Design of Turn Lane Guidelines

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July 2010
Final Report #2010-25
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.
Acknowledgements

Thanks to the following TAP members for their input to this document:

- Glen Ellis
- Jim Rosenow
- Mohammad Dehdashti
- David Engstrom
- Terry Humbert
- Adam Pohlman
- Gayle Gedstad
- Brian Gage
- Lars Impola
- Zachary Tess

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The contents of this document reflect the views of the authors who are responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the policies of the Minnesota Department of Transportation at the time of publication. This document does not constitute a standard or specification and is neither intended to be, nor does it establish, a legal standard of care for users. This document is intended to be a resource to aid designers and to provide greater consistency between the length of turn lanes and traffic characteristics.
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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

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

Figure A-1 – Mn/DOT Facilities
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)

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

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#### Taper Table
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#### Grade Adjustment Table
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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.

Source: AASHTO Green Book – Geometric Design of Highways and Streets, 2004
Part B - Process

- Step 1 - Collect Data
- Step 2 - Determine Facility Type
- Step 3 - Calculate Turn Lane Demand
- Step 4 - Calculate Turn Lane Design
- Step 5 - Determine Turn Lane Length

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).

Source: Missouri Department of Transportation
# 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

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.
Forecast Traffic Volumes

Forecast traffic volumes were estimated using the following sources:
1. Historic Traffic Growth – Linear Regression (MnDOT)
2. State Highway Manual (County growth rate)
3. US Highway 52: Orono to Pine Island Sub-Area Study

In no case should existing volumes be used in computing the estimated future demand.

Example of Different Forecast Methods

- 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_csa.html

In no case should existing volumes be used in computing the estimated future demand.
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**

- **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**

- **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.
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](http://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.
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)*.

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

*Source: CH2M HILL*
Turn Lane Length Process

**Step 1** Collect Data

**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.

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

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

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

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

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Stop Condition (feet)</th>
<th>To 15 mph (feet)</th>
<th>Stop Condition (feet)</th>
<th>To 15 mph (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>70</td>
<td>35</td>
<td>20</td>
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<td>180</td>
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<tr>
<td>50</td>
<td>425</td>
<td>390</td>
<td>275</td>
<td>240</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Stop Condition (feet)</th>
<th>To 15 mph (feet)</th>
<th>Stop Condition (feet)</th>
<th>To 15 mph (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>350</td>
<td>315</td>
<td>215</td>
<td>180</td>
</tr>
<tr>
<td>50</td>
<td>425</td>
<td>390</td>
<td>275</td>
<td>240</td>
</tr>
<tr>
<td>55</td>
<td>515</td>
<td>480</td>
<td>350</td>
<td>315</td>
</tr>
<tr>
<td>60</td>
<td>605</td>
<td>570</td>
<td>425</td>
<td>390</td>
</tr>
<tr>
<td>65</td>
<td>715</td>
<td>680</td>
<td>515</td>
<td>480</td>
</tr>
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<td>70</td>
<td>820</td>
<td>785</td>
<td>605</td>
<td>570</td>
</tr>
<tr>
<td>75</td>
<td>940</td>
<td>905</td>
<td>715</td>
<td>680</td>
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</table>
Storage Length – Unsignalized Intersection

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 = \[(\text{Turn Lane Peak Hour Volume} / 60)^2\] \* \((\% \text{ Passenger Vehicles} \times 25 \text{ feet}) + (\% \text{ HC} \times 75 \text{ feet}))\)

Table B-3

<table>
<thead>
<tr>
<th>Left-Turning Volume</th>
<th>0 – 5% Heavy Commercial</th>
<th>&gt;5 – 10% Heavy Commercial</th>
<th>&gt;10 – 15% Heavy Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>50</td>
<td>50</td>
<td>60</td>
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<td>200</td>
<td>185</td>
<td>200</td>
<td>225</td>
</tr>
</tbody>
</table>
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.

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 **ALL** vehicles in that arrival on red clear the intersection on the following green phase.

