Guidelines on the Use of Auxiliary Through Lanes (ATL) at Signalized Intersections

NCHRP Report 707

Transportation Research Board Webinar

July 11, 2012
NCHRP 3-98 Panel Members

- Michael M. Christensen (Chair)
- James H. Dunlop, North Carolina DOT
- Rashad M. Hanbali, City of Cape Coral, Florida
- Thomas Hicks, Maryland State Highway Administration
- Brent A. Sweger, Kentucky Transportation Cabinet
- Michael L. Swires, Washington State DOT
- Zhongren Wang, California DOT
- Deborah Curtis, FHWA Liaison
- Richard A. Cunard, TRB Liaison
Research Team Members

Kittelson & Associates, Inc.
- Brandon Nevers (co-Principal Investigator)
- Hermanus Steyn
- Yuri Mereszczak
- Zachary Clark

North Carolina State University
- Nagui Rouphail (co-Principal Investigator)
- Joe Hummer
- Bastian Schroeder
- Zachary Bugg

Texas Transportation Institute
- Jim Bonneson

Write Rhetoric
- Danica Rhodes

Quality Counts
- Carlos Stevenson
Research Objective

➢ To provide guidelines and procedures to analyze, justify, and design auxiliary through lanes (ATL) at signalized intersections. The results will assist transportation professionals in the effective and safe implementation of intersection auxiliary through lanes.

See Exhibit 1-1, page 1
Chapters 1: Introduction

Brandon Nevers, PE, PTOE
## Terminology

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td>ATL</td>
<td>Auxiliary Through Lane</td>
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<tr>
<td>Shared ATL</td>
<td>An ATL that accommodates through and right-turn movements</td>
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<tr>
<td>Exclusive ATL</td>
<td>An ATL that accommodates through movements only (no right-turns)</td>
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<td>CTL</td>
<td>Continuous Through Lane (at least ½ mile upstream and downstream)</td>
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<td>Prevailing Speed</td>
<td>Speed at which majority of drivers feel comfortable driving when unimpeded</td>
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<td>$\chi_T$</td>
<td>The demand-to-capacity ratio for the through movement without an ATL</td>
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See Exhibit 1-1, page 1
Common ATL Configurations – One CTL

One CTL with Shared ATL

Exclusive Right-Turn

One CTL, One ATL, and Exclusive Right-Turn

See Exhibit 2-1, page 9
Common ATL Configurations – Two CTL

Two CTLs with Shared ATL

Two CTLs, One ATL, and Exclusive Right-Turn

See Exhibit 2-1, page 9
Typical ATL Application:
- Intermediate-cost treatment to reduce delay and queuing at signalized intersections
- Applied to either major-street or minor-street approaches
- Implemented as either an interim improvement or alternative to full-lane widening

Effect:
- Increases stop-bar capacity for the approach by allowing through traffic to disperse across one additional lane
- Lower-cost compared to adding a continuous through lane
Scope of the Guidelines

- Through movements that begin upstream of a signalized intersection and end downstream of the intersection
- Right-hand “add” and merge lanes
- Provides tools and guidance to answer following questions:
  - What factors affect the use of ATLs?
  - How much traffic is likely to use an ATL?
  - What is the safety performance of ATLs?
  - What tools are available to evaluate operational and safety performance of ATLs?
  - What minimum length is needed for the upstream and downstream components of the ATL?
  - What signs and pavement markings should be applied on ATLs?
  - How can simulation be used to supplement a deterministic analysis of ATLs?
Limitations of the Guidelines

The ATL guidelines do not address the following conditions:

- Non-signalized intersections
- Intersections that serve as transitions from either four-lane to two-lane roadways or six-lane to four-lane roadways
- Left- or right-turn lanes with an upstream addition and downstream drop
- Approaches that have more than two CTLs
- Approaches that include shared left–through lanes or downstream facilities where queues extend into the ATL
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Contents</th>
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</table>
| **Chapter 2**<br>ATL Characteristics | • Description of operational, safety, and design characteristics of ATLs  
• Multi-modal user needs |
| **Chapter 3**<br>Operational Analysis | • Empirical observations of ATL use  
• Statistical models for predicting the volume of traffic in an ATL |
| **Chapter 4**<br>Safety | • Evaluation of field crash data  
• Discussion of geometric and operational factors that affect the safety performance of an ATL |
| **Chapter 5**<br>Design | • Approach for preparing a functional design plan for an ATL  
• Method for determining the minimum upstream and downstream ATL length  
• Guidance on signing and pavement markings for ATLs |
| **Chapter 6**<br>Application | • How-to example for applying ATL guidelines |
## Organization of Guidelines (cont.)

