Evaluation of Traffic Signal Displays for Protected-Permitted Left Turn Control

NCHRP Project 3-54

NOTICE: This report is being furnished to the traffic engineering community at the direction of NCHRP so to supply information about this research project and its findings. This report documents findings of the research project as of September 1999.

AGENCY SURVEY REPORT

Working Paper 2

Prepared for:

National Cooperative Highway Research Program

Project Panel Members

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AGENCY SURVEY

INTRODUCTION

Traffic congestion in urban areas has long been a source of concern for transportation engineers. Traffic volumes at many of the nation's urbanized intersections are increasing to beyond capacity – either because of the capacity limitations of the intersection or the signal's phasing operation. A balance must be found between intersection capacity and signal phasing. One of the major problems faced in timing signals is to appropriately assign time for left-turn movements. As the number of left-turning vehicles increases, average delay and accident potential for both through and left-turning vehicles also increases. Separate left-turn lanes and protected left-turn phases are commonly used to minimize the impacts of left-turning vehicles. However, when a protected left-turn phase is used, the time to provide that phase must be taken from the through phases. Other decisions the engineer must make are the type of left-turn phasing that best satisfies the left-turn demand, and the left-turn phase sequence that maximizes progression, particularly if the intersection is located on an arterial street.

There are three modes of left-turn control: permitted, protected, and protected/permitted. Transportation professionals have chosen protected/permitted left-turn (PPLT) phasing for many reasons, including minimizing delay, improving progression, and reducing fuel consumption and air pollution. An agency may use PPLT phasing to increase the operational efficiency of an intersection. PPLT phasing can also reduce delay for left-turning vehicles under low-to-moderate traffic volume conditions. Protected/permitted left-turn phasing is an especially effective remedy for reducing left-turning vehicle delay when it is operated with a coordinated signal system.

Many jurisdictions use the leading/lagging left-turn sequence at intersections within a signal system to improve progression. The benefits of the lead/lag left-turn phasing are further enhanced with protected/permitted lead/lag phasing. By allowing vehicles to turn left during the permitted interval, dedicated left-turn green time can be reduced, thereby allowing more green time for the coordinated movements. This technique is especially effective for coordinated arterial signals where the progressive platoons in each direction do not pass through the signal at exactly the same time.

In a recently completed comprehensive evaluation of the impacts of coordinated signal timing in western San Bernardino County, California, Albert Grover documented a 30 to 50 percent reduction in vehicle delay when comparing protected only to protected/permitted left-turn phasing (*1*). The City of Upland, California, where Grover conducted most of his study, uses Dallas Phasing.

While there are many reasons to use PPLT phasing, a number of problems are also associated with this type of signal phasing. One such problem is a potential "yellow trap," which occurs when a signal changes from the permitted left-turn interval in both directions to a lagging protected left-turn interval in only one direction. A motorist attempting to make a left-turn on the permitted indication becomes trapped in the intersection when the indication changes for the clearance interval. The left-turning motorist who is attempting to clear the intersection can also see the signal for the adjacent through lanes change to a yellow ball, indicating the onset of the clearance interval. This may cause the left-turning motorist to mistakenly believe that the signal for opposing traffic is also indicating the onset of the clearance interval, when in fact the opposing traffic has a permitted indication. The left-turner proceeds, creating the potential for a serious conflict with the opposing traffic.

The yellow trap can also occur in a number of other situations, such as during signal preemption for emergency vehicles, during signal preemption for railway crossings, during re-service of leading left-turn phases, and during an overlapping green extension for "slot" (or inside) clearance at an offset intersection.

OBJECTIVE

The objective of the agency survey summarized in this report is to identify the current practices related to PPLT signal display. A data collection tool, or survey, was used to gather information from transportation agencies throughout the United States. This information was then consolidated to determine how the PPLT signal display is being used and what conditions effect its use.

METHODOLOGY

A four-page survey was developed to collect information on how PPLT signal displays are used in the United States.

Survey Design

The survey consists of three sections and was packaged with a cover sheet to explain the purpose of the study and request the agency's participation in the survey. A copy of the survey is included as Appendix A.

General Information. The first section of the survey, General Information, includes questions about the number of signalized intersections within the agency's jurisdiction and the extent to which the PPLT signal display is used.

PPLT Signal Displays. The second section includes nine detailed questions about the use of the PPLT signal display, including questions about display arrangement, mounting type and location, use of secondary PPLT signal displays, and the type of signal indication used for the permitted phase of the PPLT.

Geometry and Phasing. The third section includes questions about the agency's use of the PPLT signal display under differing conditions, such as wide median intersections and narrow rights-of-way. This section also inquires if the agency uses any special phasing techniques to avoid the yellow trap problem and if there are any laws or ordinances affecting the use of PPLT signal displays.

Survey Distribution

The survey was distributed to the state traffic engineer in each of the 50 U.S. states and to traffic engineers in 275 of the largest city and county transportation agencies in the United States and Canada. In total, 325 surveys were distributed. This report documents the responses provided by the participating agencies.

SURVEY RESPONSE

One hundred eighty, or 55 percent, of the surveys were returned. This response included six surveys that were returned from Canadian agencies and another six surveys that were returned from U.S. agencies that do not use PPLT signal phasing. The remaining 168 surveys were returned from U.S. agencies that use PPLT signal phasing. Results from the latter group were used in the analysis summarized in this report.

Surveys were returned by at least one agency from each of the 50 states. Texas had the greatest response with 23 agencies responding, followed by California with 12 agencies responding. Fourteen states had a single responding agency. A complete list of the responding agencies by state is included as Appendix B.

General Information

The first section of the survey inquired about the number of signalized intersections within a given jurisdiction and the percentage of those which used PPLT phasing. By pooling the responses from the 168 agencies, a total of 107,219 signalized intersections were identified. Figure 1 illustrates the extent to which PPLT signal phasing is used at these intersections.

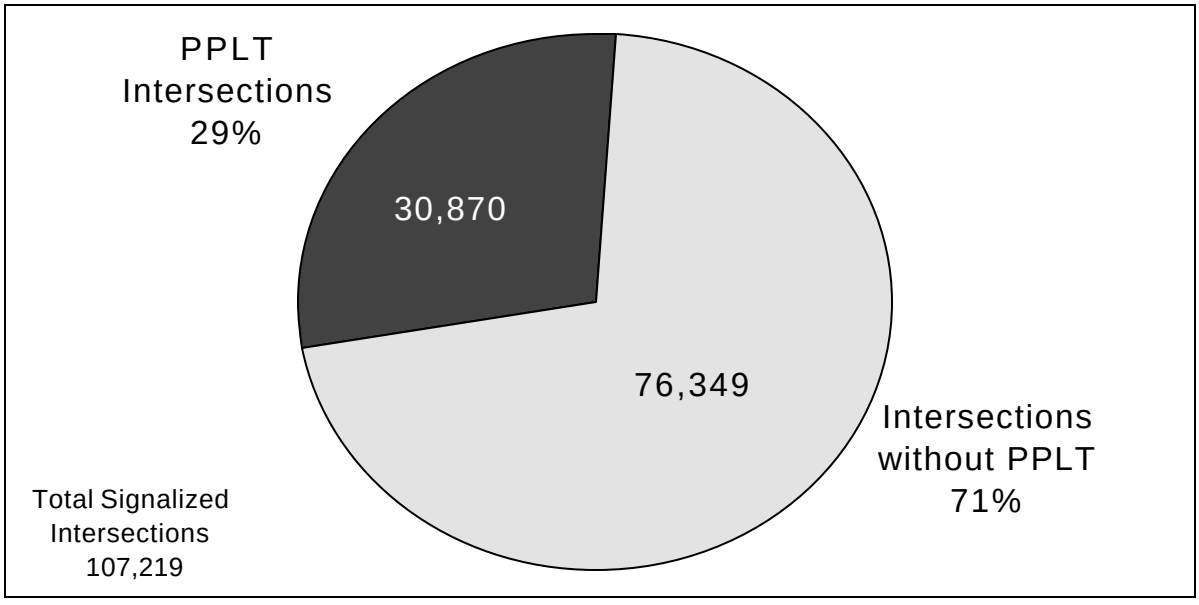


Figure 1. Total Number of Signalized Intersections With and Without PPLT Phasing.

