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The purpose of the project was to assist the Alabama Department of Transportation (ALDOT) in streamlining the plan preparation and review process, establishing standards for signal design, and providing guidance to designers and maintenance personnel in setting signal timings.

The project consisted of three phases. The first phase was the preparatory work. It included the initial literature review and the formation of a project steering committee. The second phase consisted of the development of preliminary materials for review by the steering committee. The third phase of the project consisted of the development of a draft manual.

The main deliverables of the project is draft Statewide Traffic Signal Design and Timing Manual for use by signal designers, reviewers, and maintenance personnel in Alabama. Upon completion of the draft manual, the project team will assist the Electrical Section of the ALDOT Design Bureau in obtaining State and federal approval of the manual prior to its adoption as the statewide standard.

The Alabama Statewide Traffic Signal Design and Timing Manual will serve as a reference for traffic signal design. The standards in the manual will be a resource to engineers throughout ALDOT, and will continue the trend within the department of using the Internet to convey technical information (i.e., online availability of standards drawings, CAD files and cells). The online guide will be made available to consultants performing signal designs for the state.
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Executive Summary

The Alabama Department of Transportation (ALDOT) currently contracts most signal design work on State-sponsored projects, as many as 200 intersections per year, to private consultants through its Statewide Signal Design Services contracts. Other consultants prepare traffic signal designs as part of larger ALDOT roadway design or modification projects. Traffic signals installed on state-maintained roadways by private developers are likewise designed by consultants, or local municipalities. ALDOT is charged with reviewing and approving all such designs, prepared by numerous firms and presented to ALDOT in a variety of formats. There are several references (e.g., ITE Traffic Signal Design Manual) available to design consultants but no guidelines exist for designers preparing plans specifically for ALDOT. This is important because much of the information contained within the national design guides is generic and does not address ALDOT-specific design standards and policies.

These design issues have implications not only for signal operation and safety but also for long-term maintenance of the signal equipment. Furthermore, these design issues are not addressed explicitly in the Alabama Standard Specifications for Traffic Signals, which addresses hardware specifications but not overall design requirements. While it is always necessary to provide leeway to engineers when preparing designs, it would be helpful to provide signal designers with guidelines for addressing the most commonly encountered situations.

Once traffic signals are approved and installed on State routes, the State often assumes maintenance responsibilities. Improperly designed signals can make future maintenance more difficult and costly. As an example, inadequately sized conduits or insufficient numbers of pull boxes can create future difficulties (prolonged traffic interruptions, expensive reinstallations, etc.) when maintenance crews attempt to install new loops or re-wire signal heads.

Another important aspect of signal maintenance is the evaluation and adjustment of signal timings. Changing traffic conditions require corresponding changes to signal timings in order to maintain optimal operation. Improper settings in the controller can cause a signal to operate inefficiently and create unnecessary delays. More importantly, some signal timing parameters have significant safety implications, so it is critical that there be consistency in how they are set.

Many States have addressed similar design and maintenance issues through the development of state-specific guidance and standards for traffic signal design and operation. States that have developed such guides include Florida, Georgia, Louisiana, Minnesota, North Carolina, Pennsylvania, and Texas. These guides combine general design criteria contained in the national design manuals with state specifications and local design standards in a comprehensive manual that can be used by state personnel, consultants, and local maintenance staff.
The purpose of the project was to assist ALDOT in streamlining the plan preparation and review process, establishing standards for signal design, and providing guidance to designers and maintenance personnel in setting signal timings. The main deliverable of the project is a draft *Statewide Traffic Signal Design and Timing Manual* for use by signal designers, reviewers, and maintenance personnel in Alabama. Upon completion of the draft manual, the project team will also assist the Electrical Section of the ALDOT Design Bureau in obtaining State and federal approval of the manual prior to its adoption as the statewide standard.

The project consisted of three phases. The first phase was the preparatory work. It included the initial literature review and the formation of a project steering committee. The second phase of the project consisted of the development of preliminary materials for review by the steering committee. The third phase of the project consisted of the development of a draft manual, that will also become available online.

The *Alabama Statewide Traffic Signal Design and Timing Manual* will serve as a reference for traffic signal design. The standards in the manual will be a resource to engineers throughout ALDOT, and will continue the trend within the department of using the Internet to convey technical information (i.e., online availability of standards drawings, CAD files and cells). The online guide will be made available to consultants performing signal designs for the state.