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Contents</th>
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<tbody>
<tr>
<td>Appendix A</td>
<td>• Guidance for applying microsimulation models to estimate ATL operational and safety performance</td>
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<td>Appendix B</td>
<td>• Description of computational engine</td>
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<td>Appendix C</td>
<td>• Method and equations for calculating the minimum required upstream and downstream ATL lengths</td>
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Chapter 2: 
User Considerations

Brandon Nevers, PE, PTOE
Pedestrians

- Increases pedestrian exposure to traffic
- Impacts Pedestrian LOS on side-street approaches
- Increases minimum pedestrian crossing time

Photo Credit: Hermanus Steyn
Bicyclists

- Design ATL approaches assuming bicyclists will travel within the ATL
- Bicycle lanes should be provided to the right of the ATL

See Exhibit 2-2, page 12

Photo Credit: Hermanus Steyn
Bus stops can be located on either the near-side or far-side of ATL. Merging with general traffic can be difficult for bus operators. Far-side stops allow buses to take advantage of signal progression; may impact facilitation of transfers.

See Exhibit 2-3, page 13
Motorists

- Motorists typically seek to minimize delay
- ATL becomes attractive as risk of not clearing the intersection in the CTL increases
- Messages need to be conveyed throughout ATL to encourage its use
- Aggressive drivers may use ATL as a by-pass lane

See Exhibit 2-4, page 14
Chapter 3: Operational Analysis

Nagu M. Rouphail, PhD.
Objectives

➢ Understand the factors that influence ATL use

➢ Determine the elements of ATL design consistent with its predicted use

See Exhibit 1-1, page 1
Approach

Research

- Collect data on ATL use
- Develop predictive models for ATL use
- HCM method to adjust lane utilization
- Method to estimate upstream ATL length
- Method(s) to estimate downstream ATL length

Implementation

- Identify intersection typology
- Collect intersection and approach data
- Using Computational Engine:
  - Apply predictive models and estimate utilization
  - Estimate minimum upstream ATL length
  - Estimate minimum downstream ATL length
Data Collection

- Twenty-two ATL approaches selected from five U.S. states

- Of those 14 had 1 CTL and 8 had 2 CTLs

- Mix of shared (with right turns) and exclusive ATLs (800-3,000 foot long)

- None of the sites had spillback or blocking effects (ATL counts reflected true demand)

- Observed ATL use much lower than HCM lane utilization prediction
  - 1-CTL: average ATL utilization 21% (HCM predicts 47%)
  - 2-CTL: average ATL utilization 15% (HCM predicts 31%)

- ATL downstream length did not appear to affect ATL utilization
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<th>Site #</th>
<th>Approach</th>
<th>Location</th>
<th>Length (ft)</th>
<th># 15-min Data Points</th>
<th>ATL Type</th>
<th># CTL's</th>
<th>Average ATL Utilization % Through</th>
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ATL Hourly Flow vs. Approach Through Flow

See Exhibit 3-5, page 19

NCHRP Report 707 Webinar
ATL Hourly Flow vs. Approach Through Flow

See Exhibit 3-5, page 19

NCHRP Report 707 Webinar
Variables for Predictive Models (1)

Directly from field

- Cycle-by-cycle car/truck counts from each through-movement lane
- Cycle by cycle signal indication (cycle length, effective green, effective red)
- Cycle by cycle right-turn volume
- Site characteristics including
  - ATL upstream, downstream, and total length
  - Posted speed limit
  - Sight distance
  - Presence of driveways
  - Signage of the ATL as a through-movement lane
  - Presence of an exclusive right turn lane
Variables computed from field data

- \( V_T \) = Approach through-movement flow rate (vph)
- \( X_T \) = approach through v/c ratio through-movement assuming no ATL
- \( X_R \) = right-turn v/c ratio

Data aggregated into 15-minute intervals

- Consisted of 5-10 cycles each, depending on the cycle length

Developed statistical regression models for 1-CTL and 2-CTL’s separately

- 75% of the full dataset used for model specification
- 25% reserved for model verification
Recommended Statistical models ATL use

1-CTL:

\[
ATL\ flow\ (vph) = 20.226 + 81.791 \times X_T^2 + 1.65 \times \left[ \frac{Through\ Flow}{100} \right]^2
\]

- All coefficients significant at \( p < 0.001 \)
- \( R^2 = 78\% \)

2-CTL:

\[
ATL\ flow\ (vph) = 29.24 + 17.3 \times \frac{Through\ flow}{100} - 90.291 \times X_R
\]

- All coefficients significant at \( p < 0.05 \)
- \( R^2 = 77\% \)
- Outlier site (MD-214) removed
Upper Bound on ATL use

Boundary conditions

- HCM mandates the use of equal v/c over all through-movement lanes as the upper bound for assigning through traffic to eligible lanes.