Of the 107,219 signalized intersections, 30,870 (29%) were identified as using PPLT signal phasing. This percentage is consistent with the 1996 survey conducted by McCourt (*2*).

PPLT Signal Displays

The second section of the survey consisted of nine questions, numbered 3 through 11. Questions concerned the use of PPLT signal displays including displays, mounting, and supplemental signs. Summaries for each of these questions follow.

Question 3. Respondents were asked to identify the display arrangements used for PPLT control. Optional arrangements included five-section horizontal, vertical, or cluster; four-section horizontal, vertical or cluster; and three-section vertical. Respondents could also specify an alternative arrangement. Figure 2 summarizes the responses to question 3 as consolidated from the 168 surveys. The five-section cluster display represents nearly 68 percent of all PPLT signal displays identified through the agency survey. The five-section vertical display represents approximately 20 percent of the PPLT signal displays, while the five-section horizontal display represents approximately 9 percent.

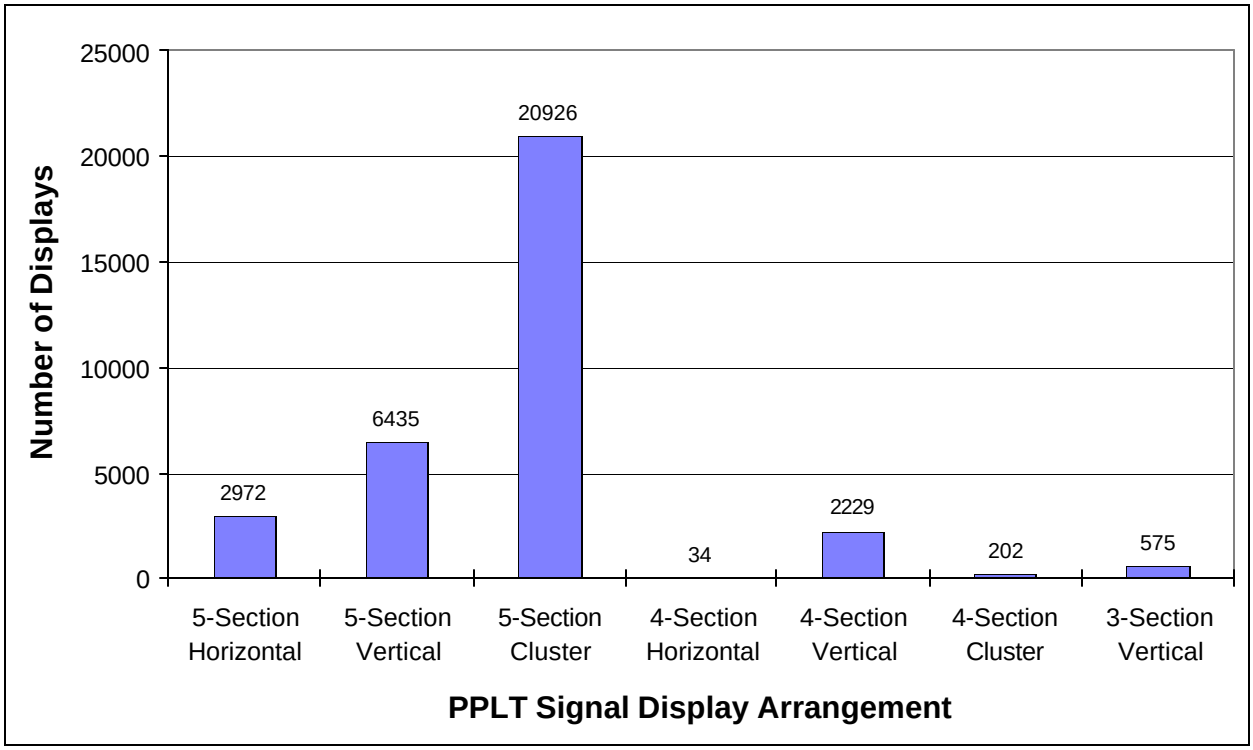


Figure 2. Distribution of PPLT Signal Display Arrangements Used.

The responses were cross-analyzed by regional location. Figure 3 shows the distribution of the different PPLT signal display arrangements. Texas and Dade County, Florida, predominantly use the five-section horizontal arrangement. Use of the five-section cluster display predominates in 34 states.

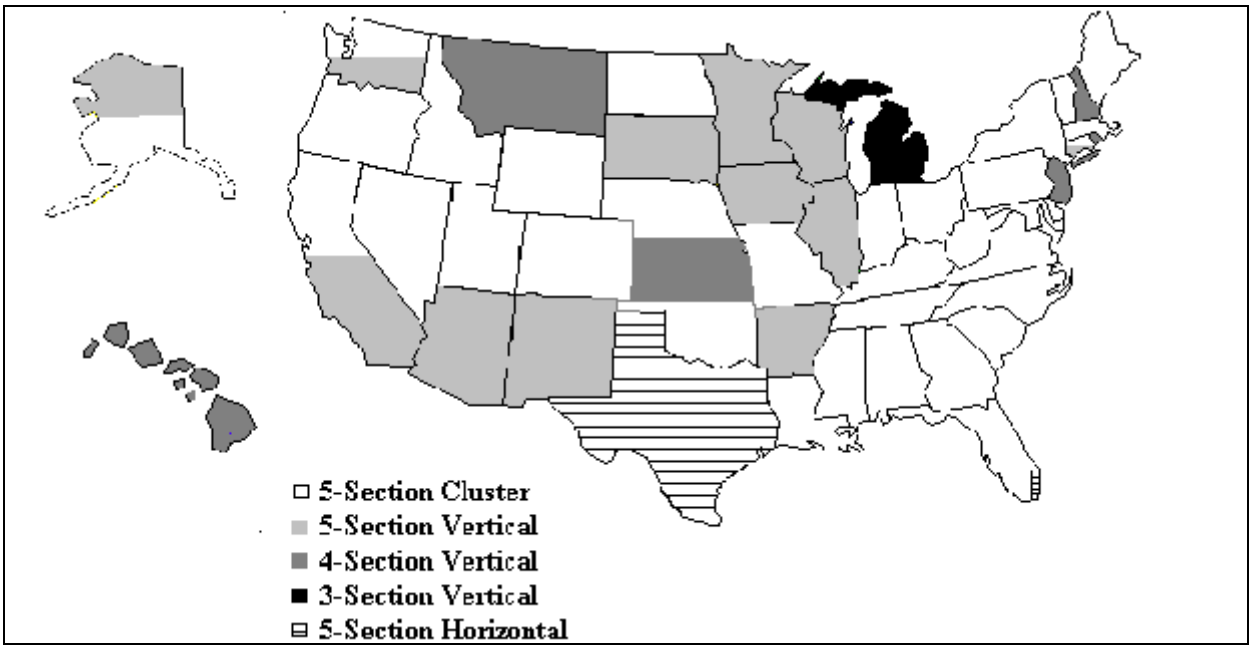


Figure 3. Predominant PPLT Signal Display Used by Each State.

Question 4. If the agency uses multiple PPLT signal display arrangements, question 4 allowed the respondent to identify the criteria used to determine which arrangement is used in a given installment. Forty-one percent of the agencies identified the use of a single PPLT signal display arrangement throughout their jurisdiction. Most agencies use a combination of a post-mounted five-section vertical display in median applications with a five-section vertical or five-section cluster display for mast-arm or span-wire mounts. Other than Texas and Dade County, Florida, most agencies used five-section horizontal displays only at bridges, in areas where drivers' sight is restricted, or in other locations were clearance between the roadway and the bottom of the signal display may be limited.

The cities of Los Angeles, California; Baton Rouge, Louisiana; and Topeka, Kansas use different PPLT signal display types depending on the signal phasing used. A five-section cluster (mast arm) or vertical

(pole mount) is used with leading left-turn signal phasing while a four-section vertical display is used in lagging left-turn phasing. Many agencies who currently use multiple PPLT signal display types indicated that they are moving towards uniformity, in most cases to the five-section cluster display. Only Dade County, Florida, and Monroe County, New York, indicated that they were moving away from the five-section cluster display to another display, in each case the five-section horizontal.