The manual developed as part of this project will provide ALDOT the tools to ensure that all signal designs submitted to the state shall conform to a standard format and that all necessary information will be included and presented in a manner that will streamline the review process. In particular, the design manual and timing guidance will serve as standards for ALDOT and its consultants at the beginning of the signal design process. This will reduce the number of revisions required throughout the process as well as reduce design costs (less design/revision time, easier checking, smoother Plans Specifications & Estimate (PS&E) review process, etc.). Adherence to the proposed manual and guide will ensure that designs are consistent, thereby ensuring ease of inspection, operation, and maintenance, as well as improving safety and efficiency. The manual and guide will also provide ALDOT and its consultants a means of consistently addressing special signal design issues such as treatments for railroads and emergency pre-emption. Finally, the manual and guide will be a useful resource to those who develop and maintain signal timings in the field, ensuring that all timings conform to state standards.

A broader benefit will also result from the fact that most municipalities rely on ALDOT design standards for their own signal designs. Design guidelines published by ALDOT will likely be adopted statewide and could provide the above benefits well beyond the network of state highways.
Section 1
Introduction

1.1. Background

The Alabama Department of Transportation (ALDOT) currently contracts most signal design work on State-sponsored projects, as many as 200 intersections per year, to private consultants through its Statewide Signal Design Services contracts. Other consultants prepare traffic signal designs as part of larger ALDOT roadway design or modification projects. Traffic signals installed on state-maintained roadways by private developers are likewise designed by consultants, or in some cases local municipalities. ALDOT is charged with reviewing and approving all such designs, prepared by numerous firms and presented to ALDOT in a variety of formats. There are several references available to design consultants, most notably the Manual of Traffic Signal Design, prepared by the Institute of Transportation Engineers (ITE), but no guidelines exist for designers preparing plans specifically for ALDOT (Kell, 1991). This is important because much of the information contained within the national design guides is generic and does not address ALDOT-specific design standards and policies. Examples of ALDOT traffic signal design elements not addressed by the ITE Manual of Traffic Signal Design include:

- Types of signal heads allowed by the ALDOT (e.g., 4-section heads are not permitted) and their proper alignment over lanes,
- Wiring standards for signal heads, pedestrian heads, and interconnect (gauge, number of conductors, etc.),
- Number and setback requirements for advance detection loops,
- Permitted methods for wiring detector loops to amplifiers,
- ALDOT preferences for selecting and designing an appropriate interconnect system (e.g., hardwire, twisted pair, fiber, or radio),
- Acceptable signal mounting configurations and associated dimensions (box span, suspended box span, “Z” span, etc.), and
- Appropriate uses of video and microwave detection.

Similar issues exist related to conduit boring, pull box spacing, railroad treatments, emergency pre-emption, and power service requirements. These design issues have implications not only for signal operation and safety but also for long-term maintenance of the signal equipment. Furthermore, these design issues are not addressed explicitly in the Alabama Standard Specifications for Traffic Signals, which addresses hardware specifications but not overall design requirements (ALDOT, 2001). While it is always necessary to provide leeway to engineers when preparing designs, it would be helpful to provide signal designers with guidelines for addressing the most commonly encountered situations.
Once traffic signals are approved and installed on State routes, the State often assumes maintenance responsibilities. Improperly designed signals can make future maintenance more difficult and costly. As an example, inadequately sized conduits or insufficient numbers of pull boxes can create future difficulties (prolonged traffic interruptions, expensive reinstallations, etc.) when maintenance crews attempt to install new loops or re-wire signal heads.

In addition to hardware issues, one of the most important aspects of signal maintenance is the evaluation and adjustment of signal timings. Changing traffic conditions require corresponding changes to signal timings in order to maintain optimal operation. Improper settings in the controller can cause a signal to operate inefficiently and create unnecessary delays. More importantly, some signal timing parameters have significant safety implications, so it is critical that there be consistency in how they are set. Some of the most commonly encountered signal timing deficiencies are:

- Inappropriate cycle lengths (either too long or too short),
- Passage times that are too long, creating inefficient operation,
- Inadequate or excessive clearance intervals (yellow and all-red times),
- Minimum green times that are too long or too short,
- Inadequate consideration of trucks when developing timings.

Some of these design issues (e.g., clearance intervals) are addressed in the ITE Manual of Traffic Signal Design, but others are covered only in general terms or not at all (Kell, 1991). Guidance for setting passage times, for instance, is very broad and seems to often result in excessive passage times in the field. Trucks and truck safety are another important consideration in Alabama, particularly on hilly and heavily used truck routes such as U.S. 280 and U.S. 78. Signal designers currently lack a set of clear guidelines for determining safe clearance intervals when heavy truck volumes are present.

