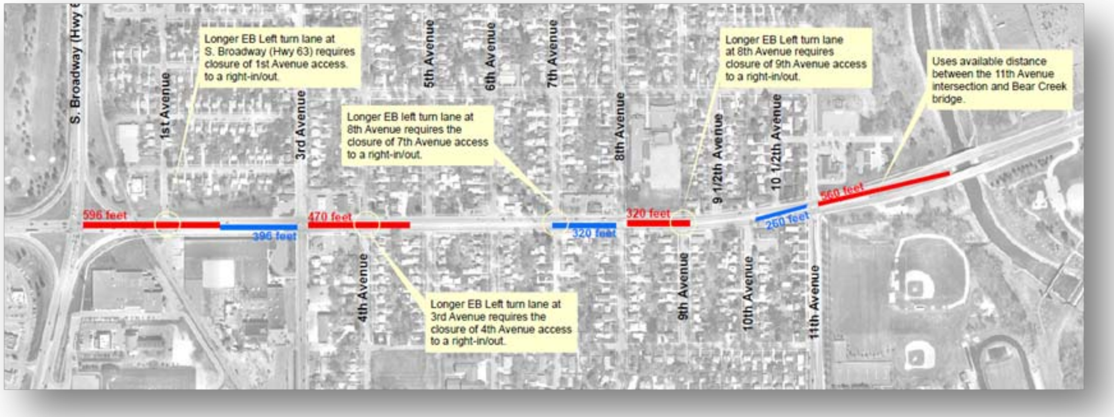
**Example of Constrained Corridor and Access/Turn Lane Design Decisions**

*Some access were closed in order to accommodate longer turn lanes at adjacent intersections.*

- The most common local constraint involves short block spacing in established urban areas, where the distance between adjacent intersections can be as little as 300 to 400 ft.
- In these cases it is important to note that vehicle speeds along urban conventional roadways are low (especially if the facility experiences congestion during peak traffic periods), so deceleration distances are relatively short. In addition, the recommended deceleration lengths in these low speed, urban conditions are further shortened as a result of allowing for a 10 mph speed reduction in the through lanes.
- In constrained urban corridors with frequent intersections and many turning opportunities, the number of turning vehicles at any one intersection will likely be low, particularly at unsignalized intersections. As a result, turn lane lengths will likely be the minimum = 60 feet taper + 60 feet full width = 120 feet. If these minimum values cannot be provided, consideration should be given to closing adjacent intersections in order to provide the space necessary for the recommended turn lane lengths.

# Adjustments – Corridor Consistency *(7 of 7)*

**Example of Corridor with Multiple Turn Lane Design**



*Source: CH2M HILL, TH 14 in Rochester*

- The key corridor consistency issue involves determining whether the design of turn lanes along a corridor is uniform because of similar conditions – volumes, speed, vehicle types – or do conditions across the corridor vary sufficiently to warrant a different design. Consistency with the design of adjacent turn lanes will better meet driver expectations throughout the corridor.
- The basic objective of turn lanes is to accommodate deceleration plus storage of the turning vehicles at an intersection. One common corridor issue on high volume urban arterials is that the queue of vehicles in the through lanes lined up from a traffic signal often extend beyond the entrance to the turn lanes. In these cases, the length necessary for deceleration plus storage in the turn lanes is less than the length of the queue in the through lanes. In order to support improved intersection operations designers should consider lengthening the full width portion of the turn lane beyond the length for storage so that turning vehicles have full access to the turn lanes.

# Turn Lane Length Process

Step 1

**Collect Data**

***Demand Factors***
- Speed
- Forecast Volumes
- Seasonal Variations
- Grade
- Heavy Commercial %

***Design Factors***
- Distance to Adjacent Intersections
- Roadway Geometry (Horizontal Curve)

Step 2

**Determine Facility Type**

- Facility type in ***Figure B-1***
- Intersection control

Step 3

**Calculate Turn Lane Demand**

- Calculate deceleration based on ***Tables B-1 & B-2***
- Calculate storage needs based on ***Tables B-3 to B-6***
- Suggested signal cycle lengths on ***Table B-7***

Step 4

**Calculate Turn Lane Design**

- Determine taper length based on ***Table B-8***
- Calculate turn lane design (turn lane demand length from Step 3 minus taper)
- Determine appropriate adjustments based on list.

Step 5

**Document Turn Lane Length**

- Depending on constraints of the area, characteristics of the intersection and their applicability to the stated assumptions, and engineering judgment, determine final length of turn lane.

# Part C - Examples

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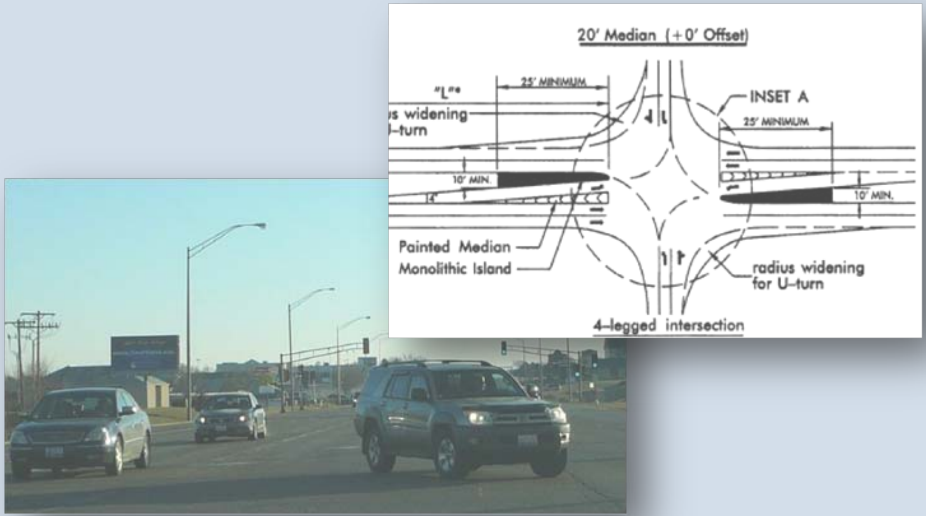
## Innovative Intersection Design Concept – *Positive Offset Turn Lanes*

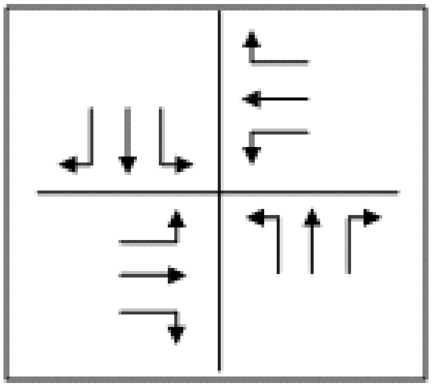


*Source: Illinois DOT Bloomington RSA, Negative/Positive Offset Turn Lanes*

- The traditional turn lane design along median divided roadways has opposing left turn lanes negatively offset – to the left each driver in the left turn lanes.
- This negative offset results in a drivers line of sight to opposing through vehicles being intercepted by the queue of vehicles in the other left turn lane and this creates conflicts at signalized intersections when the left turn movements are permitted (pick a group during the green ball instead of an exclusive turn arrow).
- An innovative solution involves creating a positive offset by putting some (or all) of the median on the right side of the left turn lane to the right and completely opens the line of sight to oncoming vehicles in the through lane.
- If there is a history of left turn (head on) crashes, at a negative offset permitted left turn lane , there are two likely mitigations – conversion to exclusive left turn phasing or construction of the positive offset. The use of the positive offset would allow the continued use of a permitted left turn operation which would result in a lower level of intersection delay and a better level of service.

# TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

## STEP 1 – DATA GATHERING

| | |
|---|---|
| **Location** | State Roadway: ______________________________ Intersection:_______________________________<br>☐ Left Turn Lane Design for Approach: N / S / E / W<br>☐ Right Turn Lane Design for Approach: N / S / E / W |
| **Vehicle Speed**<br>***Page B-2*** | Choose one. Shown in order of preference.<br>☐ Design Speed: _______ mph<br>☐ 85th Percentile Speed: _______ mph<br>☐ Statewide Average Speed: _______ mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>***Page B-3*** | Choose one. Shown in order of preference.<br>☐ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br><br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: ____________ vehicles per day<br>Minor Street Daily Traffic Volumes: _____________ vehicles per day |
| **Heavy Commercial**<br>***Page B-5*** | Percent Heavy Vehicle: __________% (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>***Page B-5*** | ☐ Upgrade ☐ Downgrade<br>Grade of approach: ________% (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>***Page B-4*** | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☐ No |
| **Roadway Geometry and Corridor Characteristics**<br>***Page B-6*** | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)<br>☐ Yes, on horizontal curve ☐ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☐ Yes, constrained location ☐ No |

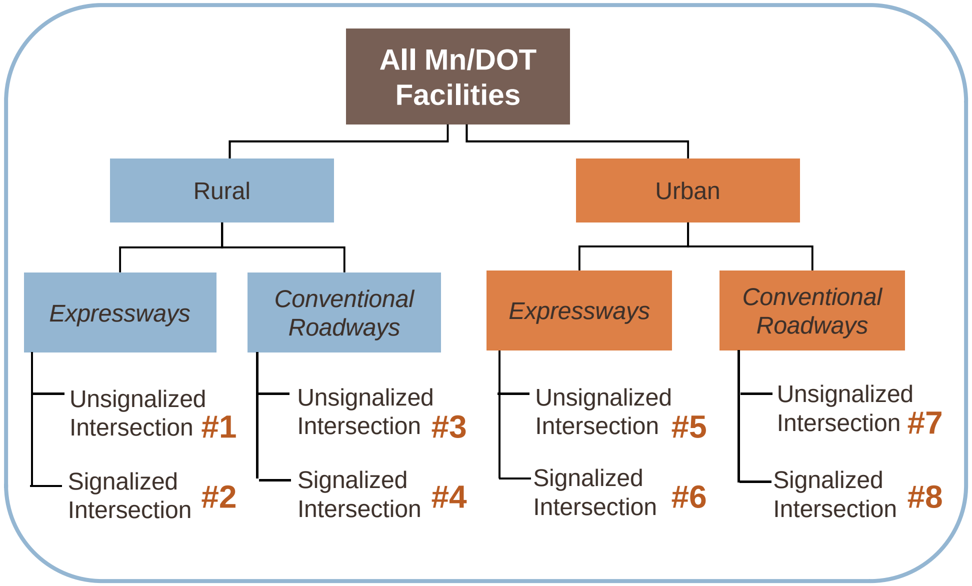
## STEP 2 – DETERMINE FACILITY TYPE

| | |
|---|---|
| **Determine Facility Type**<br>***Page B-8*** | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index. categoryassignments.html<br>☐ Urban ☐ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☐ Expressway ☐ Conventional |
| **Intersection Control**<br>***Page B-9*** | ☐ Signalized: _______sec cycle length ☐ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

# TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

<table>
<tr><th colspan="4">STEP 3 – CALCULATE TURN LANE DEMAND</th></tr>
<tr><td><b>Deceleration Length</b><br><i>Page B-11</i></td><td colspan="2">Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data.</td><td><b>Deceleration Distance</b><br>________ feet</td></tr>
<tr><td><b>Storage Length</b><br><i>Page B-12</i></td><td colspan="2">Unsignalized Intersections<br>Left Turn Lane – see <i>Table B-3</i>, based on Left-Turning Volume and Heavy Commercial %, or equation on <i>Page B-12</i>.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☐ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on <i>Page B-13</i>.<br>☐ Method 2 – Look Up Tables: <i>Tables B-4</i> through B-6 on <i>Page B-14</i> using Sum of Critical Movement Calculations (see Page 4 of checklist)</td><td><b>Storage Distance</b><br>________ feet</td></tr>
<tr><td><b>Turn Lane Demand</b></td><td colspan="2">Add the Deceleration Distance and the Storage Distance</td><td><b>Turn Lane Demand</b><br>= _______ feet</td></tr>
<tr><th colspan="4">STEP 4 – CALCULATE TURN LANE DESIGN</th></tr>
<tr><td><b>Determine Taper</b><br><i>Page B-17</i></td><td colspan="2">Determine Taper based on Facility Type<br>☐ Unconstrained Conventional/Expressway = 180 feet (1:15 taper)<br>☐ Constrained Expressway = 100 feet (1:8 taper)<br>☐ Constrained Conventional = 60 feet (1:5 taper)</td><td><b>Taper Length</b><br>________ feet</td></tr>
<tr><td><b>Full Turn Lane Length</b> (before adjustments)</td><td colspan="2">Take the <b>Turn Lane Demand</b> minus <b>Taper Length</b></td><td><b>Full Width Turn Lane Length</b> (no adjustments)<br>________ feet</td></tr>
<tr><th colspan="4">ADJUSTMENTS AND FINAL TURN LANE DESIGN</th></tr>
<tr><td><b>Adjust Taper</b><br><i>Page B-21</i></td><td colspan="2">If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet)</td><td><b>Adjusted Taper Length</b><br>________ feet</td></tr>
<tr><td rowspan="5"><b>Adjust Full turn Lane Length</b></td><td>If grade is greater than 3% adjust based on <i>Table B-9</i> (multiply the <b>Deceleration Distance</b> by adjustment in table and document the difference in deceleration to the right. <i>Page B-19</i></td><td>+ / -<br>_______ ft</td><td rowspan="5"><b>Full Width Turn Lane Length</b><br>(with adjustments)<br>________ feet</td></tr>
<tr><td>If heavy commercial is greater than averages shown in <i>Table B-10</i>, increase <b>Deceleration Distance</b> by 30% and document the difference in length to the right. <i>Page B-20</i></td><td>+<br>_______ ft</td></tr>
<tr><td>Are there more than 300 vehicles per hour? May consider <i>dual lefts</i>. The storage length required would be half of the calculated <b>Storage Distance</b>. Document the difference in distance to the right. <i>Page B-22</i></td><td>-<br>_______ ft</td></tr>
<tr><td>Are there <i>constraints</i> with the adjacent intersections or driveways? Does the <i>through lane queue</i> extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. <i>Page B-23 & B-24</i></td><td>+ / -<br>________ ft</td></tr>
<tr><td><i>Total Adjustments</i></td><td>+ / -<br>_______ ft</td></tr>
</table>

# Examples



- **All Mn/DOT Facilities**
  - Rural
    - *Expressways*
      - Unsignalized Intersection #1
      - Signalized Intersection #2
    - *Conventional Roadways*
      - Unsignalized Intersection #3
      - Signalized Intersection #4
  - Urban
    - *Expressways*
      - Unsignalized Intersection #5
      - Signalized Intersection #6
    - *Conventional Roadways*
      - Unsignalized Intersection #7
      - Signalized Intersection #8

**Examples are provided for each of the eight Mn/DOT facility type situations**

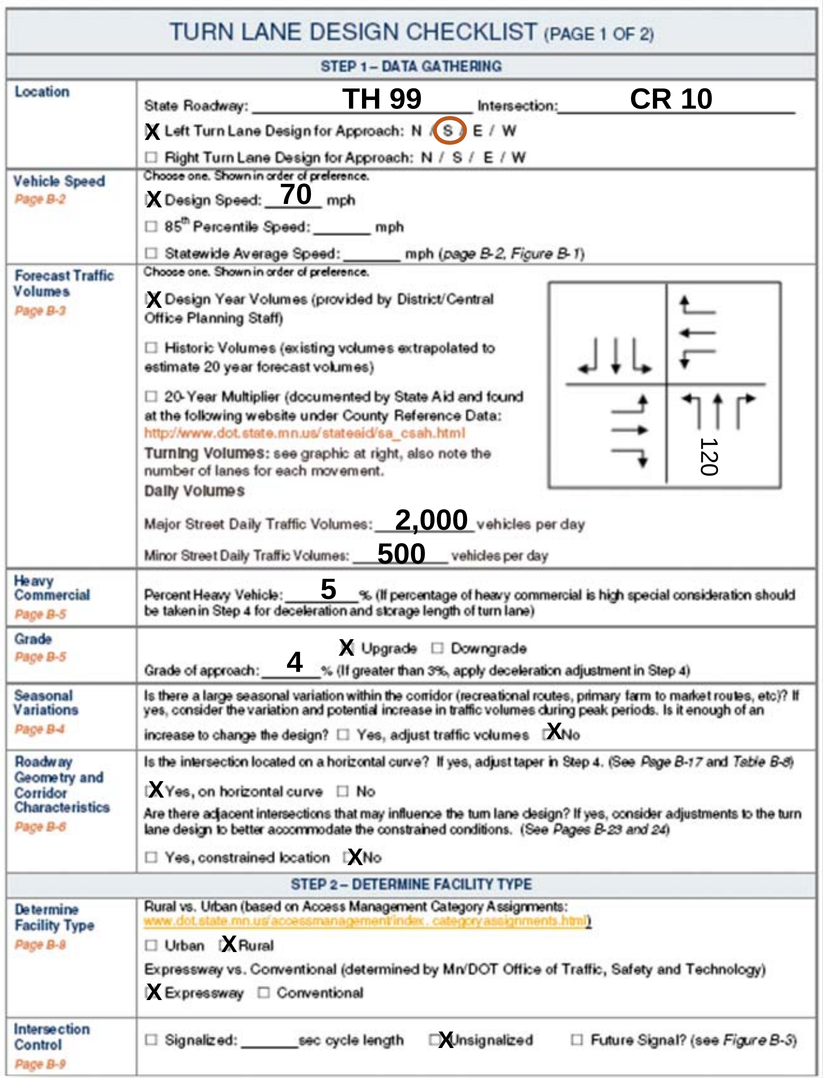
**Table C-1**

Turn Lane Calculation Examples

| | *Roadway Location* | | *Roadway Type* | | *Intersection Type* | | *Adjustments* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rural | Urban | Expressway | Conventional | Unsignalized | Signalized | Grade | Heavy Commercial | Horizontal Curve | Dual Left | Location Constraints | Corridor Consistency |
| **Example 1** | x | | x | | x | | x | | x | | | |
| **Example 2** | x | | x | | | x | | | | | x | |
| **Example 3** | x | | | x | x | | x | | x | | | |
| **Example 4** | x | | | x | | x | | | | | x | |
| **Example 5** | | x | x | | x | | | x | | | | |
| **Example 6** | | x | x | | | x | | | | | x | |
| **Example 7** | | x | | x | x | | | | | | x | x |
| **Example 8** | | x | | x | | x | x | | x | x | | |