- In the case of an exclusive ATL and 1-CTL ($f_{lu} = 0.525$):
  \[
  V_{ATL, MAX} = V_T \left(1 - \frac{0.50}{f_{LU}}\right)
  \]

- In the case of an exclusive ATL and 2-CTL ($f_{lu} = 0.908$):
  \[
  V_{ATL, MAX} = V_T \left(1 - \frac{0.667}{f_{LU}}\right)
  \]

- In the case of a shared ATL:
  \[
  V_{ATL,MAX} = \text{Max}\left\{0, \frac{V_T}{N} \times \left[1 - \frac{V_R}{S_R \times \frac{V_T}{(N-1)S_T}}\right]\right\}
  \]
Motivation for ATL use is mostly to avoid a cycle failure.

Rather than being trapped downstream in a short length.

See Exhibit 3-7, page 22,
Models Exclude Downstream Length: Why?

Motivation for ATL use is mostly to avoid a cycle failure

Rather than being trapped downstream in a short length

See Exhibit 3-7, page 22
Estimation of Upstream ATL Length

- Use the maximum 95th percentile queue over all through-movement lanes on the approach to determine upstream ATL length.

- Considers blockage of access to the ATL as well as spillback from ATL into CTL(s).

**Step 1** Gather Input Data
- Total approach through and right-turn flow rates
- Cycle length and effective green time for the subject approach
- Saturation flow rate for both through and right-turn movements.

**Step 2** Estimate ATL flow rate based on the one-CTL or two-CTL model in Chapter 3

**Step 3** Calculate the ATL through flow rate using HCM 2010
- Assume equal lane volume-to-saturation flow rate (v/s) based on HCM 2010 shared or exclusive lane group volume distribution.

**Step 4** Select the ATL volume as the lower ATL flow rate from steps (2) and (3)

**Step 5** Calculate performance measures for ATL and CTL
- Includes lane volumes, capacity, control delay, and back of queue using HCM 2010 signalized intersection procedures.
- For shared ATLs, include the right-turn flow rate in the lane flow computations.

**Step 6** Estimate the 95th percentile queues
- Calculate for both ATL and CTL using HCM 2010 procedures.

**Step 7** Determine minimum upstream ATL length
- Should provide both storage and unimpeded access to the ATL
- Determine based on the maximum of the 95th percentile queues in the ATL and CTL respectively.
- Calculate the queue storage distance based on an estimate of average vehicle spacing in a stopped queue for a given vehicle fleet mix (approximately 25 feet per vehicle).

See Exhibit 5-9, page 45
Estimation of Downstream Length

- Two criteria based either on queuing in red (DSL₁) or gap acceptance at the operating speed in green (DSL₂)
- DSL₁ based upon providing sufficient spacing between queued ATL vehicles to reach their operating speed
- DSL₂ based upon gap availability and acceptance under uninterrupted flow conditions
- For design purposes, use Max (DSL₁, DSL₂)

See Exhibit 5-13, page 51
Implementation: Computational Engine

- Developed as an Excel spreadsheet environment to implement ATL operations procedure for pre-timed signal control (*actuated control ?*)

- Includes predictive models for ATL use & ups. / downs. length estimation

- Three possible scenarios can be evaluated:
  - Add an exclusive right-turn pocket (no ATL)
  - Add a shared ATL
  - Add an exclusive ATL and an additional right-turn pocket

- Output includes lane by lane delays, LOS and queue lengths – *fixed time only*– *iterative approach with actuated control*  (Bugg et al 2012)

- Engine accessible from:
Summary and Conclusions

- ATL use is better estimated as through flow rate not utilization.
- ATL use increases with congestion and through-movement demand.
- Right turns from a shared ATL and good signal progression may lead to decrease in ATL use.
- No impact of downstream length on ATL use.
- Upstream ATL length guided by highest lane 95th queue length.
- Downstream ATL length guided by acceleration, size of standing queue and gap acceptance.
- Simulation guidance on coding ATL also provided.
Additional Resources