Many States have addressed similar design and maintenance issues through the development of state-specific guidance and standards for traffic signal design and operation. States that have developed such guides include Florida, Georgia, Louisiana, Minnesota, North Carolina, Pennsylvania, and Texas. These guides combine general design criteria contained in the national design manuals with state specifications and local design standards in a comprehensive manual that can be used by state personnel, consultants, and local maintenance staff.

1.2. Purpose & Scope

The purpose of the project was to assist ALDOT in streamlining the plan preparation and review process, establishing standards for signal design, and providing guidance to designers and maintenance personnel in setting signal timings. The main deliverables of the project is draft Statewide Traffic Signal Design and Timing Manual for use by signal designers, reviewers, and maintenance personnel in Alabama. Upon completion of the draft manual, the project team will
assist the Electrical Section of the ALDOT Design Bureau\textsuperscript{1} in obtaining State and federal approval\textsuperscript{2} of the manual prior to its adoption as the statewide standard.

\textsuperscript{1} The ALDOT entity that oversees traffic signal-related projects involving federal-aid funds.
\textsuperscript{2} In addition to being approved by ALDOT administration, the manual will also have to be approved by the Alabama Division of the Federal Highway Administration because it will affect designs on projects receiving federal-aid funds.
The project consisted of three phases. The first phase was the preparatory work. It included the initial literature review and the formation of a project steering committee. The second phase of the project consisted of the development of preliminary materials for review by the steering committee. The third phase of the project consisted of the development of a draft manual.

2.1. Literature Review

A review of traffic signal-related literature was performed. The review was intended to serve two purposes:

- Identify existing national level standards that should be accommodated into the development of the Alabama manual (Manual of Uniform Traffic Control Devices (MUTCD), ITE recommended practices, etc.);
- Identify other states that have developed similar manuals and determine what previously developed materials would be applicable in Alabama; and
- Identify current traffic signal-related issues and trends (e.g., flashing yellow arrow, left-turn lane warrants) not reflected in existing standards and provide guidance to ALDOT on the inclusion of these items into the Alabama manual.

2.1.1. Other Manuals and Standards

Interestingly, the literature review revealed that relatively few states have developed and maintain their own traffic signal design standards or manuals. Table 1-1 shows the traffic signal-related materials from other states reviewed under this project.

<table>
<thead>
<tr>
<th>State</th>
<th>Standards</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Traffic Manual</td>
<td>(CALTRANS, 2002)</td>
</tr>
<tr>
<td>Connecticut</td>
<td>Traffic Control Signal Design Manual</td>
<td>(ConnDOT, 2001)</td>
</tr>
<tr>
<td>Georgia</td>
<td>Traffic Signal Design Guidelines</td>
<td>(Gray Calhoun, 2003)</td>
</tr>
<tr>
<td>Idaho</td>
<td>Traffic Manual</td>
<td>(ITD, 2006)</td>
</tr>
<tr>
<td>Illinois</td>
<td>MUTCD Supplement</td>
<td>(IDOT, 2003)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Traffic Engineering Manuals</td>
<td>(Mn/DOT, 2004)</td>
</tr>
<tr>
<td>Texas</td>
<td>Traffic Signal Manual</td>
<td>(TDOT, 1999)</td>
</tr>
<tr>
<td>Utah</td>
<td>Guideline and Checklist for Design of Signalized Intersections</td>
<td>(UDOT, 2002)</td>
</tr>
</tbody>
</table>
2.1.2. Identification of Specific Issues for Consideration

The literature was reviewed and white papers were developed for consideration for ALDOT on the following issues:

- Guidelines for Offset Left Turn Lanes;
- Use of Flashing Yellow Indications for Protected/Permissive Left Turn Movements;
- Guidelines for Selecting Protected-Only vs. Protected/Permissive Left Turn Phasing;
- Left-Turn Signal Phasing Warrants; and

The white papers, as submitted to the steering committee, are presented in Appendix A.

2.2. Steering Committee

A steering committee was formed to guide the process of developing the Alabama manual. The committee consisted of the following representatives:

- Three staff members (including the Section Head) of the Electrical Section of the ALDOT Design Bureau;
- Division Traffic Engineers from three ALDOT Divisions;
- A representative from each of the consulting firms currently working under the Statewide Signal Design Services contracts; and
- Two members of the university research team.