Question 5. The advent of the light emitting diode (LED) technology for signal indications has led to the increased use of bi-modal arrow indications. Question 5 requested information concerning the use of the bi-modal arrow indications. As shown in Figure 4, 33 of the 168 responding agencies indicated that they currently use bi-modal yellow/green left-turn arrows. Among these 33 agencies nearly 1,650 PPLT signal displays contain the bi-modal arrow. The primary reason for using bi-modal arrows is the reduction in signal display size because five indications can be presented in only four signal sections. Further, agencies reported energy savings through the use of LED bi-modal indications.

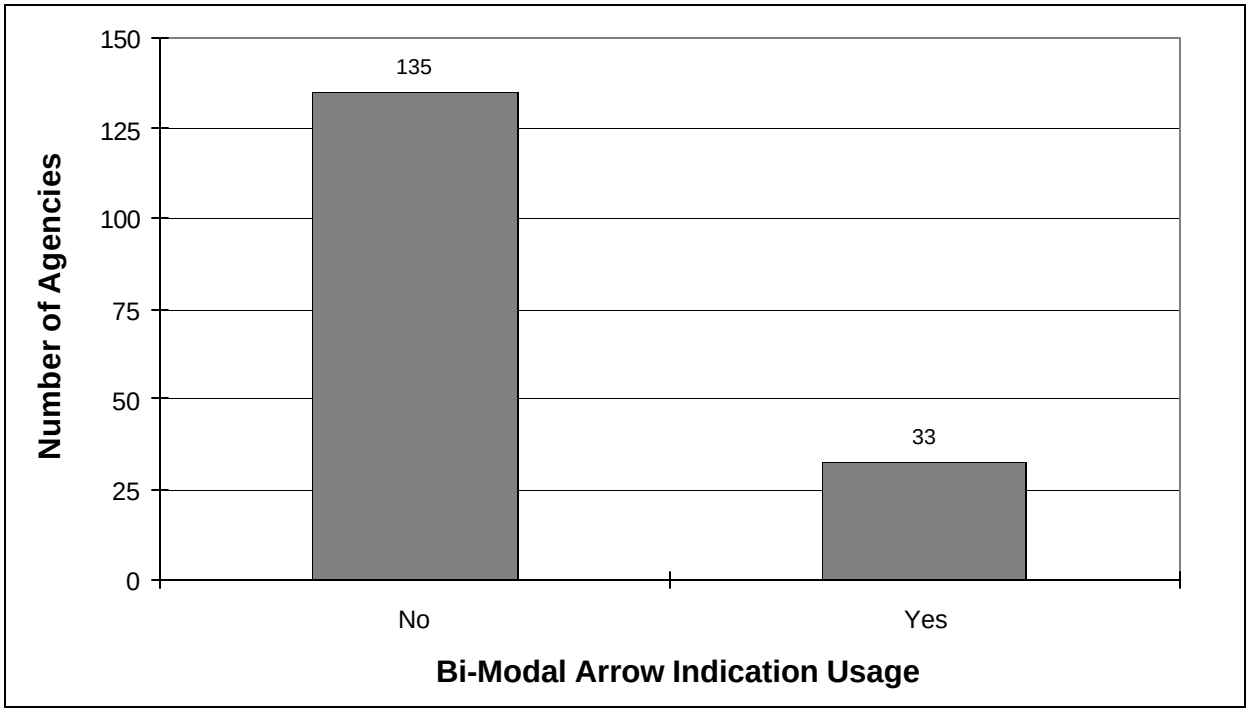


Figure 4. Use of Green/Yellow Bi-Modal Arrow Indications in PPLT Signal Displays.

Bi-modal arrow indications are primarily used in the northeast and New England states of New Hampshire, New York, New Jersey, Connecticut, Rhode Island, and Massachusetts. Illinois, Hawaii, Arizona, Kansas, Montana, Missouri, and Washington state also report the use of a limited number of bi-modal arrow indications.

Those states with a predominant number of four-section or three-section PPLT signal displays, as shown in Figure 3, generally use either a bi-modal yellow/green arrow indication or one of the unique flashing yellow or red permitted indications.

Questions 6 and 7. These survey questions explored the mounting types and locations used with PPLT signal displays. Figure 5 indicates the relationship between mounting types and the PPLT signal display arrangement used. As shown in Figure 5, the cluster display is primarily used with mast-arm and span-wire mounts. One hundred three agencies use the cluster display in combination with mast-arm mounts, whereas 92 agencies use the cluster display in combination with the span- wire mount. The vertical display is used primarily in pole-mounted applications, most often in median applications. Note that only Harris County, Texas, indicated that they use a horizontal display on a pole mount. In general, the relationship between the horizontal, vertical, and cluster displays used with mast-arm and span-wire mounting applications is consistent with the relative number of signal displays used, as presented in Figure 2.

In mast-arm or span-wire mounting applications, there was little consistency in mounting location. Fifty-two percent of responding agencies indicated that they mount the overhead PPLT signal display on the lane line between the left-turn lane and adjacent through lane. Forty percent of agencies indicated that they center the PPLT signal display over the left-turn lane. The remaining seven percent generally place the PPLT signal display somewhere between the centerline of the left-turn lane and the lane line between the left-turn lane and adjacent through lane. These results are summarized in Figure 6.

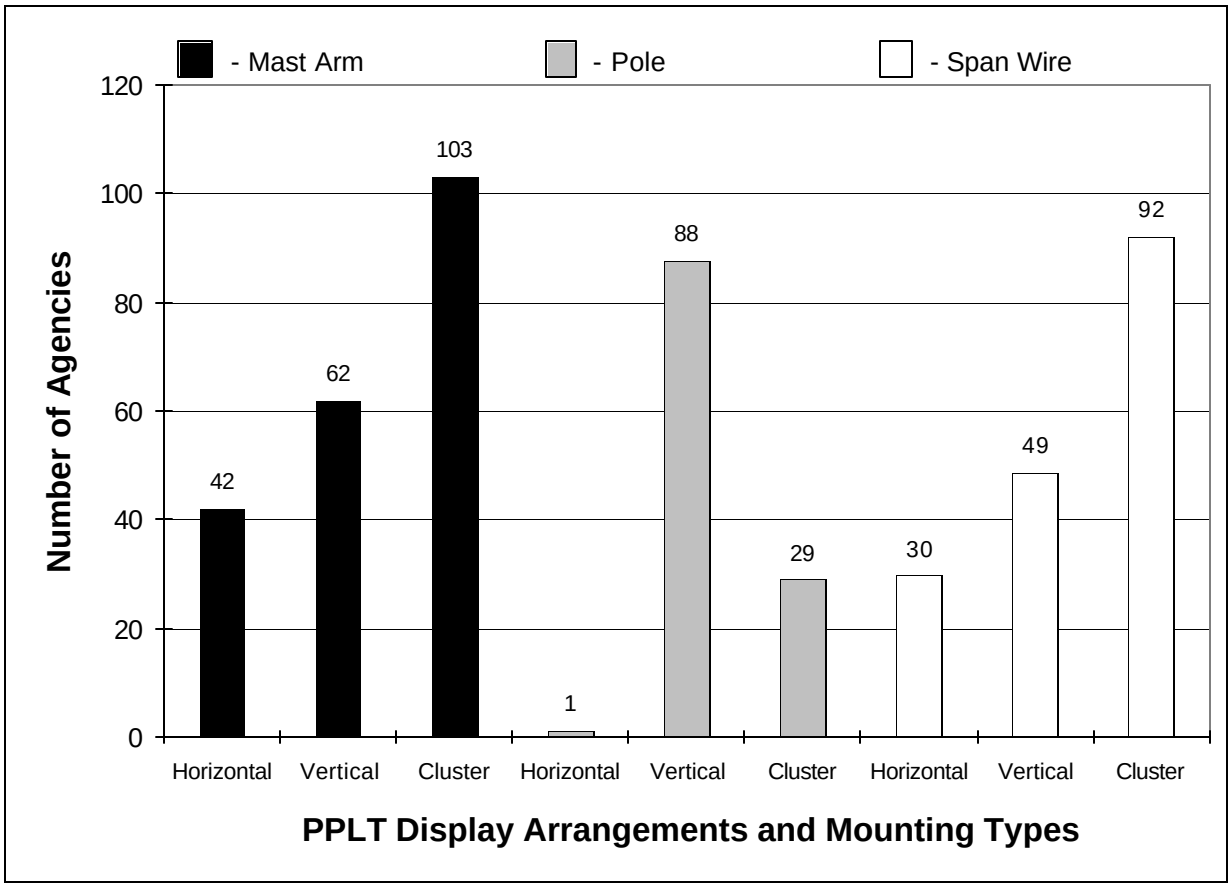


Figure 5. Signal Display Arrangements Used With Various Mounting Types.

