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16. Abstract Project

This report presents results of research conducted to determine appropriate design recommendations (length, spacing) of enforcement pullout areas within work zones. A review of existing geometric design standards, field studies of motorist behavior after being stopped for enforcement activities, and survey techniques were all used to develop the recommendations. Based on the results of the analyses, Texas Transportation Institute researchers recommend that, when used, enforcement pullout areas in work zones be at least 0.25 miles long. It is also recommended that these areas be spaced approximately 2 to 3 miles apart in long work zones where no shoulders or other locations for vehicles to be pulled over will be available. At the same time, these spacing guidelines suggest that work zones 3 to 3.5 miles or less will not need an enforcement pullout area, provided there is adequate space immediately beyond the work zone for vehicles to be pulled over and issued citations.

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FEASIBILITY AND DESIGN OF ENFORCEMENT PULLOUT AREAS FOR WORK ZONES

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ACKNOWLEDGMENTS

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1. INTRODUCTION

Law enforcement presence in work zones has long been recognized as one of the most effective speed reduction methods available to transportation officials (*1,2,3*). Unfortunately, high labor costs, manpower shortages, and the many demands placed on law enforcement make universal enforcement presence at all work zones impossible. Further complicating the problem is the fact that the design of many work zones makes effective enforcement difficult, if not impossible to achieve (*4*). Long work zones that have no emergency shoulders on either side of the roadway are especially problematic. In these situations, officers have no place to position their vehicles to monitor traffic. More importantly, these types of work zones do not offer a place for enforcement personnel to pull over violators to issue a citation. Consequently, officers attempting to stop a violator are forced to follow the violator completely through the work zone before activating their emergency lights and pulling the violator over, or activating their lights within the work zone and risk the chance that the motorist will then stop in the moving lane of traffic.

Previous research (*5*) indicates that some jurisdictions have included enforcement pullout areas within the overall design of their work zones. Enforcement pullout areas strategically placed throughout a work zone could allow enforcement officers to be more effective and operate more safely. An example of an enforcement pullout area is shown in Figure 1.

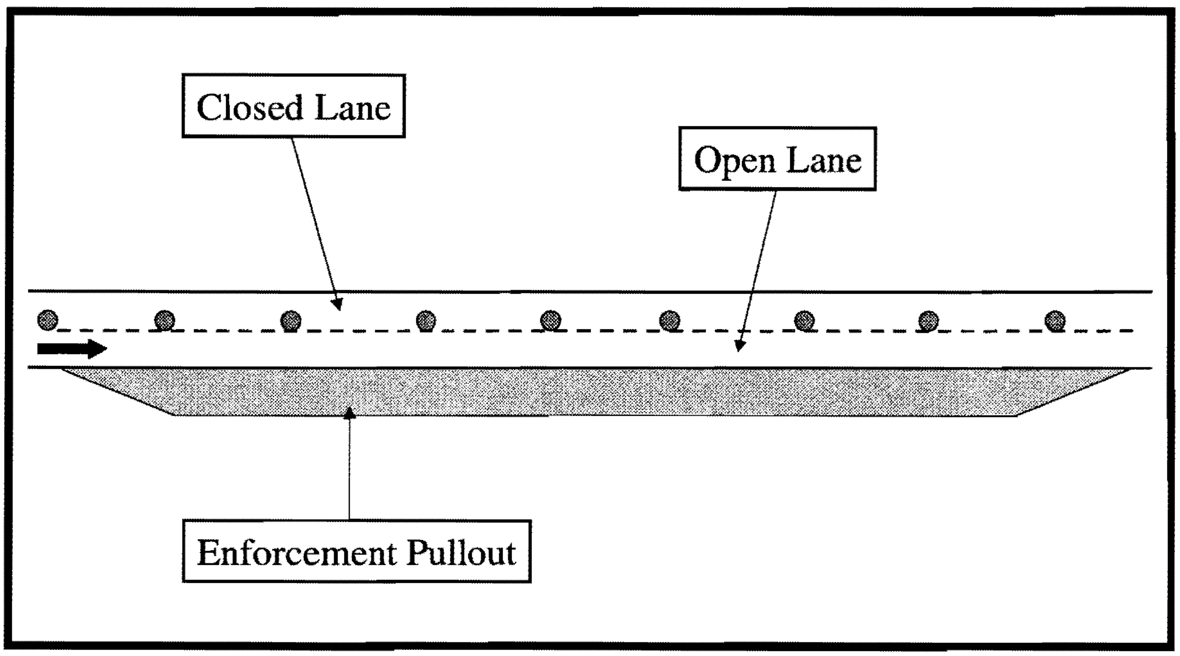

Figure 1. Basic Enforcement Pullout Configuration.

According to enforcement personnel using these areas, work zone enforcement opportunities are improved by having these areas available. However, because these areas have not seen widespread implementation within Texas or elsewhere in the U.S., there are important unanswered questions about how such enforcement areas should be designed and incorporated into construction phasing and traffic control plans.

KEY ENFORCEMENT PULLOUT AREA ISSUES

From the perspective of enforcement, it would be advantageous to always maintain full emergency shoulders on at least one side of a roadway that could be used to stop violators and issue citations. If this were possible within work zones, there would be no need for enforcement pullout areas at all. Of course, the reason that shoulders are often eliminated within work zones in the first place is that roadway space is often severely limited, and planners are forced to decide how to best allocate this space between the traffic that desires to use that roadway and the personnel and equipment required to do the roadway work. Intuitively, construction efficiency is at its highest if the maximum amount of space is allocated to the work activity and maintained throughout the work zone over the duration of the project.

Given these competing perspectives, the question that must be answered is how to best incorporate periodic enforcement areas into a work zone so to effectively support enforcement activities while at the same time not unduly penalizing the efficiency of roadwork activities. Conceptually, a spacing guideline based on maximizing a benefit-cost ratio (i.e., the incremental safety benefits derived from improved enforcement divided by the additional cost of incorporating these areas into the project) would probably be the most desirable approach. Unfortunately, no data exist upon which to base estimates of pullout area benefits (although such benefits are believed to indeed exist). At the same time, actual absolute costs to contractors and the transportation agency for incorporating pullout areas into a roadwork project depend significantly on site characteristics and cannot be assessed by a generic approach with any significant accuracy. Without accurate data on either benefits or costs, any quantitative analysis would be difficult to validate or defend.

An alternative to the benefit-cost approach is to try and **qualitatively assess the relationship between the two perspectives** (construction and enforcement) affected by the incorporation of enforcement pullout areas in roadwork activities. If the relative attractiveness or difficulty of accomplishing both the roadwork and the enforcement activities in a work zone can be ascertained as a function of the distance between enforcement pullout areas, these qualitative estimates could then be used as a basis for recommending spacings and other design features of the pullout areas. This is the approach that has been taken by researchers at the Texas Transportation Institute (TTI).

CONTENTS OF THIS REPORT

This report documents the results of the analysis and subsequent recommendations regarding the incorporation of enforcement pullout areas into highway work zone projects. Two key issues have been investigated:

- What is the appropriate length of an enforcement pullout area within a highway work zone?
- What is the "best" spacing between enforcement pullout areas? (This could also be used to determine the maximum work zone length where pullout areas would not be needed.)

The length required for a safe enforcement pullout area was examined through a review of standard engineering design for shoulders and ramps and through field studies to determine how drivers actually reenter the traffic stream after being stopped by a police officer.
In order to establish the spacing between enforcement pullout areas, researchers utilized a Delphi study of law enforcement personnel and construction contractors. The purpose of this study was to assess the relative difficulties of incorporating and using enforcement areas at various spacings in a hypothetical long work zone where no shoulders or other locations for enforcement would otherwise exist. It was expected that law enforcement officers would prefer close spacings between enforcement pullout areas in order to maximize the effectiveness of law enforcement. It was also expected that highway construction contractors would be reluctant to incorporate, construct, and maintain a large number of enforcement pullout areas within an overall project, as this could increase work zone construction complexity and could hamper scheduling. The impact of these areas upon the overall cost of construction was also expected to be a key consideration of the contractors.

2. APPROPRIATE LENGTHS OF WORK ZONE ENFORCEMENT PULLOUT AREAS

The required distance for an enforcement pullout area should depend on the acceleration and deceleration rates of the vehicles that will be moving in and out of it. For this project, the researchers assumed that passenger vehicles would be the predominant type of vehicle stopped in the enforcement pullout areas. If large trucks were expected to be a significant focus of enforcement activity within the work zone, larger areas would need to be considered. Researchers examined literature regarding driver acceleration and deceleration behavior for insights into appropriate values to use for enforcement pullout design. Researchers then conducted a series of studies to examine how motorists who have been stopped and issued citations actually behave when reentering the traffic stream as an indication of how work zone enforcement pullout areas would likely be used in actual practice.

DRIVER ACCELERATION/DECELERATION LITERATURE

Chapter Two of the American Association of State Highway and Transportation Official's (AASHTO) *A Policy on Geometric Design of Highways and Streets* (commonly known as the *Green Book*) provides a series of curves describing deceleration distances for passenger vehicles approaching intersections (Figure II-17) (6). In the National Cooperative Highway Research Program (NCHRP) Report 400, Fambro, Fitzpatrick, and Koppa analyzed this figure and created a table of values for 30- and 60-mph speeds (*7*). The deceleration rates calculated in NCHRP Report 400 have been reproduced as Table 1. In addition, Figure II-16 in the *Green Book* was reviewed to determine acceleration rates for passenger cars. Table 1 shows acceleration and deceleration rates for 30- and 60-mph speeds. Note that these values represent empirical estimates of normal driving maneuvers, and do not represent the maximum or minimum performance values of vehicles. Appendix A contains additional background information concerning these data.

Table 1. Acceleration and Deceleration Rates for Passenger Cars at Intersections.

Type of Deceleration/ Acceleration	Speed (mph)	Distance Traveled (ft)	Acceleration (ft/sec^2)
Comfortable Deceleration	60 30	475 180	-8.13 -5.37
Comfortable Acceleration	60 30	1300 220	2.97 4.4

Meanwhile, Chapter Ten of the *Green Book* provides information on desired acceleration and deceleration distances for highway entrance ramps and exit ramps. The *Green Book* provides a recommended distance for bringing a vehicle to a stop from 60 mph (88 ft/sec) of 530 ft on an exit ramp. The recommended entrance ramp distance for allowing a stopped vehicle to accelerate to 50 mph (73.3 ft/sec) is 1170 ft. Tables 2 and 3 provide other deceleration and acceleration distances for different operating speeds.

Table 2. Minimum Deceleration Lengths For Exit Terminals.

Highway Design Speed, (mph)	Deceleration Length, (ft) to Achieve Stop Condition
30	235
40	315
50	435
60	530
65	570
70	615

(Taken From Table X-6, *Green Book*)

Table 3. Minimum Acceleration Lengths For Entrance Terminals.

Highway Design Speed, (mph)	Acceleration Length, (ft) for Entrance from Stop Condition
30	190
40	380
50	760
60	1170
70	1590

(Taken From Table X-4, *Green Book*)

The *Green Book* makes the assumption that an accelerating vehicle need only accelerate to within 10 mph of the speed of the traffic stream in order to merge. Note that these values correspond closely with the distance values for intersection operations as shown in Table 1. Assuming that all deceleration and acceleration activity was to be accommodated within an enforcement pullout area, a total pullout area length of 530 + 1170 = 1700 ft (≈ 1/3 mi) would be desired for a 60-mph work zone, not including any beginning or ending tapers.

With the above value established as an ideal or optimum, TTI researchers next turned their attention to the implications of providing pullout areas shorter than this ideal length. Oftentimes, roadway space restrictions make it necessary for construction planners to adopt temporary designs that are less than ideal (narrower lanes, shorter acceleration lanes at entrance ramps, etc.). Reviewing the above values, one notes that the majority of the recommended pullout length is to allow vehicles in the enforcement pullout area to accelerate up to (nearly) normal travel speeds before reentering the traffic stream. This assumes that motorists pulled over and issued a citation will, when ready to depart, utilize the shoulder area and accelerate up to a normal traveling speed prior to merging with freeway traffic.

A review of available literature failed to uncover any data to support this assumption of behavior following the issuance of a citation. Indeed, it was hypothesized that motorists were more predisposed to move back into the traffic stream as quickly as possible and would not tend to use the shoulder as an acceleration lane. Consequently, the impact of shortening a pullout area and requiring motorists to reenter the travel lanes before reaching a desired merging speed may not be much different than normal driving behavior. To verify this hypothesis, TTI researchers conducted a series of ride-along studies with law enforcement officers in both urban and rural locations in Texas. The following section presents the results of those studies.

DRIVER BEHAVIOR FOLLOWING ENFORCEMENT ACTIVITY

Project Methodology

TTI researchers rode along with sheriff's deputies from Harris County, Texas, on June 18 and August 14, 2001, and with deputies from Midland County, Texas, on June 20 and 21, 2001. Researchers rode in the front passenger seat of the sheriff's patrol car and used Pro Laser III LIDAR guns to determine the distance traveled by a driver after being released from a traffic stop. Distance traveled was measured from the law enforcement vehicle to the point where the driver of the stopped vehicle placed all four tires of his/her vehicle in the traveled lane. In Harris County, all data were collected on urban freeways with posted speed limits of 55 mph or higher. In Midland County, some data were collected on Interstate 20 (speed limit of 70 mph), and some were collected on 2- and 4-lane rural highways (speed limits of 55 to 70 mph). All data collected in Midland County were collected during daylight. In Harris County, the data collected on June 18 were collected in daytime, and the data collected on August 14 were collected at night. All data were collected at off-peak times and locations. For Harris County data, congested areas were avoided by the officers, as a patrol vehicle on the shoulder could be detrimental to the overall safety. Researchers collected driver behavior data at a total of 85 traffic stops.

Project Results

A histogram of all data is shown in Figure 2. A comparison of means test was performed to determine if there was a statistically significant difference between the daytime urban Harris County data and the rural Midland County data. No significant difference was detected at a 0.05 level of significance. A second comparison of means test was then conducted between the daytime and nighttime data from Harris County to determine if there was a significant difference in driving behavior under these conditions. Once again, no significant difference was detected at a 0.05 level of significance. The calculations for these tests are located in Appendix B.