The steering committee met at the beginning of the project to establish initial goals and expectations. Throughout the project, guidance and insight on specific issues was sought from members of the steering committee through individual interaction. The white papers, developed around specific issues for ALDOT to consider for inclusion in the manual, were submitted to the steering committee for review and comment. Also, as draft chapters of the manual were assembled, they were also submitted for review and comment. Finally, the steering committee met to review the overall draft document before concluding the project and beginning the process of seeking State and federal approvals.
Section 3
Results

The project resulted in the development of a draft *Statewide Traffic Signal Design and Timing Manual*. The draft manual will be reviewed by ALDOT and the Alabama Division of FHWA. The table of contents of the draft manual is provided in Appendix B. The manual addresses many design topics including:

- Signal mounting configurations (box spans, “Z” spans, advantages and disadvantages);
- Pole types (steel strain, concrete, mast-arm, etc.) and their appropriate use;
- Equipment placement and clear zone requirements;
- Signal heads (acceptable configurations and alignments);
- Loop detectors (e.g., types, placement);
- Wiring standards;
- Information on other detectors (video, microwave, etc.) and applicability issues;
- Pedestrian features (guidelines for use, design standards, etc.);
- Interconnect types and criteria for determining appropriate use;
- Signal operating plans (ALDOT standard drawings as well as special sequences);
- Criteria for using permitted, protected-only, or protected/permitted phasing; and
- Criteria for using lead/lag left turn phasing.

Some of the information contained in the design manual adheres to other transportation design standards. For example, clear zone requirements for locating signal poles are described in the *Roadside Design Guide* (AASHTO, 2002) and basic guidelines for loop detector design and placement are provided in the *Manual of Traffic Signal Design* (Kell, 1991). Similarly, general guidelines for locating signal heads can be found in the *Manual on Uniform Traffic Control Devices* (USDOT, 2000) and standard signal operating plans can be found in the *State of Alabama Special and Standard Highway Drawings* (ALDOT, 2003).

Nonetheless, it is useful to designers to integrate information from these various sources into one comprehensive and cohesive manual in order to streamline design process. As an example, the selection of the signal layout often depends on clear zone requirements, so it would be helpful to have these two topics presented together. As stated previously, much of the information contained in these other sources was tailored to Alabama design standards. Many of the loop detector design criteria contained in the *Manual of Traffic Signal Design* (Kell, 1991), for example, are not consistent with current ALDOT practices.

With respect to traffic signal timing, the draft manual addresses topics such as:

- Definitions of controller settings,
- Cycle length determination,
• Initial and clearance intervals,
• Consideration of trucks and grades,
• Passage times,
• Volume density functions,
• Pedestrian timing, and
• Pre-emption timing (railroad and emergency).

The draft manual does not, however, address system timing, as that is a highly specialized area of signal design. Furthermore, system timing is generally not state-specific and there are manuals and software packages readily available to cover that topic. The manual developed as part of this project is intended to cover the operation of isolated signals or signal systems when operating in free mode.

Upon final approval from ALDOT and Federal Highway Administration (FHWA), the manual will be migrated to an interactive, web-based format. In addition to serving as tool for plan review, the online guide will serve as an interactive reference for traffic signal design. The online guide will be a resource to engineers throughout ALDOT and would continue the trend within the department of using the Internet to convey technical information (i.e., online availability of standards drawings, CAD files and cells; the Standardized Bridge System tool currently being developed by the University of Alabama at Huntsville under UTCA projects 01332, 03301, 04312, 05315, and 06303). The online guide could also be made available to consultants performing signal designs for the State.

In addition to streamlining the design process, the final manual will serve as a reference and educational/training tool for employees ALDOT and its consultants, and transportation professional within the state of Alabama and beyond. Training courses based on the new manual will be delivered through the UTCA Technology Transfer Program (UTCA Project 06113).
Section 4
Conclusions

The Statewide Traffic Signal Design and Timing Manual will serve as a reference for traffic signal design. The standards in the manual will be a resource to engineers throughout ALDOT, and will continue the trend within the department of using the Internet to convey technical information (i.e., online availability of standards drawings, CAD files and cells). The online guide will be made available to consultants performing signal designs for the state.

ALDOT will now have tools to ensure that all signal designs submitted to the state shall conform to a standard format and that all necessary information will be included and presented in a manner that will streamline the review process. In particular, the design manual and timing guidance will serve as standards for ALDOT and its consultants at the beginning of the signal design process. This will reduce the number of revisions required throughout the process as well as reduce design costs (less design/revision time, easier checking, smoother PS&E review process, etc.). Adherence to the proposed manual and guide will ensure that designs are consistent, thereby ensuring ease of inspection, operation, and maintenance, as well as improving safety and efficiency. The manual and guide will also provide ALDOT and its consultants a means of consistently addressing special signal design issues such as treatments for railroads and emergency pre-emption. Finally, the manual and guide will be a useful resource to those who develop and maintain signal timings in the field, ensuring that all timings conform to state standards.