**Different adjustments are used in each example**

# Example 1 – Rural Expressway Unsignalized *(1 of 2)*



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 1 – DATA GATHERING

| | |
|---|---|
| **Location** | State Roadway: TH 99 Intersection: CR 10<br>☒ Left Turn Lane Design for Approach: N / [✓ S] / E / W<br>☐ Right Turn Lane Design for Approach: N / S / E / W |
| **Vehicle Speed**<br>*Page B-2* | Choose one. Shown in order of preference.<br>☒ Design Speed: 70 mph<br>☐ 85th Percentile Speed: ______ mph<br>☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>*Page B-3* | Choose one. Shown in order of preference.<br>☒ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: 2,000 vehicles per day<br>Minor Street Daily Traffic Volumes: 500 vehicles per day |
| **Heavy Commercial**<br>*Page B-5* | Percent Heavy Vehicle: 5 % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>*Page B-5* | ☒ Upgrade ☐ Downgrade<br>Grade of approach: 4 % (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>*Page B-4* | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No |
| **Roadway Geometry and Corridor Characteristics**<br>*Page B-6* | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)<br>☒ Yes, on horizontal curve ☐ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☐ Yes, constrained location ☒ No |

### STEP 2 – DETERMINE FACILITY TYPE

| | |
|---|---|
| **Determine Facility Type**<br>*Page B-8* | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index_categoryassignments.html)<br>☐ Urban ☒ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☒ Expressway ☐ Conventional |
| **Intersection Control**<br>*Page B-9* | ☐ Signalized: ______ sec cycle length ☒ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

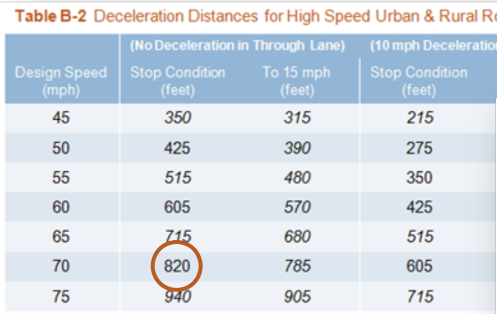


**Table B-2** Deceleration Distances for High Speed Urban & Rural Roadways

| Design Speed (mph) | (No Deceleration in Through Lane) Stop Condition (feet) | To 15 mph (feet) | (10 mph Deceleration in Through Lane) Stop Condition (feet) | To 15 mph (feet) |
|---|---|---|---|---|
| 45 | 350 | 315 | 215 | |
| 50 | 425 | 390 | 275 | |
| 55 | 515 | 480 | 350 | |
| 60 | 605 | 570 | 425 | |
| 65 | 715 | 680 | 515 | |
| 70 | 820 | 785 | 605 | |
| 75 | 940 | 905 | 715 | |

*120 turning vehicles with 5% heavy commercial*

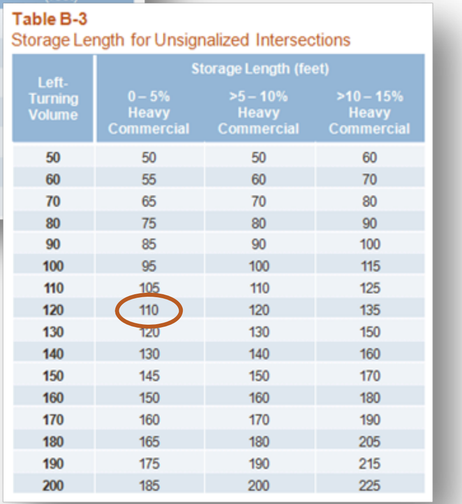
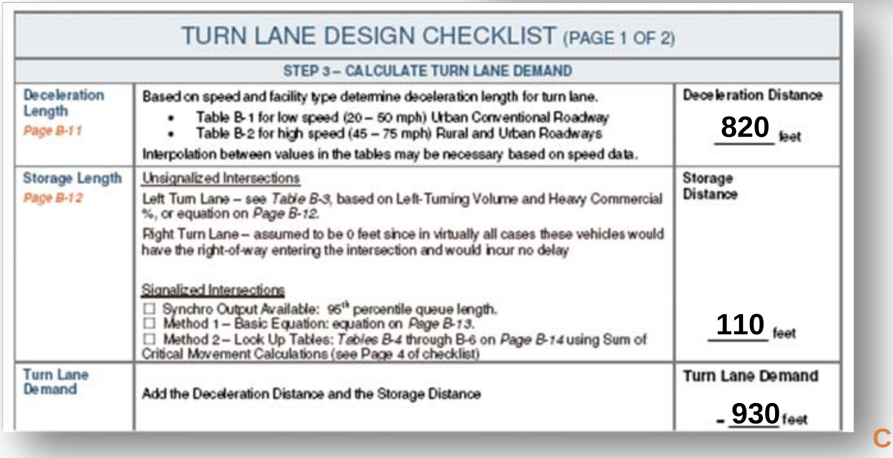


**Table B-3**
Storage Length for Unsignalized Intersections

| Left-Turning Volume | Storage Length (feet) 0 – 5% Heavy Commercial | >5 – 10% Heavy Commercial | >10 – 15% Heavy Commercial |
|---|---|---|---|
| 50 | 50 | 50 | 60 |
| 60 | 55 | 60 | 70 |
| 70 | 65 | 70 | 80 |
| 80 | 75 | 80 | 90 |
| 90 | 85 | 90 | 100 |
| 100 | 95 | 100 | 115 |
| 110 | 105 | 110 | 125 |
| 120 | 110 | 120 | 135 |
| 130 | 120 | 130 | 150 |
| 140 | 130 | 140 | 160 |
| 150 | 145 | 150 | 170 |
| 160 | 150 | 160 | 180 |
| 170 | 160 | 170 | 190 |
| 180 | 165 | 180 | 205 |
| 190 | 175 | 190 | 215 |
| 200 | 185 | 200 | 225 |

*Speed of 70 mph, No Deceleration in Through Lane on Expressways, and Stop Condition for Left Turn Lanes*

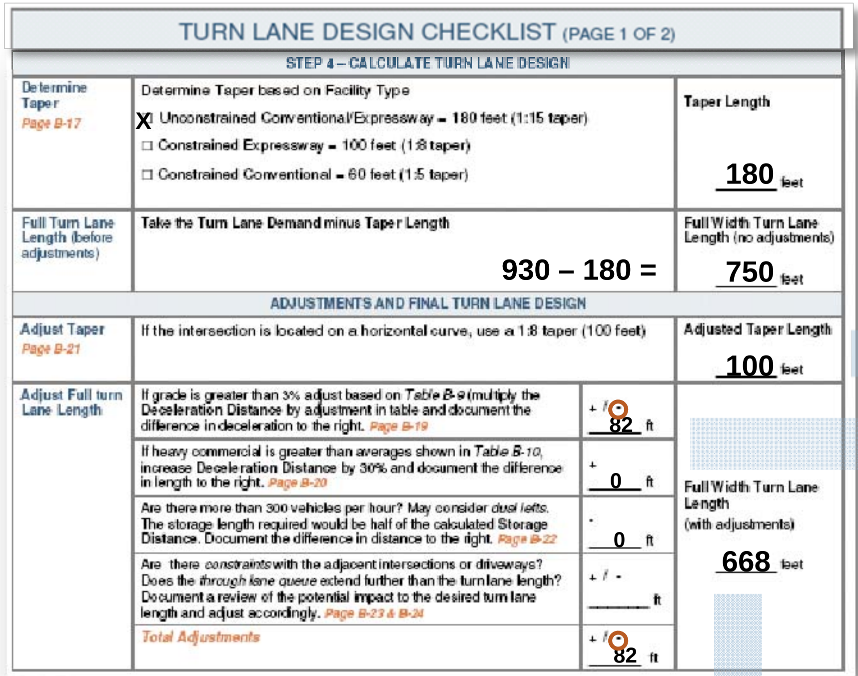


## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 3 – CALCULATE TURN LANE DEMAND

| | | |
|---|---|---|
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>820 feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☐ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on *Page B-13*.<br>☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>110 feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>- 930 feet |

# Example 1 – Rural Expressway Unsignalized (2 of 2)



TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

| | | | |
|---|---|---|---|
| STEP 4 – CALCULATE TURN LANE DESIGN | | | |
| Determine Taper<br>Page B-17 | Determine Taper based on Facility Type<br>X☐ Unconstrained Conventional/Expressway – 180 feet (1:15 taper)<br>☐ Constrained Expressway – 100 feet (1:8 taper)<br>☐ Constrained Conventional – 60 feet (1:5 taper) | | Taper Length<br>180 feet |
| Full Turn Lane Length (before adjustments) | Take the Turn Lane Demand minus Taper Length<br>930 – 180 = | | Full Width Turn Lane Length (no adjustments)<br>750 feet |
| ADJUSTMENTS AND FINAL TURN LANE DESIGN | | | |
| Adjust Taper<br>Page B-21 | If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet) | | Adjusted Taper Length<br>100 feet |
| Adjust Full turn Lane Length | If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. Page B-19 | + / [✓ -] 82 ft | Full Width Turn Lane Length (with adjustments)<br>668 feet |
| | If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. Page B-20 | + 0 ft | |
| | Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. Page B-22 | - 0 ft | |
| | Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. Page B-23 & B-24 | + / - ____ ft | |
| | *Total Adjustments* | + / [✓ -] 82 ft | |

| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

*Road curves to the right, the left turn lane would be considered on the outside of the curve so an adjustment is necessary.*

**Table B-9**
*Grade Adjustment*

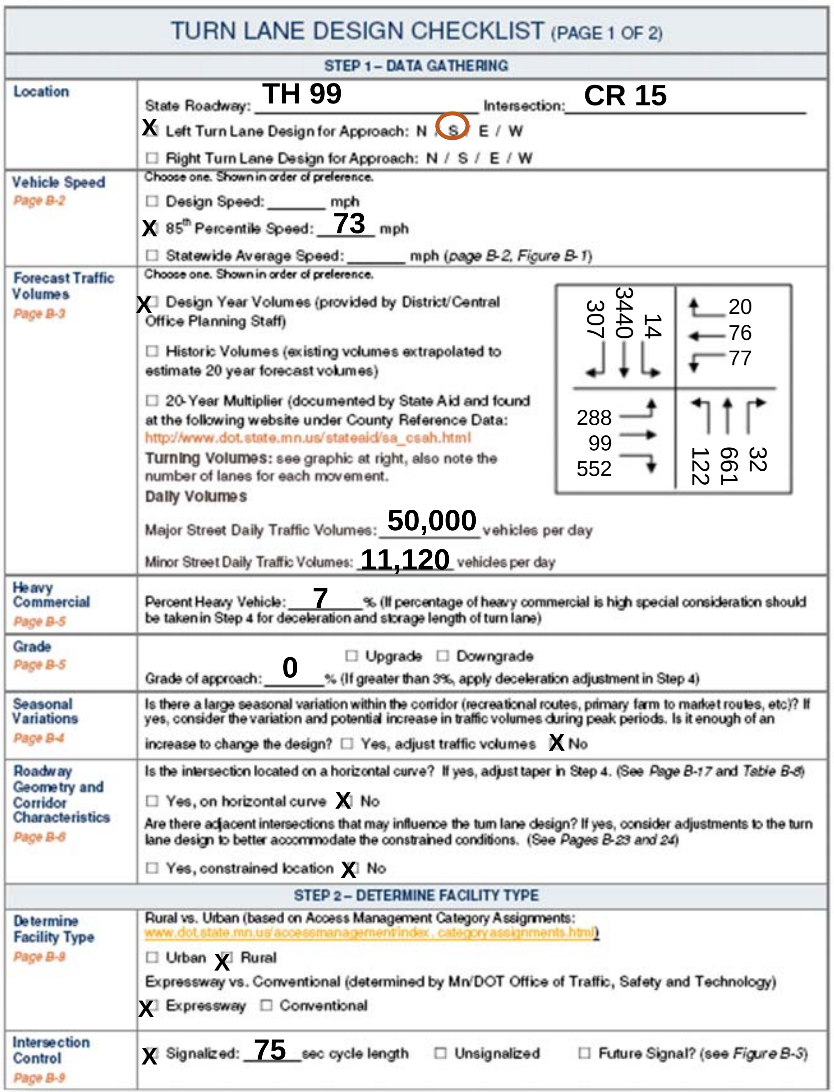
| Grade | Upgrade Adjustment | Downgrade Adjustment |
|---|---|---|
| 3% to 4% | 0.9 | 1.2 |
| 5% to 6% | 0.8 | 1.35 |

*4% upgrade, so the deceleration length determined in Step 3 (820') is shortened by 82 feet based on 10% reduction (90% of the length) shown in Table B-9*

**750** (full width from Step 4)
**– 82** (total adjustments)
**= 668**

The recommended design of this turn lane would be **100 feet taper** and **670 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

# Example 2 – Rural Expressway Signalized (1 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 1 – DATA GATHERING

| | |
|---|---|
| **Location** | State Roadway: TH 99 Intersection: CR 15<br>☒ Left Turn Lane Design for Approach: N / [✓ S] / E / W<br>☐ Right Turn Lane Design for Approach: N / S / E / W |
| **Vehicle Speed**<br>*Page B-2* | Choose one. Shown in order of preference.<br>☐ Design Speed: ______ mph<br>☒ 85th Percentile Speed: 73 mph<br>☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>*Page B-3* | Choose one. Shown in order of preference.<br>☒ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: 50,000 vehicles per day<br>Minor Street Daily Traffic Volumes: 11,120 vehicles per day |
| **Heavy Commercial**<br>*Page B-5* | Percent Heavy Vehicle: 7 % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>*Page B-5* | ☐ Upgrade ☐ Downgrade<br>Grade of approach: 0 % (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>*Page B-4* | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No |
| **Roadway Geometry and Corridor Characteristics**<br>*Page B-6* | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)<br>☐ Yes, on horizontal curve ☒ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☐ Yes, constrained location ☒ No |

### STEP 2 – DETERMINE FACILITY TYPE

| | |
|---|---|
| **Determine Facility Type**<br>*Page B-8* | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index_categoryassignments.html)<br>☐ Urban ☒ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☒ Expressway ☐ Conventional |
| **Intersection Control**<br>*Page B-9* | ☒ Signalized: 75 sec cycle length ☐ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

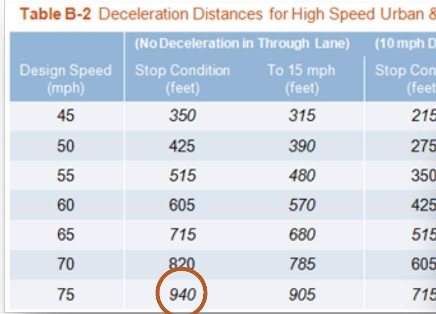
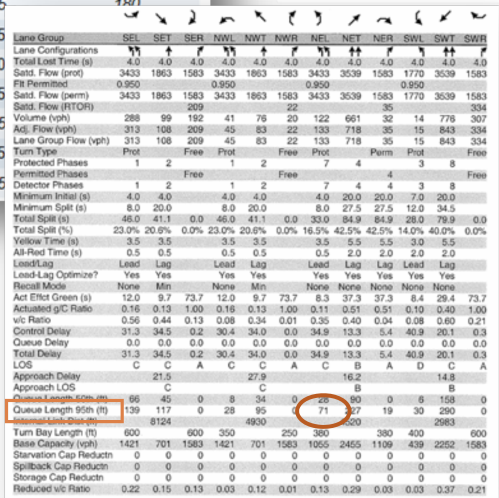


**Table B-2** Deceleration Distances for High Speed Urban & Rural Roadways

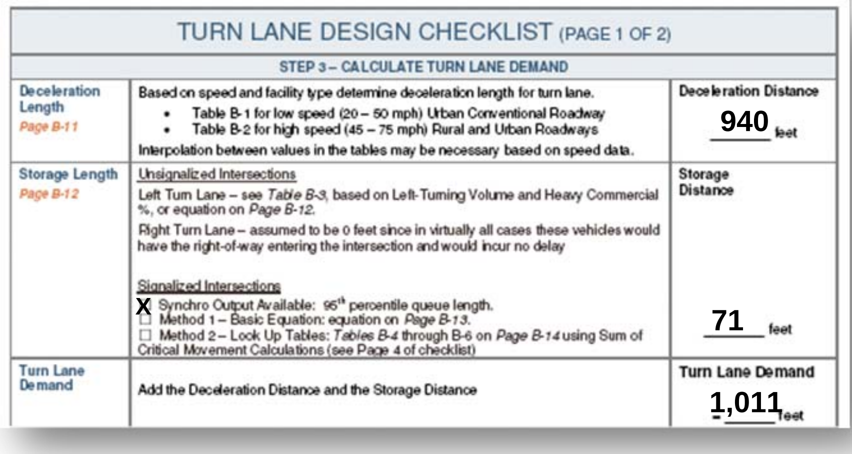
| Design Speed (mph) | (No Deceleration in Through Lane) Stop Condition (feet) | (No Deceleration in Through Lane) To 15 mph (feet) | (10 mph Deceleration in Through Lane) Stop Condition (feet) | (10 mph Deceleration in Through Lane) To 15 mph (feet) |
|---|---|---|---|---|
| 45 | 350 | 315 | 215 | 180 |
| 50 | 425 | 390 | 275 | |
| 55 | 515 | 480 | 350 | |
| 60 | 605 | 570 | 425 | |
| 65 | 715 | 680 | 515 | |
| 70 | 820 | 785 | 605 | |
| 75 | 940 | 905 | 715 | |