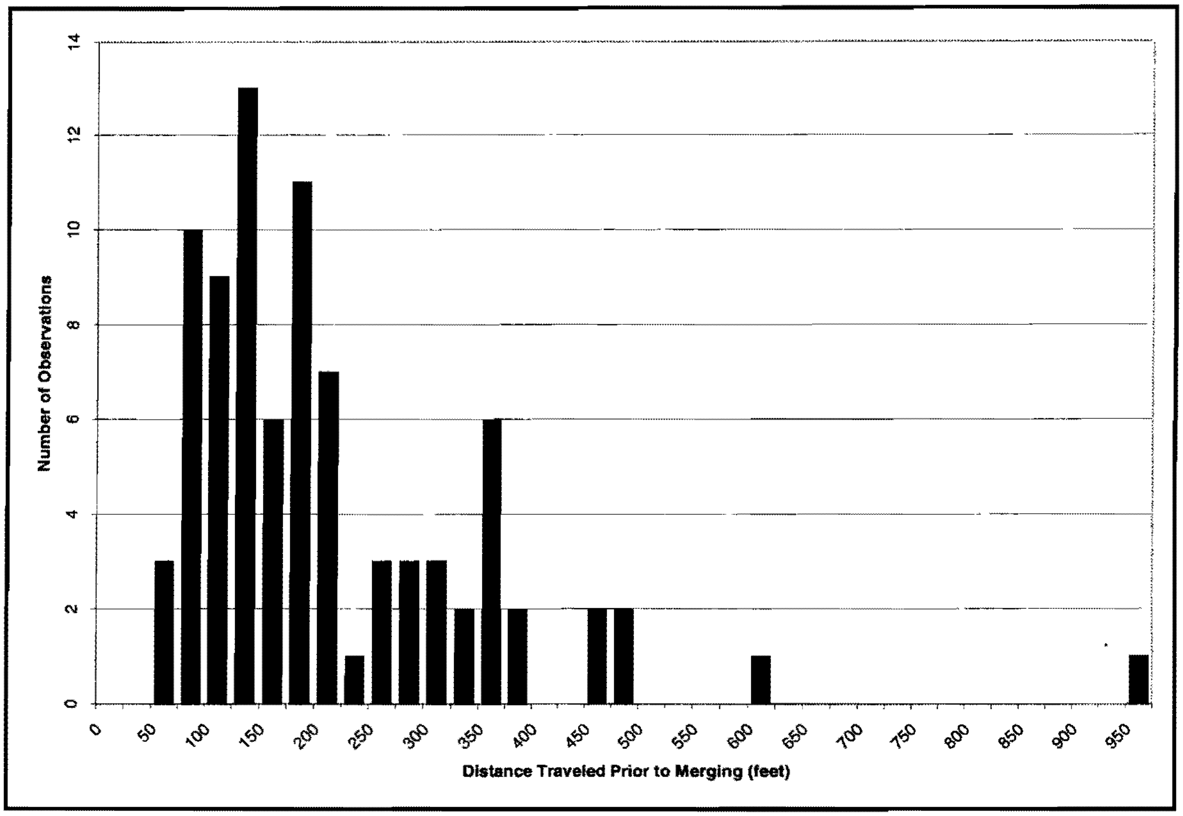

Figure 2. Histogram of Distance Traveled Prior to Merging After Traffic Stop.

Because no significant differences were found in the data as a function of time of day or type of adjacent land use, all the data points were combined to determine the median, 85th percentile, 90th percentile, and 95th percentile distances drivers traveled prior to merging back into the traveled lane. These values are shown in Table 4.

Table 4. Distances Traveled Prior to Merging.

Distribution Value	Distance (feet)
Median (50th percentile)	179
85th percentile	355
90th percentile	371
95th percentile	460

These values indicate that drivers tended to merge back into the traveled lanes after a traffic stop much earlier than estimates based on values taken from the *Green Book*. The primary reason for the difference was the fact that drivers observed in this study were willing to merge back into the traffic lane at much lower speeds than assumed in the calculations above. These values are noted in Table 5. However, assumptions regarding comfortable acceleration rates used by drivers do appear to be valid for use in enforcement area operations. As noted in Table 6, the median acceleration rate observed during this ride-along study was 3.37 ft/sec^2, which is within the range of typical acceleration rates for acceleration from a stop condition at an intersection. There was no significant difference, at the $\alpha = 0.05$ level, in reentry speeds based on the posted speed limit.

Table 5. Speeds of Vehicles at the Point of Reentering the Traveled Lane.

Distribution Value	Speed (mph)
15th Percentile	16
Median (50th)	24
85th	35
90th	37
95th	39

Table 6. Acceleration Rate Distribution Statistics of Sampled Vehicles.

Distribution Value	Acceleration Rate (ft/sec^2)
15th Percentile	2.05
Median (50th)	3.37
85th	4.95
90th	5.14
95th	5.38

It is important to acknowledge that the data were collected at times and locations when traffic volumes did not significantly hinder the ability of stopped drivers to find a gap to enter the traffic stream. Data collection personnel noted that even in Houston, where traffic volumes were fairly high, many vehicles moved out of the shoulder lane as they approached the enforcement vehicle, which offered the stopped vehicle more of a chance to find a gap in that shoulder lane and return to the traffic stream. Intuitively, higher volume conditions may eventually create a condition where stopped motorists will have difficulty merging back into traffic and may increase their travel distance on the shoulder prior to reentry. On the other hand, traffic volumes of this magnitude themselves tend to regulate traffic speeds, often to the point that enforcement activity is not required at all (some jurisdictions actually restrict enforcement activities during periods of high traffic volumes so as to not create unnecessary disturbances in the traffic stream).

ENFORCEMENT PULLOUT AREA LENGTH RECOMMENDATIONS

The above concerns notwithstanding, the data in Table 4 implies that an acceleration area as short as 500 ft long still be able to accommodate more than 95 percent of drivers who try to reenter the traffic stream following a traffic citation stop. Coupled with the required deceleration length of 530 ft previously discussed, this implies that an enforcement pullout area length of 1030 ft would be the absolute minimum necessary, significantly less than the ideal or optimum length of 1700 ft. Certainly, values closer to the optimum would be desirable whenever practical, as it would afford motorists some margin for error. As a basis of comparison, guidelines for enforcement areas on high-occupancy vehicle (HOV) lanes specify 1300 feet as the minimum acceptable length (*8*). Based on the data collected, TTI researchers recommend that designers consider a 0.25-mile enforcement pullout area as a practical minimum for work zone applications, but strive to provide additional length (up to the ideal 1700 ft) where feasible.

3. SPACING OF WORK ZONE ENFORCEMENT PULLOUT AREAS

The previous chapter addressed the question of an appropriate enforcement pullout area length within a highway work zone. In this chapter, the issue of appropriate distances between enforcement pullout areas is investigated.

As noted in the introductory chapter, the choice of pullout area spacing requires the balancing of two competing priorities. If placed too closely, pullout areas may significantly increase project costs, forcing the roadway contractor responsible for the work zone to devote extra resources to construct and maintain the many pullouts as well as complicating the construction sequencing and methods. On the other hand, if the pullouts are spaced too widely, they are likely to become less useful to law enforcement personnel, to the point where it is just as though no pullout areas are available at all. Therefore, the goal is to find a spacing between enforcement pullout areas that does not prohibitively delay the roadway contractor and is still useful for law enforcement. To accomplish this, TTI researchers turned to the experts themselves, contractors and law enforcement personnel, to provide their opinions and expectations regarding the difficulties and usefulness of pullout areas within work zones. The Delphi Method was selected as a means of assessing these perceived relative impacts. Through application of this method, it was hoped that a consensus on the issue could be reached in an objective and impartial manner.

THE DELPHI METHOD

In the 1960s, the RAND Corporation developed a process of systems analysis that depends on the intuitive judgment of experts: the Delphi Method (*9*). The Delphi Method was originally developed to ensure that the answers provided by expert panels were not dependent on human subjectivity or bias. When a group of experts meet face-to-face to reach a consensus on an issue, there is the potential that factors other than the merits of an argument could sway the group. For example, if a group member with perceived authority states an opinion, others in the group may adopt this opinion simply to go along with the superior. The Delphi Method of polling experts removes these potential biases by keeping the participants physically separated from one another in an anonymous debate (*9*). The result is a more objective analysis of the issue; resulting in better conclusions than if the subjects had met face-to-face.

The Delphi Method has yet another advantage: a large sample size is not a requirement. When validating the Delphi Method, the RAND Corporation found that the method was effective with sample sizes from five to 30 subjects (*10*). In fact, most of the RAND Corporation's validation studies used less than 15 subjects.

APPLICATION OF THE DELPHI METHOD

For the question of enforcement pullout areas, two surveys -- one for roadway contractors and one for law enforcement -- were developed. The surveys were developed to be completed in three rounds. Questions were developed to ascertain the expert's opinion as to the relative difficulty or effectiveness of a pullout area located at some arbitrary spacing through a long work zone. The spacings investigated were as follows:

- 0.5-mile,
- 1-mile,
- 2-mile,
- 3-mile,
- 4-mile, and
- 6-mile intervals.

Each round after the first provided participants with the following information from the preceding round:

- The participant's answer from the preceding round,
- The 25th percentile answer of the total distribution from the group,
- The 50th percentile (median) answer of the total distribution from the group, and
- The 75th percentile answer of the total distribution from the group.

The surveys were sent to the participants either through e-mail or facsimile machine. Participants were normally allowed one week to complete the survey and return it to the research team. The specific questions asked and the responses for the roadway contractors can be found in Appendix C. The specific questions and responses for the law enforcement officials can be found in Appendix D.

Contractor Results

Contractors used in this survey were recruited with the help of the Associated General Contractors of Texas (AGC). A total of 13 roadway contractor professionals on the Texas AGC's Safety and Health Committee agreed to participate in the survey. These participants were typically project superintendents or company safety officials for Texas construction firms. The surveys were sent to the participants during June and July 2001. Unfortunately, several participants did not complete all the phases of the survey. However, a large enough group of contractors did complete all rounds of the survey to achieve consensus for the purpose of this study. In addition, the researchers noted that most of those who did not continue participating appeared to have reached consensus with the rest of the panel before the final round of questions and may have felt no need to provide further input into the process.

The survey asked the subjects their opinions of the difficulty involved with constructing and maintaining 0.25 mile-long law enforcement pullout areas at each of the above spacings in a long hypothetical work zone. Answers were given on a 7-point scale, with a 1 indicating no difficulty and a 7 indicating extreme difficulty for the contractor. Figure 3 provides a summary of their median responses at the end of Round 3. As expected, the contractors tended to be more favorable to having fewer enforcement pullout areas and viewed densely spaced enforcement pullout areas as extremely difficult to construct and maintain. Generally speaking, the perceived difficulty of incorporating enforcement pullout areas into the construction projects begins to increase exponentially once the spacing between pullout areas diminishes to about 2 miles or less.

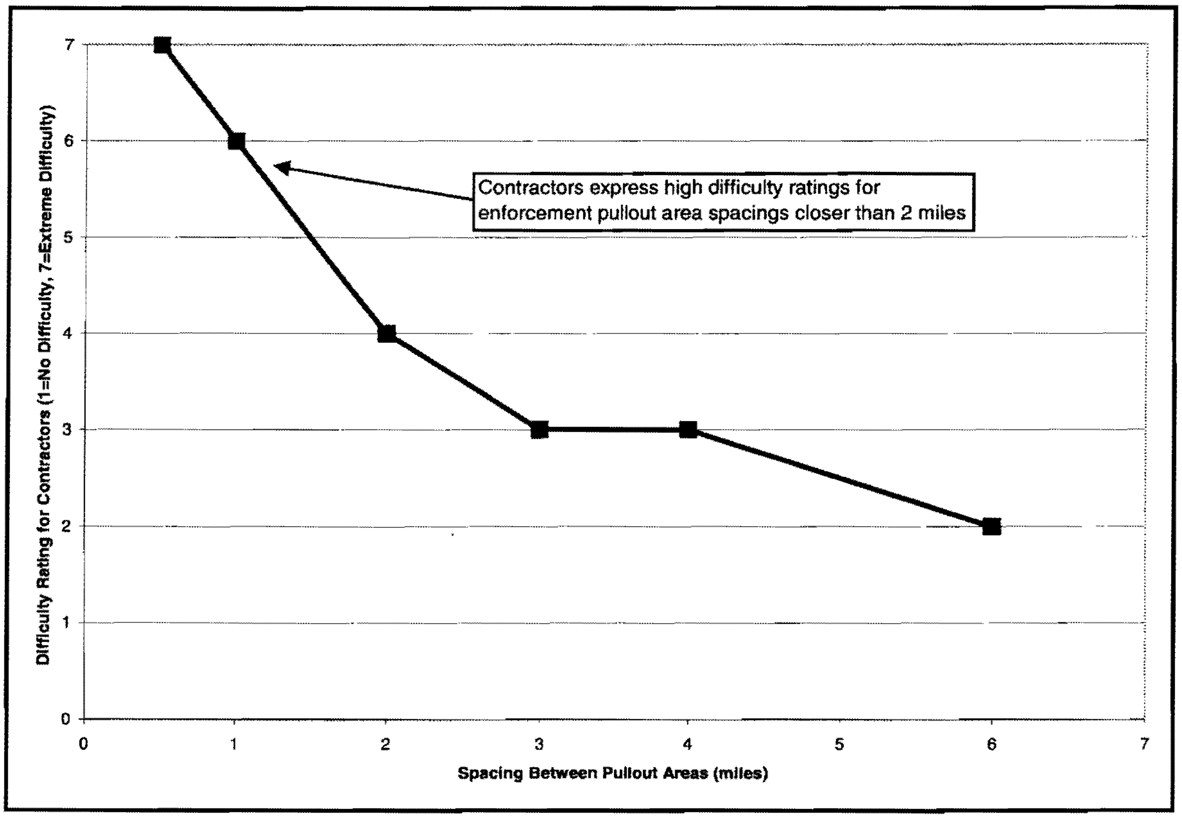

Figure 3. Response of Perceived Contractor Difficulty in Constructing and Maintaining Enforcement Pullout Areas at Various Spacings.

In rounds 2 and 3 of the survey, contractors were asked to provide written comments about the subject, and several responded. In general, the written comments corresponded to the results shown in Figure 3. The subjects expressed apprehension that too many enforcement pullout areas would slow the pace of the road construction and would become a nuisance both in project scheduling and cost. Examples of some of the comments were as follows:

- "At two-mile increments, you are approaching the borderline as to whether construction progress would be impeded."
- "(You) might as well pave the entire shoulder." (Given in response to a potential 1-mile spacing between pullout areas).
- "Two pullouts in twelve miles becomes closer to optimum. Again, lateral room, if project is phased, would be critical."

A compilation of all of the written comments can be found in Appendix C.

Enforcement Results

Seven law enforcement officials that were contacted agreed to participate in the Delphi study. Five of these were Harris County Sheriff's Deputies working in Harris County's Traffic Office. These deputies included the patrol lieutenant, a senior patrol sergeant, and several patrol deputies, several of whom were accident investigation specialists. In addition two patrol troopers of the Department of Public Safety were included in the study. These officers routinely patrol Interstate 35 in San Marcos, Texas and Austin, Texas. Both of these areas have had numerous work zones for the past several years, which these troopers have frequently patrolled. The surveys were sent out during July and August 2001.

The survey asked the subjects their opinions of the perceived usefulness to their enforcement activities of having 0.25 mile-long law enforcement pullout areas at the various spacings listed previously in a long hypothetical work zone. Answers were again given on a 7-point scale, with a 1 meaning very useful and a 7 indicating not useful at all.

Figure 4 provides a summary of their responses at the end of Round 3. As expected, the law enforcement officers tended to be more favorable to having more closely spaced pullout areas and viewed widely spaced pullout areas as not useful to traffic enforcement. All the officers believed that spacings above three miles would be of almost no use for enforcement purposes.