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

\text{DHV} = \text{Design Hourly Volume for turn lane}

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)
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>
<thead>
<tr>
<th>Table B-4 – 60 Second Signal Cycle Length</th>
<th>Table B-5 – 90 Second Signal Cycle Length</th>
<th>Table B-6 – 120 Second Signal Cycle Length</th>
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</thead>
<tbody>
<tr>
<td>Storage Length in Feet (60 second cycle)</td>
<td>Storage Length in Feet (90 second cycle)</td>
<td>Storage Length in Feet (120 second cycle)</td>
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<tr>
<td>Percent Left-Turn Green Time</td>
<td>Percent Left-Turn Green Time</td>
<td>Percent Left-Turn Green Time</td>
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<td>375 300 270 220 200 170 140 100 70</td>
<td>375 450 400 350 300 250 200 150 100</td>
<td>375 600 530 460 400 330 270 200 140</td>
</tr>
<tr>
<td>400 320 290 260 210 180 140 110 70</td>
<td>400 480 420 370 320 270 210 160 110</td>
<td>400 630 560 490 420 350 290 210 140</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Sum of Critical Volume</th>
<th>2 Phase Signal</th>
<th>5 Phase Signal</th>
<th>8 Phase Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>45</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>800</td>
<td>60</td>
<td>75</td>
<td>105</td>
</tr>
<tr>
<td>900</td>
<td>60</td>
<td>75</td>
<td>105</td>
</tr>
<tr>
<td>1000</td>
<td>75</td>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>1100</td>
<td>75</td>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>1200</td>
<td>90</td>
<td>105</td>
<td>120</td>
</tr>
<tr>
<td>1300</td>
<td>105</td>
<td>120</td>
<td>135</td>
</tr>
<tr>
<td>1400</td>
<td>120</td>
<td>135</td>
<td>150</td>
</tr>
<tr>
<td>1500</td>
<td>135</td>
<td>150</td>
<td>165</td>
</tr>
<tr>
<td>1600</td>
<td>150</td>
<td>165</td>
<td>180</td>
</tr>
<tr>
<td>1700</td>
<td>165</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>1800</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
</tbody>
</table>

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

**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.

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

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

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Taper</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconstrained Conventional/Expressway</td>
<td>1:15</td>
<td>180 feet</td>
</tr>
<tr>
<td>Constrained Expressway Roadway</td>
<td>1:8</td>
<td>100 feet</td>
</tr>
<tr>
<td>Constrained Conventional Roadway</td>
<td>1:5</td>
<td>60 feet</td>
</tr>
</tbody>
</table>

Table B-8
Taper Lengths

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)

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

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

<table>
<thead>
<tr>
<th>Grade</th>
<th>Upgrade Adjustment</th>
<th>Downgrade Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>3% to 4%</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>5% to 6%</td>
<td>0.8</td>
<td>1.35</td>
</tr>
</tbody>
</table>

---

**Example of Intersection On a Grade**
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)

---

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

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Sample Size</th>
<th>Average % Heavy Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Conventional</td>
<td>11</td>
<td>14%</td>
</tr>
<tr>
<td>Rural Expressway</td>
<td>7</td>
<td>9%</td>
</tr>
<tr>
<td>Urban Conventional</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Urban Expressway</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

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 Intersection Located on a Horizontal Curve

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
  -80 feet + 80 feet
  100 feet + 470 feet = 570 feet
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).
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.
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.
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 driver’s 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