*Speed of 75 mph, No Deceleration in Through Lane on Expressways, and Stop Condition for Left Turn Lanes*



*Synchro Output*

| Lane Group | SEL | SET | SER | NWL | NWT | NWR | NEL | NET | NER | SWL | SWT | SWR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | ↰↰ | ↑ | ↱ | ↰↰ | ↑ | ↱ | ↰↰ | ↑↑ | ↱ | ↰ | ↑↑ | ↱ |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Satd. Flow (prot) | 3433 | 1863 | 1583 | 3433 | 1863 | 1583 | 3433 | 3539 | 1583 | 1770 | 3539 | 1583 |
| Flt Permitted | 0.950 | | | 0.950 | | | 0.950 | | | 0.950 | | |
| Satd. Flow (perm) | 3433 | 1863 | 1583 | 3433 | 1863 | 1583 | 3433 | 3539 | 1583 | 1770 | 3539 | 1583 |
| Satd. Flow (RTOR) | | | 209 | | | 22 | | | 35 | | | 334 |
| Volume (vph) | 288 | 99 | 192 | 41 | 76 | 20 | 122 | 661 | 32 | 14 | 776 | 307 |
| Adj. Flow (vph) | 313 | 108 | 209 | 45 | 83 | 22 | 133 | 718 | 35 | 15 | 843 | 334 |
| Lane Group Flow (vph) | 313 | 108 | 209 | 45 | 83 | 22 | 133 | 718 | 35 | 15 | 843 | 334 |
| Turn Type | Prot | | Free | Prot | | Free | Prot | | Perm | Prot | | Free |
| Protected Phases | 1 | 2 | | 1 | 2 | | 7 | 4 | | 3 | 8 | |
| Permitted Phases | | | Free | | | Free | | | 4 | | | Free |
| Detector Phases | 1 | 2 | | 1 | 2 | | 7 | 4 | 4 | 3 | 8 | |
| Minimum Initial (s) | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 20.0 | 20.0 | 7.0 | 20.0 | |
| Minimum Split (s) | 8.0 | 20.0 | | 8.0 | 20.0 | | 8.0 | 27.5 | 27.5 | 12.0 | 34.5 | |
| Total Split (s) | 46.0 | 41.1 | 0.0 | 46.0 | 41.1 | 0.0 | 33.0 | 84.9 | 84.9 | 28.0 | 79.9 | 0.0 |
| Total Split (%) | 23.0% | 20.6% | 0.0% | 23.0% | 20.6% | 0.0% | 16.5% | 42.5% | 42.5% | 14.0% | 40.0% | 0.0% |
| Yellow Time (s) | 3.5 | 3.5 | | 3.5 | 3.5 | | 3.5 | 5.5 | 5.5 | 3.0 | 5.5 | |
| All-Red Time (s) | 0.5 | 0.5 | | 0.5 | 0.5 | | 0.5 | 2.0 | 2.0 | 2.0 | 2.0 | |
| Lead/Lag | Lead | Lag | | Lead | Lag | | Lead | Lag | Lag | Lead | Lag | |
| Lead-Lag Optimize? | Yes | Yes | | Yes | Yes | | Yes | Yes | Yes | Yes | Yes | |
| Recall Mode | None | Min | | None | Min | | None | None | None | None | None | |
| Act Effct Green (s) | 12.0 | 9.7 | 73.7 | 12.0 | 9.7 | 73.7 | 8.3 | 37.3 | 37.3 | 8.4 | 29.4 | 73.7 |
| Actuated g/C Ratio | 0.16 | 0.13 | 1.00 | 0.16 | 0.13 | 1.00 | 0.11 | 0.51 | 0.51 | 0.10 | 0.40 | 1.00 |
| v/c Ratio | 0.56 | 0.44 | 0.13 | 0.08 | 0.34 | 0.01 | 0.35 | 0.40 | 0.04 | 0.08 | 0.60 | 0.21 |
| Control Delay | 31.3 | 34.5 | 0.2 | 30.4 | 34.0 | 0.0 | 34.9 | 13.3 | 5.4 | 40.9 | 20.1 | 0.3 |
| Queue Delay | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Delay | 31.3 | 34.5 | 0.2 | 30.4 | 34.0 | 0.0 | 34.9 | 13.3 | 5.4 | 40.9 | 20.1 | 0.3 |
| LOS | C | C | A | C | C | A | C | B | A | D | C | A |
| Approach Delay | | 21.5 | | | 27.9 | | | 16.2 | | | 14.8 | |
| Approach LOS | | C | | | C | | | B | | | B | |
| Queue Length 50th (ft) | 66 | 45 | 0 | 8 | 34 | 0 | 28 | 90 | 0 | 6 | 158 | 0 |
| Queue Length 95th (ft) | 139 | 117 | 0 | 28 | 95 | 0 | 71 | 227 | 19 | 30 | 290 | 0 |
| Internal Link Dist (ft) | | 8124 | | | 4930 | | | 520 | | | 2983 | |
| Turn Bay Length (ft) | 600 | | 600 | 350 | | 250 | 380 | | 380 | 400 | | 600 |
| Base Capacity (vph) | 1421 | 701 | 1583 | 1421 | 701 | 1583 | 1055 | 2455 | 1109 | 439 | 2252 | 1583 |
| Starvation Cap Reductn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spillback Cap Reductn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Storage Cap Reductn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Reduced v/c Ratio | 0.22 | 0.15 | 0.13 | 0.03 | 0.12 | 0.01 | 0.13 | 0.29 | 0.03 | 0.03 | 0.37 | 0.21 |

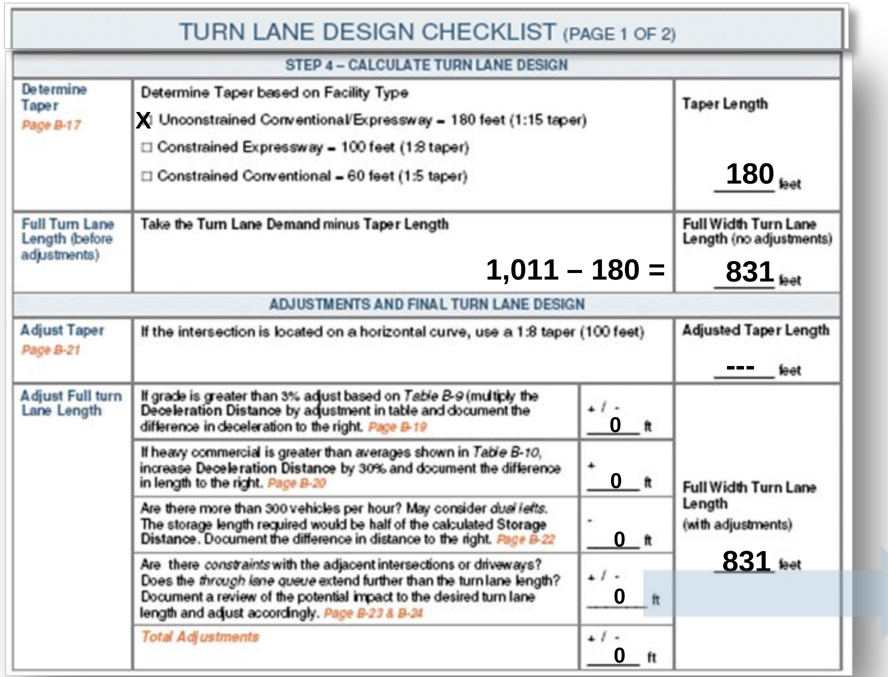


## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 3 – CALCULATE TURN LANE DEMAND

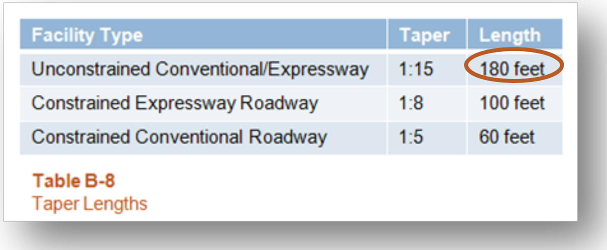
| | | |
|---|---|---|
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>940 feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☒ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on *Page B-13*.<br>☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>71 feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>1,011 feet |

# Example 2 – Rural Expressway Signalized (2 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

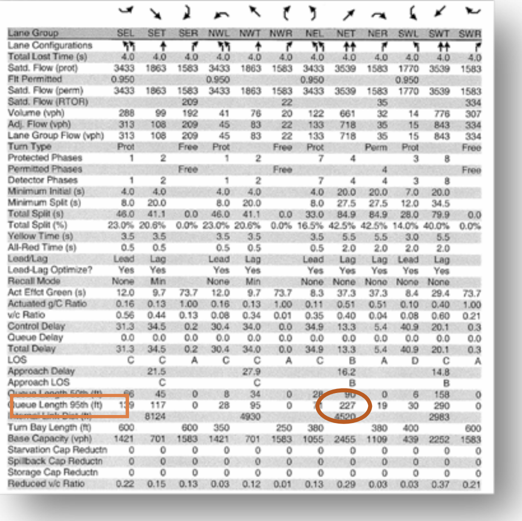
| | | | |
|---|---|---|---|
| **STEP 4 – CALCULATE TURN LANE DESIGN** | | | |
| **Determine Taper**<br>*Page B-17* | Determine Taper based on Facility Type<br>X Unconstrained Conventional/Expressway – 180 feet (1:15 taper)<br>☐ Constrained Expressway – 100 feet (1:8 taper)<br>☐ Constrained Conventional – 60 feet (1:5 taper) | | Taper Length<br>**180** feet |
| **Full Turn Lane Length (before adjustments)** | Take the Turn Lane Demand minus Taper Length<br>**1,011 – 180 =** | | Full Width Turn Lane Length (no adjustments)<br>**831** feet |
| **ADJUSTMENTS AND FINAL TURN LANE DESIGN** | | | |
| **Adjust Taper**<br>*Page B-21* | If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet) | | Adjusted Taper Length<br>**---** feet |
| **Adjust Full turn Lane Length** | If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. *Page B-19* | + / -<br>**0** ft | Full Width Turn Lane Length<br>(with adjustments)<br>**831** feet |
| | If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. *Page B-20* | +<br>**0** ft | |
| | Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. *Page B-22* | -<br>**0** ft | |
| | Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. *Page B-23 & B-24* | + / -<br>**0** ft | |
| | *Total Adjustments* | + / -<br>**0** ft | |



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

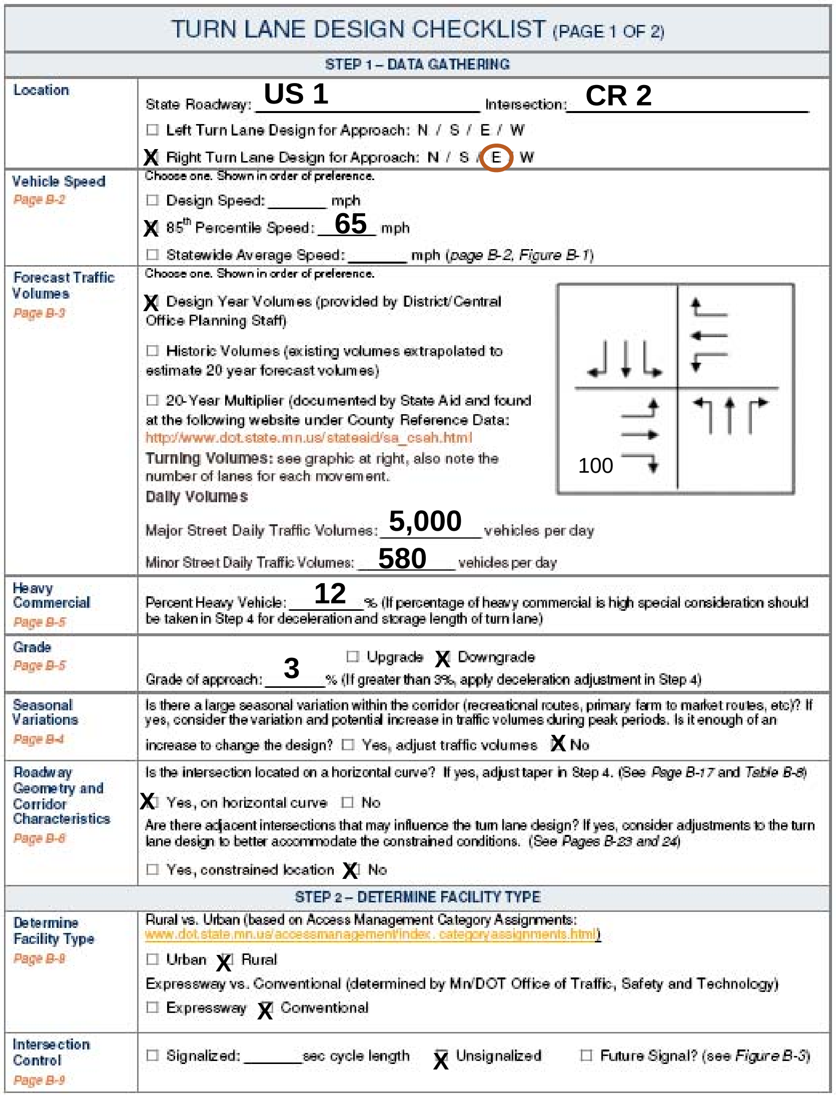
*Check for blockage by queues in the northeast bound through lane. The queue in the through lane is 227 feet, less than the full width turn lane length, therefore no adjustment is necessary.*



| Lane Group | SEL | SET | SER | NWL | NWT | NWR | NEL | NET | NER | SWL | SWT | SWR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | ↰↰ | ↑ | ↱ | ↰↰ | ↑ | ↱ | ↰↰ | ↑↑ | ↱ | ↰ | ↑↑ | ↱ |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Satd. Flow (prot) | 3433 | 1863 | 1583 | 3433 | 1863 | 1583 | 3433 | 3539 | 1583 | 1770 | 3539 | 1583 |
| Flt Permitted | 0.950 | | | 0.950 | | | 0.950 | | | 0.950 | | |
| Satd. Flow (perm) | 3433 | 1863 | 1583 | 3433 | 1863 | 1583 | 3433 | 3539 | 1583 | 1770 | 3539 | 1583 |
| Satd. Flow (RTOR) | | | 209 | | | 22 | | | 35 | | | 334 |
| Volume (vph) | 288 | 99 | 192 | 41 | 76 | 20 | 122 | 661 | 32 | 14 | 776 | 307 |
| Adj. Flow (vph) | 313 | 108 | 209 | 45 | 83 | 22 | 133 | 718 | 35 | 15 | 843 | 334 |
| Lane Group Flow (vph) | 313 | 108 | 209 | 45 | 83 | 22 | 133 | 718 | 35 | 15 | 843 | 334 |
| Turn Type | Prot | | Free | Prot | | Free | Prot | | Perm | Prot | | Free |
| Protected Phases | 1 | 2 | | 1 | 2 | | 7 | 4 | | 3 | 8 | |
| Permitted Phases | | | Free | | | Free | | | 4 | | | Free |
| Detector Phases | 1 | 2 | | 1 | 2 | | 7 | 4 | 4 | 3 | 8 | |
| Minimum Initial (s) | 4.0 | 4.0 | | 4.0 | 4.0 | | 4.0 | 20.0 | 20.0 | 7.0 | 20.0 | |
| Minimum Split (s) | 8.0 | 20.0 | | 8.0 | 20.0 | | 8.0 | 27.5 | 27.5 | 12.0 | 34.5 | |
| Total Split (s) | 46.0 | 41.1 | 0.0 | 46.0 | 41.1 | 0.0 | 33.0 | 84.9 | 84.9 | 28.0 | 79.9 | 0.0 |
| Total Split (%) | 23.0% | 20.6% | 0.0% | 23.0% | 20.6% | 0.0% | 16.5% | 42.5% | 42.5% | 14.0% | 40.0% | 0.0% |
| Yellow Time (s) | 3.5 | 3.5 | | 3.5 | 3.5 | | 3.5 | 5.5 | 5.5 | 3.0 | 5.5 | |
| All-Red Time (s) | 0.5 | 0.5 | | 0.5 | 0.5 | | 0.5 | 2.0 | 2.0 | 2.0 | 2.0 | |
| Lead/Lag | Lead | Lag | | Lead | Lag | | Lead | Lag | Lag | Lead | Lag | |
| Lead-Lag Optimize? | Yes | Yes | | Yes | Yes | | Yes | Yes | Yes | Yes | Yes | |
| Recall Mode | None | Min | | None | Min | | None | None | None | None | None | |
| Act Effct Green (s) | 12.0 | 9.7 | 73.7 | 12.0 | 9.7 | 73.7 | 8.3 | 37.3 | 37.3 | 8.4 | 29.4 | 73.7 |
| Actuated g/C Ratio | 0.16 | 0.13 | 1.00 | 0.16 | 0.13 | 1.00 | 0.11 | 0.51 | 0.51 | 0.10 | 0.40 | 1.00 |
| v/c Ratio | 0.56 | 0.44 | 0.13 | 0.08 | 0.34 | 0.01 | 0.35 | 0.40 | 0.04 | 0.08 | 0.60 | 0.21 |
| Control Delay | 31.3 | 34.5 | 0.2 | 30.4 | 34.0 | 0.0 | 34.9 | 13.3 | 5.4 | 40.9 | 20.1 | 0.3 |
| Queue Delay | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Delay | 31.3 | 34.5 | 0.2 | 30.4 | 34.0 | 0.0 | 34.9 | 13.3 | 5.4 | 40.9 | 20.1 | 0.3 |
| LOS | C | C | A | C | C | A | C | B | A | D | C | A |
| Approach Delay | | 21.5 | | | 27.9 | | | 16.2 | | | 14.8 | |
| Approach LOS | | C | | | C | | | B | | | B | |
| Queue Length 50th (ft) | 66 | 45 | 0 | 8 | 34 | 0 | 28 | 90 | 0 | 6 | 158 | 0 |
| Queue Length 95th (ft) | [illegible] | 117 | 0 | 28 | 95 | 0 | 71 | 227 | 19 | 30 | 290 | 0 |
| Internal Link Dist (ft) | | 8124 | | | 4930 | | | 4520 | | | 2983 | |
| Turn Bay Length (ft) | 600 | | 600 | 350 | | 250 | 380 | | 380 | 400 | | 600 |
| Base Capacity (vph) | 1421 | 701 | 1583 | 1421 | 701 | 1583 | 1055 | 2455 | 1109 | 439 | 2252 | 1583 |
| Starvation Cap Reductn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spillback Cap Reductn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Storage Cap Reductn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Reduced v/c Ratio | 0.22 | 0.15 | 0.13 | 0.03 | 0.12 | 0.01 | 0.13 | 0.29 | 0.03 | 0.03 | 0.37 | 0.21 |