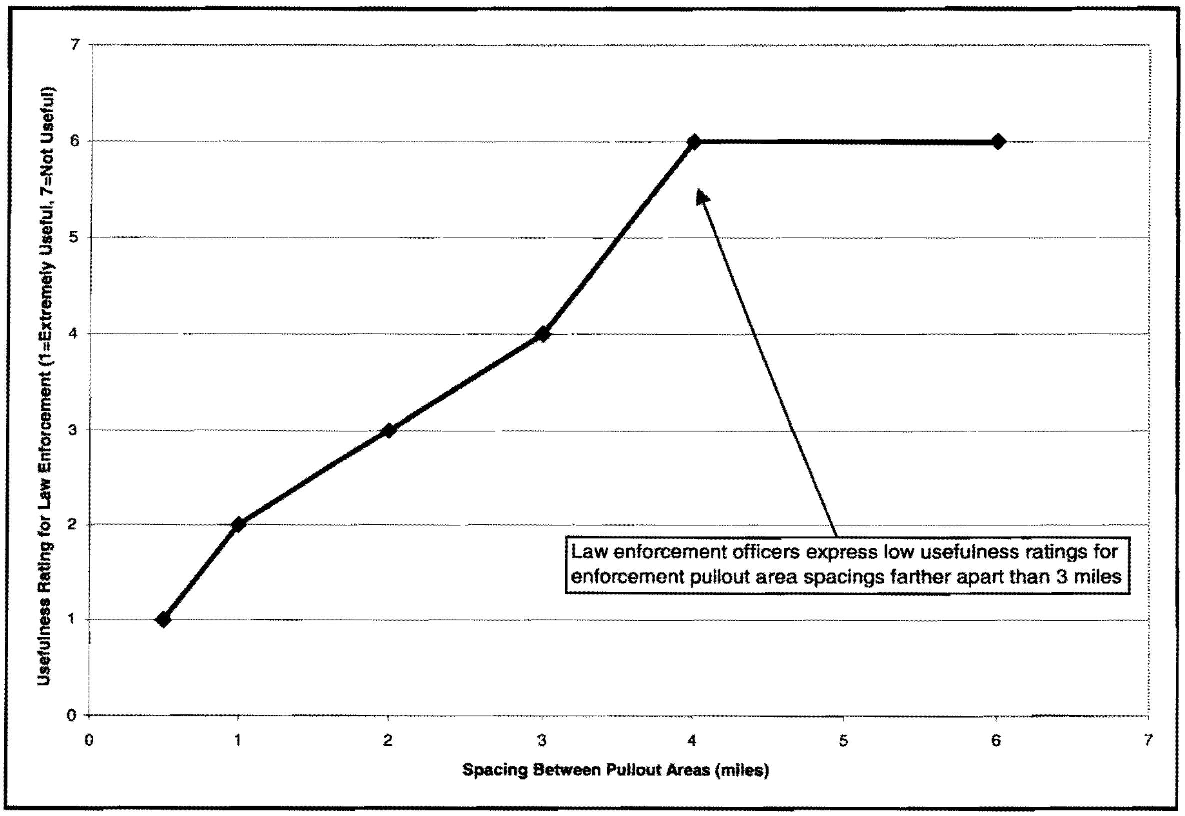

Figure 4. Response of Perceived Law Enforcement Usefulness of Enforcement Pullout Areas at Various Spacings.

The written comments provided by the officers in Round 3 of the survey were generally positive regarding the concept of enforcement pullout areas. All of the officers believed that this strategy would make them more effective when patrolling work zones. One officer also expressed the belief that simply having the option of stopping drivers within a work zone could have a calming effect on traffic, as drivers would never know where an officer might be positioned through the work zone. A complete list of the law enforcement officer comments is provided in Appendix D.

Based on the results of the survey, law enforcement officers believe pullout areas would be most useful to them when spaced in the range of 0.75 miles to 3 miles. Spaced more closely than this, officers would not be able to use all the available areas; spaced more widely than this, the officers would have to drive too far between areas to be effective.

DESIGN IMPLICATIONS OF SURVEY RESULTS

As noted above, construction contractors were generally against placing pullout areas at spacings closer than 2 miles, indicating that more pullouts would dramatically lengthen project time and increase cost. By contrast, law enforcement officers indicated that at spacings greater than 3 miles, the pullout area would not be useful for traffic enforcement purposes. By comparing the results of the two surveys, the range of between 2 and 3 miles emerges as the spacing between pullout areas that would be acceptable to both contractors and traffic law enforcement officers. This comparison is illustrated in Figure 5.

From this comparison, TTI researchers recommend that enforcement pullout areas in work zones be spaced approximately 2 to 3 miles apart, or that work zones where enforcement activities will be difficult be limited to less than 3 to 3.5 miles in length. A work zone should be suspected as being "difficult" from an enforcement perspective if all of the following conditions are likely to be present:

- emergency shoulders will be eliminated on both sides of the roadway;
- concrete barriers, drop-offs, or other traffic control devices will be continuously present immediately adjacent to the travel lane that would prohibit a motorist from pulling off of the pavement; and
- roadway conditions are expected to be maintained at a fairly high level throughout the project such that excessive travel speeds may be an ongoing problem.

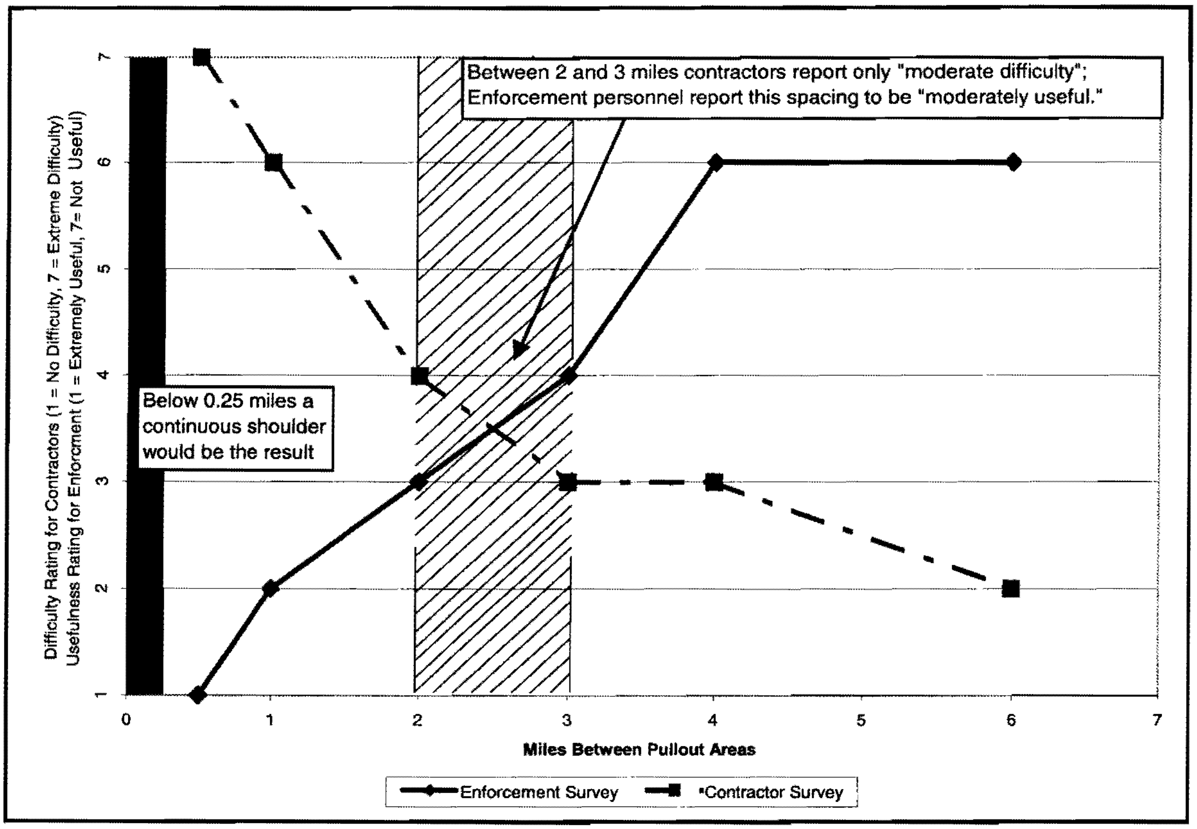

Figure 5. Comparison of Median Responses from Contractor and Law Enforcement Surveys.

4. CONCLUSIONS AND FUTURE RESEARCH

CONCLUSIONS

Previous research has suggested that enforcement pullout areas within work zones could be an effective method to improve work zone enforcement effectiveness (and by association, overall motorist safety). The goal of this project was to determine appropriate enforcement pullout area lengths for various traffic speeds, and to determine the appropriate spacing between multiple enforcement pullout areas when two or more are placed in the same work zone. This spacing value would also serve as an indication of the length of work zone where no enforcement areas at all would be necessary (assuming adequate space exists beyond the work zone for enforcement activities to occur).

The distance required for an effective work zone enforcement pullout area was examined based on the driving behavior of passenger car drivers who accelerate and merge into traffic after a traffic stop at a non-work zone location, and through a review of AASHTO's *Green Book* for accepted design policies. At this time, TTI researchers have concluded that a **0.25-mile long** enforcement pullout area would likely be sufficient for use in a highway work zone with a speed limit of 60 mph.

The spacing between multiple enforcement pullout areas was evaluated through a battery of surveys of both traffic law enforcement officers and highway construction contractors. Based on the results of these surveys, **spacing the pullout areas between 2 to 3 miles is recommended.** Spacing at this distance will likely prevent the pullout areas from becoming a great inconvenience to the project in terms of scheduling and cost, while still having spacing sufficient for officers to be more effective in work zones.

The recommended spacing value also provides an indication of the length of work zone which can reasonably accommodate enforcement activities, even when roadway space limitations require the elimination of emergency shoulders within the limits of the work zone. Generally speaking, it appears that work zones shorter than 3 to 3.5 miles would not significantly benefit from the incorporation of one or more enforcement pullout areas into the zone.

It is important to recognize that passenger vehicles were used as the design vehicle in this analysis. If large trucks are the primary enforcement concern within a given work zone, pullout lengths much larger than those recommended above will be required.

FUTURE RESEARCH

These recommendations provide key guidance for the incorporation of enforcement pullout areas into construction projects currently under design. Questions still remain as to the best way to provide signage for such areas, and for determining the other key site features that should exist to effectively utilize these enforcement areas (i.e., agreement from local law enforcement concerning the need for such pullout areas, location recommendations relative to roadway geometrics, minimum traffic volumes needed to justify their implementation, etc.). These issues are being explored during the next year of this project.

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APPENDIX A: ENFORCEMENT PULLOUT AREA LENGTH CALCULATIONS

Curves showing how enforcement pullout lengths changed for varying acceleration and deceleration rates were plotted. Also, graphs showing the minimum accelerations required for a 0.25-mile enforcement pullout for varying entering speeds were prepared. Graphs showing the exiting speeds of vehicles versus the entering speeds for both the "AASHTO ideal" enforcement pullout and the 0.25-mile pullout were prepared. In addition, acceleration and deceleration values determined by Samuels for intersection movements in Australia were considered for comparison (*11*). Figures A1 through A3 show these graphs.

Table A1. Acceleration and Deceleration Rates Used in Figures 2 through 5.

Acceleration and Deceleration Rate Sources	Acceleration Rate (ft/sec^2)	Deceleration Rate (ft/sec^2)
AASHTO (Green Book Tables X-4, X-6)	2.3	-7.3
AASHTO (Green Book Figures II-16 and II-17)	3.0	-8.1
Samuels	5.5	-6.8

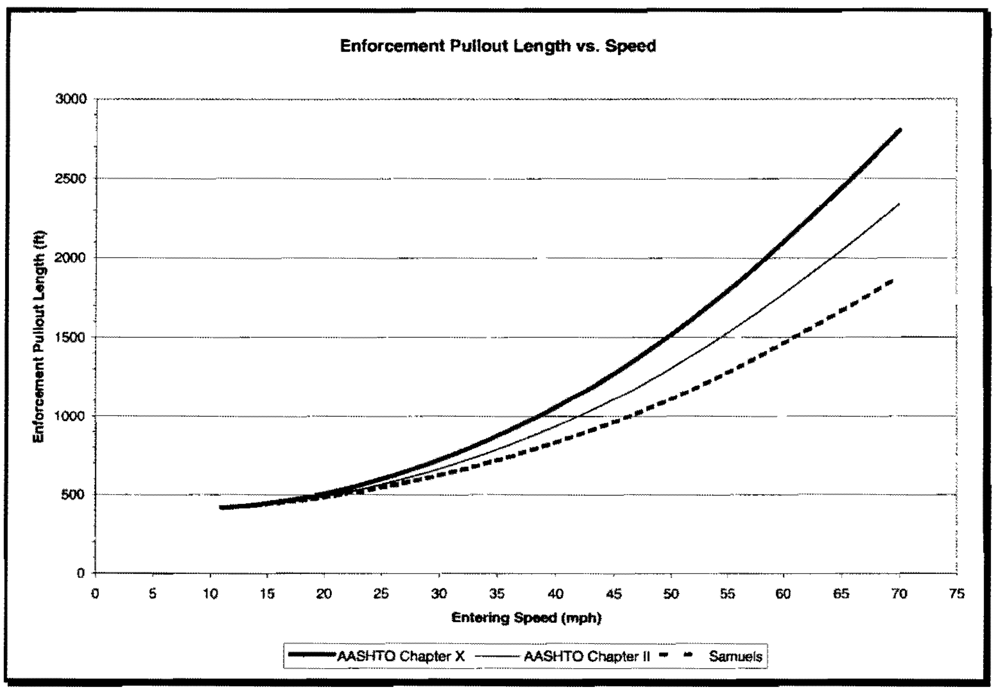


Figure A1. Enforcement Pullout Length vs. Speed for Various Acceleration and Deceleration Rates.

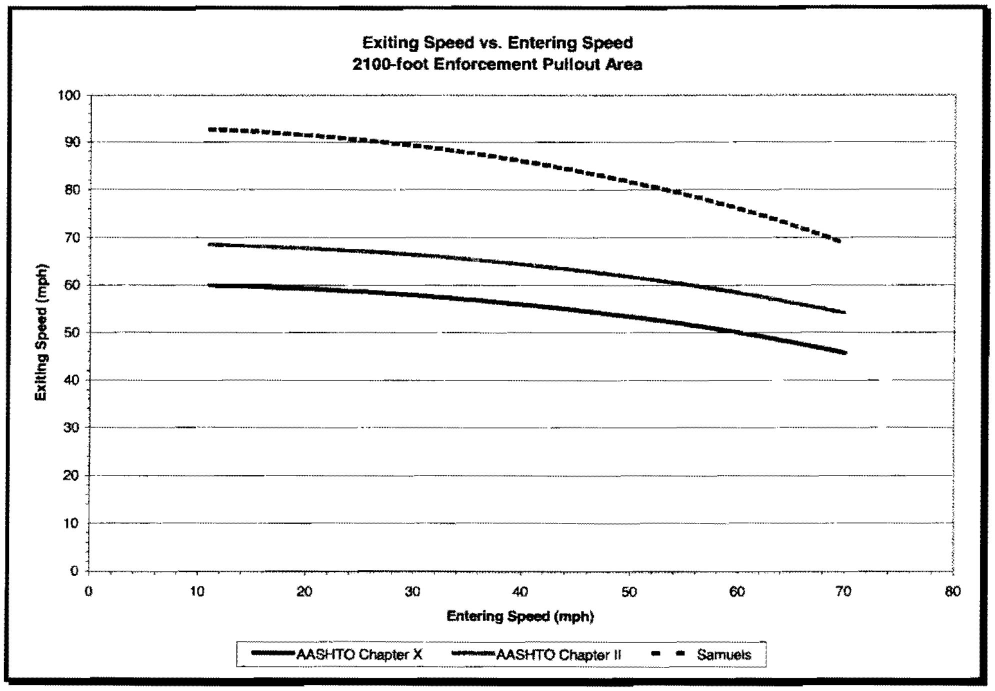


Figure A2. Exiting Speeds vs. Entering Speeds for 2100-foot Enforcement Pullout.

