Auxiliary Turn Lanes

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INTRODUCTION

- SPR Project: Criteria for the Design and Justification of Auxiliary Turn lanes

- Purpose
  - Provide consistent and clear left and right turn-lane warrants
  - Develop standards for their design
  - Alternative turn lane designs (“blister” or “bump-out”)
  - Positive offset of left-turn lanes
  - Warrants and standards for two-way left-turn lanes (TWLTL)
Background

*Left Turn Lane Warrants*

- KYTC Design Policy
  - Median openings on divided roadways
  - All non-stopping approaches of rural arterials and collectors
  - All other approaches where required on the basis of capacity, safety, and operational analysis
Background

Left Turn Lane Warrants

- KYTC Permit Policy
  - Median openings on divided roadways
  - All other approaches based on highway Research Record 211
Background

*Turn Lane Length*

- KYTC Design Policy
  - Storage Length: 1.5 to 2 times average number of arrivals per cycle
  - Deceleration Length: Common practice is to accept a moderate amount of deceleration within the through lanes...
Agenda

- Turn Lane Design
  - Approach Taper
  - Turn Lane Length
- Alternative Designs
- Positive Offset of Left-Turn Lanes
- Two-Way Left-Turn Lanes
LEFT-TURN LANE WARRANTS

- Signalized Intersections
  - All arterials and collectors must have left-turn lanes
  - All other roadways; left-turn lanes only when required by capacity analysis
LEFT-TURN LANE WARRANTS

- Stop Controlled Approaches
  - Left-turn lanes shall be provided at median openings on divided roadways
  - Left-turn lanes only when required by capacity analysis
  - Left-turn lanes should be considered as a safety countermeasure, e.g. where sight distance of approaching traffic is limited.
LEFT-TURN LANE WARRANTS

- Uncontrolled Approaches
  - Left-turn lanes shall be provided at median openings on divided roadways
  - Left-turn lanes shall be provided if traffic volumes at the intersection meet the thresholds identified in Figures 1 and 2.
  - Left-turn lanes should be considered as a safety countermeasure, e.g. where sight distance of approaching traffic is limited.
LEFT-TURN LANE WARRANTS

- 2 Graphs
  - measure probability of stopped vehicle blocking lane
  - $\leq 45$ MPH ($P = 0.02$)
  - $>45$ MPH ($P = 0.01$)
LEFT-TURN LANE WARRANTS

- **Inputs**
  - $L = \text{Percent Left-Turns}$
  - Advancing Volume = Through + Left + Right-Turn Traffic
  - Opposing Volume = Through + Left + Right-Turn Opposing Traffic
LEFT-TURN LANE WARRANTS

$L = \text{Percent Left-Turns} = \frac{32}{32+372+40} = 0.07$

Advancing Traffic
$= 32 + 372 + 40 = 444$

Opposing Traffic
$= 40 + 500 + 71 = 611$
LEFT-TURN LANE WARRANTS

The diagram illustrates the relationship between advancing volume and opposing volume for determining the need for a left turn lane. The graph includes various lines indicating different levels of left-turn volume (L) as a percentage. The area shaded in dark gray represents scenarios where a left turn lane is not required, while the area in light gray indicates where a left turn lane is required. The point (444,611) is marked, indicating a specific volume pair that requires a left turn lane.
LEFT-TURN LANE WARRANTS

Heavy Vehicles = 6%

L = Percent Left-Turns

\[ L = \frac{32 (32+372+40)}{32+372+40} = 0.07 \]

Advancing Traffic

\[ = 32 + 372 + 40 = 444 \]

\[ = 455 \]

Opposing Traffic

\[ = 40 + 500 + 71 = 611 \]
LEFT-TURN LANE WARRANTS

- Heavy Vehicle Adjustment Factor
  \[ v'_A = v_A [1 + P_{HV}(E_{HV})] \]
  - \( v'_A \) = Adjusted advancing traffic volume
  - \( v_A \) = Unadjusted advancing traffic volume
  - \( P_{HV} \) = Percent heavy vehicles
  - \( E_{HV} \) = Passenger car equivalency factor
    - \( = 0.00035 \ (v_O) \) (two-lane facilities)
    - \( = 0.0007 \ (v_O) \) (four and six-lane facilities)
  - \( v_O \) = Opposing traffic volume
LEFT-TURN LANE WARRANTS

- Heavy Vehicle Adjustment Factor
  - \( v_A = \) Unadjusted advancing traffic volume = 444 vph
  - \( P_{HV} = \) Percent Heavy Vehicles = 0.06
  - \( v_O = \) opposing traffic volume = 611 vph
  - \( E_{HV} = \) Passenger Car Equivalency Factor
    - \( = 0.0007 \cdot v_O \) (four and six-lane facilities)
    - \( = 0.0007 \cdot 611 = 0.428 \)