A broader benefit will also result from the fact that most municipalities rely on ALDOT design standards for their own signals. Design guidelines published by ALDOT will likely be adopted statewide and could provide the above benefits well beyond the network of state highways.
Section 5
Acknowledgements

This study was made possible with the funding provided by the Alabama Department of Transportation. The project team would especially like to express appreciation for the input and guidance provided by the project Steering Committee.
Section 8
References


Appendices
White Papers
White Paper A
Guidelines for Offset Left Turn Lanes

Description

At intersections with wide medians (over 18’), the alignment of traditional left turn lanes often obstructs sight distance for vehicles making permissive left turns (see Figure A1 below). Several states, including Georgia, require the use of offset left turn lanes at new signalized intersections where wide medians exist. Offset left turn lanes improve sight distances for turning vehicles by aligning the turn lanes as shown in Figure A2. The question has been raised whether ALDOT should adopt a similar policy.

Figure A1. Traditional left turn lanes in a wide median restrict sight distance
Figure A2. Offset left turn lanes in a wide median enhance sight distance
Current Practices

Research has verified that offset left-turn lanes can operate safely (Harwood et al., 1995), but there are no solid estimates of their safety effectiveness. Researchers in Nebraska [“Estimated Accident Costs Associated with Offset and Traditional Left-Turn Lanes at Rural Four-Lane Expressway Intersections with Two-Way Stop Control (Schurr et al., 2003) studied behaviors of left-turning drivers traversing offset left-turn lanes and traditional left-turn lanes on rural unsignalized four-lane expressways in Nebraska with 40 ft medians and posted speeds of 55 and 65 mph. Data collected showed that while offset left-turn lanes enhanced safety by improving sight distance, they decrease safety due to left-turners decelerating more significantly before entering the offset left-turn bay. It is believed the sharper tapers, typically associated with offset left turn lanes, cause drivers to slow more in the travel lanes before entering the taper. The authors recommended 20:1 tapers for offset left turn lanes in rural areas, which would translate into a 360 foot taper for an 18’ offset. No data were provided for urban intersections.

A study performed in Florida found some safety improvement associated with offset left turn lanes but it relied on a small sample size and looked at data from a limited time frame. No long term studies are currently available.

Recommendations

It has been shown that offset left turn lanes improve sight distance at an intersection, but there is not enough reliable data demonstrating the safety benefits of offset left turn lanes to justify a change in current ALDOT design standards. It is recommended, however, that offset left turn lanes allowed on a case by case basis on new designs and intersection reconstructions (widening projects). Where implemented, they will allow ALDOT to collect and analyze safety data and evaluate the possible need for a standard in the future.
Use of Flashing Yellow Indications for Protected/Permissive Left Turn Movements

Description

Kittelson & Associates (2000) conducted a study of the use of protected-permissive left turn phasing (PPLT) within the United States and abroad. The findings were reported in NCHRP 493 under Project 3-54. This project specifically researched alternatives to the traditional PPLT phase indications used by most states. The most common arrangement used in Alabama is the 5-section signal head combined with the R10-12 “Left Turn Yield on Green ●” sign, where the permissive portion of the left turn phase is indicated by a solid green ball. In an effort to improve driver recognition and safety associated with permissive left turns, other states have tested alternative signal arrangements, including a flashing yellow arrow and a flashing red arrow. The study found that the flashing yellow arrow, used in a 4 or 5-section signal head, was the most effective indication for permissive left turns. It was recommended that the flashing yellow arrow be added to the MUTCD as an acceptable alternative for protected/permissive phasing.

Current Practice

A summary of states that have tested alternative protected/permissive signal indications is presented in the Table B1.

<table>
<thead>
<tr>
<th>State/City</th>
<th>Left Turn Indication Protected Mode</th>
<th>Left Turn Indication Permissive Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington State*</td>
<td>Green Arrow</td>
<td>Flashing Circular Yellow</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>Green Arrow</td>
<td>Flashing Yellow Arrow</td>
</tr>
<tr>
<td>Sparks, NV</td>
<td>Green Arrow</td>
<td>Flashing Yellow Arrow &amp; Circular Green</td>
</tr>
<tr>
<td>Reno, NV</td>
<td>Green Arrow</td>
<td>Flashing Yellow Arrow</td>
</tr>
</tbody>
</table>


In the NCHRP study, approximately 325 surveys were mailed to state DOT’s and large transportation agencies across the United States. The survey asked various questions regarding the use of PPLT and found that only about two percent of the agencies used alternative phasing (any phasing other than circular green for permissive). Accident analysis was performed at a number of test sites as well as at control intersections and it was found that flashing yellow indications provided reductions in accident rates. It was also found that the public responded well to the new indications and that no supplemental signs were needed. In fact, the public seemed to prefer the flashing yellow to the standard green ball when responding to surveys.
The study recommended that the flashing yellow arrow (in a 4-section or 5 section head) be added to the MUTCD as an acceptable indication, and that recommendation will be reflected in the next edition of the MUTCD.