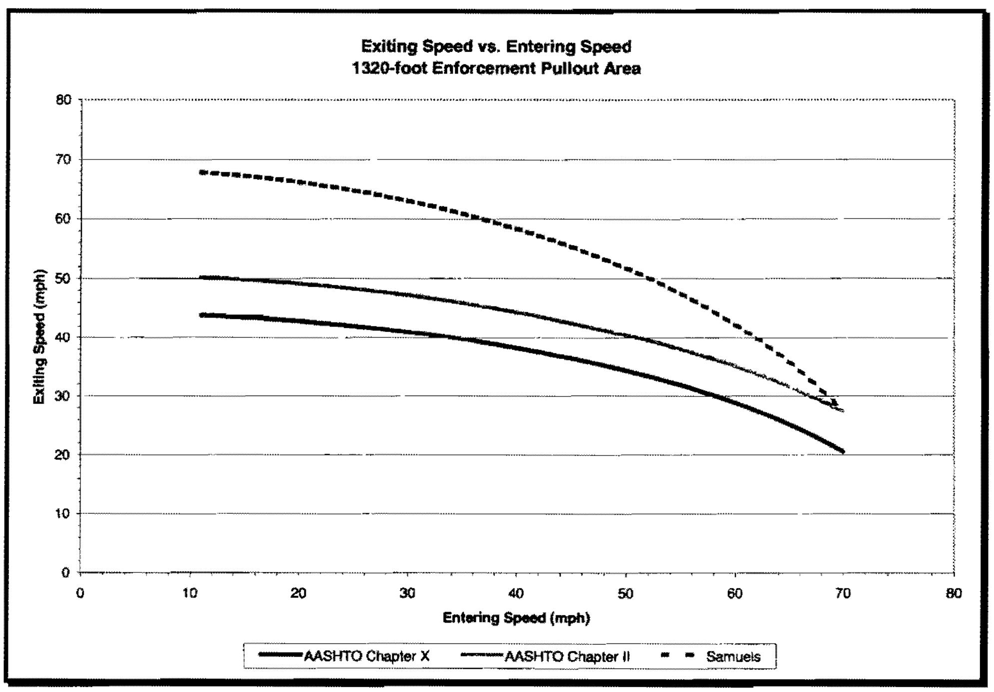


Figure A3. Exiting Speeds vs. Entering Speeds for 1320-foot Enforcement Pullout.

APPENDIX B: ENFORCEMENT RIDE-ALONG DATA AND ANALYSIS

TTI researchers rode with one Harris County Sheriff's deputy on June 18 and August 14, 2001. The research trip on June 18 was conducted during daylight hours, and the August 18 trip was conducted at nighttime. All data collected were on major urban roadways in Harris County, including Interstate 10, Texas Highway 225, Texas Highway 146, and Beltway 8.

TTI researchers rode with two Midland County Sheriff's deputies on June 20–21, 2001. All data were collected during daylight hours and included a mix of data collected on both Interstate 20 and several rural 2- and 4-lane highways.

Data collectors rode in the front passenger seat of a deputy's patrol car and used a Pro Laser III LIDAR gun. All data were collected by measuring the distance from the patrol car to the departing vehicle just at the point when all four wheels reentered the adjacent traffic lane after being released from a traffic stop. The data were recorded on paper data sheets designed for this purpose.

TABLE B1. Traffic Merging After a Traffic Stop.

Date	Location	Point when the Vehicle Reenters the Traffic Stream	
		Vehicle Speed (mph)	Distance Traveled (feet)
6/18/01	Harris County	25	216.7
6/18/01	Harris County	18	90.8
6/18/01	Harris County	24	125.0
6/18/01	Harris County	27	184.0
6/18/01	Harris County	19	128.1
6/18/01	Harris County	29	123.6
6/18/01	Harris County	21	120.0
6/18/01	Harris County	23	125.0
6/18/01	Harris County	9	138.6
6/18/01	Harris County	27	148.0
6/18/01	Harris County	24	162.6
6/18/01	Harris County	29	180.5
6/18/01	Harris County	21	147.6
6/18/01	Harris County	23	158.3

TABLE B1. Traffic Merging After a Traffic Stop (cont.).

Date	Location	Point when the Vehicle Reenters the Traffic Stream	
		Vehicle Speed (mph)	Distance Traveled (feet)
6/18/01	Harris County	35	195.8
6/18/01	Harris County	42	320.3
6/18/01	Harris County	36	372.1
6/18/01	Harris County	22	117.9
6/18/01	Harris County	27	155.4
6/18/01	Harris County	37	475.7
6/18/01	Harris County	27	224.1
6/18/01	Harris County	30	380.0
6/18/01	Harris County	54	600.0
6/18/01	Harris County	29	182.8
6/18/01	Harris County	17	95.5
6/18/01	Harris County	26	178.7
6/18/01	Harris County	32	326.6
6/18/01	Harris County	36	258.3
6/18/01	Harris County	29	208.9
6/18/01	Harris County	31	369.4
6/18/01	Harris County	28	461.3
6/18/01	Harris County	31	263.7
6/20/01	Midland County	9	70.2
6/20/01	Midland County	14	79.5
6/20/01	Midland County	11	188.5
6/20/01	Midland County	16	93.1

TABLE B1. Traffic Merging After a Traffic Stop (cont.).

Date	Location	Point when the Vehicle Reenters the Traffic Stream	
		Vehicle Speed (mph)	Distance Traveled (feet)
6/20/01	Midland County	12	77.0
6/20/01	Midland County	35	120.0
6/20/01	Midland County	19	145.3
6/20/01	Midland County	20	152.6
6/20/01	Midland County	15	99.1
6/21/01	Midland County	38	350.2
6/21/01	Midland County	20	132.0
6/21/01	Midland County	39	510.8
6/21/01	Midland County	24	170.5
6/21/01	Midland County	33	333.2
6/21/01	Midland County	26	206.5
6/21/01	Midland County	25	214.2
6/21/01	Midland County	33	223.0
6/21/01	Midland County	20	272.3
6/21/01	Midland County	32	312.0
6/21/01	Midland County	37	369.7
6/21/01	Midland County	40	362.0
6/21/01	Midland County	19	169.4
6/21/01	Midland County	15	100.0
6/21/01	Midland County	31	314.2
6/21/01	Midland County	20	120.0
6/21/01	Midland County	15	120.0

TABLE B1. Traffic Merging After a Traffic Stop (cont.).

Date	Location	Point when the Vehicle Reenters the Traffic Stream	
		Vehicle Speed (mph)	Distance Traveled (feet)
6/21/01	Midland County	36	287.9
6/21/01	Midland County	19	121.5
6/21/01	Midland County	9	55.9
6/21/01	Midland County	26	197.0
6/21/01	Midland County	31	288.3
6/21/01	Midland County	52	953.8
6/21/01	Midland County	32	212.6
8/14/01	Harris County	20	116.6
8/14/01	Harris County	17	101.6
8/14/01	Harris County	18	146.1
8/14/01	Harris County	14	96.4
8/14/01	Harris County	17	184.6
8/14/01	Harris County	23	178.2
8/14/01	Harris County	25	145.7
8/14/01	Harris County	14	130.1
8/14/01	Harris County	23	202.0
8/14/01	Harris County	15	91.2
8/14/01	Harris County	22	138.2
8/14/01	Harris County	37	361.0
8/14/01	Harris County	8	62.4
8/14/01	Harris County	38	452.7
8/14/01	Harris County	24	202.8

TABLE B1. Traffic Merging After a Traffic Stop (cont.).

Date	Location	Point when the Vehicle Reenters the Traffic Stream	
		Vehicle Speed (mph)	Distance Traveled (feet)
8/14/01	Harris County	25	132.5
8/14/01	Harris County	17	115.6
8/14/01	Harris County	20	284.6
8/14/01	Harris County	20	231.4
8/14/01	Harris County	27	378.6

Data Analysis

The equations used in a comparison of means test are:

$$(\bar{y}_1 - \bar{y}_2) \pm t_{\alpha/2} * s_p * \sqrt{\frac{1}{n_1} + \frac{1}{n_2}},$$

where,

$$s_p = \sqrt{\frac{(n_1 - 1) * s_1^2 + (n_2 - 1) * s_2^2}{n_1 + n_2 - 2}}$$, the pooled standard deviation of the samples,

$df = n_1 + n_2 - 2$,

n = sample size, and

s = sample standard deviation.

If the confidence interval includes 0, then there is no evidence of a statistical difference between samples.

For this research, the assumption was made that the true variances of the two samples were identical, allowing the use of the pooled sample standard deviation. The confidence coefficient will remain relatively stable as long as both sample distributions are mound shaped (approximately normal) and the sample sizes are approximately equal, allowing this assumption to be made (*12*).

Normally, the t-statistic is preferred for use instead of the Z-statistic when the sample sizes being tested are below 30. Several of the sample sizes tested here are slightly over 30. The t-statistic was used instead of the Z-statistic because while the two distributions are similar above a sample size of 30, the t-statistic is slightly more conservative.

Urban versus Rural

For the urban versus rural comparison, daytime values from Harris County are called Sample 1, and the values from Midland County are Sample 2. A summary of the statistics is provided in Table B2.

There is no evidence of a statistical difference between the distance data collected in Midland County and the distance data collected in Harris County at the 0.05 level of significance.

Additionally, the difference of means for the speeds of the daytime vehicles were compared between Midland and Harris Counties. The results of the analysis are provided in Table B3.

There is no evidence of a statistical difference between the speed data collected in Midland County and the speed data collected in Harris County at the 0.05 level of significance.

TABLE B2. Urban versus Rural Enforcement Ride-Along Data: Distances.

Statistic	Sample 1 (Harris County in Daylight)	Sample 2 (Midland County)
$\bar{y}$ (ft)	226.1	224.9
n (observations)	32	33
s (ft)	125.2	169.8
df	63	
s_p	149.6	
α	0.05	
$t_{\alpha/2}$	1.999	
Confidence Interval	(-66.4, 82.0)	

TABLE B3. Urban versus Rural Enforcement Ride-Along Data: Speeds.

Statistic	Sample 1 (Harris County in Daylight)	Sample 2 (Midland County)
$\bar{y}$ (mph)	27.8	24.9
n (observations)	32	33
s (mph)	8.16	10.57
df	63	
s_p	10.57	
α	0.05	
$t_{\alpha/2}$	1.999	
Confidence Interval	(-1.9, 7.5)	

Urban Daytime versus Nighttime

For the urban daytime versus nighttime comparison, daytime values from Harris County are called Sample 1, and the nighttime values from Harris County are called Sample 2. A summary of the statistics is provided in Table B4.

There is no evidence of a statistical difference between the distance data collected in Harris County during daylight versus nighttime at the 0.05 level of significance.

The differences between the means of the daytime speeds recorded in Harris County were compared to the nighttime speeds. The results of the analysis are provided in Table B5.

There is evidence at the 0.05 level of significance that the speed data collected in Harris County during the daytime was higher than the speed data collected in Harris County during nighttime. There are several possible explanations for this difference. First, lower traffic volumes were experienced at night, providing drivers the opportunity to merge into the shoulder lane at a more leisurely pace. Second, with reduced light at night, drivers may have been less comfortable driving on the shoulder for fear of hitting trash or debris, possibly resulting in a flat tire.

It is not clear that this difference would impact the design of an enforcement pullout area, as they would be designed for use both during the day and night. The faster speeds and corresponding longer acceleration distances experienced during the daytime would govern the design.

TABLE B4. Urban Daytime versus Nighttime Enforcement Ride-Along Data: Distances.

Statistic	Sample 1 (Harris County in Daylight)	Sample 2 (Harris County at Nighttime)
$\bar{y}$ (ft)	226.1	187.6
N (observations)	32	20
s (ft)	125.2	105.6
df	50	
s_p	118.1	
α	0.05	
$t_{\alpha/2}$	2.0105	
Confidence Interval	(-29.2, 106.2)	

TABLE B5. Urban Daytime vs. Nighttime Enforcement Ride-Along Data: Speeds

Statistic	Sample 1 (Harris County in Daylight)	Sample 2 (Harris County at Nighttime)
$\bar{y}$ (mph)	27.8	21.2
n (observations)	32	20
s (mph)	8.2	7.2
df	50	
s_p	7.8	
α	0.05	
$t_{\alpha/2}$	1.999	
Confidence Interval	(2.1,11.0)	

APPENDIX C: DELPHI SURVEY INSTRUMENT AND RESPONSES FROM CONTRACTORS

The Texas Department of Transportation (TxDOT) asked the Texas Transportation Institute (TTI) to provide guidelines for improving the effectiveness of law enforcement activities in work zone areas. One of the methods we are investigating is providing paved shoulder pullouts within a work zone for use by police officers. These enforcement pullout areas would be used to safely stop traffic violators within a work zone without affecting other traffic and without requiring the officer to follow the violator to the end of the work zone.

The study in which you have agreed to participate is designed to gain insight on the level of difficulty a contractor might experience if enforcement pullout areas were added to a construction project. A scenario of how enforcement pullout areas might be designed and situated is presented in Figure C1.

Your task is to answer each question to the best of your ability. There are no "right" or "wrong" answers, and there should not be any need for more than the simplest of calculations. We want you to give honest answers based on your experiences. All of your comments will remain anonymous, and your name or firm will never be associated with your answers. Please do not discuss your answers with other participants.

The study consists of four questionnaires; the first round of questions are below. You should receive the remaining three questionnaires about a week apart for the next three weeks. Each round of questions builds on your previous responses and the responses of others, and should provide some of the same results as if each of you were all in the same room on an expert panel. Each round is designed so that you can complete it in less than 15 minutes. Figures C2-C10 show the responses to the questions.

Scenario for Enforcement Pullouts

For the questions you are about to answer, imagine that the enforcement pullout area will be included on a long-length work zone project. The scenario we ask you to consider involves a work zone **12 miles** in length on a rural interstate highway. In each direction, two traveled lanes will be reduced to just one. In addition, some of the shoulder area will be used for the traveled lane, so any enforcement pullout areas would require new pavement. Assume that each enforcement pullout area is 0.25 miles long, and not near any obstructions, such as ramps or bridges. An example of what an enforcement pullout area might look like is provided below.

Questions

For each question, place an "**X**" at the appropriate location on the difficulty scale (1 to 7), indicating your opinion as to how much more difficult would the entire project be to construct with the pullout area(s) than without the pullout area(s) included in the project.