The recommended design of this turn lane would be **180 feet taper** and **830 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

# Example 3 – Rural Conventional Unsignalized (1 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

| STEP 1 – DATA GATHERING | |
|---|---|
| **Location** | State Roadway: **US 1** Intersection: **CR 2**<br>☐ Left Turn Lane Design for Approach: N / S / E / W<br>☒ Right Turn Lane Design for Approach: N / S / [✓ E] / W |
| **Vehicle Speed**<br>*Page B-2* | Choose one. Shown in order of preference.<br>☐ Design Speed: ______ mph<br>☒ 85th Percentile Speed: **65** mph<br>☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>*Page B-3* | Choose one. Shown in order of preference.<br>☒ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>100<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: **5,000** vehicles per day<br>Minor Street Daily Traffic Volumes: **580** vehicles per day |
| **Heavy Commercial**<br>*Page B-5* | Percent Heavy Vehicle: **12** % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>*Page B-5* | ☐ Upgrade ☒ Downgrade<br>Grade of approach: **3** % (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>*Page B-4* | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No |
| **Roadway Geometry and Corridor Characteristics**<br>*Page B-6* | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-6*)<br>☒ Yes, on horizontal curve ☐ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☐ Yes, constrained location ☒ No |
| **STEP 2 – DETERMINE FACILITY TYPE** | |
| **Determine Facility Type**<br>*Page B-8* | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index . categoryassignments.html)<br>☐ Urban ☒ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☐ Expressway ☒ Conventional |
| **Intersection Control**<br>*Page B-9* | ☐ Signalized: ______ sec cycle length ☒ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

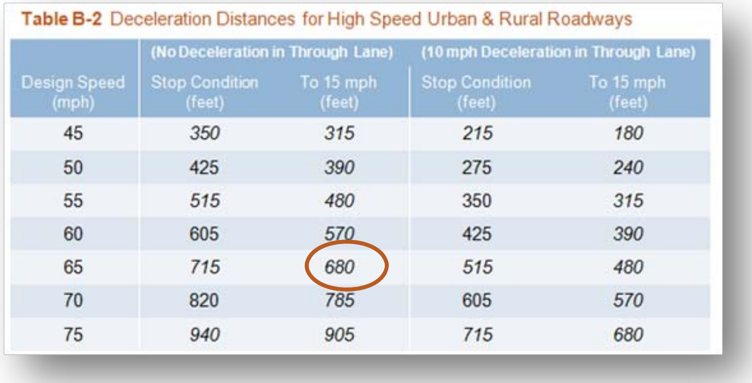
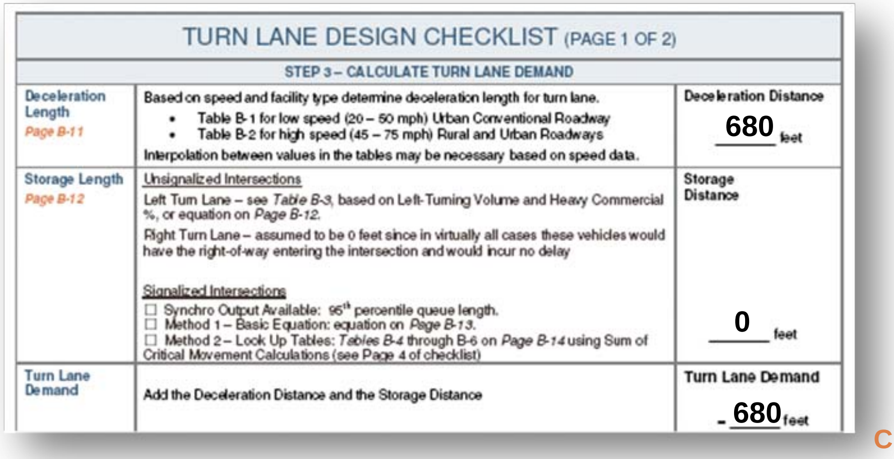


**Table B-2** Deceleration Distances for High Speed Urban & Rural Roadways

| | (No Deceleration in Through Lane) | | (10 mph Deceleration in Through Lane) | |
|---|---|---|---|---|
| Design Speed (mph) | Stop Condition (feet) | To 15 mph (feet) | Stop Condition (feet) | To 15 mph (feet) |
| 45 | 350 | 315 | 215 | 180 |
| 50 | 425 | 390 | 275 | 240 |
| 55 | 515 | 480 | 350 | 315 |
| 60 | 605 | 570 | 425 | 390 |
| 65 | 715 | [✓ 680] | 515 | 480 |
| 70 | 820 | 785 | 605 | 570 |
| 75 | 940 | 905 | 715 | 680 |

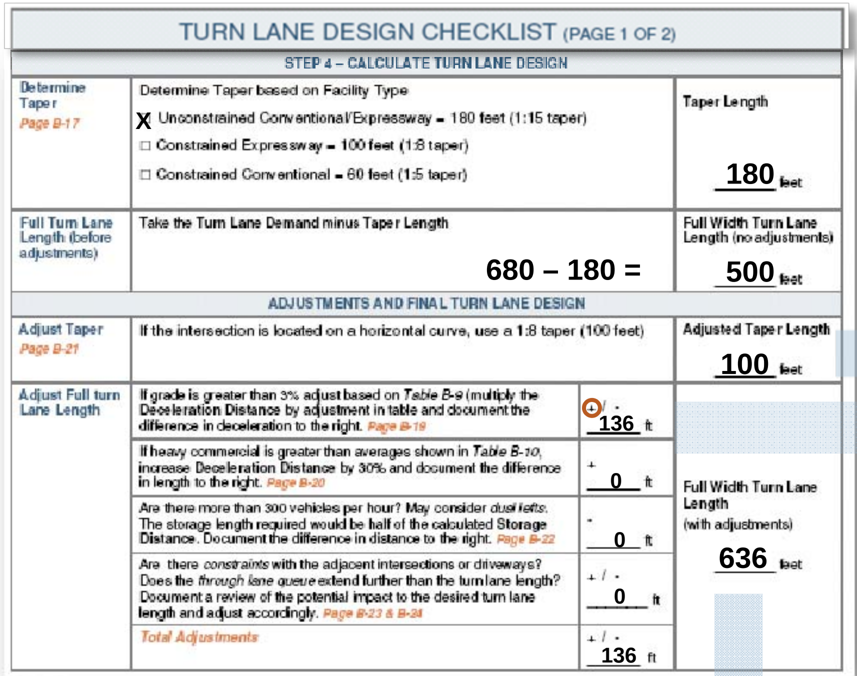
*85th Percentile speed of 65 mph, No Deceleration in Through Lane on Rural Conventional, and up to 15 mph condition for Right Turn Lanes*



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

| STEP 3 – CALCULATE TURN LANE DEMAND | | |
|---|---|---|
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>**680** feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☐ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on *Page B-13*.<br>☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>**0** feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>**680** feet |

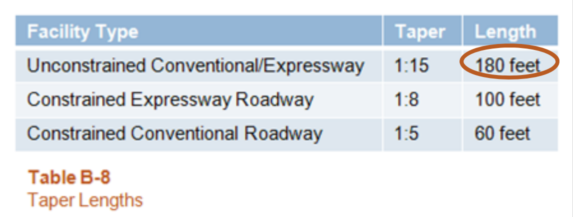
# Example 3 – Rural Conventional Unsignalized (2 of 2)



TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

STEP 4 – CALCULATE TURN LANE DESIGN

| | | | |
|---|---|---|---|
| Determine Taper<br>*Page B-17* | Determine Taper based on Facility Type<br>☒ Unconstrained Conventional/Expressway – 180 feet (1:15 taper)<br>☐ Constrained Expressway – 100 feet (1:8 taper)<br>☐ Constrained Conventional – 60 feet (1:5 taper) | | Taper Length<br>**180** feet |
| Full Turn Lane Length (before adjustments) | Take the Turn Lane Demand minus Taper Length<br>**680 – 180 =** | | Full Width Turn Lane Length (no adjustments)<br>**500** feet |
| ADJUSTMENTS AND FINAL TURN LANE DESIGN | | | |
| Adjust Taper<br>*Page B-21* | If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet) | | Adjusted Taper Length<br>**100** feet |
| Adjust Full turn Lane Length | If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. *Page B-19* | [✓ +] / - **136** ft | Full Width Turn Lane Length<br>(with adjustments)<br>**636** feet |
| | If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. *Page B-20* | + **0** ft | |
| | Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. *Page B-22* | - **0** ft | |
| | Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. *Page B-23 & B-24* | + / - **0** ft | |
| | *Total Adjustments* | + / - **136** ft | |



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

*Turn Lane is on the outside of a horizontal curve, the taper is shortened to 100 feet (1:8 taper instead of the typical 1:15)*

*3% downgrade, so the deceleration length determined in Step 3 (680') is lengthened by 135 feet based on 20% increase shown in Table B-9*

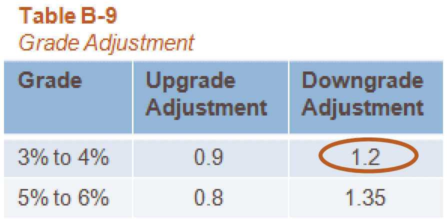


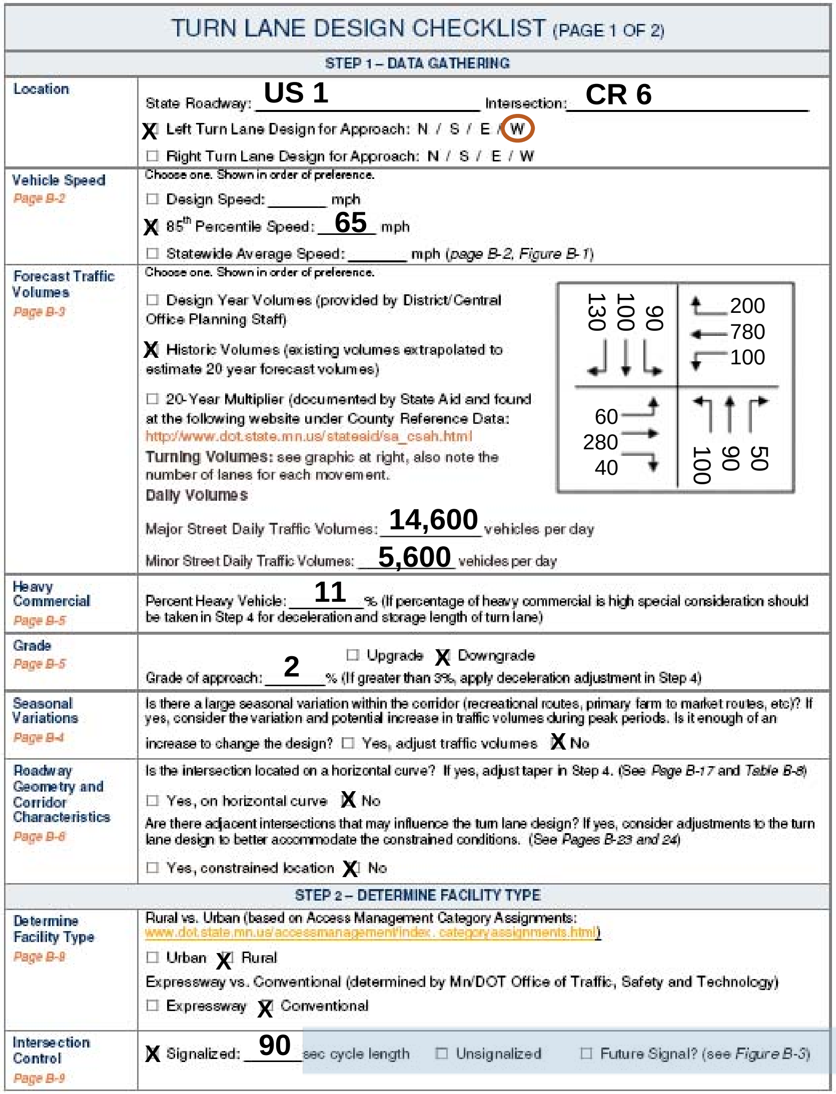
**Table B-9**
*Grade Adjustment*

| Grade | Upgrade Adjustment | Downgrade Adjustment |
|---|---|---|
| 3% to 4% | 0.9 | 1.2 |
| 5% to 6% | 0.8 | 1.35 |

**500** (full width from Step 4)
**+ 136** (total adjustments)
**= 636**

The recommended design of this turn lane would be **100 feet taper** and **640 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

# Example 4 – Rural Conventional Signalized (1 of 3)



TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

| | |
|---|---|
| **STEP 1 – DATA GATHERING** | |
| **Location** | State Roadway: US 1 Intersection: CR 6<br>☒ Left Turn Lane Design for Approach: N / S / E / [✓ W]<br>☐ Right Turn Lane Design for Approach: N / S / E / W |
| **Vehicle Speed**<br>*Page B-2* | Choose one. Shown in order of preference.<br>☐ Design Speed: ______ mph<br>☒ 85th Percentile Speed: 65 mph<br>☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>*Page B-3* | Choose one. Shown in order of preference.<br>☐ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☒ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>130 100 90<br>200<br>780<br>100<br>60<br>280<br>40<br>100 90 50<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: 14,600 vehicles per day<br>Minor Street Daily Traffic Volumes: 5,600 vehicles per day |
| **Heavy Commercial**<br>*Page B-5* | Percent Heavy Vehicle: 11 % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>*Page B-5* | ☐ Upgrade ☒ Downgrade<br>Grade of approach: 2 % (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>*Page B-4* | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No |
| **Roadway Geometry and Corridor Characteristics**<br>*Page B-6* | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)<br>☐ Yes, on horizontal curve ☒ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☐ Yes, constrained location ☒ No |
| **STEP 2 – DETERMINE FACILITY TYPE** | |
| **Determine Facility Type**<br>*Page B-9* | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index. categoryassignments.html)<br>☐ Urban ☒ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☐ Expressway ☒ Conventional |
| **Intersection Control**<br>*Page B-9* | ☒ Signalized: 90 sec cycle length ☐ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

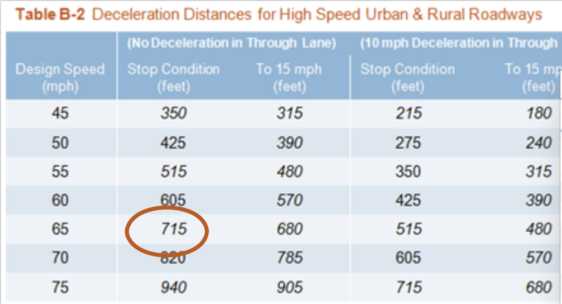


**Table B-2** Deceleration Distances for High Speed Urban & Rural Roadways

| Design Speed (mph) | (No Deceleration in Through Lane) Stop Condition (feet) | (No Deceleration in Through Lane) To 15 mph (feet) | (10 mph Deceleration in Through Lane) Stop Condition (feet) | (10 mph Deceleration in Through Lane) To 15 mph (feet) |
|---|---|---|---|---|
| 45 | 350 | 315 | 215 | 180 |
| 50 | 425 | 390 | 275 | 240 |
| 55 | 515 | 480 | 350 | 315 |
| 60 | 605 | 570 | 425 | 390 |
| 65 | 715 | 680 | 515 | 480 |
| 70 | 820 | 785 | 605 | 570 |
| 75 | 940 | 905 | 715 | 680 |

*Speed of 65 mph, No Deceleration in Through Lane on Expressways, and Stop Condition for Left Turn Lanes*