The flashing yellow is tied to the green for the opposing through movement, which differs from current practice. This eliminates the left-turn trap associated with traditional prot/perm phasing. The study did not recommend the use of flashing red indications, except in situations where it is advisable for drivers to come to a complete stop before turning.

**Recommendation**

It is our recommendation that ALDOT permit the use of the flashing yellow protected/permissive indications for all new and upgraded signals. It may be beneficial to recommend this treatment at existing intersections that have experienced significant accident rates related to protected/permissive left turns but do not meet the accident warrant criteria for protected-only left turns. If there is a positive impact on accident rates observed over several years, ALDOT could consider making this the standard treatment throughout the state.

Allowing flashing yellow indications for protected/permissive left turn movements will require that ALDOT make any changes known to the public through the Driver’s Handbook. Interestingly, the NCHRP study found that supplemental signing is not required (although it can be provided) and that most drivers found the flashing yellow more readily understandable than the standard green ball.
From a capacity standpoint, protected/permissive left turn phasing (PPLT) is generally more efficient than protected-only phasing because it allows a portion of the turning volume to utilize gaps in the opposing traffic stream, thus minimizing the amount of green time required for the protected phase. This can result in increased intersection capacity, shorter cycle lengths, and shorter turning queues. Where left turn phasing is required, ALDOT should encourage the use of protected/permissive left turn phasing and allow protected-only phasing only when required.

### Current Practice

Many states provide guidelines for the use of protected/permissive and protected-only left turn phasing. They are generally very similar, taking into account accident rates, speeds, sight distances, and lane configurations. A brief summary of selected states is provided in Table C1.

<table>
<thead>
<tr>
<th>State/Org.</th>
<th>Conditions for use</th>
<th>protected-permissive</th>
<th>protected-only</th>
</tr>
</thead>
</table>
| Georgia    | Use wherever possible. | All sites unless compelling reason for other phasing exists. If situation is unclear, install as prot/perm and monitor on trial basis. | • left turn accident history  
• inadequate sight distance  
• dual lefts  
• opposing thru movement 3+ lanes with speeds >50 mph. |
| Florida    | All sites that fail to meet protected-only criteria. | Speed of opposing traffic >45 mph  
• Left turn accidents ≥5/year  
• 3+ lanes of opposing traffic  
• dual lefts  
• inadequate sight distances  
• U-turns permitted |
| Oregon     | All sites not covered under protected-only criteria. | Speed of opposing traffic >45 mph  
• Left turn accidents ≥5/year  
• 3+ lanes of opposing traffic  
• dual lefts  
• inadequate sight distances  
• U-turns permitted |
| Arizona    | All sites not requiring protected-only. | Speed of opposing traffic >45 mph  
• Left turn accidents ≥5/year  
• 3+ lanes of opposing traffic  
• dual lefts  
• inadequate sight distances |

Some states discourage combinations of protected-only and protected/permissive left turn phasing on opposing left turn movements. Other states, such as Idaho, make a point to allow this practice. There was no evidence found in the literature that combinations of protected and protected/permissive left turn phasing create an unsafe condition.
Recommendations

The following policy regarding protected-only and protected/permissive left turn phasing is proposed. The policy is presented in language similar to that that would appear in the formal guidelines.

1. Where left turn phasing is warranted, ALDOT recommends the use of protected/permissive phasing except in cases where conditions satisfy one or more of the following conditions for protected-only left turn phasing:
   - speed of opposing through traffic = 50 mph or higher;
   - inadequate sight distance for permissive left turns;
   - dual or triple left turn lanes;
   - 3 or more lanes of opposing traffic with speeds = 45 mph or higher;
   - an approach with 5 or more accidents in a 12 month period related to permissive left turns that can not be addressed by other means;

2. ALDOT will consider protected-only left turn phasing for approaches that do not meet the criteria listed above if the designer can demonstrate that it is necessary for proper intersection function and safety.

3. ALDOT permits combinations of protected/permissive and protected-only phasing on opposing left turn movements provided they meet all requirements for safety and sight distance.