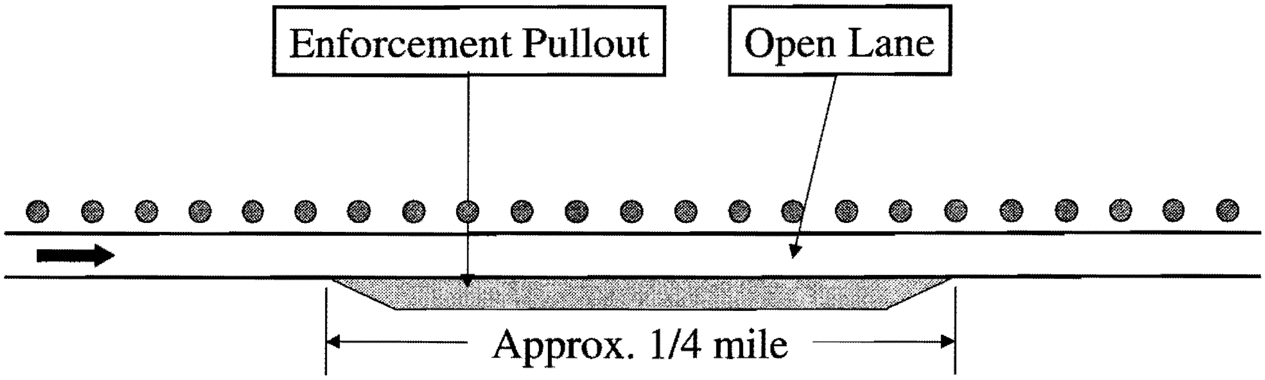


Figure C1. Basic Enforcement Pullout Configuration.

Question 1

Question 1: What **difficulty rating** would you think appropriate if the project described above included one pullout area, located midway through the work zone?

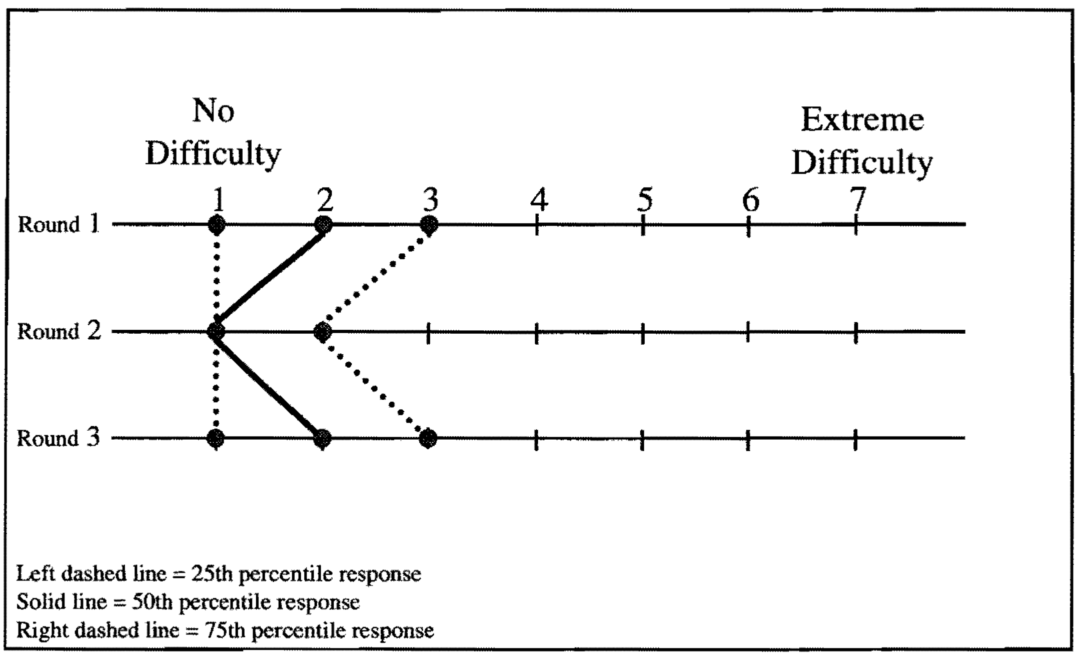


Figure C2. Survey Responses for Question 1.

Written Responses to Question 1

"This design is not cost effective." [Round 2]

"Difficulty is not a problem." [Round 2]

"Any pullout located on site would affect production on project when in use." [Round 3]

"Should not be a problem."

Question 2

Question 2: What **difficulty rating** would you think appropriate if the project described above included two enforcement pullouts, located at four-mile increments throughout the work zone?

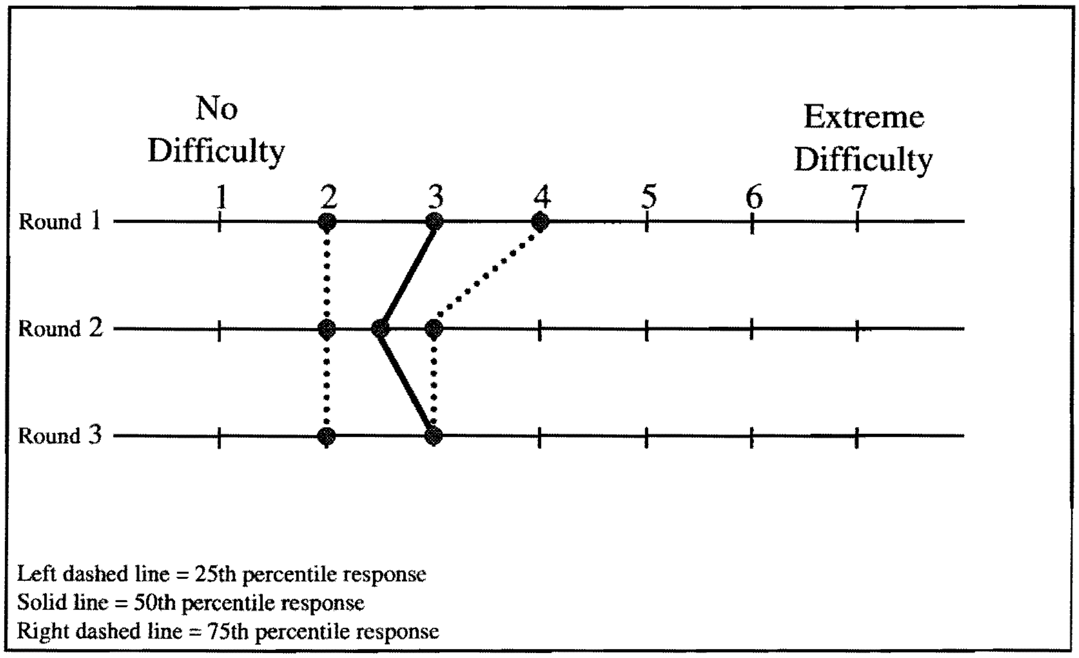


Figure C3. Survey Responses for Question 2.

Written Responses to Question 2

"If we create a pullout there is really no problem to create a second pullout." [Round 2]

"This design is cost effective." [Round 2]

"Any pullout located on site would affect production on project when in use." [Round 3]

"Two pullouts in twelve miles becomes closer to optimum. Again, lateral room, if project is phased, would be critical." [Round 3]

"Strongly believe that for this length of project only one is required." [Round 3]

Question 3

Question 3: What **difficulty rating** would you think appropriate if the project described above included three enforcement areas, located at three-mile increments throughout the work zone?

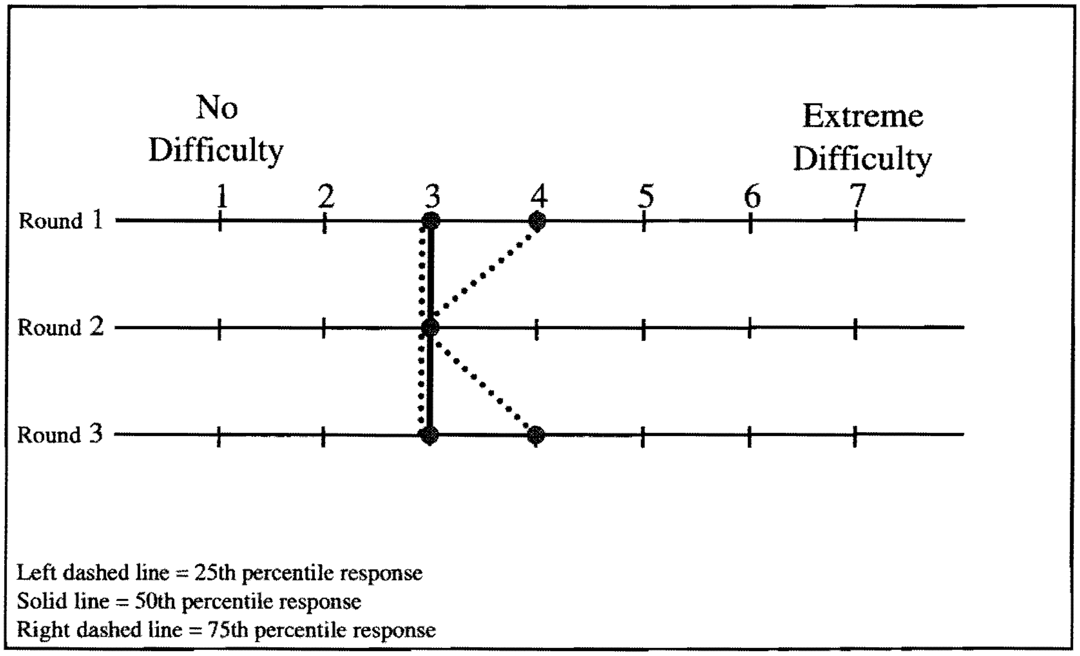


Figure C4. Survey Responses for Question 3.

Written Responses to Question 3

"If the pullouts become a part of the project they are not difficult to create." [Round 2]

"This design is not cost effective." [Round 2]

"Any pullout located on site would affect production on project when in use." [Round 3]

"If room is available for three pullouts, they could probably be accommodated. It becomes a trade-off – if the pullouts are effective for law enforcement agencies to control traffic, it begins to be a benefit at this point." [Round 3]

"Still adding cost and throw away construction to the ultimate project." [Round 3]

Question 4

Question 4: What **difficulty rating** would you think appropriate if the project described above included five enforcement pullouts, located at two-mile increments throughout the work zone?

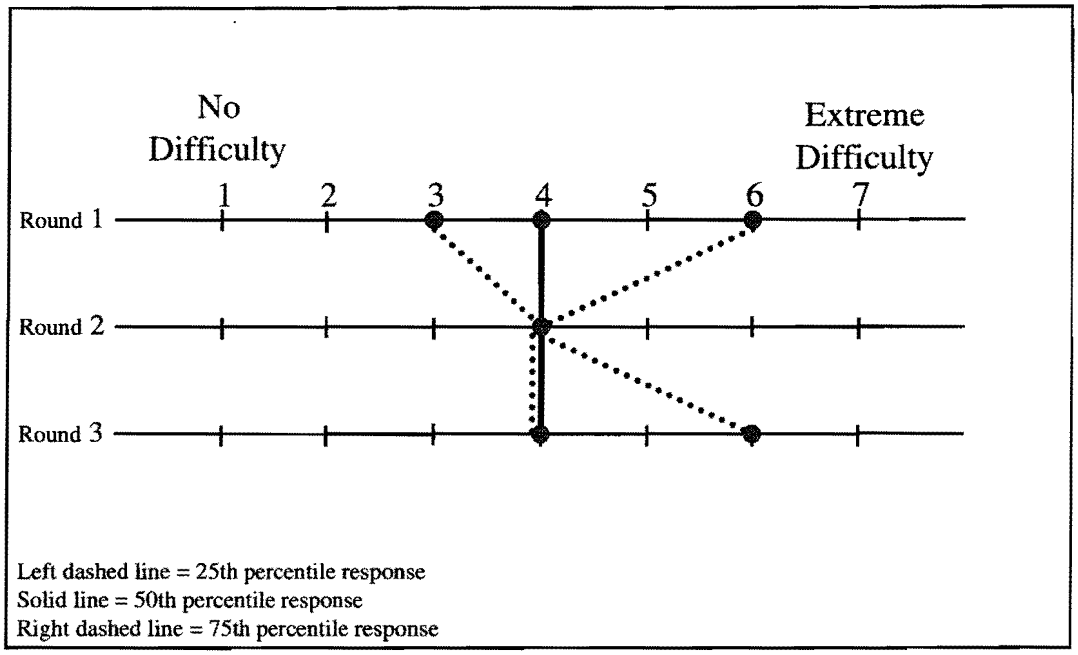


Figure C5. Survey Responses for Question 4.

Written Responses to Question 4

"This is about the extent of the quantity that would be considered no problem; any additional turnouts would create a burden on the contractor and the cost of the project." [Round 2]

"This design is not cost effective." [Round 2]

"Any pullout located on site would affect production on project when in use." [Round 3]

"At two-mile increments, you are approaching the borderline as to whether construction progress would be impeded." [Round 3]

"Still believe that one pullout in twelve miles is all that is required." [Round 3]

Question 5

Question 5: What **difficulty rating** would you think appropriate if the project described above included eleven enforcement pullouts, located at one-mile increments throughout the work zone?

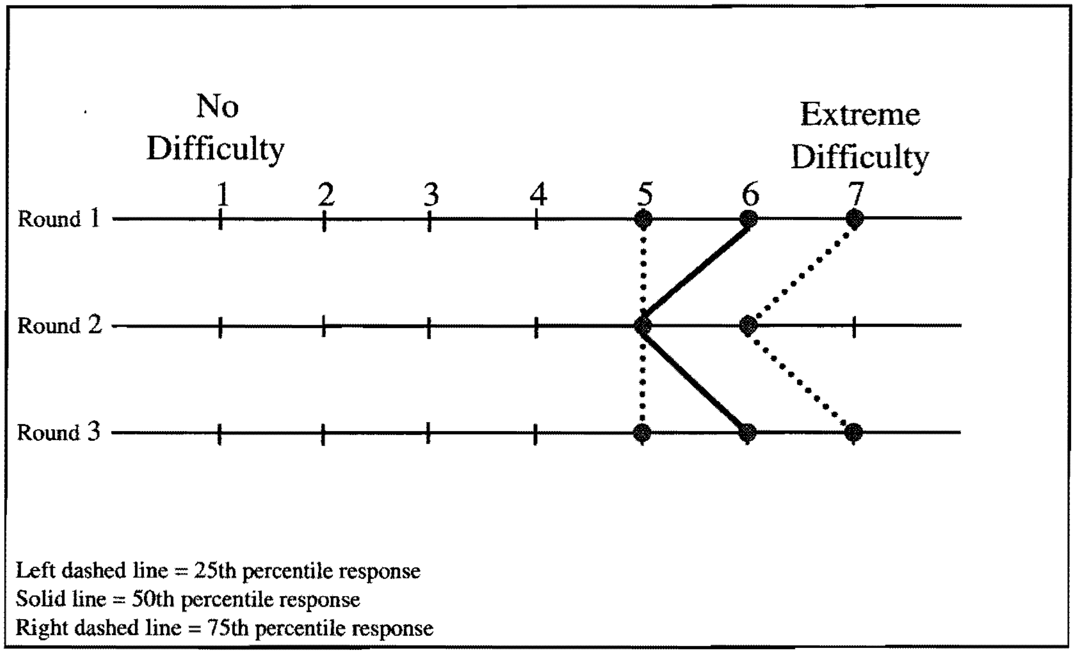


Figure C6. Survey Responses for Question 5.

Written Responses to Question 5

"Too many pullouts. They would complicate the construction of the project on this spacing. It could also impact the project's phasing." [Round 2]

"Might as well pave the entire shoulder." [Round 2]

"A shoulder should be built instead of pullouts." [Round 3]

"Even at one-mile increments, considering the necessary tapers, the frequency would cause problems with production." [Round 3]

Question 6

Question 6: What **difficulty rating** would you think appropriate if the project described above included 23 enforcement pullouts, located at ½-mile increments throughout the work zone?