Papers and Presentations


Chapter 4: Safety
Background

- Do ATLs have any effect on safety when implemented at signalized intersections?
- Hypothetically, ATLs could create risk through additional merging conflicts
- Tendencies may be partially offset through reduced queuing and cycle failures
Objective

- Achieve an understanding of the safety effects of ATLs
- Examine the safety effects of key ATL design parameters
- Exercise a validated Surrogate Safety Assessment Model (SSAM) with VISSIM
Conceptualized Approach

- Three methods considered to evaluate ATL safety effects
  - Before and after study of collision data
  - Collision model
  - Use SSAM to predict conflicts rather than collisions
Conceptualized Approach

Surrogate Safety Assessment Model (SSAM)

- Developed by FHWA
- Uses trajectory files from microsimulation packages
- Designates events as conflicts using a time-to-collision (TTC) threshold
- Classifies conflicts by angle
- Outputs coordinates and links to allow the analyst to estimate conflicts along the length of a network
- Attempt to validate with collision data
Methodology

- Sixteen ATL approaches at eight intersections in four U.S. states were selected for data collection
  - Contained basic ATL geometry
  - Wide range of congestion and ATL length
  - Little to no effects from neighboring intersections

- Collision data were compiled for a nine-year period (2000-2008)

- Operational data (signal timing, TMCs) collected for AM peak, PM peak, mid-day and off-peak periods

- Average ATL utilization collected during the peak period
Four VISSIM models (AM peak, PM peak, mid-day, and off-peak) developed for each three-year time period (2000-2002, 2003-2005, 2006-2008)

- ATL utilization achieved by altering the lane change distance (LCD) of the downstream connector

- Some of the study approaches were not built as ATLs during the early time periods, so VISSIM models not developed for those time periods
VISSIM Calibration – Major Assumptions

- AADT was used to determine traffic growth or decline
- One simulation run from each model manually observed to verify that signal timing plans adequately moved traffic
- Traffic composition and ATL utilization assumed consistent with field observations in 2009-2010
- Authors calibrated ATL utilization for one time period and let VISSIM logic determine utilization during other time periods
Results

Collision Data Trends

See Exhibit 4-1, page 31
Results

Rear End Collisions and Congestion

See Web-Only Document 178 Figure 33, page 69
Results

Collision Data Trends

- No relationship evident between rear end collisions and either ATL utilization or ATL flow rate

- No relationship evident between sideswipe collisions and total ATL length
Results

SSAM Conflicts and Collision Data

- Conflicts roughly followed collisions for a few sites
- Only 563 rear end and sideswipe collisions observed over 16 intersection approaches over about 9 years
- Average of 4.5 collisions/year per approach
- Worst site had 8.8 collisions/year per approach
Results

Comparison of SSAM Rear End Conflicts to Collisions

See Web-Only Document 178: Figure 39, page 75
Results

Comparison of SSAM Sideswipe Conflicts to Collisions

See Web-Only Document 178, Figure 40, page 75
Conclusions

- Low sample size limited conclusiveness but indicated that analyzed ATLs do not appear to be unsafe.
- ATL length does not appear to affect collision rate.
- A bottleneck downstream of the intersection may cause unsafe merging due to traffic spilling back into the ATL.
- SSAM conflicts related to collision data only at high aggregation level.
- Authors recommend using either a greater number of study sites or a before-and-after study to further investigate safety at ATLs.
Chapter 5: Design

Hermanus Steyn, Pr.Eng., PE

NCHRP Report 707 Webinar
Design Approach Flowchart

Existing Intersection Configuration

One-CTL

Two-CTL

Shared Through/Right

Exclusive Right

Potential Improvements

Add Exclusive Right

Add ATL with Shared Through/Right

Add ATL with Exclusive Right

Convert Right to ATL with Shared Through/Right

Add ATL with Exclusive Right

See Exhibit 5-4, page 40
Auxiliary Through Lane (ATL) Components

» ATL Configuration and Design Parameters

See Exhibit 1-1, page 1

» ATL Segments Requiring Unique Driver Action

See Exhibit 5-7, page 49
Design Segment: Approaching ATL

Inform approaching driver of start of additional through lane at signal

Operations

- Unconstrained
  - Length of upstream ATL portion determined by CTL queue
  - Motorists need access to ATL at back of queue

- Constrained
  - Access to ATL may be blocked
  - Expect lower ATL utilization

See Exhibit 5-1, page 38

See Exhibit 5-2, page 38
Design Considerations

- Add lane configuration sign
- Add lane use pavement markings

Passive taper rate introducing the ATL did not influence accessing the ATL.