4. In most cases ALDOT discourages the use of protected/permissive left turn phasing for dual left turn lanes; however, ALDOT will consider protected-permissive left turn phasing for dual left turn lanes if all of the following conditions are satisfied:
   - dual left turn lanes are on a minor street approach, or a major street approach where the 85th percentile approach speed does not exceed 30 mph;
   - adequate sight distances exist;
   - this phasing will significantly enhance intersection operation.
White Paper D
Left-Turn Signal Phasing Warrants

Description

To reduce the unnecessary use of left turn phasing and thus maximize intersection capacity it is proposed that ALDOT adopt left turn signal phasing warrants. Designers would be required to justify providing left turn phasing based on warrants that consider traffic volumes, intersection geometrics, speeds, and sight distances.

Current Practice

Four primary warrant criteria are used by other states: 1) the cross-product method, 2) accident warrant, 3) safety considerations, and 4) the Texas Left Turn Phase warrants. Each is described below.

Cross-Product Warrant – Discussed in the ITE Manual of Traffic Signal Design (Kell, 1991), the cross-product method is used by many states including Georgia, Arizona, New York, and California. The method uses the product of the left turning volume and the opposing through movement to determine whether left turn phasing is warranted. Threshold values depend on lane configuration and vary by State. A summary is provided in Table D1.

<table>
<thead>
<tr>
<th>State/Org.</th>
<th>Area Type</th>
<th>2-lane</th>
<th>4-lane</th>
<th>6-lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITE</td>
<td>All</td>
<td>50,000</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>Arizona</td>
<td>Urban</td>
<td>75,000</td>
<td>150,000</td>
<td>225,000</td>
</tr>
<tr>
<td></td>
<td>Rural</td>
<td>50,000</td>
<td>100,000</td>
<td>150,000</td>
</tr>
<tr>
<td>California</td>
<td>All</td>
<td>50,000</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>Georgia</td>
<td>All</td>
<td>60,000</td>
<td>120,000</td>
<td>-</td>
</tr>
<tr>
<td>Oregon</td>
<td>All</td>
<td>50,000</td>
<td>100,000</td>
<td>-</td>
</tr>
<tr>
<td>New York</td>
<td>All</td>
<td>50,000</td>
<td>100,000</td>
<td>-</td>
</tr>
</tbody>
</table>

Several states have additional requirements that left turn volumes must be a minimum of 50 vph during the peak hour before the cross-product criteria can be applied. While the cross-product method provides a good rule of thumb, it does not explicitly consider intersection capacity or the amount of green time under which vehicles could turn permissively. There may be cases where the cross product is high but available green time is still sufficient to serve the left turning volumes.

Accident Warrant – Many states have warrants which recommend left turn phasing if there is a history of left-turn accidents at an intersection, although determining what number of accidents constitutes a problem is sometimes left to the engineer. The minimum accident criteria used by selected states is summarized in Table D2.
### Table D2. Summary of accident warrants for left turn phasing

<table>
<thead>
<tr>
<th>State/Org.</th>
<th># of left turn accidents past 12 months</th>
<th># of left turn accidents past 24 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITE</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Arizona</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Oregon</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>California</td>
<td>decided by engineer</td>
<td></td>
</tr>
</tbody>
</table>

**Safety Considerations** – Many states require left turn signal phasing if the geometric conditions at the intersection do not allow for safe permissive left turns. These conditions can include:
- 3 or more lanes of opposing through traffic with speeds over 35 mph;
- opposing through traffic speeds in excess of 45 mph;
- inadequate sight distance;
- dual left turn lanes.

**Texas Left Turn Phase Warrants** – Developed by the Center for Transportation Research at the University of Texas, these warrant criteria are used in Texas and Idaho. It is a more sophisticated method than the cross-product in which the left turn volumes and opposing thru volumes are adjusted based on available unprotected green time for that movement (green time/cycle length). The method is summarized in the Table D3.

### Table 3. Summary of Texas left turn phase warrant criteria

<table>
<thead>
<tr>
<th>Number of Opposing Lanes</th>
<th>Opposing volume V adjusted by G/C</th>
<th>Minimum critical left turn volume L (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 &lt; V(G/C) &lt; 1000</td>
<td>764(G/C) – 0.634V</td>
</tr>
<tr>
<td></td>
<td>1000 &lt; V(G/C) &lt; 1350</td>
<td>484(G/C) – 0.348V</td>
</tr>
<tr>
<td>2</td>
<td>0 &lt; V(G/C) &lt; 1000</td>
<td>855(G/C) – 0.500V</td>
</tr>
<tr>
<td></td>
<td>1000 &lt; V(G/C) &lt; 1350</td>
<td>680(G/C) – 0.353V</td>
</tr>
<tr>
<td></td>
<td>1350 &lt; V(G/C) &lt; 2000</td>
<td>390(G/C) – 0.167V</td>
</tr>
<tr>
<td>3</td>
<td>0 &lt; V(G/C) &lt; 1000</td>
<td>892(G/C) – 0.448V</td>
</tr>
<tr>
<td></td>
<td>1000 &lt; V(G/C) &lt; 1350</td>
<td>735(G/C) – 0.297V</td>
</tr>
<tr>
<td></td>
<td>1350 &lt; V(G/C) &lt; 2400</td>
<td>390(G/C) – 0.112V</td>
</tr>
</tbody>
</table>

Left turn volumes less than the critical lane volume could be adequately served with permissive left turn phasing, provided there are no geometric deficiencies. This method explicitly considers signal timing in determining whether left turn phasing is warranted.