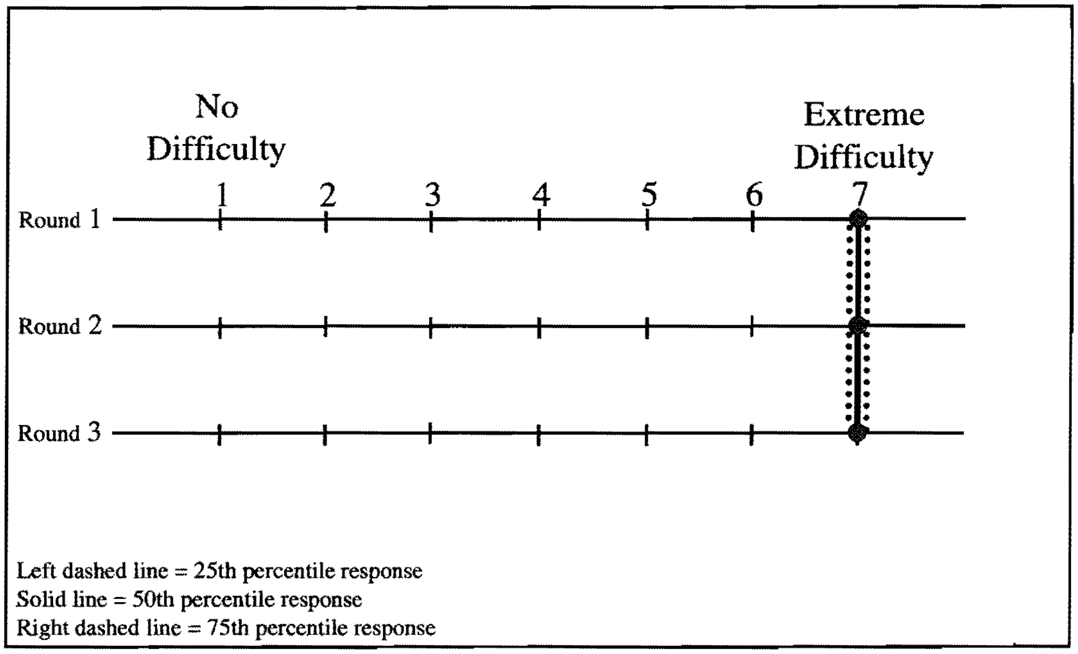


Figure C7. Survey Responses for Question 6.

Written Responses to Question 6

"Too many pullouts. They would complicate the construction of the project on this spacing. It could also impact the project's phasing." [Round 2]

"A shoulder should be built instead of pullouts." [Round 3]

"It would seriously impede construction progress at some phases to install, work around, and remove so many pullouts." [Round 3]

Question 7

Question 7: What is the longest **distance** between pullout areas (from beginning of one pullout to the beginning of the next) where it would be easier to simply construct a continuous enforcement area (a continuous lane) instead of a large number of individual areas? (Note: for this answer, provide a distance in miles)

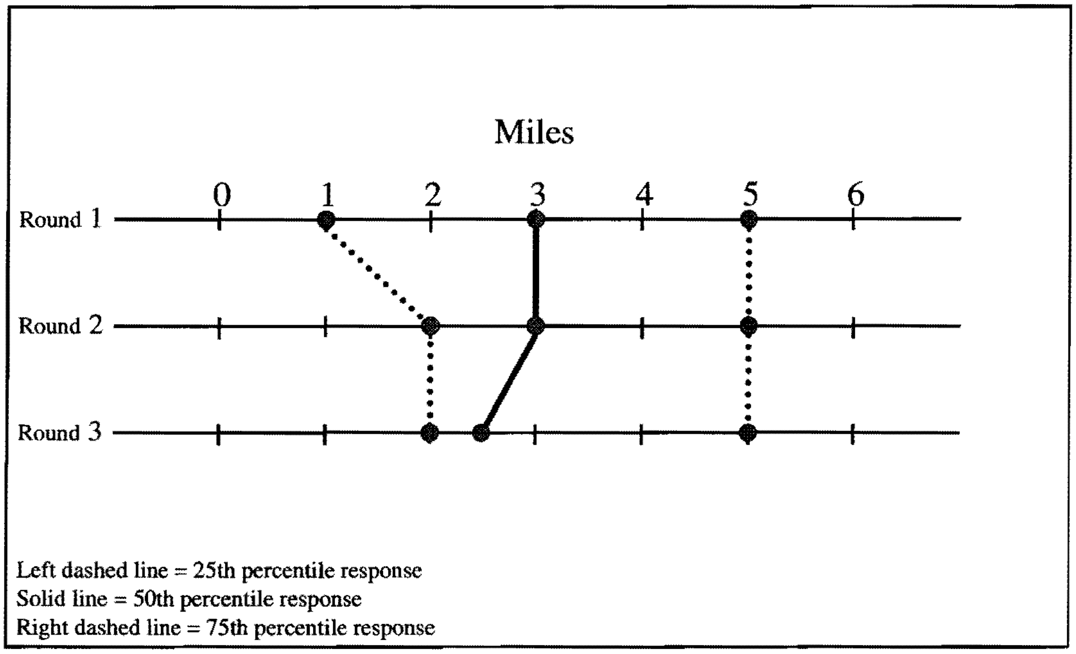


Figure C8. Survey Responses for Question 7.

Written Responses to Question 7

"I will go with the middle group. If the distance between the pullouts is less than two miles, it would be easier to construct a continuous lane if room allowed it and TxDOT was willing to pay for it." [Round 2]

"This design is not cost effective." [Round 2]

"Anything less than two-mile intervals would be more conducive to a continuous lane by the time you include taper lengths." [Round 3]

"I agree with the comments from Round 2." [Round 3]

Question 8

Question 8: What is the shortest **distance** between pullout areas (from beginning of one pullout to the beginning of the next) where you believe the pullouts would become a nuisance in performing your primary task of highway construction? (Note: for this answer, provide a distance in miles)

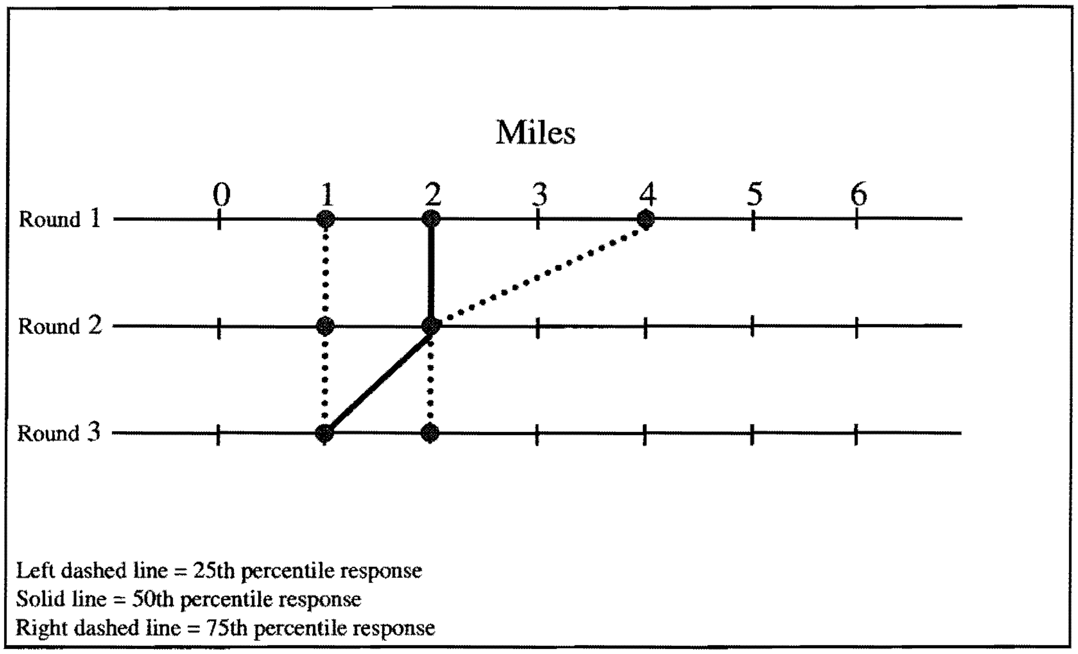


Figure C9. Survey Responses for Question 8.

Written Responses to Question 8

"This design is not cost effective." [Round 2]

"Similar to Question 7. Even at two-mile intervals, the frequency of pullouts would impact construction, but could be accommodated if lateral space lane phasing allow it." [Round 3]

"A construction phasing nightmare." [Round 3]

General Responses (provided in Round 3)

"The concept is a good idea. The pullout obviously provides a place for law enforcement to monitor traffic through the construction zone but also allows an emergency pullover for other vehicles. Space in construction zones is usually at a premium. Where these would be most needed – urban freeway rehabilitation – space is extremely limited due to the complex phasing and traffic. An example of a solution can be found on the winning design/build project in Denver. The winning bid chose to build an extra lane throughout the project to facilitate traffic (HOV lane). The addition of lanes for extra traffic or emergency pullout areas adds cost to the project."

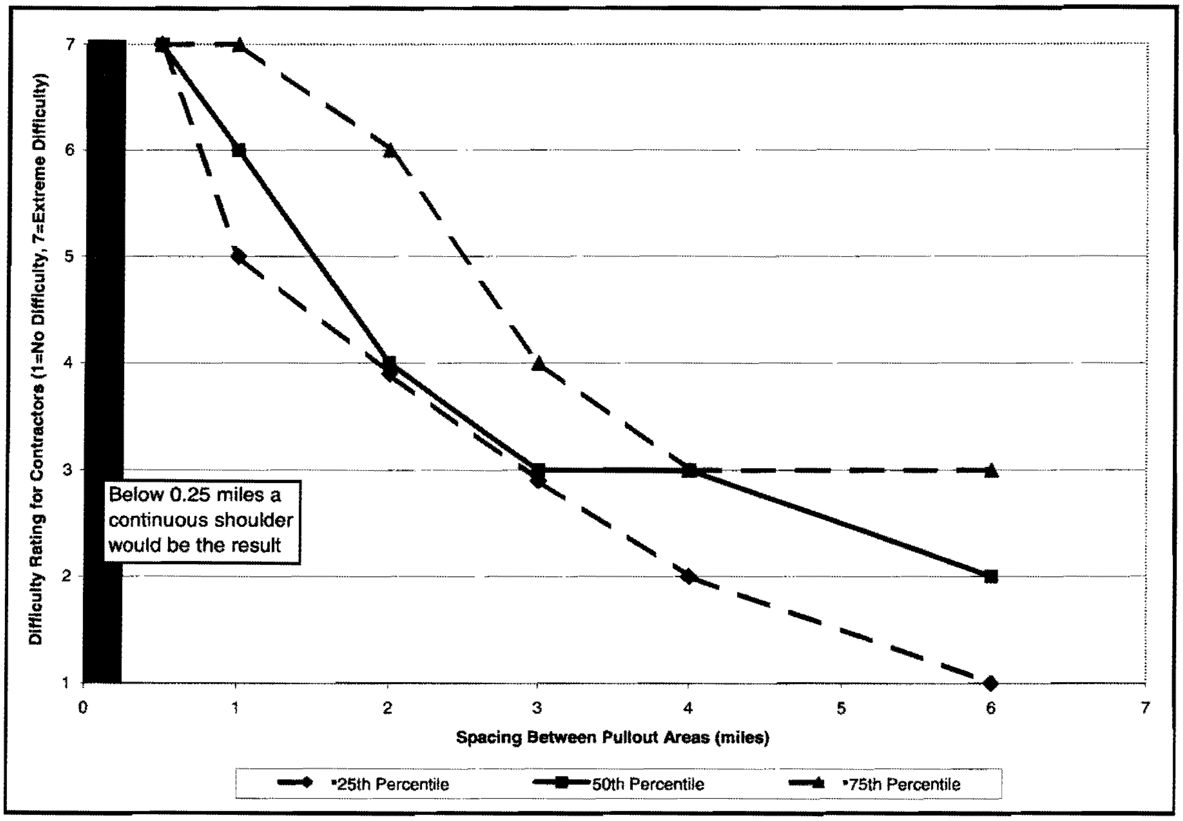


Figure C10. Response of Perceived Contractor Difficulty in Constructing and Maintaining Enforcement Pullout Areas at Various Spacings.

APPENDIX D: DELPHI SURVEY INSTRUMENT AND RESPONSES FROM LAW ENFORCEMENT

Subjects selected for this project were experts in the area of traffic law enforcement and consisted of sheriff's deputies from Harris County, Texas, and the Texas Department of Public Safety.

Survey Instrument

The Delphi Method relies on asking identical questions on several rounds of questionnaires to be completed by the same subjects. The form of the survey provides anonymous feedback to other participants and is similar to an expert panel without requiring the subjects to be in the same room. An advantage of the Delphi Method is that subjects will not be unduly swayed by responses provided from another participant with perceived authority. For example, a subject will not know whether any of the written responses from other subjects was from a higher-ranking officer or not. The subject must objectively evaluate the written responses on their own merits.

In Round 1, the subjects answer the questions to the best of their ability. In Round 2, the subjects are asked the same set of questions and are provided a summary of the answer distribution from Round 1. If a subject disagrees with the answers provided by the rest of the group of subjects, they are also provided with the opportunity to provide written commentary. Round 3 asks the same set of questions again, and includes the summary of the Round 2 answer distribution. In addition, all written commentary from Round 2 is provided so other subjects can read and perhaps be swayed by the other participants.

Introductory Material Accompanying Round 1

The Texas Transportation Institute (TTI) has been asked by the Texas Department of Transportation (TxDOT) to provide guidelines for improving the effectiveness of traffic law enforcement activities in work zone areas. One of the methods we are investigating is providing paved shoulder pullouts within a work zone for use by police officers. These enforcement pullout areas would be used to safely stop traffic violators within a work zone without affecting other traffic and without requiring the officer to follow the violator to the end of the work zone.

The study in which you have agreed to participate is designed to gain insight on the level of usefulness a law enforcement officer might experience if enforcement pullout areas were added to a long work zone. A scenario of how enforcement pullout areas might be designed and situated is presented below.

Your task is to answer each question to the best of your ability. There are no "right" or "wrong" answers; we want you to give honest answers based on your experiences. All of your comments will remain anonymous, and your name and agency will never be directly associated with your answers. We only ask this information to keep track of participants during the study.

The study consists of four questionnaires. The first round of questions begins on the next page. You should receive the remaining three questionnaires about a week apart for the next three weeks. Each round of questions builds on your previous responses and the anonymous responses of others, and should provide some of the same results as if all the participants were in the same room on an expert panel. Each questionnaire is designed so that you can complete it in less than 15 minutes.

For the questions you are about to answer, imagine that the enforcement pullout area will be included on a long work zone project. The scenario we ask you to consider involves a work zone **12 miles** in length on a rural interstate highway. In each direction, two traveled lanes will be reduced to just one. In addition, some of the shoulder area will be used for the traveled lane, so any enforcement pullout areas would require new pavement. Assume that each enforcement pullout area is 0.25 miles long, and not near any obstructions, such as ramps or bridges. An example of what an enforcement pullout area might look like is provided in Figure D1 below.