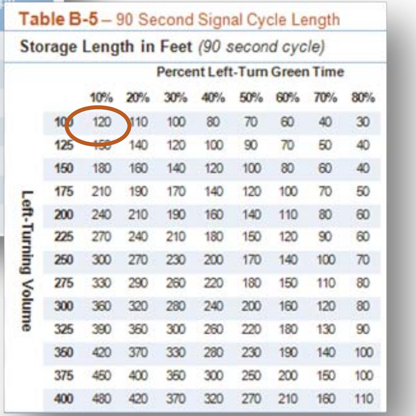
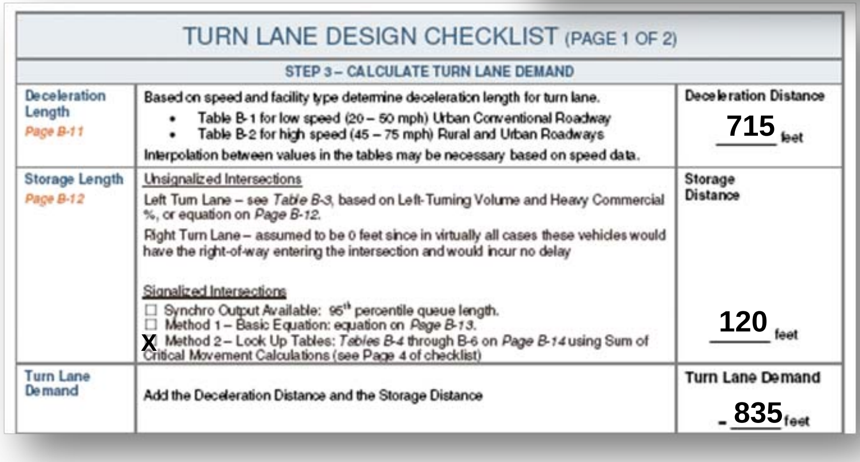


**Table B-5** – 90 Second Signal Cycle Length

**Storage Length in Feet** *(90 second cycle)*

| Left-Turning Volume | Percent Left-Turn Green Time 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% |
|---|---|---|---|---|---|---|---|---|
| 100 | 120 | 110 | 100 | 80 | 70 | 60 | 40 | 30 |
| 125 | 150 | 140 | 120 | 100 | 90 | 70 | 50 | 40 |
| 150 | 180 | 160 | 140 | 120 | 100 | 80 | 60 | 40 |
| 175 | 210 | 190 | 170 | 140 | 120 | 100 | 70 | 50 |
| 200 | 240 | 210 | 190 | 160 | 140 | 110 | 80 | 60 |
| 225 | 270 | 240 | 210 | 180 | 150 | 120 | 90 | 60 |
| 250 | 300 | 270 | 230 | 200 | 170 | 140 | 100 | 70 |
| 275 | 330 | 290 | 260 | 220 | 180 | 150 | 110 | 80 |
| 300 | 360 | 320 | 280 | 240 | 200 | 160 | 120 | 80 |
| 325 | 390 | 360 | 300 | 260 | 220 | 180 | 130 | 90 |
| 350 | 420 | 370 | 330 | 280 | 230 | 190 | 140 | 100 |
| 375 | 450 | 400 | 350 | 300 | 250 | 200 | 150 | 100 |
| 400 | 480 | 420 | 370 | 320 | 270 | 210 | 160 | 110 |



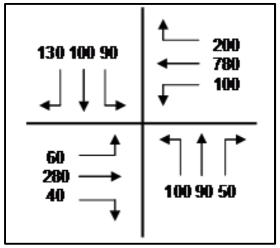
TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

| | | |
|---|---|---|
| **STEP 3 – CALCULATE TURN LANE DEMAND** | | |
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>715 feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☐ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on *Page B-13*.<br>☒ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>120 feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>835 feet |

See next page (Page 2 of 3 for Example 4) for Forecast using Historical Volumes and Sum of Critical Movement Analysis to determine Cycle Length & Percent of Left-Turn Green Time

# Example 4 – Rural Conventional Signalized (2 of 3)

### Estimate Cycle Length & % Left Turn Green Time based on Sum of Critical Movements and Table B-5

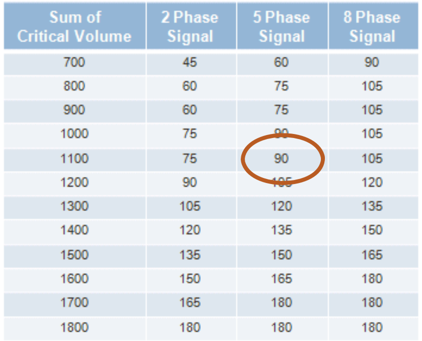


$$\text{E/W: } 60 + 780 = \boxed{840} \quad \text{or} \quad 100 + 280 = 380$$

$$\text{N/S: } 90 + 90 = 180 \quad \text{or} \quad 100 + 100 = \boxed{200}$$

Sum of Critical Movements = 1,040

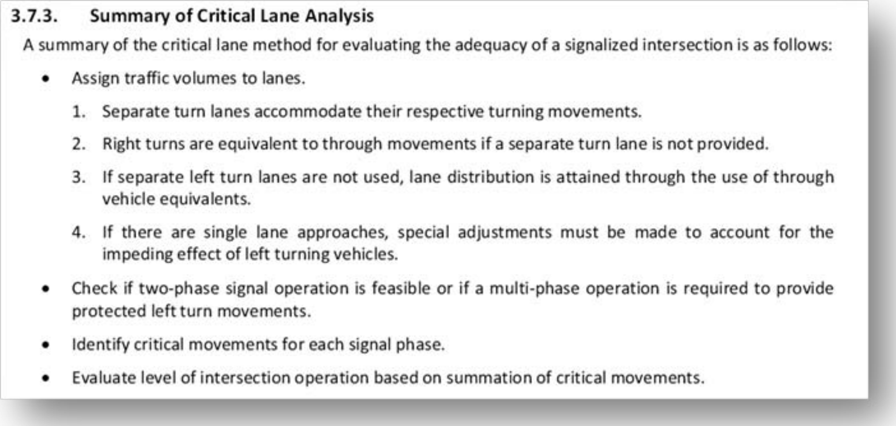
**Table B-7**
Suggested Signal Cycle Lengths



| Sum of Critical Volume | 2 Phase Signal | 5 Phase Signal | 8 Phase Signal |
|---|---|---|---|
| 700 | 45 | 60 | 90 |
| 800 | 60 | 75 | 105 |
| 900 | 60 | 75 | 105 |
| 1000 | 75 | 90 | 105 |
| 1100 | 75 | 90 | 105 |
| 1200 | 90 | 105 | 120 |
| 1300 | 105 | 120 | 135 |
| 1400 | 120 | 135 | 150 |
| 1500 | 135 | 150 | 165 |
| 1600 | 150 | 165 | 180 |
| 1700 | 165 | 180 | 180 |
| 1800 | 180 | 180 | 180 |

Cycle Length = **90 sec (*Table B-7*)**

$$\text{\% Left Turn Green Time} = \frac{\text{100 left turns}}{\text{1,040 sum of critical}} = 10\%$$



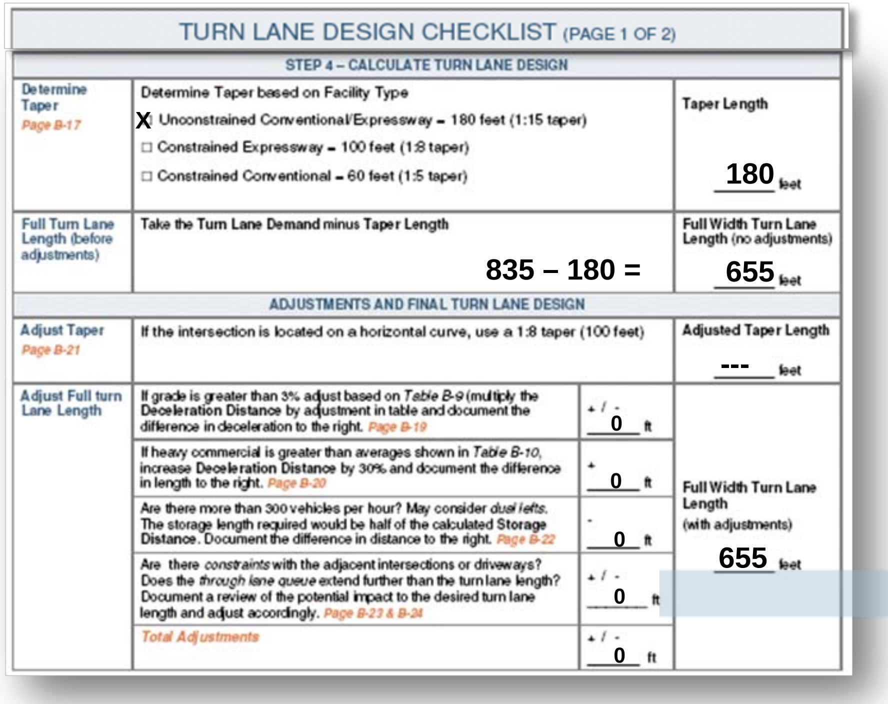
**3.7.3. Summary of Critical Lane Analysis**

A summary of the critical lane method for evaluating the adequacy of a signalized intersection is as follows:

- Assign traffic volumes to lanes.
  1. Separate turn lanes accommodate their respective turning movements.
  2. Right turns are equivalent to through movements if a separate turn lane is not provided.
  3. If separate left turn lanes are not used, lane distribution is attained through the use of through vehicle equivalents.
  4. If there are single lane approaches, special adjustments must be made to account for the impeding effect of left turning vehicles.
- Check if two-phase signal operation is feasible or if a multi-phase operation is required to provide protected left turn movements.
- Identify critical movements for each signal phase.
- Evaluate level of intersection operation based on summation of critical movements.

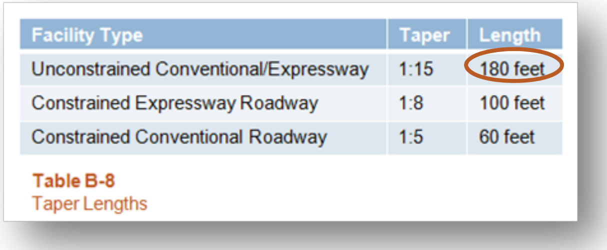
*Source: Mn/DOT Traffic Signal Timing and Coordination Manual*

# Example 4 – Rural Conventional Signalized (3 of 3)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

<table>
<tr><th colspan="4">STEP 4 – CALCULATE TURN LANE DESIGN</th></tr>
<tr><td>Determine Taper<br>Page B-17</td><td colspan="2">Determine Taper based on Facility Type<br>X Unconstrained Conventional/Expressway – 180 feet (1:15 taper)<br>☐ Constrained Expressway – 100 feet (1:8 taper)<br>☐ Constrained Conventional – 60 feet (1:5 taper)</td><td>Taper Length<br>180 feet</td></tr>
<tr><td>Full Turn Lane Length (before adjustments)</td><td colspan="2">Take the Turn Lane Demand minus Taper Length<br>835 – 180 =</td><td>Full Width Turn Lane Length (no adjustments)<br>655 feet</td></tr>
<tr><th colspan="4">ADJUSTMENTS AND FINAL TURN LANE DESIGN</th></tr>
<tr><td>Adjust Taper<br>Page B-21</td><td colspan="2">If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet)</td><td>Adjusted Taper Length<br>--- feet</td></tr>
<tr><td rowspan="5">Adjust Full turn Lane Length</td><td>If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. Page B-19</td><td>+ / -<br>0 ft</td><td rowspan="5">Full Width Turn Lane Length<br>(with adjustments)<br>655 feet</td></tr>
<tr><td>If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. Page B-20</td><td>+<br>0 ft</td></tr>
<tr><td>Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. Page B-22</td><td>-<br>0 ft</td></tr>
<tr><td>Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. Page B-23 & B-24</td><td>+ / -<br>0 ft</td></tr>
<tr><td>*Total Adjustments*</td><td>+ / -<br>0 ft</td></tr>
</table>



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

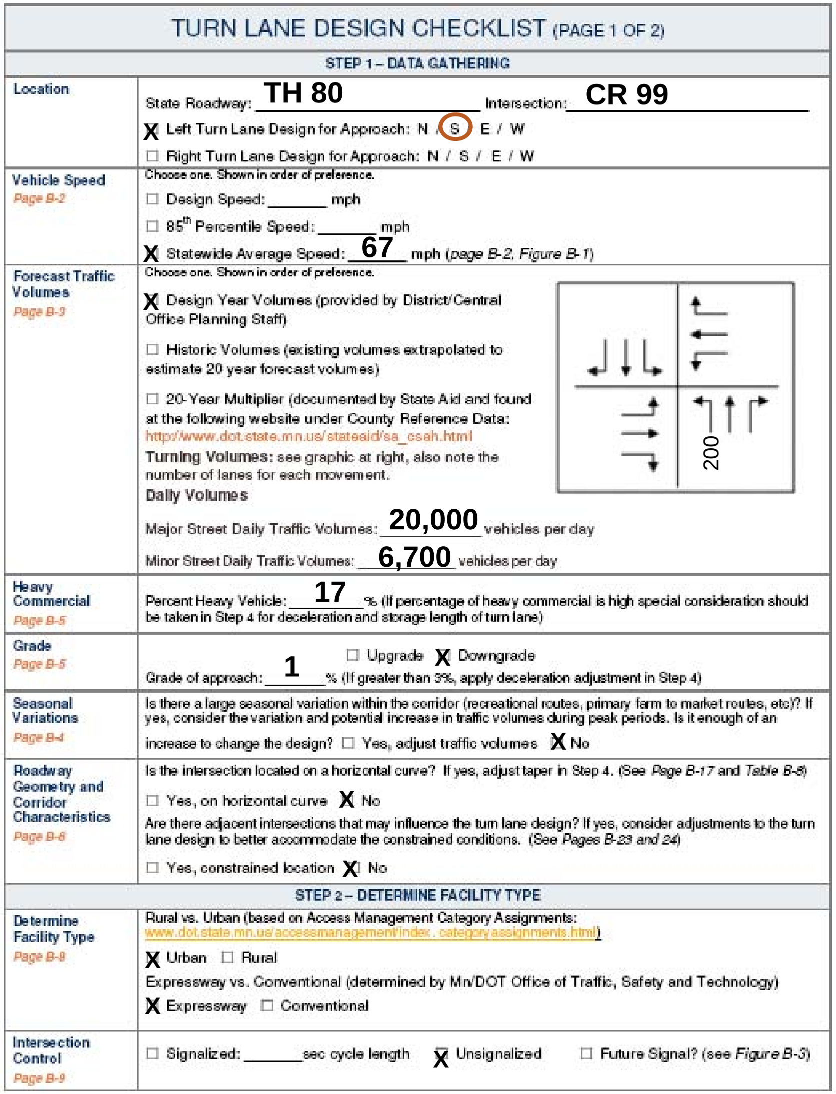
*Check for blockage by queues in the northeast bound through lane – the through lane is 245 feet, less than the full width turn lane length, therefore no adjustment is necessary.*

*Queue Through Lane = (1 – G/C) (DHV) (25) (2) / (cycles/hr)*
*= (1 – 780/1,040) (780) (25) (2) / 40 = 245 feet*

**655** (full width from Step 4)
**+ 0** (total adjustments)
**= 655**

The recommended design of this turn lane would be **180 feet taper** and **660 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

# Example 5 – Urban Expressway Unsignalized (1 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 1 – DATA GATHERING

| | |
|---|---|
| **Location** | State Roadway: **TH 80** Intersection: **CR 99**<br>☒ Left Turn Lane Design for Approach: N / [✓ S] / E / W<br>☐ Right Turn Lane Design for Approach: N / S / E / W |
| **Vehicle Speed**<br>*Page B-2* | Choose one. Shown in order of preference.<br>☐ Design Speed: _______ mph<br>☐ 85th Percentile Speed: _______ mph<br>☒ Statewide Average Speed: **67** mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>*Page B-3* | Choose one. Shown in order of preference.<br>☒ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: **20,000** vehicles per day<br>Minor Street Daily Traffic Volumes: **6,700** vehicles per day |
| **Heavy Commercial**<br>*Page B-5* | Percent Heavy Vehicle: **17** % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>*Page B-5* | ☐ Upgrade ☒ Downgrade<br>Grade of approach: **1** % (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>*Page B-4* | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No |
| **Roadway Geometry and Corridor Characteristics**<br>*Page B-6* | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)<br>☐ Yes, on horizontal curve ☒ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☐ Yes, constrained location ☒ No |

### STEP 2 – DETERMINE FACILITY TYPE

| | |
|---|---|
| **Determine Facility Type**<br>*Page B-8* | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index_categoryassignments.html)<br>☒ Urban ☐ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☒ Expressway ☐ Conventional |
| **Intersection Control**<br>*Page B-9* | ☐ Signalized: _______ sec cycle length ☒ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

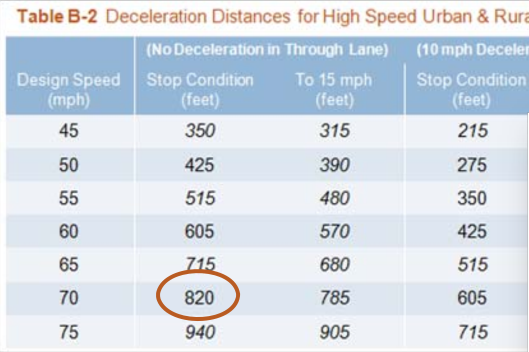


**Table B-2** Deceleration Distances for High Speed Urban & Rural Roadways

| Design Speed (mph) | (No Deceleration in Through Lane) | | (10 mph Deceleration in Through Lane) | |
|---|---|---|---|---|
| | Stop Condition (feet) | To 15 mph (feet) | Stop Condition (feet) | To 15 mph (feet) |
| 45 | 350 | 315 | 215 | |
| 50 | 425 | 390 | 275 | |
| 55 | 515 | 480 | 350 | |
| 60 | 605 | 570 | 425 | |
| 65 | 715 | 680 | 515 | |
| 70 | 820 | 785 | 605 | |
| 75 | 940 | 905 | 715 | |