See Exhibit 5-8, page 44
Design Segment: Approaching Intersection

Remind driver that current lane configuration continues through the intersection

Operations

- Signal timing modifications such as less green time for approach may encourage more drivers to use ATL

Photo Credit: Yuri Mereszczak
Design Segment: Approaching Intersection (cont.)

Design Considerations

- Add lane configuration signage
  - side mounted
  - overhead on signal mast arm
- Larger curb-return radius for right-turns

See Exhibit 5-10, page 47

Photo Credit: Hermanus Steyn
Design Segment: Leaving Intersection

- Reassure through lanes are continuing to some distance beyond intersection

- Operations
  - Signal timing modifications such as less green time for approach may encourage more drivers to use ATL

Photo Credit: Hermanus Steyn
Design Considerations

- Add “LANE ENDS MERGE LEFT/RIGHT” sign with plaque indicating distance beyond intersection

Photo Credit: Hermanus Steyn

See Exhibit 5-12, page 49
Design Segment: Merge at End of ATL

- Extra lane is ending and appropriate merge behavior is encouraged

- Operations
  - Operational affects similar for unconstrained and constrained sites

Photo Credit: Hermanus Steyn
Design Considerations

- Add “LANE ENDS” sign
- Active taper rates consistent with MUTCD guidance

See Exhibit 5-16, page 54
Chapter 6: Application

Hermanus Steyn, Pr.Eng., PE
Sample Application

- Assess Multimodal Needs
- Evaluate Traffic Operations
- Assess Safety Effects
- Calculate Design Elements
- Lay Out Individual Segments

See Exhibit 6-1, page 56

NOTES
- No additional data required beyond traditional intersection analysis
- Applicable to approaches with one or two continuous through lanes and an exclusive or shared right-turn lane
NCHRP 707 Example: Turning Movement Volumes

See Exhibit 6-3, page 58
### NCHRP 707 Example: Computational Engine Input

#### 1-CTL ONLY

**COMPUTATIONS OF ATL LENGTHS (UPSTREAM AND DOWNSTREAM)-- FOR VARIOUS LANE CHOICES**

**INPUT DATA HERE - CASE I IS THE BASELINE (SINGLE SHARED THRU+RIGHT LANE)
ALL CELLS  EXCEPT INPUT CELLS ARE PROTECTED**

<table>
<thead>
<tr>
<th></th>
<th>HYPOTHETICAL CASE STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong></td>
<td>ENTER THE CASE STUDY ID OR TITLE IN YELLOW BOX</td>
</tr>
<tr>
<td><strong>2.</strong></td>
<td>ENHANCEMENT: EXCLUSIVE RIGHT TURN LANE (Y/N)?</td>
</tr>
<tr>
<td><strong>3.</strong></td>
<td>ENHANCEMENT: ADDITIONAL EXCLUSIVE ATL (Y/N) ?</td>
</tr>
<tr>
<td><strong>4.</strong></td>
<td>TOTAL APPROACH THROUGH VOLUME=</td>
</tr>
<tr>
<td><strong>5.</strong></td>
<td>RIGHT TURN VOLUME=</td>
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<tr>
<td><strong>6.</strong></td>
<td>APPROACH SPEED (MPH)=</td>
</tr>
<tr>
<td><strong>7.</strong></td>
<td>THRU SATFLOW PER LANE=</td>
</tr>
<tr>
<td><strong>8.</strong></td>
<td>RIGHT SATFLOW PER LANE=</td>
</tr>
<tr>
<td><strong>9.</strong></td>
<td>APPROACH EFFECTIVE GREEN=</td>
</tr>
<tr>
<td><strong>10.</strong></td>
<td>INTERSECTION CYCLE LENGTH=</td>
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<tr>
<td><strong>11.</strong></td>
<td>APPROACH EFFECTIVE GREEN WITH ATL / OTHER ADDS=</td>
</tr>
<tr>
<td><strong>12.</strong></td>
<td>AVERAGE VEHICLE SPACING AT STOP=</td>
</tr>
<tr>
<td><strong>13.</strong></td>
<td>AVERAGE ACCELERATION RATE FROM STOP =</td>
</tr>
<tr>
<td><strong>14.</strong></td>
<td>INTERSECTION WIDTH (STOPLINE TO FAR CURB)=</td>
</tr>
<tr>
<td><strong>15.</strong></td>
<td>CRITICAL GAP IN NEIGHBORING CTL TRAFFIC LANE=</td>
</tr>
<tr>
<td><strong>16.</strong></td>
<td>DRIVER REACTION TIME=</td>
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</tbody>
</table>