<table>
<thead>
<tr>
<th><strong>Location</strong></th>
<th>State Roadway: ___________________________ Intersection: ___________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Left Turn Lane Design for Approach: N / S / E / W</td>
</tr>
<tr>
<td></td>
<td>□ Right Turn Lane Design for Approach: N / S / E / W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Vehicle Speed</strong></th>
<th>Choose one. Shown in order of preference.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Design Speed: _______ mph</td>
</tr>
<tr>
<td></td>
<td>□ 85th Percentile Speed: _______ mph</td>
</tr>
<tr>
<td></td>
<td>□ Statewide Average Speed: _______ mph</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Forecast Traffic Volumes</strong></th>
<th>Choose one. Shown in order of preference.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Design Year Volumes (provided by District/Central Office Planning Staff)</td>
</tr>
<tr>
<td></td>
<td>□ Historic Volumes (existing volumes extrapolated to estimate 20 year forecast volumes)</td>
</tr>
<tr>
<td></td>
<td>□ 20-Year Multiplier (documented by State Aid and found at the following website under County Reference Data: <a href="http://www.dot.state.mn.us/stateaid/sa_csah.html">http://www.dot.state.mn.us/stateaid/sa_csah.html</a>)</td>
</tr>
</tbody>
</table>

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

**Daily Volumes**

- Major Street Daily Traffic Volumes: ____________ vehicles per day
- Minor Street Daily Traffic Volumes: ____________ vehicles per day

<table>
<thead>
<tr>
<th><strong>Heavy Commercial</strong></th>
<th>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)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Grade</strong></th>
<th>Grade of approach: _______% (If greater than 3%, apply deceleration adjustment in Step 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Upgrade □ Downgrade</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Seasonal Variations</strong></th>
<th>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?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Yes, adjust traffic volumes □ No</td>
</tr>
<tr>
<td></td>
<td>□ Yes, on horizontal curve □ No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Roadway Geometry and Corridor Characteristics</strong></th>
<th>Is the intersection located on a horizontal curve? If yes, adjust taper in Step 4. (See Page B-17 and Table B-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Yes, on horizontal curve □ No</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th><strong>Determine Facility Type</strong></th>
<th>Rural vs. Urban (based on Access Management Category Assignments: <a href="http://www.dot.state.mn.us/accessmanagement/index_categoryassignments.html">www.dot.state.mn.us/accessmanagement/index_categoryassignments.html</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>□ Urban □ Rural</td>
</tr>
</tbody>
</table>

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

- □ Expressway □ Conventional

<table>
<thead>
<tr>
<th><strong>Intersection Control</strong></th>
<th>□ Signalized: _______ sec cycle length □ Unsignalized □ Future Signal? (see Figure B-3)</th>
</tr>
</thead>
</table>

**Development of Turn Lane Design Guidelines**
# 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**

\[
\text{Deceleration Distance} = \boxed{\text{feet}}
\]

### 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 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**

\[
\text{Storage Distance} = \boxed{\text{feet}}
\]

### Turn Lane Demand

Add the Deceleration Distance and the Storage Distance

**Turn Lane Demand**

\[
\text{Turn Lane Demand} = \boxed{\text{feet}}
\]

## 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**

\[
\text{Taper Length} = \boxed{\text{feet}}
\]

### Full Turn Lane Length (before adjustments)

Take the Turn Lane Demand minus Taper Length

**Full Turn Lane Length (no adjustments)**

\[
\text{Full Turn Lane Length} = \boxed{\text{feet}}
\]

## 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**

\[
\text{Adjusted Taper Length} = \boxed{\text{feet}}
\]

### 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

**Full Width Turn Lane Length (with adjustments)**

\[
\text{Full Width Turn Lane Length} = \boxed{\text{feet}}
\]

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

\[
\text{Deceleration Distance} = \boxed{\text{feet}}
\]

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

\[
\text{Storage Distance} = \boxed{\text{feet}}
\]

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

\[
\text{Full Turn Lane Length} = \boxed{\text{feet}}
\]

**Total Adjustments**

\[
\text{Total Adjustments} = \boxed{\text{feet}}
\]
Examples

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

Table C-1
Turn Lane Calculation Examples

<table>
<thead>
<tr>
<th>Roadway Location</th>
<th>Roadway Type</th>
<th>Intersection Type</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rural</td>
<td>Urban</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expressway</td>
<td>Conventional</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unsignalized</td>
<td>Signalized</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade</td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Horizontal</td>
<td>Left</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corridor</td>
<td>Consistency</td>
<td></td>
</tr>
</tbody>
</table>