### Recommendation

Based on the review of available practices, it is recommended that ALDOT adopt the following warrants and practices for determining whether left turn phasing is required:

1. ALDOT should require that a standard left turn phase warrant worksheet be submitted with every signal design. The worksheet will show for each approach whether left turn phasing is justified.
2. Traffic volume warrants should be based on the Texas left turn phase methodology (Table D3). This could very easily be incorporated into a spreadsheet\(^3\) available on the ALDOT website.

3. Left turn phasing should be *considered* on approaches where there have been a minimum of 5 left turn related accidents in a 12 month period and they can not be effectively addressed by other means.

4. Left turn phasing should be *required* under the following conditions:
   - sight distance is inadequate for observed speeds;
   - dual left turn lanes;
   - 3 or more lanes of opposing traffic with speeds >45 mph;

5. ALDOT should *consider* approving left turn phasing for reasons not listed above if the designer can demonstrate that it is necessary for intersection function, capacity, or safety.

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\(^3\) A sample spreadsheet is provided as an appendix to this white paper and an electronic version will be sent to the steering committee for review.
Traffic Signal Warrants: Guidelines for Determining Right Turn Volume Reductions

Description

When performing a signal warrant analysis, right turn volumes on the minor street approaches are often adjusted to reflect the fact that right turning vehicles can often turn without the benefit of a signal. This right turn adjustment is intended to reduce the instances of signals being installed based on right turn volumes that could well be served without a signal. The MUTCD states that signal warrant analysis “should consider the effects of the right turn vehicles from the minor street approach. Engineering judgment should be used to determine what, if any, portion of the right turn traffic is subtracted from the minor street traffic count when evaluating the counts against the warrant”. This engineering judgment provides a great deal of leeway to engineers but does not provide any real guidance. It would be desirable for ALDOT to provide guidance to engineers regarding the reduction of right turn volumes in signal warrant analysis.

Current Practice

A review of available literature found that most states simply follow the MUTCD recommendations for adjusting right turn volumes, which is to say they do not provide any additional guidance. Two state DOT’s were found to provide additional guidance: Oregon and Illinois. The practices of each state are summarized below.

Oregon DOT – 85% of the right turn lane or shared lane capacity is subtracted from the right turn volume. If the value of (0.85 x the computed lane capacity), measured in vph, exceeds the right turn volume, no right turn volumes are included in the analysis. If the right turn volumes are greater, they are reduced by the value of (0.85 x the computed lane capacity). The lane capacity is computed using the HCM methodology for unsignalized intersections.

This method is useful in that it takes into account not only traffic volumes on the side street, but also traffic conditions on the mainline which affect the ability of vehicles to turn right from the side street. The HCM methodology computes side street lane capacities based on side street lane configurations, main street lane configurations and traffic volumes, median type, and truck percentages. The disadvantage of this methodology is that side street lane capacities must be computed for each of the 12 hours counted.

Illinois DOT (District One) – IDOT District One uses a process called Pagones Theorem, developed in-house, to estimate right turn reductions on side streets. The reduction criteria are based on lane configuration and approach volumes and are summarized on the following page. As with the Oregon method, the right turn reduction factor is based on traffic volumes and must be computed for each of the 12 hours in the analysis period. It is a more simple calculation than the Oregon method.
A representative of the Illinois DOT said that the process has worked well for the past ten years and is widely used in the Chicago area by other municipalities. He felt that it had prevented numerous unnecessary signals from being warranted. It is also interesting to note that on routes designated “Strategic Regional Arterials” the Illinois DOT does not permit the use of the peak hour or four hour warrants for signal warrant analysis.

**Recommendations**

We recommend ALDOT adopt the following policy related to adjusting right turn volumes for signal warrants:

1. Continue to follow the general MUTCD warrants for traffic signals.

2. Use the Pagones Theorem.
Appendix B
Table of Contents of Statewide Traffic Signal Design and Timing Manual

ALDOT Traffic Signal Design Guide
And Timing Manual

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