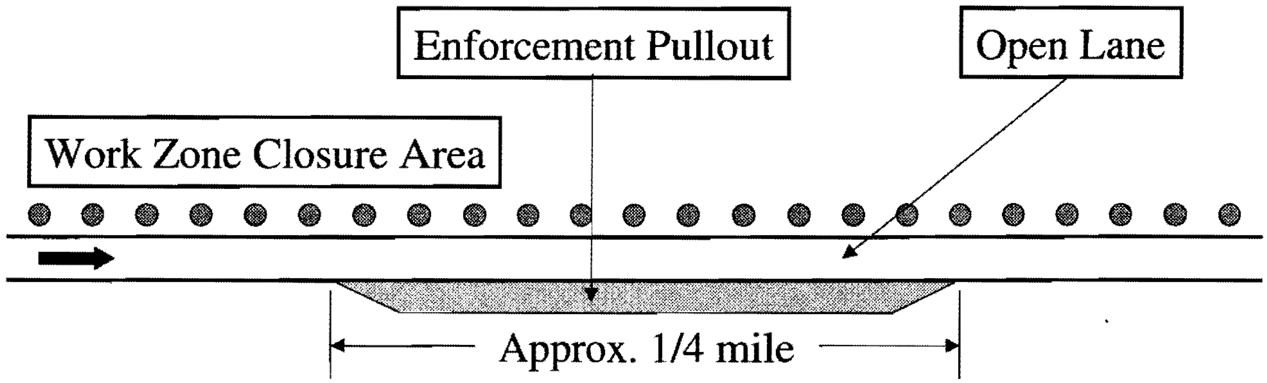


Figure D1. Basic Enforcement Pullout Configuration.

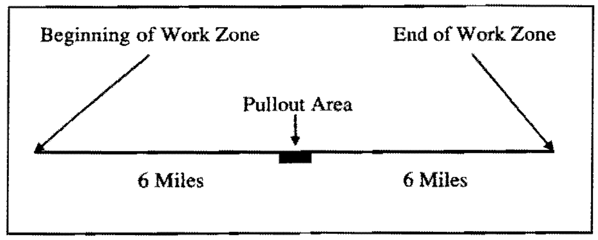
For each question below, place an "X" at the appropriate location on the usefulness scale, indicating your opinion as to how much more useful it would be to have the pullout area(s) included in the work zone than to not include them, **purely from an enforcement standpoint**. Usefulness is defined as how much more effective a traffic law enforcement officer is while performing his/her duties in a work zone as a result of the pullout areas.

Questions and responses

The following questions were asked in each round of the survey. Questions 1 though 6 were to be answered on a scale from 1 to 7, with a 1 labeled as "Extremely Useful" and 7 labeled as "Not Useful." Question 7 provided a blank line where the subjects merely wrote the value they found appropriate. Figures D2-D9 show the survey responses.

Question 1

Question 1: What **usefulness rating** would you think appropriate if the project described above included one pullout area, located midway through the work zone?



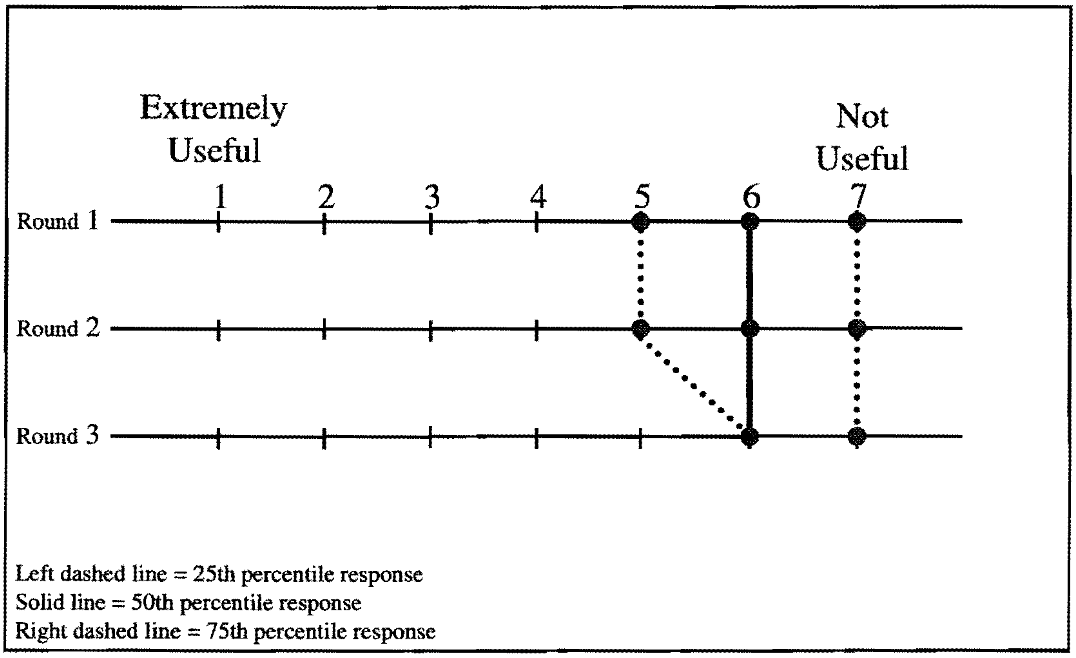


Figure D2. Survey Responses for Question 1.

Written Responses for Question 1

"Due to the amount of traffic in our area, which is heavy, one pullout would not be useful." [Round 2]

"Having only one pullout would make working traffic in the construction zone difficult and unsafe." [Round 2]

"At present I have not had any pullout areas and this would be better than none." [Round 2]

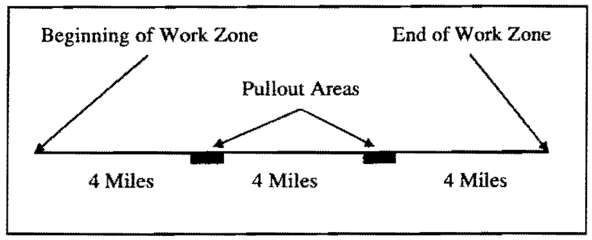
"I agree with one subject that one pullout is better than none. However, a few more would make even more sense. One pullout is more useful than none." [Round 3]

I agree that working inside construction zones with just one pullout can be difficult and unsafe." [Round 3]

"Any pullout is better than none." [Round 3]

Question 2

Question 2: What **usefulness rating** would you think appropriate if the project described above included two enforcement pullouts, located at four-mile increments throughout the work zone?



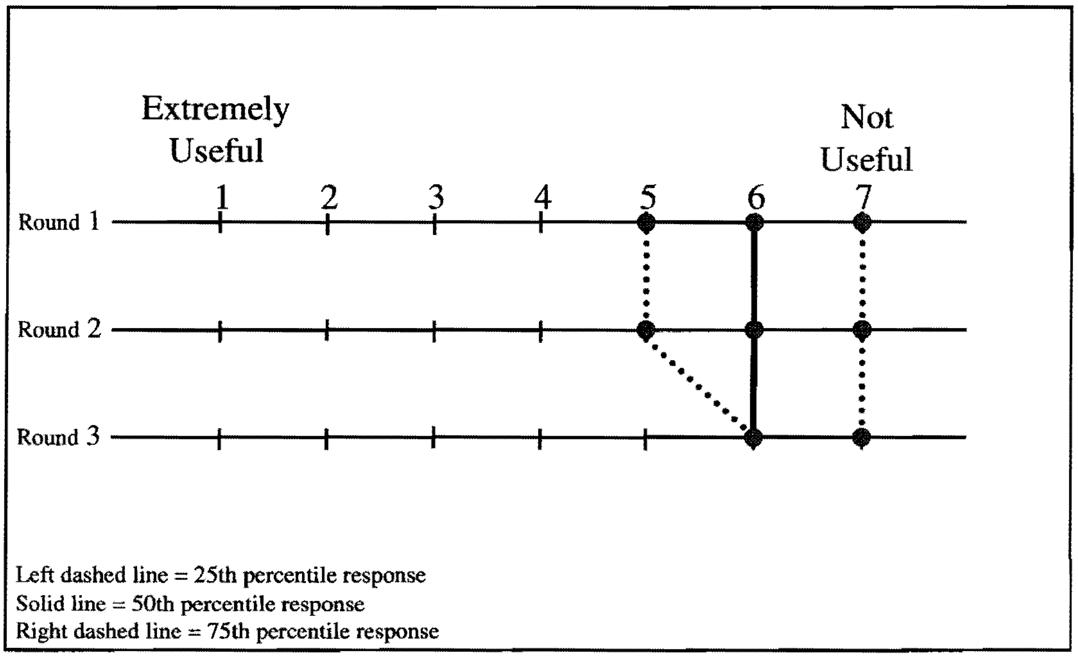


Figure D3. Survey Responses for Question 2.

Written Responses for Question 2

"Again, due to the amount of traffic, [this design would be] very unuseful. It takes too long to catch up to somebody and get them stopped." [Round 2]

"Having only two would also be difficult but more useful than one, no one wants to chase [a violator] for four miles looking for somewhere to pull over." [Round 2]

"This would help to some degree." [Round 2]

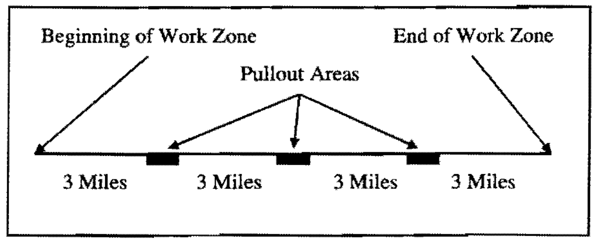
"It is still not quite enough if an officer were assigned to work a particular work area making a number of stops in a given shift, but it is more useful for that officer that was on routine patrol and found himself observing a violation in that work zone." [Round 3]

"Yes, two is better than one, but in some cases with a high volume of traffic this is unuseful." [Round 3]

"Basically, it's better than nothing, but still too long a gap for effective enforcement. These scenarios provide for occasional enforcement or a place to pull an accident off at." [Round 3]

Question 3

Question 3: What **usefulness rating** would you think appropriate if the project described above included three enforcement areas, located at three-mile increments throughout the work zone?



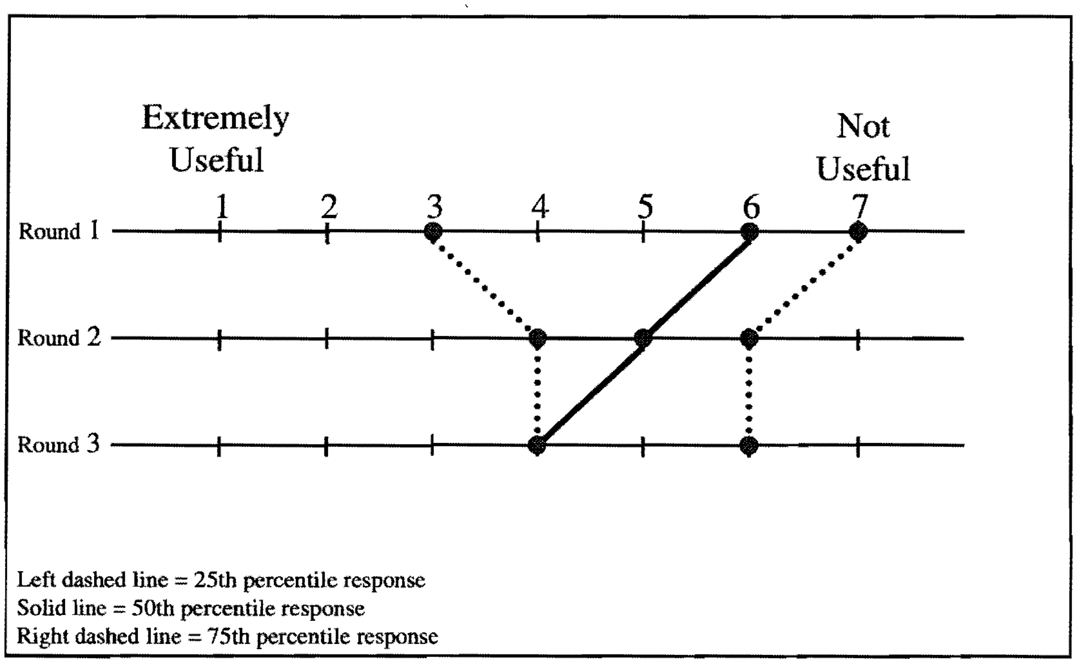


Figure D4. Survey Responses for Question 3.

Written Responses for Question 3

"Having three pullout areas would be good if the area were less than 12 miles. Still too far to chase someone." [Round 2]

"Although equally spaced this does not yet get the correct enforcement." [Round 2]

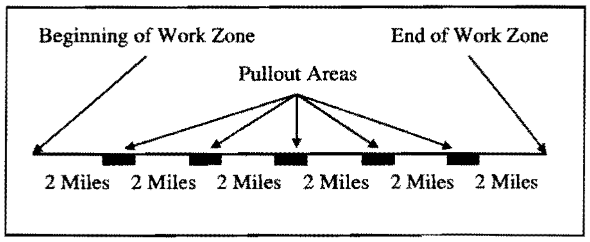
"This is not the best place but it does give the officer the opportunity to check the plate through his dispatch and receive a return before effecting a stop." [Round 3]

"You still wouldn't get to spend the amount of time needed to work the construction zone." [Round 3]

"Chase distance is directly proportional to how much space you have available to reach speed. You should see the violator and start rolling as he is drawing near to your position. Consideration should be given to too short a distance as this could cause accidents as people stop suddenly when a patrol car pulls out with its lights on." [Round 3]

Question 4

Question 4: What **usefulness rating** would you think appropriate if the project described above included five enforcement pullouts, located at two-mile increments throughout the work zone?



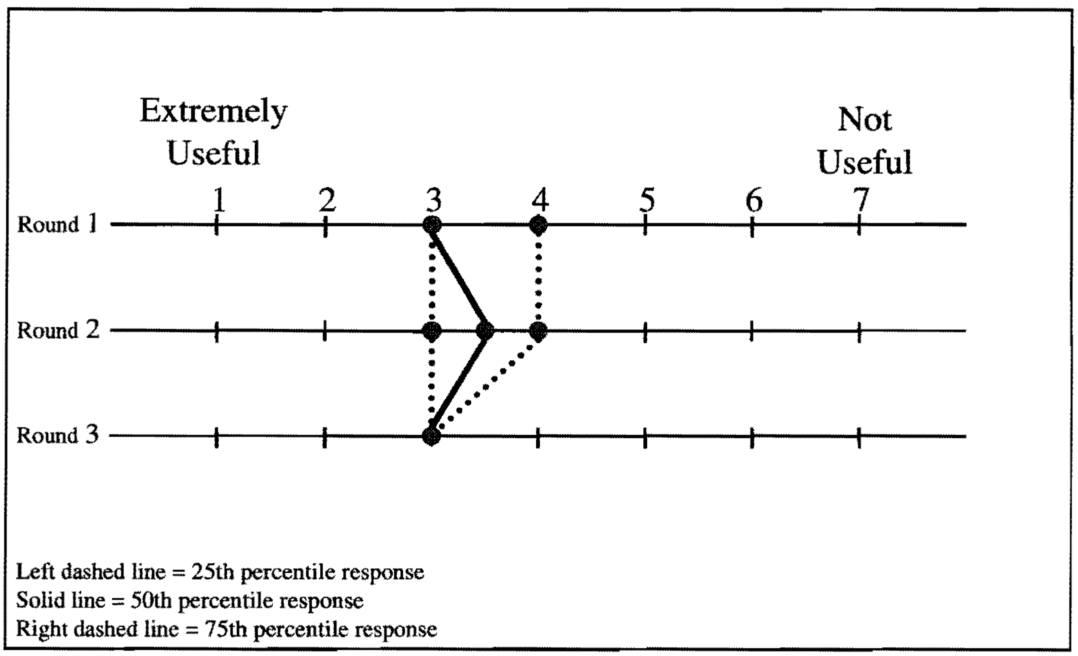


Figure D5. Survey Responses for Question 4.