- Solving for \( v_A' \):
  - \( v_A' = v_A \cdot [1 + P_{HV} \cdot E_{HV}] \)
  - \( v_A' = 444 \cdot [1 + 0.06 \cdot 0.428] \)
  - \( v_A' = 455 \) vph
LEFT-TURN LANE DESIGN

- Departure Taper ($L_D$)
- Approach Taper ($L_A$)
- Bay Taper
- Deceleration Length
- Storage Length
- TURN LANE LENGTH
- $W_D$
- $W_A$
LEFT-TURN LANE DESIGN

- 3 primary components
  - Approach Taper
  - Bay Taper
  - Turn Lane Length
    - Deceleration Length
    - Storage Length
LEFT-TURN LANE DESIGN

- Approach Taper

  - $\geq 45$ MPH $L = W \times S$
  - $< 45$ MPH, $L = \frac{WS^2}{60}$

- Where:
  
  $L = \text{Taper length in feet}$
  
  $W = \text{Width of roadway offset for taper in feet}$
  
  $S = \text{Speed in miles per hour (MPH)}$
LEFT-TURN LANE DESIGN

- Bay Taper
  - $\geq 45 \text{ MPH} \ L = 100 \ \text{ft}$
  - $< 45 \text{ MPH}, \ L = 50 \ \text{ft}$
LEFT-TURN LANE DESIGN

- Turn Lane Length
  - Deceleration Length
  - Storage Length
# LEFT-TURN LANE DESIGN

- Turn Lane Length

## Table 1: Auxiliary Turn Lane Length by Turn Type and Intersection Control

<table>
<thead>
<tr>
<th>Approach Control</th>
<th>Turn Type</th>
<th>Turn Lane Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled</td>
<td>Left-Turn</td>
<td>Greater of Method 1(^A) or Method 2(^A)</td>
</tr>
<tr>
<td>Stop Controlled</td>
<td>Left-Turn</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>Signal Control(^B)</td>
<td>Left-Turn</td>
<td>Greater of Method 1 or Method 2</td>
</tr>
</tbody>
</table>

**Notes:**

A. See Table 2 below.

B. At signalized intersections the length of turn lanes should be extended so that it is not blocked by the queue of adjacent through traffic.
LEFT-TURN LANE DESIGN

- Turn Lane Length

<table>
<thead>
<tr>
<th>Speed (MPH)</th>
<th>Method 1: Deceleration Only</th>
<th>Method 2: Moderate Deceleration + Storage</th>
<th>Method 3: Full Deceleration + Storage (Rural Arterial ≥45 mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>125 ft</td>
<td>Storage + Bay + Taper</td>
<td>N/A</td>
</tr>
<tr>
<td>25</td>
<td>125 ft</td>
<td>Storage + Bay + Taper</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>125 ft</td>
<td>Storage + Bay + Taper</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>125 ft</td>
<td>Storage + Bay + Taper</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>170 ft</td>
<td>70 ft + Storage</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>220 ft</td>
<td>115 ft + Storage</td>
<td>340 ft + Storage</td>
</tr>
<tr>
<td>50</td>
<td>275 ft</td>
<td>170 ft + Storage</td>
<td>410 ft + Storage</td>
</tr>
<tr>
<td>55</td>
<td>340 ft</td>
<td>220 ft + Storage</td>
<td>485 ft + Storage</td>
</tr>
<tr>
<td>60</td>
<td>410 ft</td>
<td>275 ft + Storage</td>
<td>565 ft + Storage</td>
</tr>
<tr>
<td>65</td>
<td>485 ft</td>
<td>340 ft + Storage</td>
<td>645 ft + Storage</td>
</tr>
</tbody>
</table>

B: At signalized intersections the length of turn lanes should be extended so that it is not blocked by the queue of adjacent through traffic.
LEFT-TURN LANE DESIGN

- Storage Length (Signal and Stop Control)
  - Stop Control Cycle Length = 60 (sec)
  - 2 x Average Arrival per Cycle
LEFT-TURN LANE DESIGN

- Storage Length (Uncontrolled Approach)
  - 2 Graphs (≤ 45 mph; > 45mph)
LEFT-TURN LANE DESIGN

- Storage Length (Uncontrolled Approach)
  - 75 ft
RIGHT-TURN LANE WARRANTS

- Signalized Intersection:
  - Right-turn lanes shall be provided if traffic volumes at the intersection meet the thresholds identified in Figure 3.
  - May also be considered to reduce the frequency of rear end crashes at intersections with a high volume of right-turns.