*Average Facility speed of 67 mph, No Deceleration in Through Lane on Rural Conventional, and Stop condition for Left Turn Lanes*

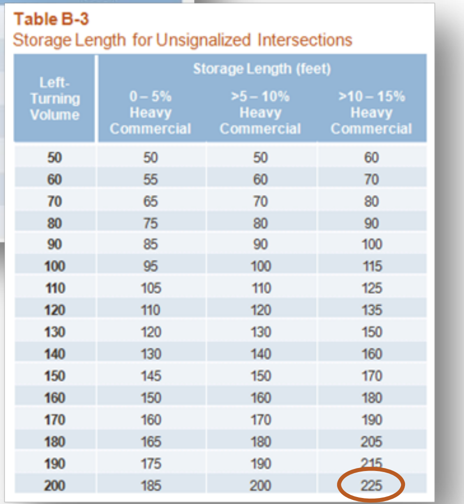
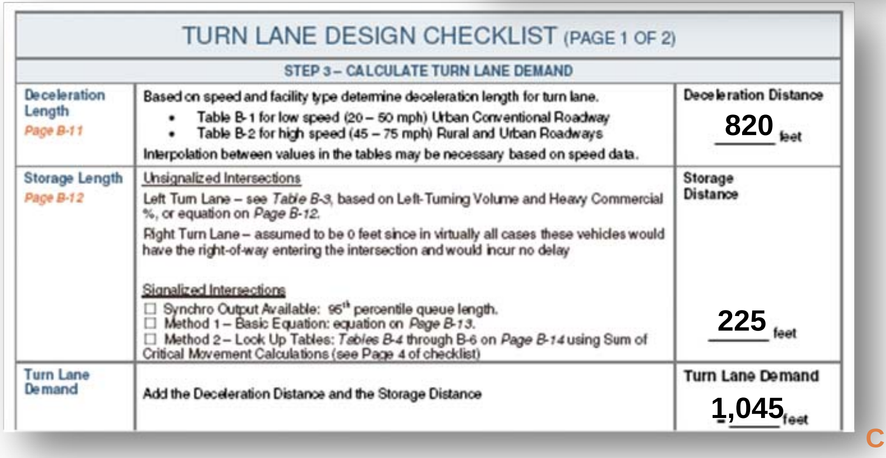


**Table B-3**
Storage Length for Unsignalized Intersections

| Left-Turning Volume | Storage Length (feet) | | |
|---|---|---|---|
| | 0 – 5% Heavy Commercial | >5 – 10% Heavy Commercial | >10 – 15% Heavy Commercial |
| **50** | 50 | 50 | 60 |
| **60** | 55 | 60 | 70 |
| **70** | 65 | 70 | 80 |
| **80** | 75 | 80 | 90 |
| **90** | 85 | 90 | 100 |
| **100** | 95 | 100 | 115 |
| **110** | 105 | 110 | 125 |
| **120** | 110 | 120 | 135 |
| **130** | 120 | 130 | 150 |
| **140** | 130 | 140 | 160 |
| **150** | 145 | 150 | 170 |
| **160** | 150 | 160 | 180 |
| **170** | 160 | 170 | 190 |
| **180** | 165 | 180 | 205 |
| **190** | 175 | 190 | 215 |
| **200** | 185 | 200 | 225 |

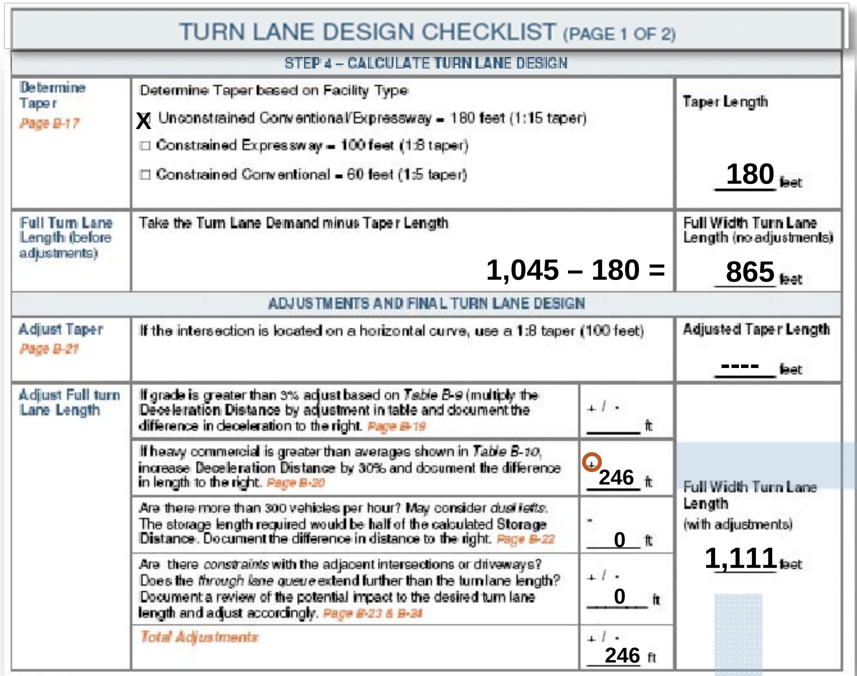


## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 3 – CALCULATE TURN LANE DEMAND

| | | |
|---|---|---|
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>**820** feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☐ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on *Page B-13*.<br>☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>**225** feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>**1,045** feet |

# Example 5 – Urban Expressway Unsignalized (2 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

**STEP 4 – CALCULATE TURN LANE DESIGN**

**Determine Taper** *Page B-17*

Determine Taper based on Facility Type

☒ Unconstrained Conventional/Expressway – 180 feet (1:15 taper)
☐ Constrained Expressway – 100 feet (1:8 taper)
☐ Constrained Conventional – 60 feet (1:5 taper)

Taper Length 180 feet

**Full Turn Lane Length (before adjustments)**

Take the Turn Lane Demand minus Taper Length

**1,045 – 180 =**

Full Width Turn Lane Length (no adjustments) **865** feet

**ADJUSTMENTS AND FINAL TURN LANE DESIGN**

**Adjust Taper** *Page B-21*

If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet)

Adjusted Taper Length **----** feet

**Adjust Full turn Lane Length**

If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. *Page B-19* + / - ____ ft

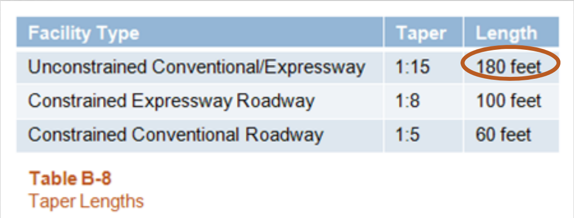
If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. *Page B-20* [✓ +] **246** ft

Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. *Page B-22* - **0** ft

Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. *Page B-23 & B-24* + / - **0** ft

*Total Adjustments* + / - **246** ft

Full Width Turn Lane Length (with adjustments) **1,111** feet



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

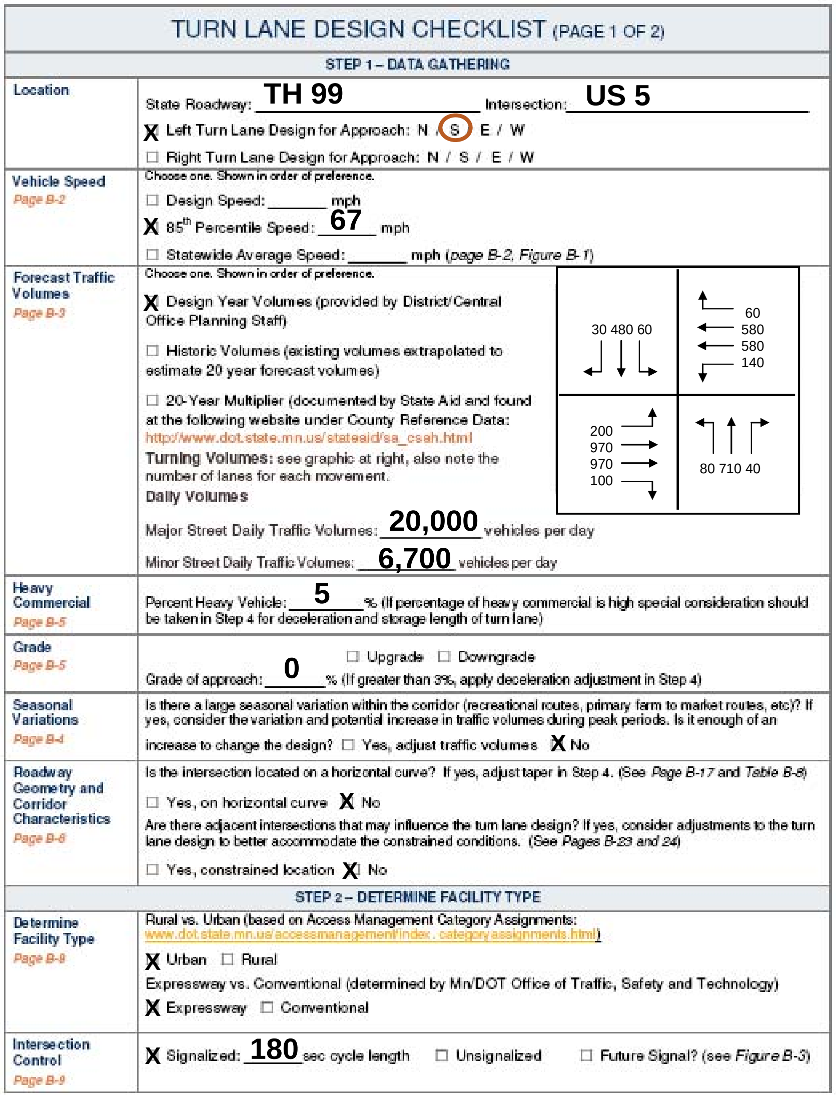
**Table B-8**
Taper Lengths

*Heavy Commercial of 17% is above the average of 4% for an Urban Expressway so the deceleration length was increased to accommodate the higher % of heavy commercial*

**865** (full width from Step 4)
**+ 246** (total adjustments)
**= 1,111**

The recommended design of this turn lane would be **180 feet taper** and **1,110 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

# Example 6 – Urban Expressway Signalized (1 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 1 – DATA GATHERING

**Location**

State Roadway: TH 99 Intersection: US 5

X Left Turn Lane Design for Approach: N / [✓ S] / E / W

☐ Right Turn Lane Design for Approach: N / S / E / W

**Vehicle Speed** *Page B-2*

Choose one. Shown in order of preference.

☐ Design Speed: ______ mph

X 85th Percentile Speed: 67 mph

☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*)

**Forecast Traffic Volumes** *Page B-3*

Choose one. Shown in order of preference.

X Design Year Volumes (provided by District/Central Office Planning Staff)

☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)

☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html

**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.

30 480 60

60
580
580
140

200
970
970
100

80 710 40

**Daily Volumes**

Major Street Daily Traffic Volumes: 20,000 vehicles per day

Minor Street Daily Traffic Volumes: 6,700 vehicles per day

**Heavy Commercial** *Page B-5*

Percent Heavy Vehicle: 5 % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane)

**Grade** *Page B-5*

☐ Upgrade ☐ Downgrade

Grade of approach: 0 % (If greater than 3%, apply deceleration adjustment in Step 4)

**Seasonal Variations** *Page B-4*

Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes X No

**Roadway Geometry and Corridor Characteristics** *Page B-6*

Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)

☐ Yes, on horizontal curve X No

Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)

☐ Yes, constrained location X No

### STEP 2 – DETERMINE FACILITY TYPE

**Determine Facility Type** *Page B-8*

Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index . categoryassignments.html)

X Urban ☐ Rural

Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)

X Expressway ☐ Conventional

**Intersection Control** *Page B-9*

X Signalized: 180 sec cycle length ☐ Unsignalized ☐ Future Signal? (see *Figure B-3*)

**Interpolate between the 65 mph and 70 mph stop condition (left turn lane) and no deceleration in through lane for Expressways = 750 feet*

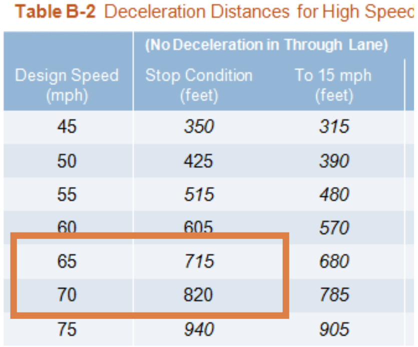
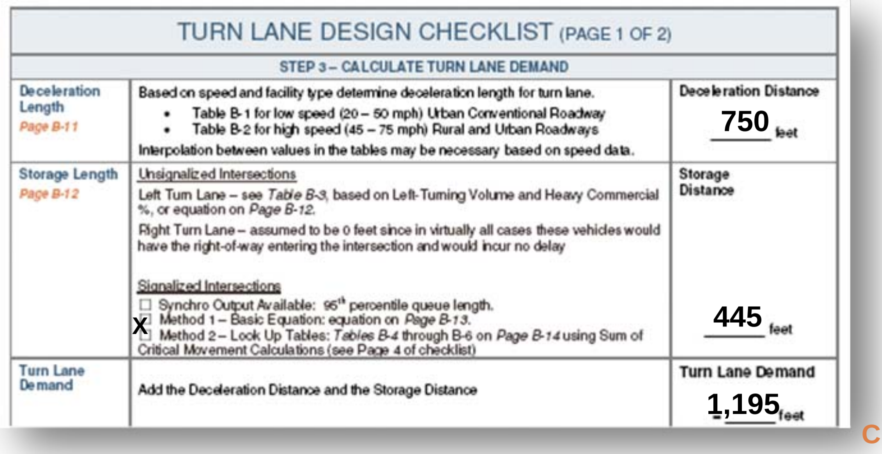


**Table B-2** Deceleration Distances for High Speec

| Design Speed (mph) | (No Deceleration in Through Lane)<br>Stop Condition (feet) | To 15 mph (feet) |
|---|---|---|
| 45 | 350 | 315 |
| 50 | 425 | 390 |
| 55 | 515 | 480 |
| 60 | 605 | 570 |
| 65 | 715 | 680 |
| 70 | 820 | 785 |
| 75 | 940 | 905 |

*Use the Storage Length equation for the 180 second cycle length.*

**Storage Length** = (1 – G/C) (DHV) (25) (2) / (cycles/hr)
= (1 – 20/180) ( 200) (25) (2) / 20 = **445 feet**



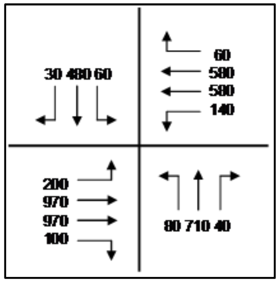
## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 3 – CALCULATE TURN LANE DEMAND

| | | |
|---|---|---|
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>750 feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☐ Synchro Output Available: 95th percentile queue length.<br>X Method 1 – Basic Equation: equation on *Page B-13*.<br>☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>445 feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>1,195 feet |

# Example 6 – Urban Expressway Signalized (2 of 3)

## *Estimate Cycle Length & % Left Turn Green Time based on Sum of Critical Movements and Table B-7*



E/W: 200 + 580 = 780 or 140 + 970 = $\boxed{1{,}110}$

N/S: 80 + 480 = 560 or 60 + 710 = $\boxed{770}$

Sum of Critical Movements = 1,880

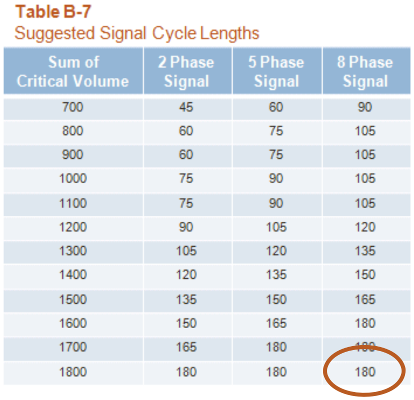
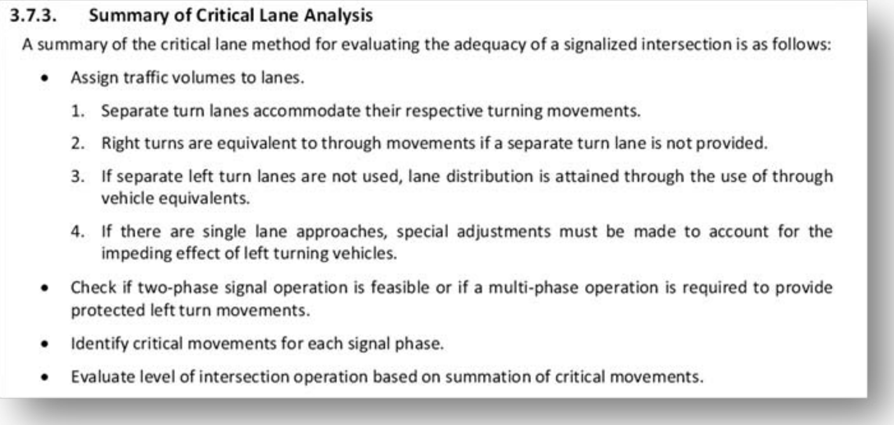