**Please enter data in CAPS for first two entries**  
**This entry cannot be "Y" if previous entry is "N"**

---

**BASED ON THE INPUTS- THIS IS ANALYSIS CASE III 1-CTL+SHARED ATL**

---

See Exhibit 6-5, page 59
### Operational Analysis - Computational Engine is Online


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<th>Lane</th>
<th>$V_{TH}$</th>
<th>$V_{RT}$</th>
<th>$V_{Tot}$</th>
<th>$v/c$</th>
<th>Delay (sec)</th>
<th>LOS</th>
<th>95th% Queue (ft)</th>
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<td>Base Case</td>
<td>CTL+RT</td>
<td>425</td>
<td>75</td>
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<td>800</td>
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<td>75</td>
<td>75</td>
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<td>36</td>
<td>D</td>
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<tr>
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<td>75</td>
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<td>75</td>
<td>75</td>
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<td>0.70</td>
<td>49</td>
<td>D</td>
<td>300</td>
</tr>
</tbody>
</table>

See Exhibit 6-6, page 60
**ADD A SHARED THROUGH/RIGHT ATL**

**Condition** | **Upstream ATL Length Based on Storage Q-Length (ft)** | **Downstream ATL Length (ft)** | **Downstream ATL Length Based on CTL-Gap Acceptance Distance (ft)**
--- | --- | --- | ---
Add Shared ATL | 300 | 220 DSL₁ | 250 DSL₂

See Exhibit 6-7, page 63
NCHRP 707 Example: Preliminary Design

➤ Upstream Passive Taper
  ▪ Minimum rate = 10:1
  ▪ 11-foot lane → 110 feet

Photo Credit: Hermanus Steyn
NCHRP 707 Example: Preliminary Design

- Upstream ATL
  - Distance based on 95th percentile queue in CTL
  - Skip stripe along entire length
  - MUTCD R3-8 sign & lane-use markings
  - Overhead lane configuration signs on signal mast arm
NCHRP 707 Example: Preliminary Design

- **Downstream ATL**
  - Skip stripe along entire length
  - MUTCD W9-1 sign ~50' (min.) from intersection
  - MUTCD W4-2 sign halfway between W9-1 sign & end of downstream full-width lane segment
  - Note: Min. 100’ between W4-2 & W9-1
NCHRP 707 Example: Preliminary Design

Downstream Active Taper

- MUTCD Guidance
  - WS\(^2/60\) (speeds < 45 MPH)
  - WS (speeds ≥ 45 MPH)
- 11 foot lane, 35 MPH → 225 feet

Photo Credit: Hermanus Steyn
NCHRP 707 Example: Preliminary Design

- **Approaching ATL**
  - Passive taper
  - Side mounted lane configurations sign

- **Approaching Signal**
  - Overhead lane configuration signs

- **Leaving Intersection**
  - “Right Lane Ends” and “Lane End” warning signs

- **Merge at End of ATL**
  - Active taper

See Exhibit 6-8, page 65
Guidelines on the Use of Auxiliary Through Lanes at Signalized Intersections

TRB's National Cooperative Highway Research Program (NCHRP) Report 707: Guidelines on the Use of Auxiliary Through Lanes at Signalized Intersections provides guidelines to help in the justification, design, and analysis of auxiliary through lanes (ATLs) at signalized intersections.

ATLs are lanes for through movements that begin upstream of a signalized intersection and end downstream of the intersection. They are typically added to support the demand requirements and overall corridor capacity.

A report that describes the methods used for the development of NCHRP Report 707 has been released as an NCHRP Web Only Document 179: Assessment of Auxiliary Through Lanes at Signalized Intersections.

A spreadsheet-based computational engine is also available online.

ScreenPrint of Website

NCHRP Report 707 Webinar
Questions/Comments

Brandon Nevers, PE, PTOE
- Principal Engineer, Kittelson & Associates, Inc.
- bnevers@kittelson.com

Nagui Rouphail, PhD.
- Director, Institute for Transportation Research & Education
- rouphail@ncsu.edu

Zachary Bugg
- Research Assistant, Institute for Transportation Research & Education
- zhubugg@ncsu.edu

Hermanus Steyn, Pr.Eng., PE
- Principal Engineer, Kittelson & Associates, Inc.
- hsteyn@kittelson.com