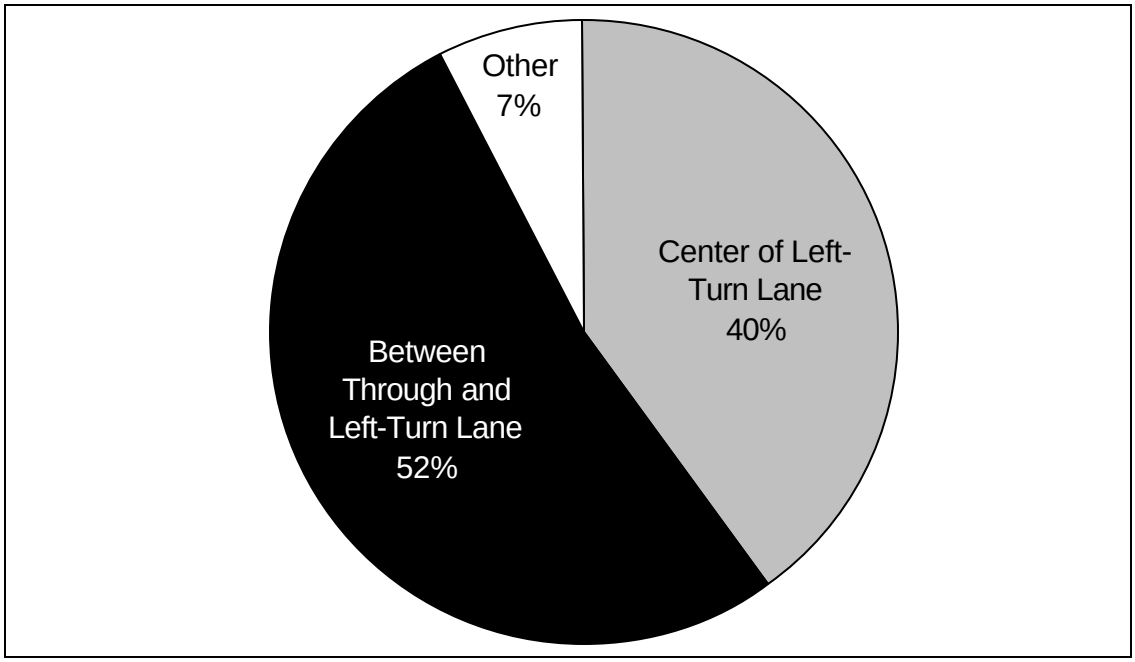


Figure 6. Overhead Mounting Location of Primary PPLT Signal Display.

Several agencies indicated that they center the PPLT signal display over the leftmost through lane. Agencies that use mast arms indicated that the exact placement of the PPLT signal display is often determined by the available length of the mast arm.

Question 8. This survey question explored the mounting location of secondary or additional PPLT signal displays. Eighty-three agencies indicated that they use a secondary PPLT signal display, while 85 indicated that they did not; thus, there is nearly an even split between agencies that do and do not use a secondary PPLT signal display.

Of the agencies that use a secondary or additional PPLT signal display, the majority place the additional display on a farside pole mount. Sixty-seven agencies indicated that they place the secondary PPLT signal display at the farside. Twenty-two agencies indicated that they place the secondary PPLT signal display in a median pole-mount location, and eight agencies use a nearside pole mount location. The 11 agencies that indicated *other* in the survey response generally use a second overhead PPLT signal display, either mast-arm or span-wire mounted. Table 1 is a summary of the responses.

Table 1. Mounting Location of Secondary PPLT Signal Display (When Used).

	Mounting Location			
Number of Agencies Responding	Nearside	Median	Farside	Other
	8	22	67	11

Question 9. The agencies were asked whether they use the PPLT signal display as one of the two through movement signal displays required by the MUTCD. The responses to question 9 are summarized in Table 2. Thirty-eight agencies indicated that they never do, 63 agencies indicated that they always do, and 68 agencies indicated that they sometimes do. Note that Oakland County, Michigan, is counted twice because they always use the five-section cluster display as one of the two required through-movement displays, but never use the three-section vertical display as one of the required through-movement displays. Many agencies that indicated they sometimes use the PPLT signal display as the through-movement display base their decision on the geometry of the roadway. Generally, if only one left-turn lane and one through lane exists, the PPLT signal display will be used as a through-movement display. If additional through lanes exist, a third signal display is added.

Table 2. PPLT Display Used as One of Two Required Signal Displays for Through Traffic.

	Amount Used		
Number of Agencies Responding	**Never**	**Always**	**Sometimes**
	38	63	68

Question 10. This survey question provided the respondent with an opportunity to identify all of the signal indications the agency uses for the permitted phase of the PPLT. Figure 7 is a summary of the responses. Over 98 percent of responding agencies (165/168) use the green ball permitted signal indication as defined in the MUTCD.

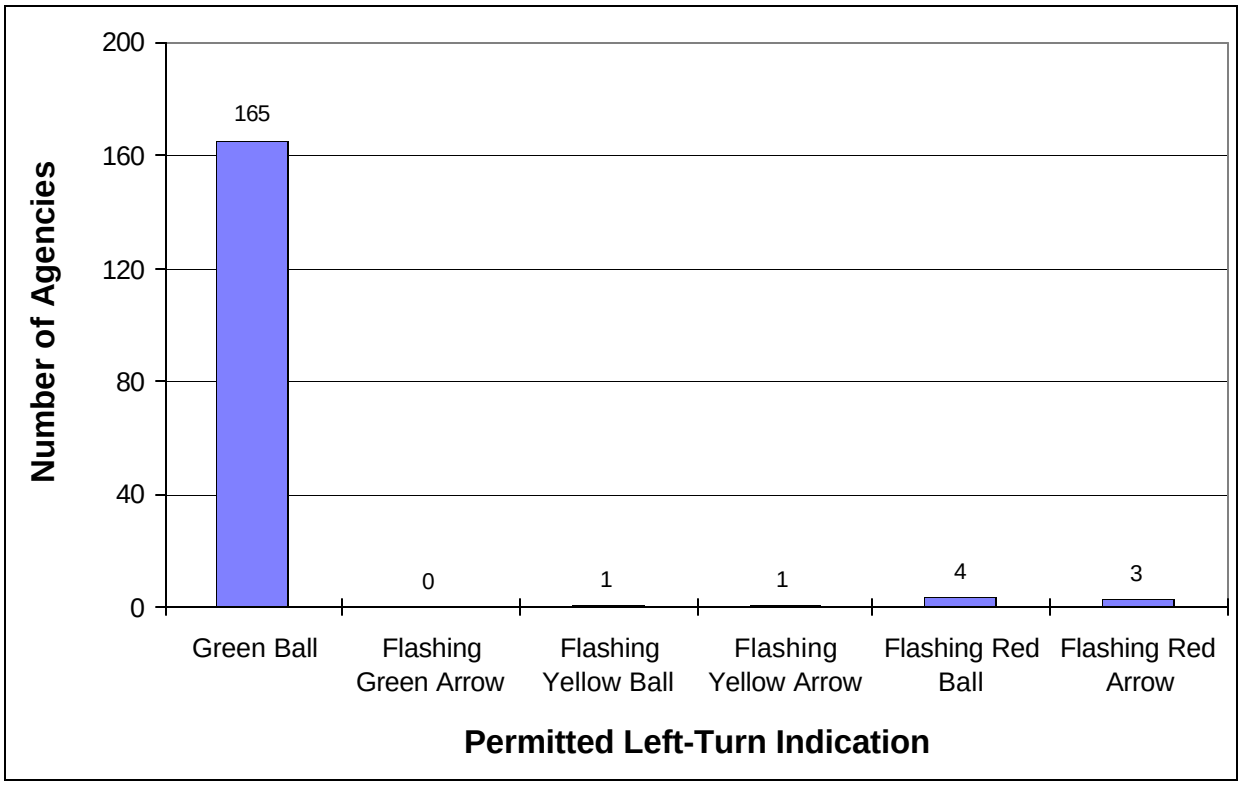


Figure 7. Type of Permitted Signal Indication Used With PPLT Signal Phasing.