**Table B-7**
Suggested Signal Cycle Lengths

| Sum of Critical Volume | 2 Phase Signal | 5 Phase Signal | 8 Phase Signal |
|---|---|---|---|
| 700 | 45 | 60 | 90 |
| 800 | 60 | 75 | 105 |
| 900 | 60 | 75 | 105 |
| 1000 | 75 | 90 | 105 |
| 1100 | 75 | 90 | 105 |
| 1200 | 90 | 105 | 120 |
| 1300 | 105 | 120 | 135 |
| 1400 | 120 | 135 | 150 |
| 1500 | 135 | 150 | 165 |
| 1600 | 150 | 165 | 180 |
| 1700 | 165 | 180 | 180 |
| 1800 | 180 | 180 | 180 |

Cycle Length = **180 sec (*Table B-7*)**

% Left Turn Green Time = $\frac{\text{200 left turns}}{\text{1,880 sum of critical}}$ = **11%**



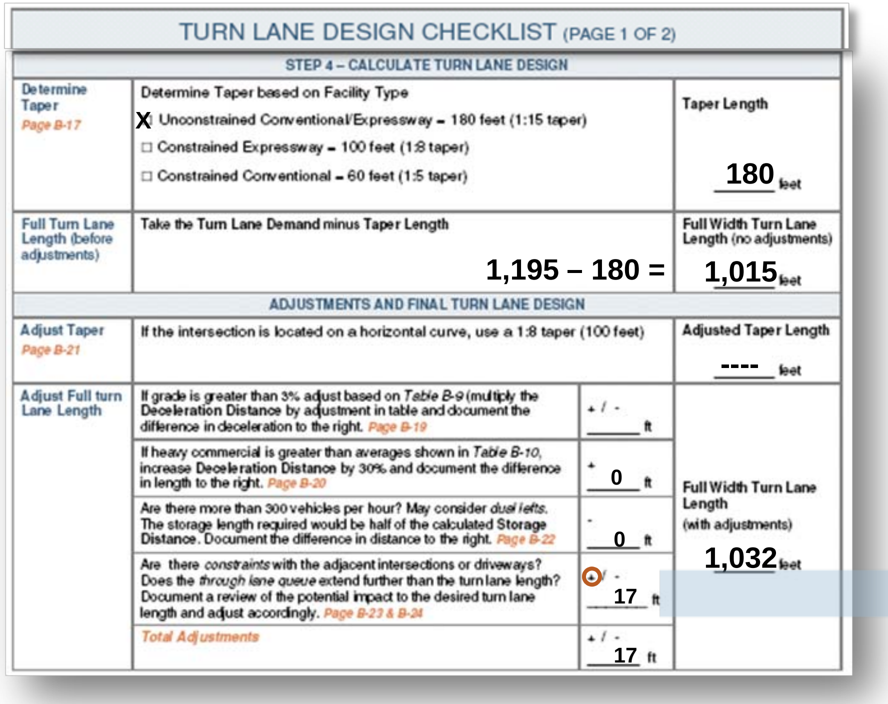
**3.7.3. Summary of Critical Lane Analysis**

A summary of the critical lane method for evaluating the adequacy of a signalized intersection is as follows:

- Assign traffic volumes to lanes.
  1. Separate turn lanes accommodate their respective turning movements.
  2. Right turns are equivalent to through movements if a separate turn lane is not provided.
  3. If separate left turn lanes are not used, lane distribution is attained through the use of through vehicle equivalents.
  4. If there are single lane approaches, special adjustments must be made to account for the impeding effect of left turning vehicles.
- Check if two-phase signal operation is feasible or if a multi-phase operation is required to provide protected left turn movements.
- Identify critical movements for each signal phase.
- Evaluate level of intersection operation based on summation of critical movements.

*Source: Mn/DOT Traffic Signal Timing and Coordination Manual*

# Example 6 – Urban Expressway Signalized (3 of 3)



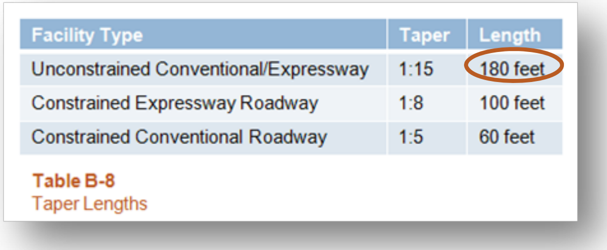
TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

STEP 4 – CALCULATE TURN LANE DESIGN

| | | | |
|---|---|---|---|
| **Determine Taper**<br>*Page B-17* | Determine Taper based on Facility Type<br>☒ Unconstrained Conventional/Expressway – 180 feet (1:15 taper)<br>☐ Constrained Expressway – 100 feet (1:8 taper)<br>☐ Constrained Conventional – 60 feet (1:5 taper) | | Taper Length<br>**180** feet |
| **Full Turn Lane Length (before adjustments)** | Take the Turn Lane Demand minus Taper Length<br>**1,195 – 180 =** | | Full Width Turn Lane Length (no adjustments)<br>**1,015** feet |

ADJUSTMENTS AND FINAL TURN LANE DESIGN

| | | | |
|---|---|---|---|
| **Adjust Taper**<br>*Page B-21* | If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet) | | Adjusted Taper Length<br>**----** feet |
| **Adjust Full turn Lane Length** | If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. *Page B-19* | + / -<br>____ ft | Full Width Turn Lane Length<br>(with adjustments)<br>**1,032** feet |
| | If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. *Page B-20* | +<br>**0** ft | |
| | Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. *Page B-22* | -<br>**0** ft | |
| | Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. *Page B-23 & B-24* | [✓ +] / -<br>**17** ft | |
| | *Total Adjustments* | + / -<br>**17** ft | |



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

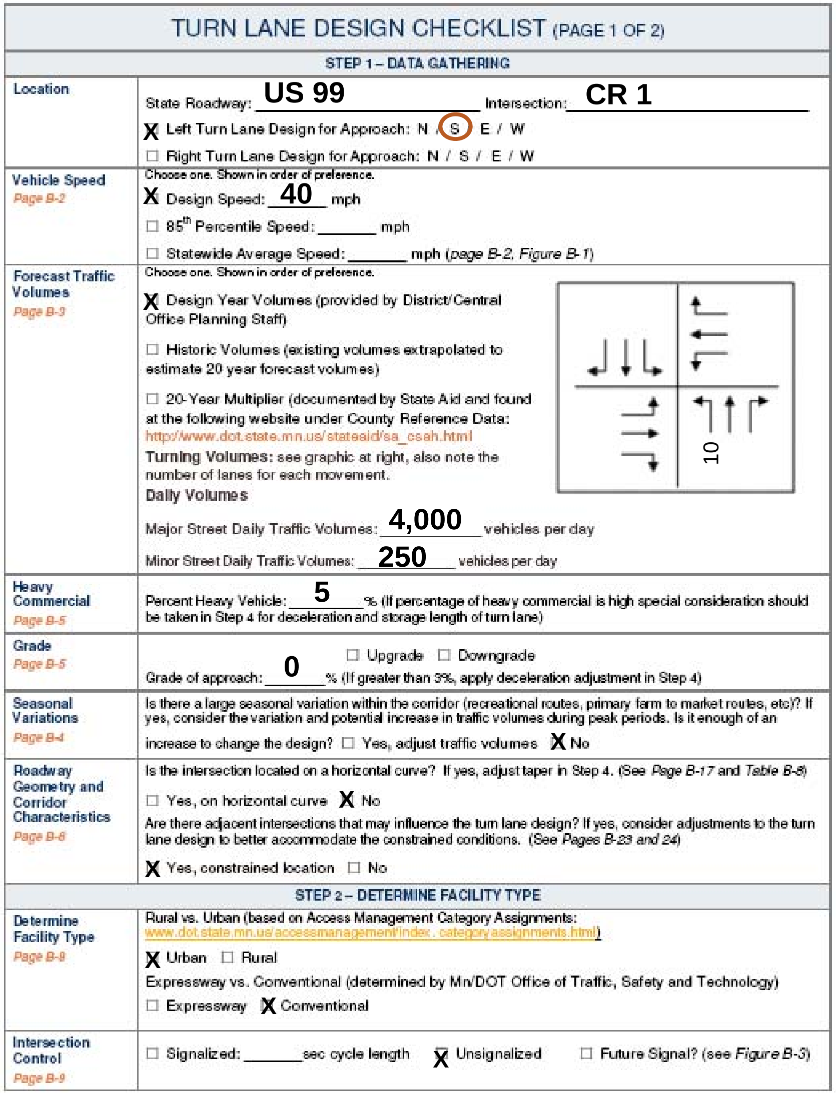
*Check for blockage by queues in the through lane – the through lane queue is 1,212 feet, more than the full width plus taper turn lane length. Consideration should be given to extending the left turn lane 17 feet to have the taper start at the end of the through lane queue.*

*Queue Through = (1 – G/C) (DHV) (25) (2) / (cycles/hr)*
*= (1 – 50/180) (970) (25) (2) / 20 = 1,212 feet*

**1015** (full width from Step 4)
**+ 17** (total adjustments)
**= 1,032**

The recommended design of this turn lane would be **180 feet taper** and **1,040 feet** (rounding to the nearest 10 foot) **of full width turn lane.**

# Example 7 – Urban Conventional Unsignalized (1 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 1 – DATA GATHERING

**Location**

State Roadway: US 99 Intersection: CR 1

☒ Left Turn Lane Design for Approach: N / [✓ S] / E / W

☐ Right Turn Lane Design for Approach: N / S / E / W

**Vehicle Speed** Page B-2

Choose one. Shown in order of preference.

☒ Design Speed: 40 mph

☐ 85th Percentile Speed: ______ mph

☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*)

**Forecast Traffic Volumes** Page B-3

Choose one. Shown in order of preference.

☒ Design Year Volumes (provided by District/Central Office Planning Staff)

☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)

☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html

**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.

**Daily Volumes**

Major Street Daily Traffic Volumes: 4,000 vehicles per day

Minor Street Daily Traffic Volumes: 250 vehicles per day

**Heavy Commercial** Page B-5

Percent Heavy Vehicle: 5 % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane)

**Grade** Page B-5

☐ Upgrade ☐ Downgrade

Grade of approach: 0 % (If greater than 3%, apply deceleration adjustment in Step 4)

**Seasonal Variations** Page B-4

Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No

**Roadway Geometry and Corridor Characteristics** Page B-6

Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)

☐ Yes, on horizontal curve ☒ No

Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)

☒ Yes, constrained location ☐ No

### STEP 2 – DETERMINE FACILITY TYPE

**Determine Facility Type** Page B-8

Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index . categoryassignments.html)

☒ Urban ☐ Rural

Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)

☐ Expressway ☒ Conventional

**Intersection Control** Page B-9

☐ Signalized: ______ sec cycle length ☒ Unsignalized ☐ Future Signal? (see *Figure B-3*)

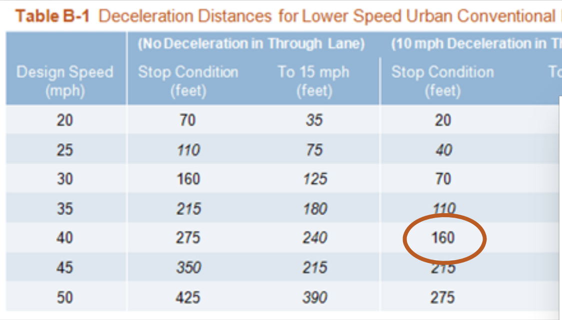


**Table B-1** Deceleration Distances for Lower Speed Urban Conventional Roadways

| Design Speed (mph) | (No Deceleration in Through Lane) Stop Condition (feet) | (No Deceleration in Through Lane) To 15 mph (feet) | (10 mph Deceleration in Through Lane) Stop Condition (feet) | (10 mph Deceleration in Through Lane) To 15 mph (feet) |
|---|---|---|---|---|
| 20 | 70 | *35* | 20 | |
| 25 | *110* | *75* | *40* | |
| 30 | 160 | *125* | 70 | |
| 35 | *215* | *180* | *110* | |
| 40 | 275 | *240* | 160 | |
| 45 | *350* | *215* | *215* | |
| 50 | 425 | *390* | 275 | |

*Design Speed is 40 mph, 10 mph Deceleration in Through Lane on Urban Conventional, and Stop condition for Left Turn Lanes*

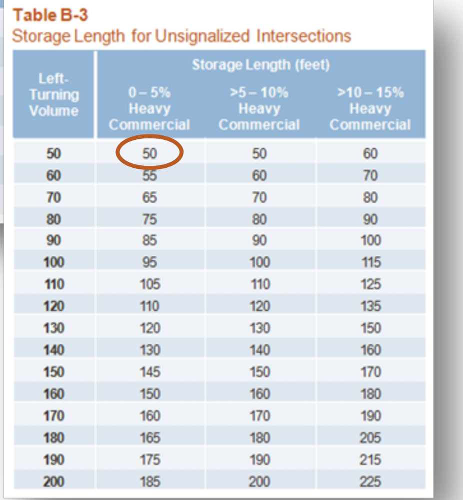
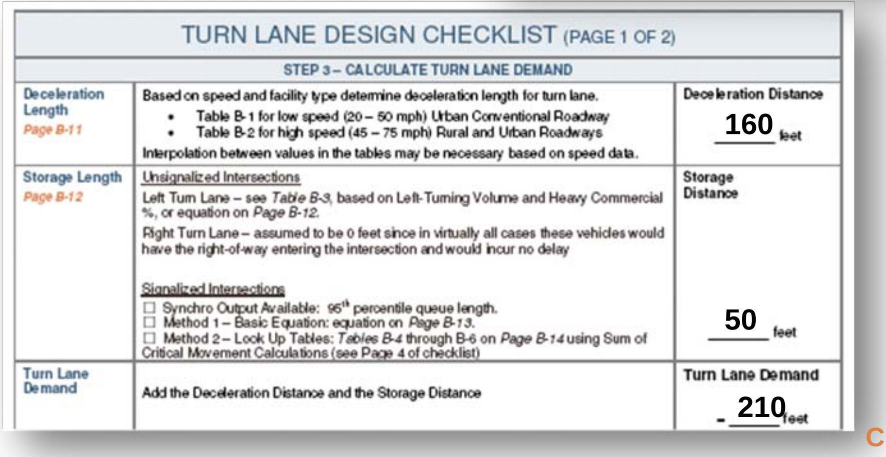


**Table B-3**
Storage Length for Unsignalized Intersections

| Left-Turning Volume | Storage Length (feet) 0 – 5% Heavy Commercial | >5 – 10% Heavy Commercial | >10 – 15% Heavy Commercial |
|---|---|---|---|
| 50 | 50 | 50 | 60 |
| 60 | 55 | 60 | 70 |
| 70 | 65 | 70 | 80 |
| 80 | 75 | 80 | 90 |
| 90 | 85 | 90 | 100 |
| 100 | 95 | 100 | 115 |
| 110 | 105 | 110 | 125 |
| 120 | 110 | 120 | 135 |
| 130 | 120 | 130 | 150 |
| 140 | 130 | 140 | 160 |
| 150 | 145 | 150 | 170 |
| 160 | 150 | 160 | 180 |
| 170 | 160 | 170 | 190 |
| 180 | 165 | 180 | 205 |
| 190 | 175 | 190 | 215 |
| 200 | 185 | 200 | 225 |

*Storage Defaults to the minimum of 50 feet*



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 3 – CALCULATE TURN LANE DEMAND

**Deceleration Length** Page B-11

Based on speed and facility type determine deceleration length for turn lane.

- Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway
- Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways

Interpolation between values in the tables may be necessary based on speed data.

**Deceleration Distance** 160 feet

**Storage Length** Page B-12

Unsignalized Intersections

Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.

Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay

Signalized Intersections

☐ Synchro Output Available: 95th percentile queue length.

☐ Method 1 – Basic Equation: equation on *Page B-13*.

☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist)

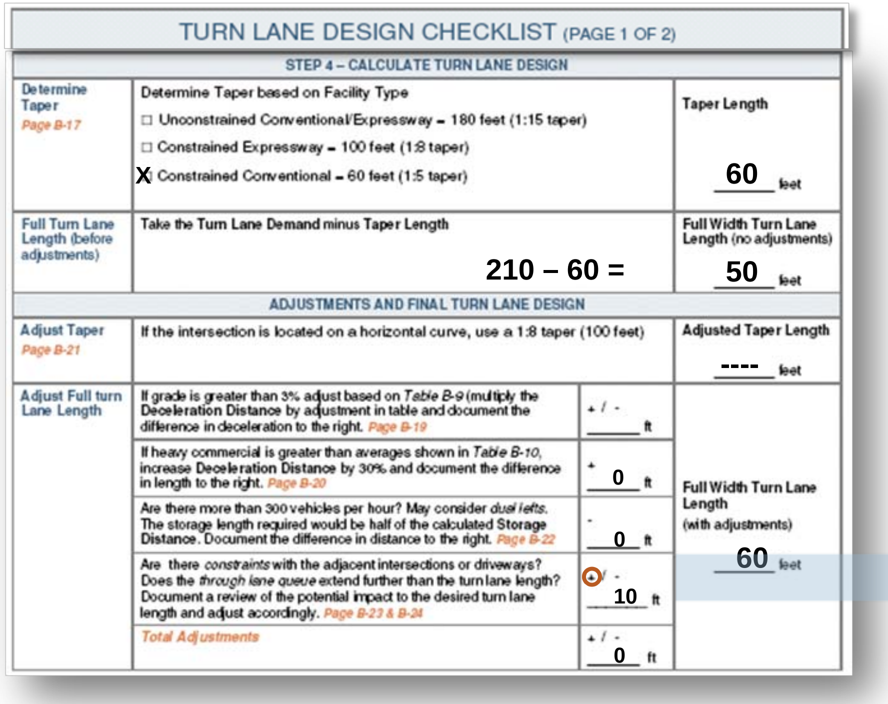
**Storage Distance** 50 feet

**Turn Lane Demand**

Add the Deceleration Distance and the Storage Distance

**Turn Lane Demand** 210 feet

# Example 7 – Urban Conventional Unsignalized (2 of 2)



TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

STEP 4 – CALCULATE TURN LANE DESIGN

**Determine Taper** *Page B-17*

Determine Taper based on Facility Type

☐ Unconstrained Conventional/Expressway – 180 feet (1:15 taper)

☐ Constrained Expressway – 100 feet (1:8 taper)

☒ Constrained Conventional – 60 feet (1:5 taper)

Taper Length 60 feet

**Full Turn Lane Length (before adjustments)**

Take the Turn Lane Demand minus Taper Length

210 – 60 =

Full Width Turn Lane Length (no adjustments) 50 feet

ADJUSTMENTS AND FINAL TURN LANE DESIGN

**Adjust Taper** *Page B-21*

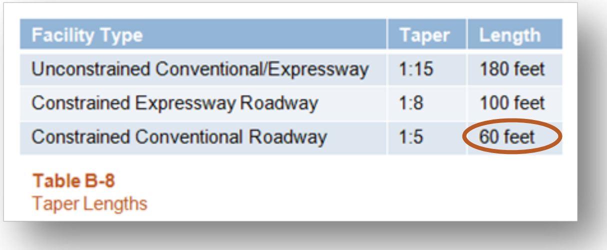
If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet)

Adjusted Taper Length ---- feet

**Adjust Full turn Lane Length**

| | |
|---|---|
| If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. *Page B-19* | + / - ____ ft |
| If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. *Page B-20* | + 0 ft |
| Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. *Page B-22* | - 0 ft |
| Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. *Page B-23 & B-24* | [✓ +] / - 10 ft |
| *Total Adjustments* | + / - 0 ft |

Full Width Turn Lane Length (with adjustments) 60 feet



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

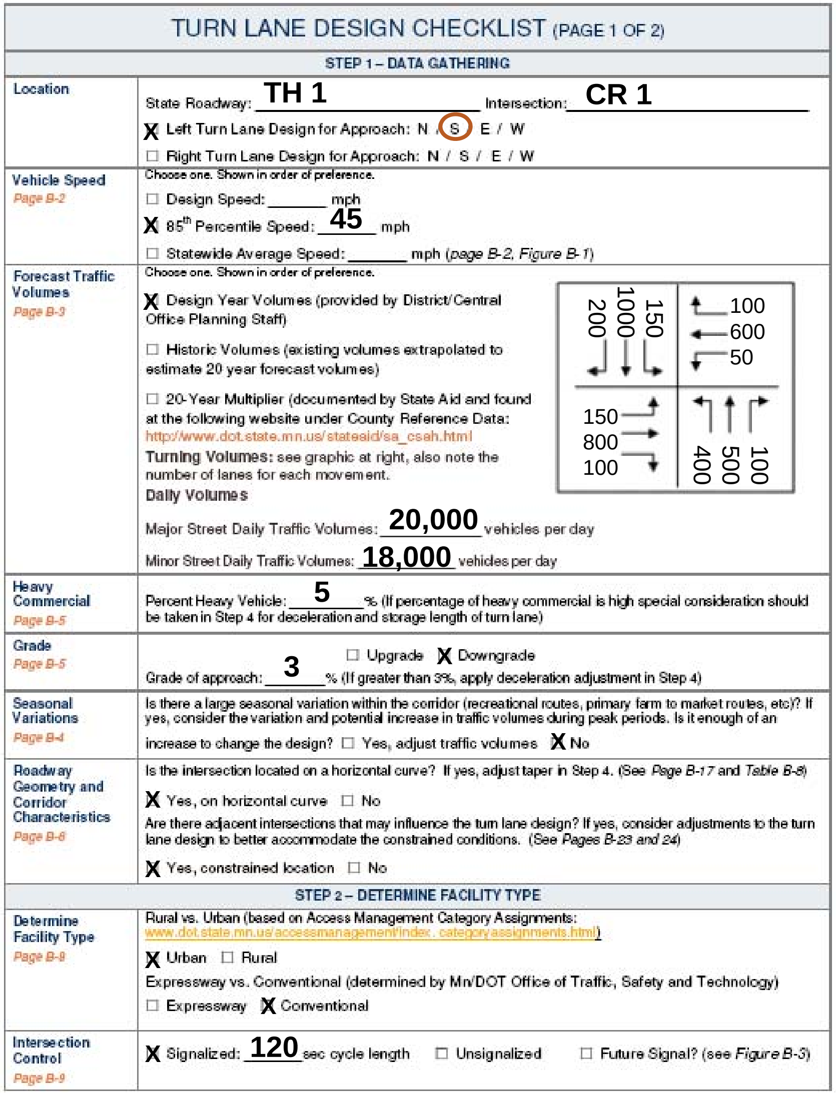
**Table B-8**
Taper Lengths

*The taper length can not be longer than the full turn lane length. Add 10 feet to have equal taper to full length.*

**50** (full width from Step 4)
**+10** (total adjustments)
**=60**

The recommended design of this turn lane would be **60 feet taper** and **60 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

# Example 8 – Urban Conventional Signalized (1 of 2)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 1 – DATA GATHERING

| | |
|---|---|
| **Location** | State Roadway: TH 1 Intersection: CR 1<br>☒ Left Turn Lane Design for Approach: N / [✓ S] / E / W<br>☐ Right Turn Lane Design for Approach: N / S / E / W |
| **Vehicle Speed**<br>*Page B-2* | Choose one. Shown in order of preference.<br>☐ Design Speed: ______ mph<br>☒ 85th Percentile Speed: 45 mph<br>☐ Statewide Average Speed: ______ mph (*page B-2, Figure B-1*) |
| **Forecast Traffic Volumes**<br>*Page B-3* | Choose one. Shown in order of preference.<br>☒ Design Year Volumes (provided by District/Central Office Planning Staff)<br>☐ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)<br>☐ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: http://www.dot.state.mn.us/stateaid/sa_csah.html<br>**Turning Volumes:** see graphic at right, also note the number of lanes for each movement.<br>200 1000 150<br>100 600 50<br>150 800 100<br>400 500 100<br>**Daily Volumes**<br>Major Street Daily Traffic Volumes: 20,000 vehicles per day<br>Minor Street Daily Traffic Volumes: 18,000 vehicles per day |
| **Heavy Commercial**<br>*Page B-5* | Percent Heavy Vehicle: 5 % (If percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane) |
| **Grade**<br>*Page B-5* | ☐ Upgrade ☒ Downgrade<br>Grade of approach: 3 % (If greater than 3%, apply deceleration adjustment in Step 4) |
| **Seasonal Variations**<br>*Page B-4* | Is there a large seasonal variation within the corridor (recreational routes, primary farm to market routes, etc)? If yes, consider the variation and potential increase in traffic volumes during peak periods. Is it enough of an increase to change the design? ☐ Yes, adjust traffic volumes ☒ No |
| **Roadway Geometry and Corridor Characteristics**<br>*Page B-6* | Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See *Page B-17* and *Table B-8*)<br>☒ Yes, on horizontal curve ☐ No<br>Are there adjacent intersections that may influence the turn lane design? If yes, consider adjustments to the turn lane design to better accommodate the constrained conditions. (See *Pages B-23 and 24*)<br>☒ Yes, constrained location ☐ No |

### STEP 2 – DETERMINE FACILITY TYPE

| | |
|---|---|
| **Determine Facility Type**<br>*Page B-8* | Rural vs. Urban (based on Access Management Category Assignments: www.dot.state.mn.us/accessmanagement/index . categoryassignments.html)<br>☒ Urban ☐ Rural<br>Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)<br>☐ Expressway ☒ Conventional |
| **Intersection Control**<br>*Page B-9* | ☒ Signalized: 120 sec cycle length ☐ Unsignalized ☐ Future Signal? (see *Figure B-3*) |

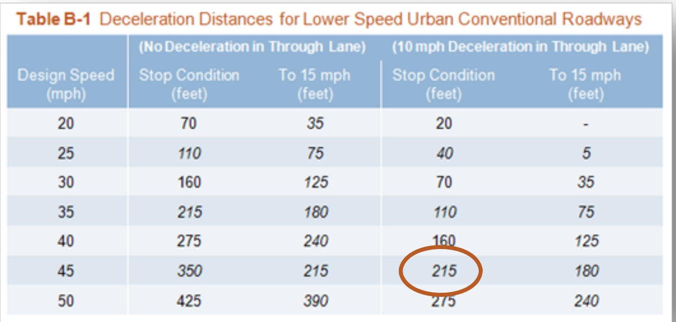
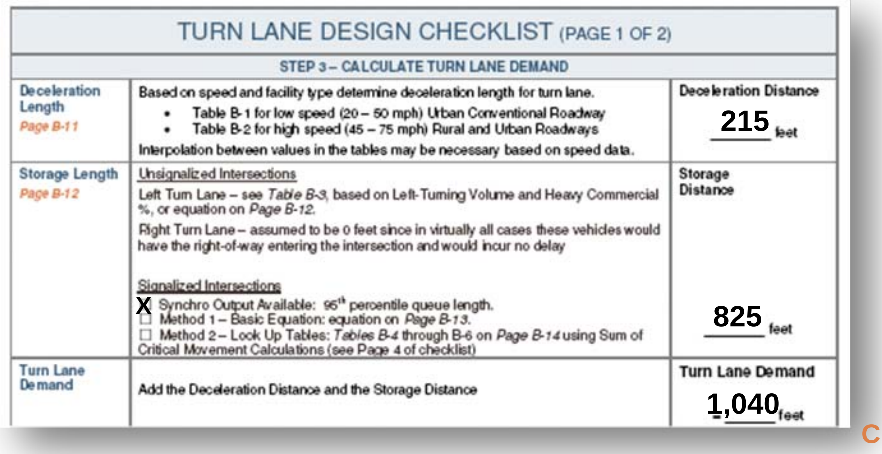


**Table B-1** Deceleration Distances for Lower Speed Urban Conventional Roadways

| Design Speed (mph) | (No Deceleration in Through Lane) Stop Condition (feet) | To 15 mph (feet) | (10 mph Deceleration in Through Lane) Stop Condition (feet) | To 15 mph (feet) |
|---|---|---|---|---|
| 20 | 70 | 35 | 20 | - |
| 25 | 110 | 75 | 40 | 5 |
| 30 | 160 | 125 | 70 | 35 |
| 35 | 215 | 180 | 110 | 75 |
| 40 | 275 | 240 | 160 | 125 |
| 45 | 350 | 215 | 215 | 180 |
| 50 | 425 | 390 | 275 | 240 |

*Design Speed is 45 mph, 10 mph Deceleration in Through Lane on Urban Conventional, and Stop condition for Left Turn Lanes*

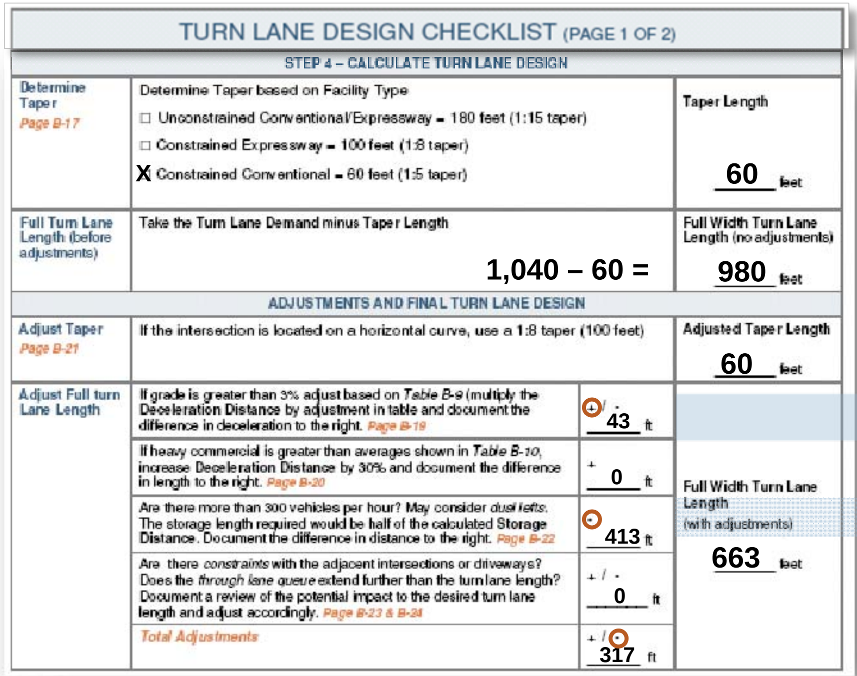


## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

### STEP 3 – CALCULATE TURN LANE DEMAND

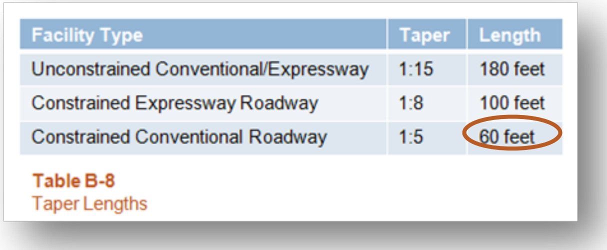
| | | |
|---|---|---|
| **Deceleration Length**<br>*Page B-11* | Based on speed and facility type determine deceleration length for turn lane.<br>• Table B-1 for low speed (20 – 50 mph) Urban Conventional Roadway<br>• Table B-2 for high speed (45 – 75 mph) Rural and Urban Roadways<br>Interpolation between values in the tables may be necessary based on speed data. | **Deceleration Distance**<br>215 feet |
| **Storage Length**<br>*Page B-12* | Unsignalized Intersections<br>Left Turn Lane – see *Table B-3*, based on Left-Turning Volume and Heavy Commercial %, or equation on *Page B-12*.<br>Right Turn Lane – assumed to be 0 feet since in virtually all cases these vehicles would have the right-of-way entering the intersection and would incur no delay<br>Signalized Intersections<br>☒ Synchro Output Available: 95th percentile queue length.<br>☐ Method 1 – Basic Equation: equation on *Page B-13*.<br>☐ Method 2 – Look Up Tables: *Tables B-4* through B-6 on *Page B-14* using Sum of Critical Movement Calculations (see Page 4 of checklist) | **Storage Distance**<br>825 feet |
| **Turn Lane Demand** | Add the Deceleration Distance and the Storage Distance | **Turn Lane Demand**<br>1,040 feet |

# Example 8 – Urban Conventional Signalized (3 of 3)



## TURN LANE DESIGN CHECKLIST (PAGE 1 OF 2)

| | | | |
|---|---|---|---|
| **STEP 4 – CALCULATE TURN LANE DESIGN** | | | |
| Determine Taper<br>*Page B-17* | Determine Taper based on Facility Type<br>☐ Unconstrained Conventional/Expressway – 180 feet (1:15 taper)<br>☐ Constrained Expressway – 100 feet (1:8 taper)<br>☒ Constrained Conventional – 60 feet (1:5 taper) | | Taper Length<br>**60** feet |
| Full Turn Lane Length (before adjustments) | Take the Turn Lane Demand minus Taper Length<br>**1,040 – 60 =** | | Full Width Turn Lane Length (no adjustments)<br>**980** feet |
| **ADJUSTMENTS AND FINAL TURN LANE DESIGN** | | | |
| Adjust Taper<br>*Page B-21* | If the intersection is located on a horizontal curve, use a 1:8 taper (100 feet) | | Adjusted Taper Length<br>**60** feet |
| Adjust Full turn Lane Length | If grade is greater than 3% adjust based on *Table B-9* (multiply the Deceleration Distance by adjustment in table and document the difference in deceleration to the right. *Page B-19* | [✓ +] / - **43** ft | Full Width Turn Lane Length (with adjustments)<br>**663** feet |
| | If heavy commercial is greater than averages shown in *Table B-10*, increase Deceleration Distance by 30% and document the difference in length to the right. *Page B-20* | + **0** ft | |
| | Are there more than 300 vehicles per hour? May consider *dual lefts*. The storage length required would be half of the calculated Storage Distance. Document the difference in distance to the right. *Page B-22* | [✓ -] **413** ft | |
| | Are there *constraints* with the adjacent intersections or driveways? Does the *through lane queue* extend further than the turn lane length? Document a review of the potential impact to the desired turn lane length and adjust accordingly. *Page B-23 & B-24* | + / - **0** ft | |
| | *Total Adjustments* | + / [✓ -] **317** ft | |



| Facility Type | Taper | Length |
|---|---|---|
| Unconstrained Conventional/Expressway | 1:15 | 180 feet |
| Constrained Expressway Roadway | 1:8 | 100 feet |
| Constrained Conventional Roadway | 1:5 | 60 feet |

**Table B-8**
Taper Lengths

*3% downgrade, so the deceleration length determined in Step 3 (215') is lengthened by 43 feet based on 20% increase shown in Table B-9*

**Table B-9**
*Grade Adjustment*

| Grade | Upgrade Adjustment | Downgrade Adjustment |
|---|---|---|
| 3% to 4% | 0.9 | 1.2 |
| 5% to 6% | 0.8 | 1.35 |

*There are 400 turning vehicles in the peak hour, a dual left turn lane would cut the required storage need by ½ (825 feet of storage/2 = 413)*

**980** (full width from Step 4)
**+ 43** (grade adjustment)
**- 413** (single turn lane to a dual turn lane)
**= 663**

The recommended design of this turn lane would be **60 feet taper** and **660 feet** (rounding to the nearest 10 foot) **of full width turn lane**.

Mn/DOT Research Services Section
MS 330, 395 John Ireland Blvd
St. Paul, MN 55155

CH2MHILL