- Example 1: x x x x x x x
- Example 2: x x x x
- Example 3: 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
- Example 8: x x x x x x
Example 1 – Rural Expressway Unsignalized (1 of 2)

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

120 turning vehicles with 5% heavy commercial
Example 1 – Rural Expressway Unsignalized (2 of 2)

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

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

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>(No deceleration in through lane)</th>
<th>(10 mph deceleration in through lane)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stop Condition</td>
<td>To 15 mph (feet)</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td>45</td>
<td>350</td>
<td>315</td>
</tr>
<tr>
<td>50</td>
<td>425</td>
<td>390</td>
</tr>
<tr>
<td>55</td>
<td>515</td>
<td>480</td>
</tr>
<tr>
<td>60</td>
<td>605</td>
<td>570</td>
</tr>
<tr>
<td>65</td>
<td>716</td>
<td>680</td>
</tr>
<tr>
<td>70</td>
<td>930</td>
<td>785</td>
</tr>
<tr>
<td>75</td>
<td>940</td>
<td>905</td>
</tr>
</tbody>
</table>

Synchro Output

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

TURN LANE DESIGN CHECKLIST

<table>
<thead>
<tr>
<th>Location</th>
<th>State Roadway: TH 99</th>
<th>Intersection: CR 15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Step 1: Data Gathering
  - Vehicle Speed
    - Design Speed: 85th Percentile: 73 mph
  - Statewide Average Speed: 50,000 vehicles per day
- Forecast Traffic Volumes
  - Design Year Volumes (provided by District Central Office Planning Staff)
- Heavy Commercial
  - Percent Heavy Vehicle: 7% (percentage of heavy commercial is high special consideration should be taken in Step 4 for deceleration and storage length of turn lane)
- Grade
  - Grade of approach: 0%
- Readway Geometry and Control Characteristics
  - Is the intersection located on horizontal curve? Yes, on horizontal curve: X No
  - Are there adjacent intersections that may influence the turn lane design? Yes, constriction location: X No

- Step 2: Determine Facility Type
  - Rural vs. Urban (based on Access Management Category Assignments)
  - Expressway vs. Conventional (determined by Mn/DOT Office of Traffic, Safety and Technology)

- Intersection Center
  - Signaled: 75 sec cycle length

- Step 3: Calculate Turn Lane Demand
  - Deceleration Length
  - Storage Length

- Deceleration Distance
  - 940 feet

- Storage Distance
  - 71 feet

- Turn Lane Demand
  - 1,011 feet
Example 2 – Rural Expressway Signalized (2 of 2)

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)

**Location**
- **State Roadway:** US 1
- **Intersection:** CR 2

**Vehicle Speed**
- **Design Speed:** __________ mph
- **85th Percentile Speed:** __________
- **Statewide Average Speed:** __________ mph (page B-2, Figure B-1)

**Forecast Traffic Volumes**
- **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:

![Traffic Volume Diagram](image)

**Heavy Commercial**
- **Percent Heavy Vehicles:** __________ % (if percentage of heavy commercial is high spatial consideration should be taken in Step 2 for deceleration and storage length of turn lane)

**Roadway Geometry and Corridor Characteristics**
- **Yes:** on horizontal curve  
- **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 intersection conditions. (See Page B-20 and B-24)

**Step 2 – Calculate Turn Lane Demand**
- **Design Speed (mph):**
  - [Table B-2](#)
- **Stop Condition:**
  - [Table B-2](#)
- **To 15 mph:**
  - [Table B-2](#)
- **10 mph Deceleration:**
  - [Table B-2](#)
  - [Table B-2](#)

**Interaction Control**
- **Signaled:** __________
- **Cycle Length:** __________
- **Unsignalized:**
- **Future Signal? (see Figure B-2):**