The three agencies that do not use the green ball indication are Cupertino, California (flashing red arrow); Wayne County, Michigan (Flashing red ball); and Seattle, Washington (flashing yellow ball). A number of agencies use the green ball permitted indication as well as a unique permitted indication. Tucson, Arizona, uses the flashing yellow arrow. The flashing red ball is used by three agencies in the Detroit, Michigan area as well as Broward County, Florida. Along with Cupertino, California, the flashing red arrow is used in the Dover, Delaware, area and in Maryland. Figure 8 illustrates the geographical locations of the flashing permitted left-turn signal indications.

Figure 8. Geographic Location of Unique PPLT Permitted Indications.

Question 11. Question 11 asked agencies to indicate if they use supplemental signs with their PPLT signal displays and, if so, what supplemental sign message is used. As shown in Table 3, eighty-two agencies responded that supplemental signs are always used with PPLT signal phasing. Twenty-eight agencies indicated they never use supplemental signs. Fifty-two agencies indicated they use supplemental signs under certain conditions but not in all cases, and 7 agencies indicated that they use different supplemental signs for different conditions. Cupertino, California, responded twice, indicating that they always use supplemental signs and also use different signs for different conditions.

Table 3. Use of Supplemental Signs With PPLT Signal Displays.

Number of Agencies Responding	Use of Supplemental Signs			
	No	Always	Under Certain Conditions	Different Signs for Different Conditions
	28	82	52	7

Figure 9 illustrates the particular supplemental signs used by the responding agencies. Five percent use the PROTECTED LEFT ON GREEN ARROW sign (these agencies were all in Texas), 6.9 percent use the LEFT TURN SIGNAL sign, 3.8 percent use the LEFT TURN SIGNAL—YIELD ON GREEN (ball) sign, and 75.5 percent use the LEFT TURN YIELD ON GREEN (ball) sign. Alternative supplemental signs are used by 8.8 percent of the agencies.

Note that the MUTCD indicates that only the LEFT TURN YIELD ON GREEN (ball) sign (R10-12) should be used with PPLT signal phasing. Several agencies indicated that alternative supplemental signs are used. Table 4 lists *other* supplemental signs reported.

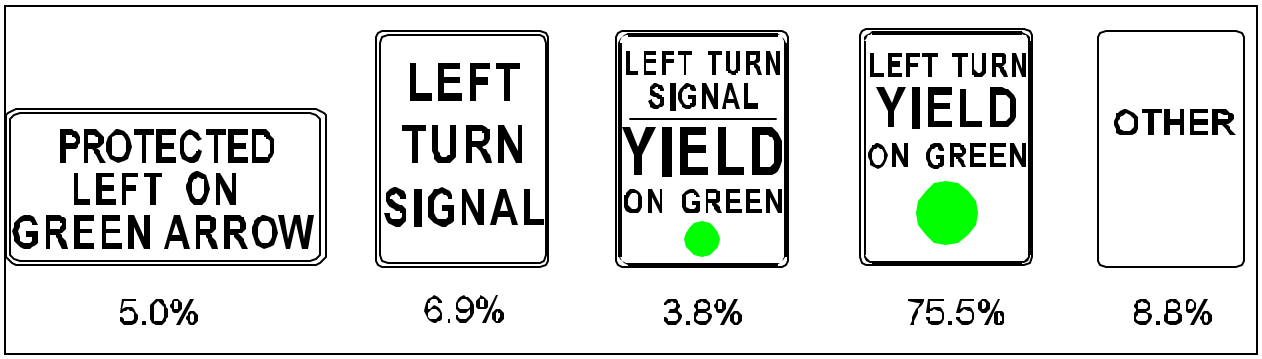


Figure 9. Supplemental Signs Used.

Table 4. Other Supplemental Signs.

Location	Supplemental Sign
Alaska	ONLY (green arrow) - YIELD ON (green ball)
Cupertino, CA	LEFT TURN YIELD ON FLASHING RED ARROW
Cupertino, CA	STOP THEN YIELD ON FLASHING RED ARROW
Monroe, LA	LEFT TURN PROTECTED ON ARROW ONLY
Maryland	LEFT TURN PERMITTED ON FLASHING RED AFTER STOP
Michigan	LEFT
Minnesota	LEFT TURN ON (green ball) MUST YIELD
Wyoming	YIELD ON GREEN BALL

Geometry and Phasing

The third section of the survey was concerned with identifying different intersection geometry and signal phasing techniques used by the agencies. This section consisted of five questions, numbered 12 through 16.

Question 12. This question inquired as to whether the agency does anything different or unique with PPLT signal phasing, mounting locations, mounting type, or signal display arrangements in wide median intersections or in narrow right-of-way intersections with no median.

Only 39 agencies indicated that they did something different with PPLT at wide median intersections, while 32 agencies indicated that they did something different at narrow right-of-way intersections. The responses are summarized in Figure 10. At wide median intersections, the most commonly reported difference was the addition of another PPLT signal display, either median or farside pole mounted. The addition of another PPLT signal display may also require the repositioning of the other signal displays at the intersection. The only other commonly cited difference at wide median intersections was the elimination of PPLT signal phasing. Fifteen agencies indicated that they would not use PPLT signal phasing at wide median intersections.

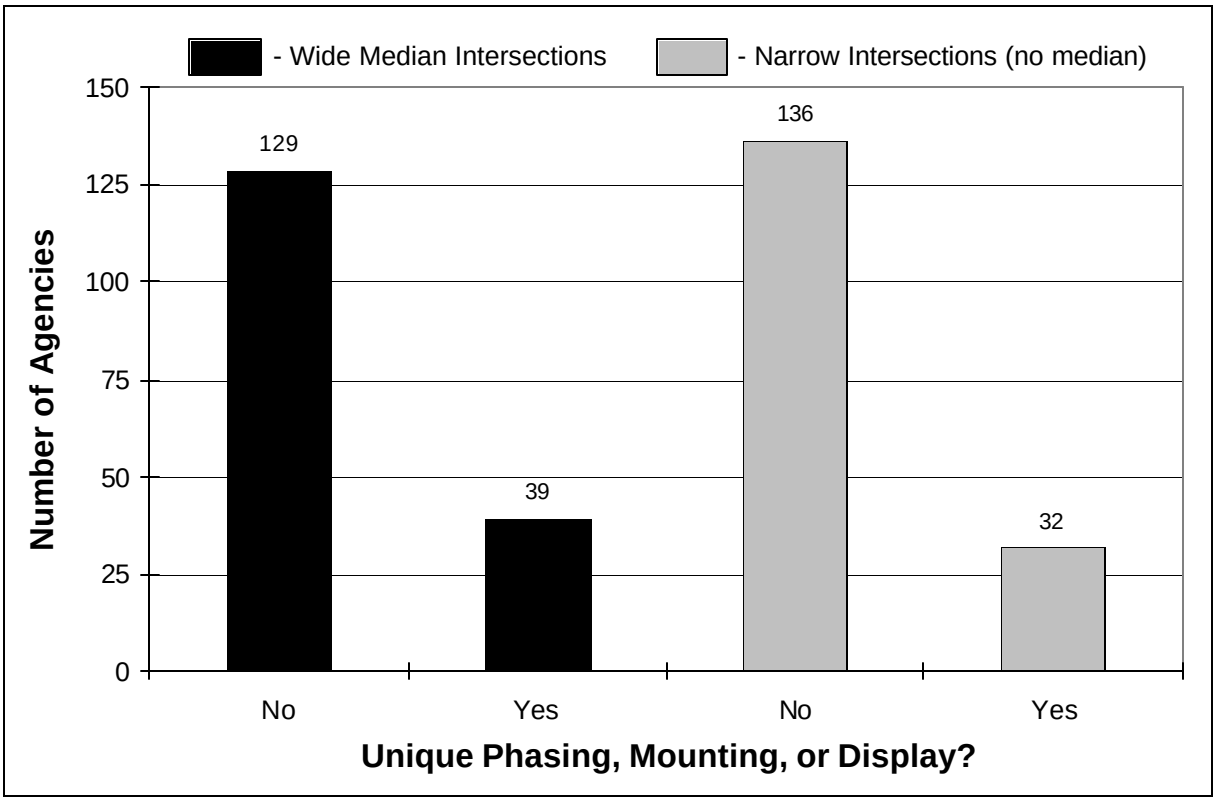


Figure 10. Use of Unique Phasing, Mounting, or Display Arrangements at Wide Median and Narrow Right-of-Way (No Median) Intersections.