Written Responses for Question 4

"On more occasions than not, traffic violators miss easy pullover opportunities and even stop on the roadway. Therefore, more pullout spots are better." [Round 2]

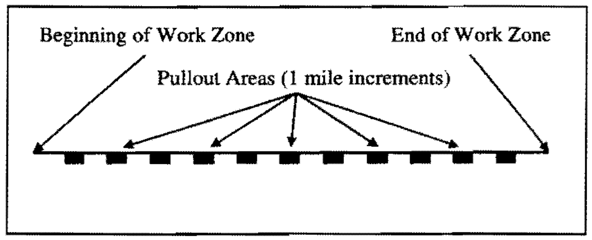
"Two miles is about the average you have to chase someone if stationary on the interstate or major roadway." [Round 2]

"This would be extremely helpful and would work." [Round 2]

"Two miles is closer to an acceptable interval so I will increase my opinion somewhat." [Round 3]

Question 5

Question 5: What **usefulness rating** would you think appropriate if the project described above included eleven enforcement pullouts, located at one-mile increments throughout the work zone?



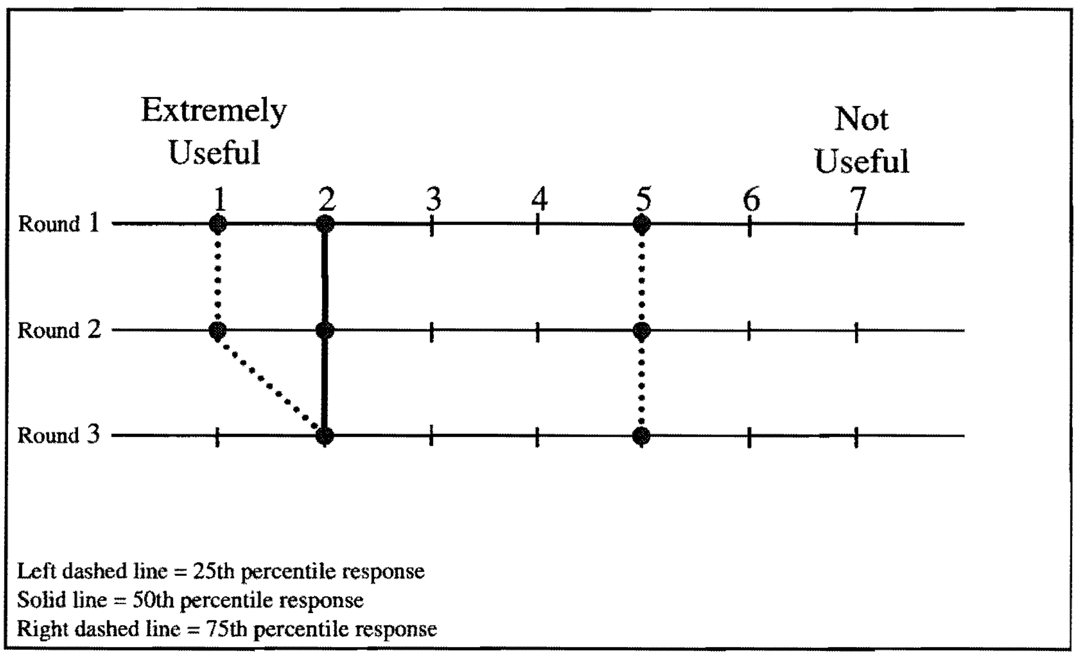


Figure D6. Survey Responses for Question 5.

Written Responses for Question 5

"The more of these pullout areas the better." [Round 2]

"One mile is still a long way to follow a car." [Round 2]

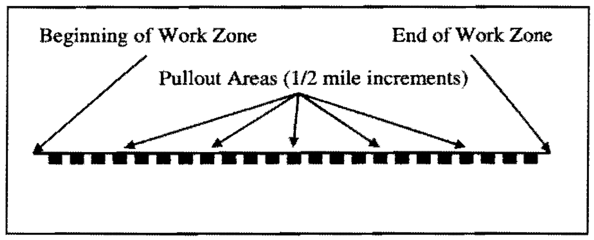
"This would be ideal and would provide for the best enforcement." [Round 2]

"One mile is a long way to follow a car, but from my experience it takes at least two miles to catch up to and stop a violator. I disagree that one mile is too long to follow a car." [Round 3]

"One mile is about the average distance of following or chasing a routine stop." [Round 3]

Question 6

Question 6: What **usefulness rating** would you think appropriate if the project described above included 23 enforcement pullouts, located at ½-mile increments throughout the work zone?



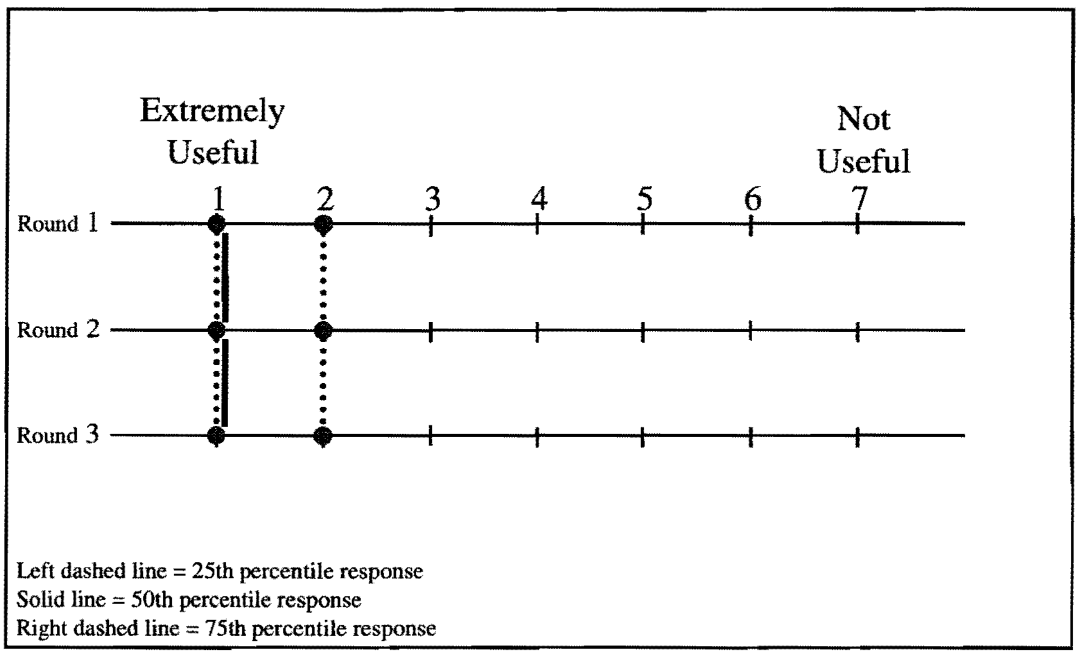


Figure D7. Survey Responses for Question 6.

Written Responses for Question 6

"Just as I answered earlier, I work in a volume of traffic that is very heavy. A violator which had more opportune places to stop would be much safer." [Round 2]

"This would be the most effective and best way to go if you are going to have designated pullouts." [Round 2]

"This would be very useful, however somewhat impractical." [Round 2]

"I think this would be very effective from an enforcement standpoint but I do not believe it is economically feasible and therefore it will never be placed into operation." [Round 3]

Question 7

Question 7: What would you consider (based on your experience) the ideal **distance** between pullout areas (from beginning of one pullout to the beginning of the next)? Consider the case where an officer waits in the first pullout for a speeding vehicle, moves into the traffic stream to catch up to the speeding vehicle, and pulls the speeding vehicle into the very next pullout. (Note: for this answer, provide a distance in miles)

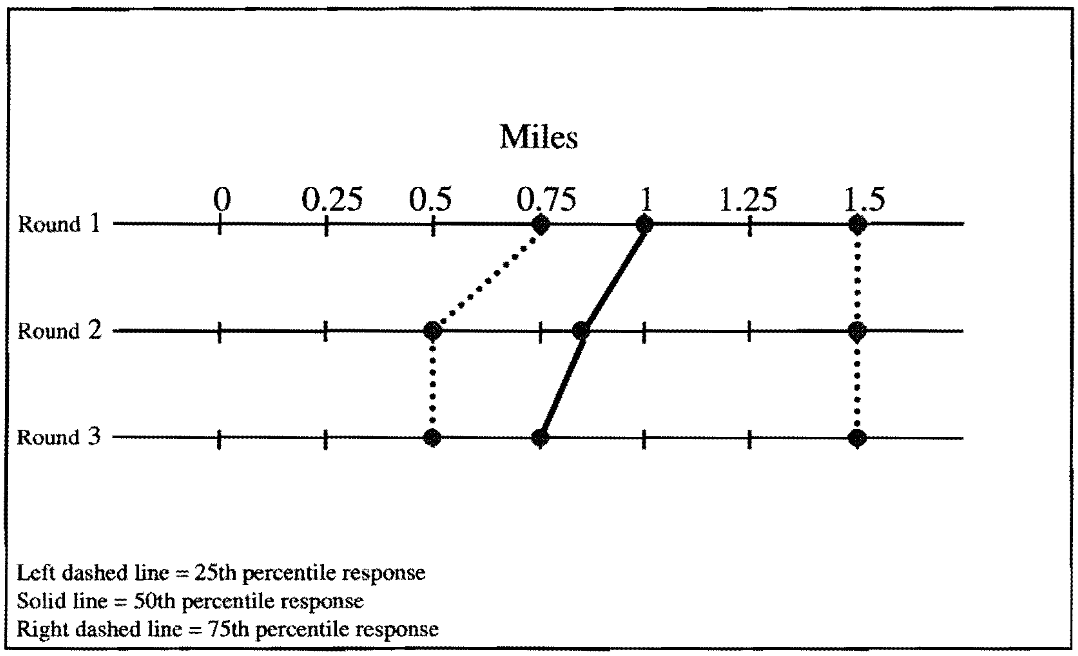


Figure D8. Survey Responses for Question 7.

Written Responses for Question 7

"With the slow pursuit vehicles we have it takes a longer distance to catch up to and stop a violator." [Round 2]

The perfect idea would be to have an extra lane or pullout area the length of the construction area." [Round 2]

"This would provide for the best coverage of the work zone with little difference to the work crews." [Round 2]

"Chase distance is directly proportional to how much space you have available to reach speed. You should see the violator and start rolling as he is drawing near to your position. Consideration should be given to too short a distance as this could cause accidents as people stop suddenly when a patrol car pulls out with its lights on." [Round 3]

General Responses (provided in Round 3)

"What would these areas be constructed of, thinking of the motorcycle officers that would also be stopping vehicles in these areas? A loose gravel area would be somewhat unsafe for them."

"In a work zone with many pullout areas, one might consider making one of them large enough to stop a semi-truck. That would at least provide one place for truck enforcement within the work zone."

"The main objective working a construction zone is to be seen and to slow people down. The more pullouts available the more time you are going to spend in the construction zone."

"I have received a number of complaints from motorists who are offended by the reckless driving and excessive speeding through the construction zones and want more police patrol in these areas."

"There has always been a need for some type of enforcement zone. I have witnessed many violations in construction zones but there is no place to make a stop without causing greater danger. One needs only to look at the fatal crash involving Pasadena [Texas] Police last week [August 20, 2001] to see the problems of leaving an emergency vehicle in a lane of traffic on a controlled access highway. Even one or two zones would have an effect on driver behavior because once people realized that there might be an officer ahead in the construction zone, it would cause them to react accordingly. As construction zones are now set up, you know there is NO way that any enforcement is lurking ahead. If the workers aren't present, and sometimes even when they are, people use this knowledge of 'no enforcement possible' as an opportunity to speed away."

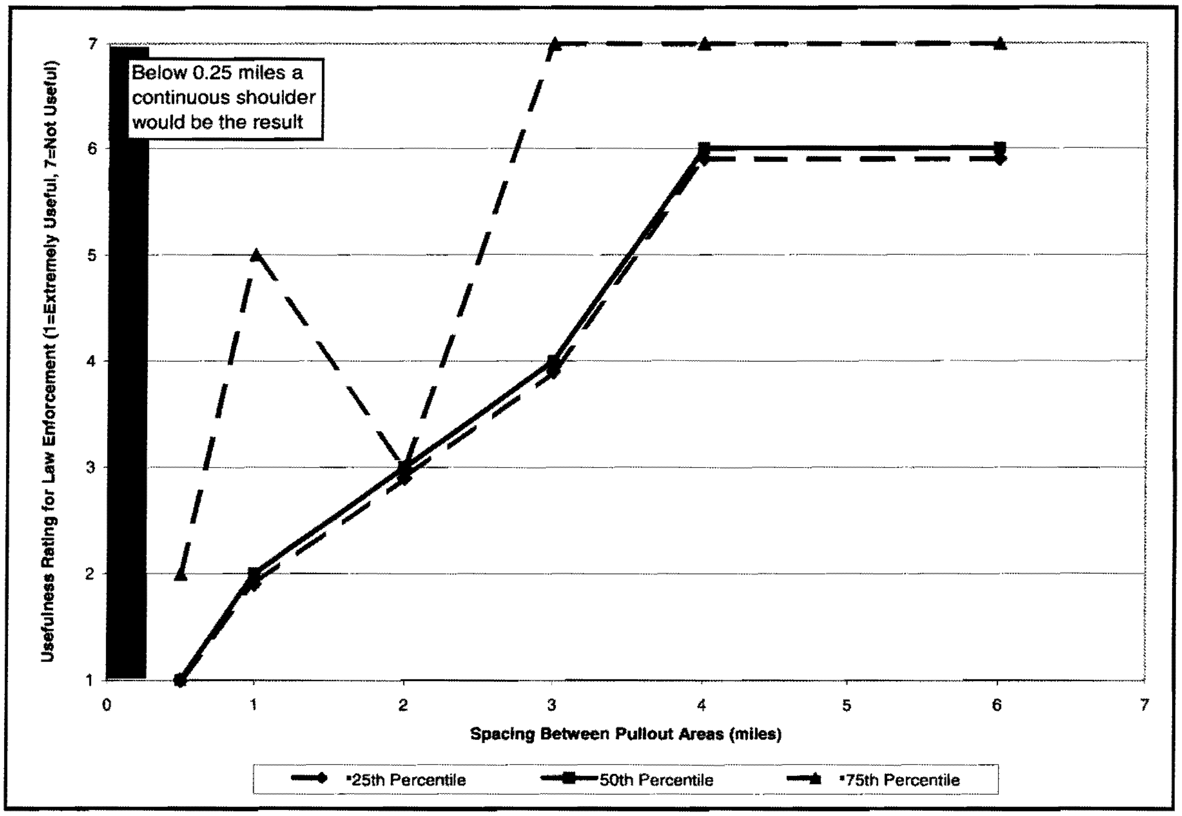


Figure D9. Response of Perceived Law Enforcement Usefulness of Enforcement Pullout Areas at Various Spacings.