- Stop Controlled Approaches:
  - Right-turn lanes only when required by capacity analysis
RIGHT-TURN LANE WARRANTS

- Uncontrolled Approaches
  - Right-turn lanes shall be provided if traffic volumes at the intersection meet the thresholds identified in Figure 3.
  - Right-turn lanes should be considered as a safety countermeasure, e.g. where sight distance of approaching traffic is limited.
RIGHT-TURN LANE WARRANTS

1 Graph measures probability of turning vehicle blocking lane

- \( \leq 45 \text{ MPH} \) (\( P = 0.02 \))
- \( > 45 \text{ MPH} \) (\( P = 0.01 \))
RIGHT-TURN LANE WARRANTS

- Inputs
  - Percent Right-Turns
  - Advancing Volume = Through + Left + Right-Turn Traffic

NO HEAVY VEHICLE ADJUSTMENT FACTOR
RIGHT-TURN LANE WARRANTS

Advancing Traffic = 40 + 500 + 71 = 611

Percent Right Turns = 40 / 611 = 0.07
RIGHT-TURN LANE WARRANTS

- Right-turn lane warranted when:
  - Advancing traffic < 45 mph
  - Percent right turns ≥ 0.07

- Right-turn lane not warranted when:
  - Advancing traffic > 45 mph

Graph showing the relationship between percent right turns and advancing traffic for determining right-turn lane warrants.
RIGHT-TURN LANE DESIGN

- Bay Taper
- Deceleration Length
- Storage Length
- TURN LANE LENGTH
RIGHT-TURN LANE DESIGN

- 2 primary components
  - Bay Taper
  - Turn Lane Length
    - Deceleration Length
    - Storage Length
RIGHT-TURN LANE DESIGN

- Bay Taper
  - ≥ 45 MPH L = 100 ft
  - < 45 MPH, L = 50 ft
RIGHT-TURN LANE DESIGN

- Turn Lane Length
  - Deceleration Length
  - Storage Length
# RIGHT-TURN LANE DESIGN

## Turn Lane Length

### Table 1: Auxiliary Turn Lane Length by Turn Type and Intersection Control

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<tbody>
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<td>Method 1&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Stop Controlled</td>
<td>Right-Turn</td>
<td>Storage + Bay taper</td>
</tr>
<tr>
<td>Signal Control&lt;sup&gt;B&lt;/sup&gt;</td>
<td>Right-Turn</td>
<td>Greater of Method 1&lt;sup&gt;A&lt;/sup&gt; or Method 2&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes:  
A: See Table 2 below.  
B: At signalized intersections the length of turn lanes should be extended so that it is not blocked by the queue of adjacent through traffic.

### Table 2: Turn Lane Length by Speed

<table>
<thead>
<tr>
<th>Speed (MPH)</th>
<th>Method 1: Deceleration Only</th>
<th>Method 2: Moderate Deceleration + Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>100 ft</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>25</td>
<td>100 ft</td>
<td>Storage + Bay Taper</td>
</tr>
<tr>
<td>30</td>
<td>100 ft</td>
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</tr>
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</tr>
</tbody>
</table>
RIGHT-TURN LANE DESIGN

- Storage Length (Signal and Stop Control)
  - Stop Control Cycle Length = 60 (sec)
  - 2 x Average Arrival per Cycle
ALTERNATIVE DESIGNS

Guidance for Reduction of the turn lane length is recommended only when site constraints make it impractical to provide a full length turn lane. Reduced turn lane length should not be used for the sole purpose of reducing construction costs.
POSITIVE OFFSET

<table>
<thead>
<tr>
<th>Design Speed (MPH)</th>
<th>Intersection Sight Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passenger Car ($t_n = 5.5$)</td>
</tr>
<tr>
<td>25</td>
<td>205</td>
</tr>
<tr>
<td>35</td>
<td>285</td>
</tr>
<tr>
<td>45</td>
<td>365</td>
</tr>
<tr>
<td>55</td>
<td>445</td>
</tr>
<tr>
<td>65</td>
<td>525</td>
</tr>
<tr>
<td>75</td>
<td>605</td>
</tr>
</tbody>
</table>
TWO-WAY LEFT-TURN LANE

- Used to mitigate delay to through traffic resulting from the cumulative impact of consecutive access points
TWO-WAY LEFT-TURN LANE

- Operating speeds \( \leq 45 \text{ MPH} \)
- ADT \( \leq 17,000 \) (Two-Lane)
  
  ADT \( \leq 24,000 \) (Multi-Lane)
- Access \( \geq 10 \) access points per mile.
- Minimum TWLTL Length 425 foot typical section
- Maximum Access Density \( \leq 85 \) access points per mile.
QUESTIONS

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