Question 12 also inquired about the use of PPLT signal phasing at narrow intersections, or intersections with a narrow right-of-way. Nearly all agencies who responded to this question indicated that the PPLT signal phasing would not be used in this condition. Each agency indicated that split phasing would most likely be used if a narrow right-of-way exists. Two agencies indicated that the signal displays would be relocated to accommodate the narrow space and one agency indicated that Arlington phasing would be used in such a condition.

Question 13. Each agency was asked to indicate the percentage of shared, exclusive, and combination left-turn lanes in their jurisdiction. Pooling the responses, 89 percent of all left-turn lanes are exclusive, eight percent are shared, and three percent are a combination of exclusive and shared lanes. The states of Rhode Island, Pennsylvania, Maine, and Louisiana indicated that 50 percent or more of the left-turn lanes in their jurisdiction are shared. In contrast, 53 agencies indicated that 100 percent of the left-turn

lanes are exclusive. Phoenix, Arizona, and Shelby County, Tennessee, indicated that all left-turns lanes in their jurisdiction are combination left-turn lanes.

The agency was also asked to identify the percentage of PPLT signal phasing in their jurisdiction that use a leading, lagging, or lead/lag sequence. The results are presented in Figure 11. Combining the responses of the agencies, 83 percent of the PPLT signalized intersections use a leading left-turn sequence, 11 percent a lagging sequence, and 6 percent a lead/lag sequence.

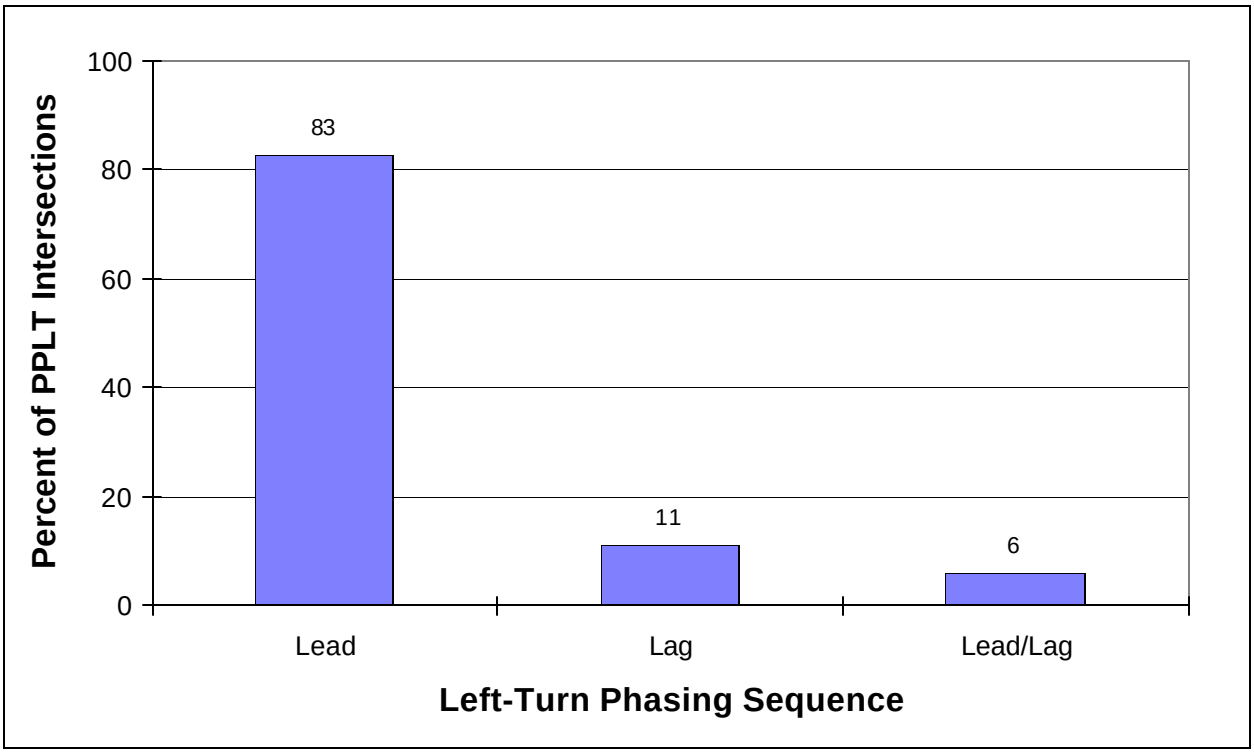


Figure 11. Left-Turn Phasing Sequence Used With PPLT.

Question 14. Question 14 addressed the yellow trap problem. Agencies were asked to identify what, if any, special phasing or techniques to avoid yellow traps. Fifty-seven percent of the surveyed agencies indicated that they did not use any special phasing or techniques to avoid yellow traps. Eight agencies indicated that they used either Dallas or Arlington phasing, 30 agencies indicated that they use exclusive

left lead with PPLT lag, and 42 agencies indicated that they used some other method. Almost all of the other methods were the inclusion of an anti-backup device in the controller that forced the service of a side street before returning to service a left-turn call. The responses to the special phasing technique question are summarized in Figure 12.

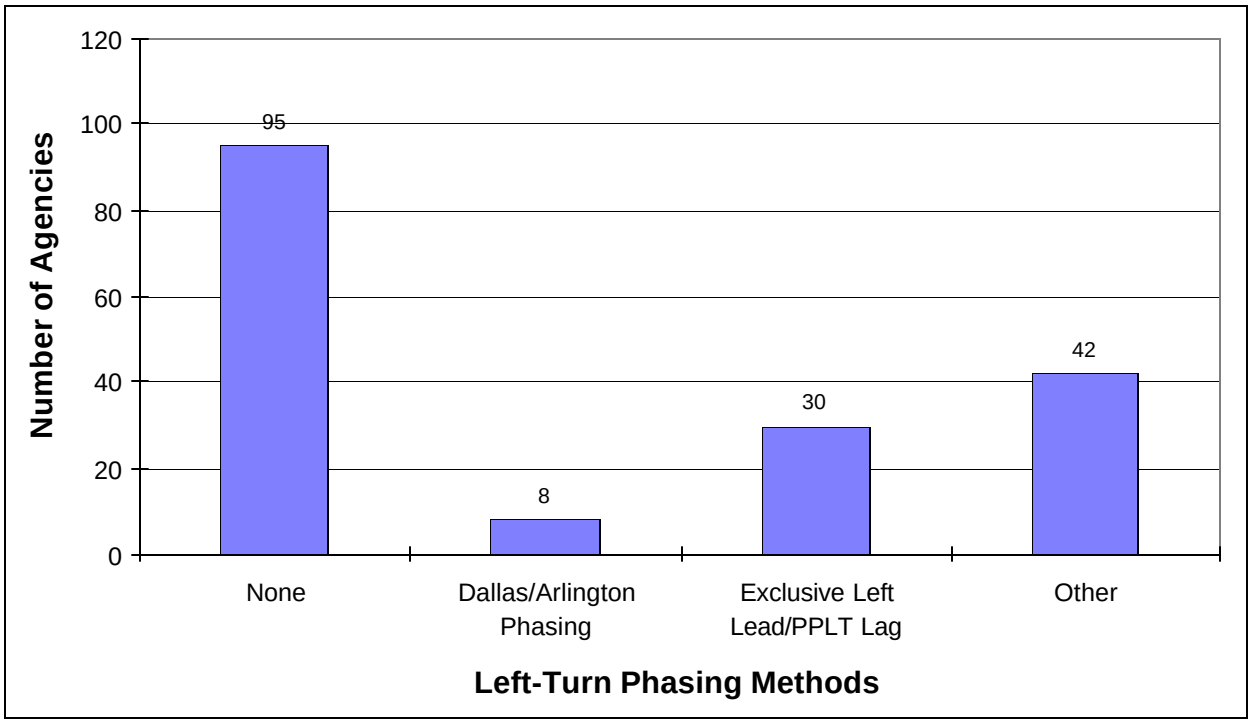


Figure 12. Special Phasing or Techniques Used to Avoid the Yellow Trap.