---

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

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Stop Condition (ft)</th>
<th>To 15 mph (ft)</th>
<th>10 mph Deceleration (ft)</th>
<th>To 15 mph (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>350</td>
<td>315</td>
<td>215</td>
<td>190</td>
</tr>
<tr>
<td>50</td>
<td>425</td>
<td>390</td>
<td>275</td>
<td>240</td>
</tr>
<tr>
<td>55</td>
<td>515</td>
<td>480</td>
<td>350</td>
<td>315</td>
</tr>
<tr>
<td>60</td>
<td>605</td>
<td>570</td>
<td>425</td>
<td>390</td>
</tr>
<tr>
<td>65</td>
<td>715</td>
<td>680</td>
<td>515</td>
<td>480</td>
</tr>
<tr>
<td>70</td>
<td>820</td>
<td>765</td>
<td>605</td>
<td>570</td>
</tr>
</tbody>
</table>

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

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

E/W:
- 60 +780 = 840
- 100 +280 = 380

N/S:
- 90 +90 = 180
- 100 +100 = 200

Sum of Critical Movements = 1,040

Cycle Length = 90 sec (Table B-7)

% Left Turn Green Time = \( \frac{100 \text{ left turns}}{1,040 \text{ sum of critical movements}} \) = 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.
- Separate turn lanes accommodate their respective turning movements.
- Right turns are equivalent to through movements if a separate turn lane is not provided.
- If separate left turn lanes are not used, lane distribution is attained through the use of through vehicle equivalents.
- 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)

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)

Average Facility speed of 67 mph, No Deceleration in Through Lane on Rural Conventional, and Stop condition for Left Turn Lanes.
Example 5 – Urban Expressway Unsignalized (2 of 2)

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**.

---

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

**STEP 1. CALCULATE TURN LANE DESIGN**

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Taper</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconstrained Conventional/Expressway</td>
<td>1.15</td>
<td>180 feet</td>
</tr>
<tr>
<td>Constrained Expressway Roadway</td>
<td>1.8</td>
<td>100 feet</td>
</tr>
<tr>
<td>Constrained Conventional Roadway</td>
<td>1.5</td>
<td>60 feet</td>
</tr>
</tbody>
</table>

**Table B-8**

**Taper Lengths**

<table>
<thead>
<tr>
<th>Adjust Taper</th>
<th>Adjusted Taper Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>865 (full width from Step 4) + 246 (total adjustments) = 1,111</td>
<td></td>
</tr>
</tbody>
</table>

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

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

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

\[
\text{Storage Length} = \left(1 - \frac{G}{C}\right) \left(\text{DHVs} \times 25 \times 2\right) / \text{cycles/hr}
\]

\[
= (1 - 20/180) \times 200 \times 25 \times 2 / 20 = 445 \text{ feet}
\]

Part C - Examples
**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
  - **1,110**

- **N/S:**
  - 80
  - +480
  - 560
  - or 60
  - +710
  - **770**

**Sum of Critical Movements = 1,880**

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

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

---

**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.
- Separate turn lanes accommodate their respective turning movements.
- Right turns are equivalent to through movements if a separate turn lane is not provided.
- If separate left turn lanes are not used, lane distribution is attained through the use of through vehicle equivalents.
- 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)

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**.

Queue Through = \((1 - \frac{G}{C}) \times (DHV) \times 25 \times 2 / \text{cycles/hr}\)

\[ = (1 - \frac{50}{180}) \times 970 \times 25 \times 2 / 20 = 1,212 \text{ feet} \]
Example 7 – Urban Conventional Unsignalized (1 of 2)

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

**Storage Defaults to the minimum of 50 feet**
Example 7 – Urban Conventional Unsignalized (2 of 2)

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)

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

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>(Not) Deceleration in Through Lane</th>
<th>(Not) Deceleration in Through Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>110</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>160</td>
<td>70</td>
</tr>
<tr>
<td>35</td>
<td>215</td>
<td>110</td>
</tr>
<tr>
<td>40</td>
<td>275</td>
<td>180</td>
</tr>
<tr>
<td>45</td>
<td>350</td>
<td>215</td>
</tr>
<tr>
<td>50</td>
<td>425</td>
<td>275</td>
</tr>
</tbody>
</table>

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