Question 15. The final question in the survey inquired as to whether any laws or ordinances within each jurisdiction affect the use of PPLT signal phasing or mandate a specific signal display or signal indication. Only 12 of the responding agencies indicated that there was a law or ordinance that required certain practices in the use of PPLT signal phasing. All of these agencies referred to state statutes or local ordinances that require either specific display types, display indications, or compliance with state manuals. The city of Milwaukee, Wisconsin, was unique because there is an ordinance that prevents the traffic engineer from using PPLT in dual left-turn lane situations and also prevents the use of phasing sequences that can produce the yellow trap.

SUMMARY OF AGENCY SURVEY

The survey responses received from the 168 U.S. state agencies were consolidated into the following summary statements:

- Approximately one-fourth of all signalized intersection in the U.S. include PPLT signal phasing;
- The five-section cluster display is most often used as the primary signal display for PPLT applications;
- There is little agreement as to the best location for mounting overhead PPLT signal displays: 52 percent of agencies mount the PPLT display between the left-turn lane and through lane, 40 percent center the display on the left-turn lane, and 7 percent do something different; and
- There is little agreement as to the benefit or detriment of using the PPLT signal display as one of the two required through signal displays. Twenty-three percent of agencies do not use the PPLT signal display as a through display, 37 percent do, and 40 percent vary depending on the conditions at the intersection.

The MUTCD green ball permitted indication is used predominantly except at the seven geographical locations identified previously. There is no consistency in the use of supplemental signs: 17 percent of agencies do not use signs, 49 percent always use signs, and 34 percent use signs only in certain conditions. When signs are used, the MUTCD R10-12 signs is used more than 75 percent of the time; however, a large number of other supplemental signs are also used, some of which may not be appropriate for PPLT applications.

The majority (89 percent) of left-turn lanes at signalized intersection are exclusive. Eighty-three percent of all PPLT intersections use a leading left-turn phase sequence, while only six percent use a lead/lag sequence. Fifty-seven percent of all agencies do nothing to prevent the yellow trap. Thirty of these agencies use lead/lag left-turn signal phasing. Finally, there is little legal control over the use of PPLT signal phasing. Many states allow the local traffic engineer to select signal displays, display arrangement, signal phasing, and display placement based on his or her personal preference.

REFERENCES

1. Grover, Albert L., and John A. Taylor. *Protected/Permissive Left Turn Phasing - An Overview*. Albert Grover & Associates, 1994.

2. McCourt, R.S. Traffic Signal Maintenance and Design Survey. DKS Associates, Portland, Oregon, 1996.

APPENDIX A

AGENCY SURVEY

EVALUATION OF TRAFFIC SIGNAL DISPLAYS FOR PROTECTED/PERMITTED LEFT-TURN CONTROL

Dear Traffic Engineer:

The National Cooperative Highway Research Program (NCHRP) is sponsoring a research study with the primary objective of developing a uniform traffic signal display(s) for protected/permitted left-turn (PPLT) control. PPLT phasing provides a protected phase for left-turns and a permitted phase during which left-turns can be made if gaps in the opposing traffic stream allow. Many agencies have implemented PPLT phasing because of its demonstrated benefits in reducing delay and increasing capacity for left-turn operations.

PPLT signal displays have been implemented in a variety of ways in different geographical regions. The National Committee on Uniform Traffic Control Devices is concerned that the variety of PPLT displays and indications may be confusing to drivers. Additionally, the phasing used with some varieties of PPLT signal phasing may lead to a condition commonly referred to as the yellow trap. The yellow trap occurs when a signal changes from the permissive left-turn in both directions to the lagging exclusive left-turn in only one direction. The driver attempting to turn left on the permissive green ball sees the change to a yellow ball and thinks the opposing through traffic is also seeing a change to yellow and therefore will stop, when in fact, the opposing through traffic continues to see a green ball. The left-turn driver becomes *trapped* in the intersection. Because of the variability in signal displays and controller phasing currently in use, there is a need for research to evaluate the safety and driver confusion problem associated with PPLT control.

To begin this research study, we need your help. Please take a few minutes to complete this survey. Provide written or numerical responses in the space provided or check the appropriate box(es). *In each question, check ALL boxes that apply*. Please attach additional pages for responses, comments, or suggestions if needed. If you do not have precise quantities that are requested by some questions, please give you best "estimate."

YOUR RESPONSE IS ESSENTIAL TO THE SUCCESS OF THIS VERY IMPORTANT STUDY.

Please FAX the completed survey *using this page as your transmittal cover* by June 1, 1998.

FAX TRANSMITTAL	
PLEASE DELIVER TO:	**From:**
David A. Noyce Texas Transportation Institute **Texas A&M University** **College, Station, TX 77843**	**Message: NCHRP 3-54 PPLT Survey**
FAX NUMBER: (409) 845-6481	**THIS IS PAGE ONE OF A ____ PAGE FAX**

PPLT SURVEY

RESPONDENT

Name:_____ **Title:**_____

Organization:_____ **Telephone:**_____

Address:_____

City:_____ **State:**_____ **Zip Code:**_____

I. GENERAL INFORMATION

1. How many signalized intersections are currently operated and maintained by your jurisdiction?_____

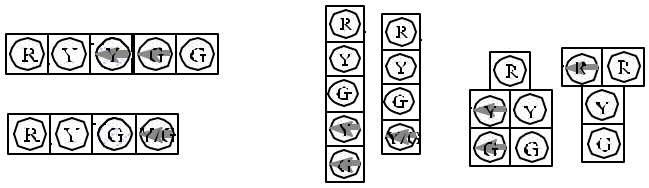
2. How many signalized intersections with PPLT phasing are currently operated and maintained by your jurisdiction? _____
   (If your answer to Question 2 is 0, please explain why you do not use PPLT and go to question 15)

II. PPLT SIGNAL DISPLAYS

3. Of the total number of PPLT signalized intersections reported in question 2, how many of the PPLT signalized intersections contain the following left-turn signal display arrangements:

   5-Section Horizontal? _____
   5-Section Vertical? _____
   5-Section Cluster? _____
   4-Section Horizontal? _____
   4-Section Vertical? _____
   4-Section Cluster? _____
   3-Section Vertical? _____
   Other (*please specify*) _____

   Left-turn signal display example arrangements:



   Horizontal *Vertical* *Cluster*

4. If you identified multiple signal display arrangements in Question 3, are there geometric conditions, phasing types, or other factors that your agency uses as criteria for selecting one PPLT signal display arrangement over another?

   ❒ NO
   ❒ YES (*please explain*) _____
   _____

5. Do you use Green and Yellow (bi-modal) arrow indications in the same section of a PPLT signal display in one or more PPLT intersections in your jurisdiction?

   ❒ NO
   ❒ YES ⇒ If YES, how many? _____

6. What type of PPLT signal display arrangements do you use with the following mounting types: *(check all that apply)*

Mast Arm	Pole	Span Wire
❒ Horizontal	❒ Horizontal	❒ Horizontal
❒ Vertical	❒ Vertical	❒ Vertical
❒ Cluster	❒ Cluster	❒ Cluster
❒ Other_____	❒ Other_____	❒ Other_____

7. When using Mast Arm or Span Wire mounts, the primary PPLT signal display(s) is mounted:

   ❒ Centered on the left-turn lane(s)
   ❒ Between the left-turn lane(s) and adjacent through lane(s)
   ❒ Other (*please specify*)_____

8. If a secondary PPLT signal display(s) is used, where is it mounted? (*check all that apply*)

   ❒ Near side pole mount
   ❒ Median pole mount
   ❒ Far side pole mount
   ❒ Other (*please specify*)_____

9. Do you use the PPLT signal display as one of the two required signal displays for through traffic?

   ❒ NEVER
   ❒ ALWAYS
   ❒ SOMETIMES (*please explain*) _____

10. What type of signal indication is used for the permitted phase of PPLT? (*check all that apply*)

    ❒ Circular Green (non-flashing)
    ❒ Green Arrow (flashing)
    ❒ Circular Yellow (flashing)
    ❒ Yellow Arrow (flashing)
    ❒ Circular Red (flashing)
    ❒ Red Arrow (flashing)

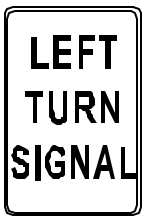
    Other (*please specify*)_____

11. Do you use supplemental signs with your PPLT signal displays?

❒ NO

❒ YES ⇒ ❒ Sign is always used
⇓ ❒ Sign is used under certain conditions
⇓ ❒ Use different signs for different conditions
⇓

If YES, please circle the type(s) of supplemental sign(s) used. *(If your sign is not shown, please sketch)*



R10-10

{R10-10 / R10-12}

R10-12

_____

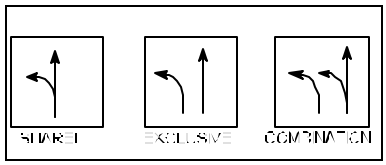
(Sketch)

III. GEOMETRY AND PHASING

12. Does your jurisdiction do anything different or unique with PPLT signal phasing, mounting location, mounting type, or signal display arrangement in the following conditions:

Condition	NO	YES *(Please Explain)*	
Wide Median Intersections *(Median separates the left-turn lane from the adjacent through lanes and/or medians wider than 18 feet)*	❒	❒ - Arrangement	_____
		❒ - Mounting Type	_____
		❒ - Mounting Location	_____
		❒ - Signal Phasing	_____
Narrow Intersections/ Narrow Right-of Way *(No median and shared* through/left-turn lanes)	❒	❒ - Arrangement	_____
		❒ - Mounting Type	_____
		❒ - Mounting Location	_____
		❒ - Signal Phasing	_____
Other (*describe condition*) _____ _____ _____	❒	❒ - _____	_____
		❒ - _____	_____

13. What percentage of PPLT usage in your jurisdiction are used with the following left-turn lane and phasing types:



Left-Turn Lane Type

Shared Lane	_____
Exclusive Lane	_____
Combination	_____
Other _____	_____
TOTAL	**100%**

Phasing Sequence of Intersection

Leading Lefts	_____
Lagging Lefts	_____
Lead/Lag	_____
Other _____	_____
TOTAL	**100%**

14. Do you use *special* phasing or techniques to avoid the yellow trap problem?

- ❒ NO
- ❒ YES - *Dallas/Arlington* Phasing
- ❒ YES - Exclusive left lead/PPLT lag
- ❒ YES - Other (*please specify*) _____

15. Are there laws/ordinances within your jurisdiction that effect the usage of PPLT phasing or mandate the signal indications shown with the protected or permitted phase?

- ❒ NO
- ❒ YES *(please explain)* _____
  _____
  _____

16. Would you be willing to work with the research team in identifying appropriate PPLT intersections/signal heads in your area for further study and analysis?

- ❒ NO
- ❒ YES *(Please see "Request for Information and Assistance" page)*

END OF SURVEY
THANK YOU FOR COMPLETING AND RETURNING THIS SURVEY!

APPENDIX B
AGENCY SURVEY
RESPONDING TRANSPORTATION AGENCIES

State	Organization	State	Organization	State	Organization	State	Organization
AK	City-Anchorage	IL	Lake County	NC	City-Charlotte		TxDOT-Austin
	DOT-Juneau		City-Peoria		DOT-Raleigh		TxDOT-Corp. Christi
AL	City-Montgomery		DOT-Carbondale		City-Greensboro		TxDOT-Paris
AR	City-Little Rock		DOT-Ottawa	ND	DOT-Bismarck		City-Houston
AZ	Pima County		DOT-Collinsville		City-Fargo		TxDOT-Wichita Falls
	City-Scottsdale		DOT-Effingham	NE	City-Omaha		Harris County
	City-Tucson		DOT-Peoria		DOT-Lincoln		TxDOT-Waco
	City-Mesa	IN	City-Indianapolis	NH	DOT-Concord		TxDOT-Houston
	City-Phoenix		City-Kokomo	NJ	DOT-Trenton		City-Garland
	City-Glendale		DOT-Indianapolis	NM	City-Albuquerque		TxDOT-Dallas
CA	City-Modesto		DOT-Boise	NV	City-Henderson		TxDOT-Lufkin
	City-Lancaster	IL	Lake County		City-Reno		TxDOT-Fort Worth
	City-San Francisco		City-Peoria		City-Las Vegas		TxDOT-Beaumont
	City-Los Angeles		DOT-Carbondale		Clark Country		TxDOT-Atlanta
	City-Stockton		DOT-Ottawa	NY	Monroe County		TxDOT-Tyler
	City-San Bernardino		DOT-Collinsville		DOT-Hauppauge		City-Amarillo
	City-San Jose		DOT-Effingham		DOT-Binghampton		City-Austin
	County-LA		DOT-Peoria		DOT-Watertown		City-Dallas
	City-Palm Springs	IN	City-Indianapolis		DOT-Hornell		City-Arlington
	City-Cupertino		City-Kokomo		DOT-Hamburg		City-Grand Prairie
	City-San Diego		DOT-Indianapolis		DOT-Pittsford	UT	City-Salt Lake City
	DOT-Santa Ana	KS	City-Overland Park		DOT-Syracuse		DOT-Salt Lake City
CO	City-Boulder		DOT-Topeka		DOT-Utica	VA	City-Norfolk
	City-Pueblo		City Topeka		DOT-Albany		DOT-Staunton
CT	DOT-Newington	KY	DOT-Frankfort	OH	Hamilton County		DOT-Bristol
DE	DOT-Dover	LA	City-Baton Rouge		City-Columbus		Arlington County
FL	Dade County		DOT-Baton Rouge		City-Dayton		DOT-Fredricksburg
	Marion County		City-Shrevport		DOT-Columbus		DOT-Lynchburg
	Orange County		City-Monroe	OK	City-Tulsa		DOT-Richmond
	City-Punta Gorda	MA	City-Sommerville	OR	DOT(2) - Salem		DOT-Fairfax
	City-Boca Raton		DOT-Boston		City-Portland		DOT-Culpepper
	City-Tallahassee	MD	Anne Arundel Co.		City-Eugene	VT	City-Burlington
	Broward County		DOT-Hanover		DOT-Salem	WA	Clark County
	City-Jacksonville	ME	DOT-Augusta	PA	City-Allentown		City-Tacoma
	DOT-Tampa	MI	Wayne County		DOT-Harrisburg		Pierce County
	Palm Beach County		City-Jackson	RI	RIDOT - Providence		City-Seattle
GA	Cobb County		Oakland County	SC	City-Greenville		DOT-Seattle
	DOT-Atlanta		DOT-Lansing	SD	City-Sioux Falls		DOT-Olympia
	Qwinnett County	MN	Ramsey County		DOT-Pierre	WI	DOT-Madison
HI	Hawaii County		City-Minneapolis	TN	Shelby County		City-Milwaukee
IA	DOT - Ames		DOT-Roseville		Knoxville		City-Madison
	City-Cedar Rapids	MO	DOT - Jefferson City		City-Nashville	WV	DOT-Charleston
ID	Ada County		City-Kansas City	TX	Richardson	WY	DOT-Basin
	DOT-Boise	MS	DOT - Jackson		TxDOT-Pharr		DOT-Cheyenne
		MT	City-Helena		TxDOT-Amarillo		City-Cheyenne