# Traffic Control Guidelines for Urban Arterial Work Zones

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Urban arterial work zones have several unique characteristics that have not been adequately addressed in previous research. These characteristics were identified, and traffic control guidelines for urban arterial work zones were developed. Significant research activities included a review of previous literature and current practice, analysis of traffic and accident data, surveys of motorists, measurement of the capacity of an arterial lane closure, and a signal operations analysis near a lane closure. The literature review indicated a lack of previous research, although limited portions of other work zone research were found to be useful. The review of current practice explored the opinions of traffic engineers and examined work zone traffic control manuals of local agencies. Accident, volume, and travel time data were collected and analyzed to determine trends specific to arterial work zones and to identify characteristics that needed to be addressed in the guidelines. Motorist surveys attempted to evaluate driver comprehension of work zone traffic control devices and to identify some of the more significant driver concerns about urban arterial work zones. Other study activities included investigations into arterial lane closure capacity and the relationship between traffic signals and lane closures. The research results were used to develop guidelines addressing traffic control for urban arterial work zones. Use of these guidelines should help to improve safety and traffic flow in arterial work zones.

Urban arterial work zones have several unique characteristics that distinguish them from rural highway or freeway work zones. The characteristics are primarily related to traffic conditions, traffic signals, geometrics, and limitations on work zone traffic control. Among the most important of the characteristics are higher speed variations, highly variable volumes, limited maneuvering space, frequent turning and crossing maneuvers, multiple access points, higher pedestrian volumes, frequent traffic obstructions, greater competition for driver attention, and more traffic signals. These characteristics require special consideration when preparing a traffic control plan for construction activities. Unfortunately, urban arterial work zones are not sufficiently addressed in current work zone guidelines, and the topic has not been adequately researched in the past. A recently completed research study sponsored by the Texas Department of Transportation (*1*) evaluated some of the unique characteristics of urban arterial work zones and developed guidelines for traffic control in this type of work zone.

## STUDY ACTIVITIES

The guidelines were developed through the completion of several research activities, which included a review of pertinent literature and current practices, an analysis of traffic and accident data, two surveys of motorists, the measurement of the capacity of an urban arterial lane closure, and the analysis of signal operations near a lane closure.

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### Literature Review

Previous work zone research has traditionally focused on freeway and rural highway work zones. Therefore, it was not surprising to find that there have been few research projects specifically addressing urban arterial work zones. However, some limited portions of other work zone research that could be applied to urban arterials were identified in the course of the review. Most useful information is located in the *Manual on Uniform Traffic Control Devices* (MUTCD) (*2*) and the *Traffic Control Devices Handbook* (TCDH) (*3*), although these documents do not specifically address the needs of urban arterial work zones. Because of the limited amount of previous research on urban arterials, most of the guidelines developed in this study were the result of other research activities.

### Current Practice

The lack of previous research created the need to identify the current traffic control practices being used in urban arterial work zones. These practices were identified through discussions with traffic engineers at local transportation agencies and examinations of work zone traffic control manuals produced by a number of local agencies.

The discussions with traffic engineers indicated that there is variation in the emphasis given to traffic control for arterial work zones. Several engineers indicated the MUTCD did not sufficiently address traffic control for arterial work zones and that the more significant problem areas involve intersections and intersection-related traffic control. Several individuals described the benefits of having one or more inspectors whose only responsibility was inspecting traffic control in the work zones.

Traffic control manuals produced by local agencies rely heavily on the MUTCD, although some agencies have modified the MUTCD guidelines. Table 1 indicates the variability in sign spacing existing between several agencies.

### Accident and Traffic Data Analysis

Some of the more obvious characteristics of urban arterial work zones can be identified by simple comparisons with other

**TABLE 1 Comparison of Arterial Work Zone Sign Spacings**

| Speed - kph (mph) | Distance Between Signs - meters (feet) | | | | |
|---|---|---|---|---|---|
| | TCDH (3) | TxDOT (4) | Arlington (5) | Seattle (6) | Victoria (7) |
| 48 (30) | 76 (250) | 24 (80) | 38 (125) | 46 (150) | not available |
| 56 (35) | 76 (250) | 37 (120) | 49 (160) | Note: Seattle specifies sign spacing according to roadway classification, not roadway speed | 46-73 (150-240) |
| 64 (40) | 76-153 (250-500) | 49 (160) | 61 (200) | | not available |
| 72 (45) | 153 (500) | 73 (240) | 76 (250) | | 73-110 (240-360) |
| 81 (50) | 153 (500) | 98 (320) | 92 (300) | | not available |

types of work zones. On the other hand, other characteristics can only be ascertained by analyzing traffic data from urban arterial work zones. In this study, accident, volume, and travel time data were collected at three urban arterial work zone sites. Each site was a four-lane arterial being widened to six lanes. Two sites were in Houston and the third was in Dallas.

The safety impacts of work zones on urban arterials were assessed by comparing preconstruction and during-construction accidents in several different categories, including accident frequency, accident rates, accident types, causes of accidents, locations of accidents, and accident periods. Statistical analysis of the data indicated that there are overall increases in accident frequency and rate in an urban arterial work zone. The increase in frequency ranged from 35 to 77 percent, and the increase in rate ranged from 59 to 106 percent. The arterial construction appears to have caused a statistically significant increase in the number of accidents occurring at or near intersections and driveways and in the number of nighttime accidents. Figure 1 shows the accident rate for arterial segments at one of the study sites. The figure shows the increase in accidents at intersection and driveway locations during the period of construction.

Average weekday traffic volumes and average travel times were also collected to identify the traffic flow characteristics of arterial work zones. However, the traffic volume and travel time data were highly variable and did not indicate any trends unique to urban arterials. It appears that the traffic volumes are lower when the construction area is located in the middle of the roadway between opposing traffic flows. The data indicated a wide variation in the traffic volumes, and therefore the traffic control plan should be prepared to accommodate traffic volumes that are comparable with preconstruction volumes. Increases in travel time through the work zones could not be attributed to changes in traffic control within the work zone.

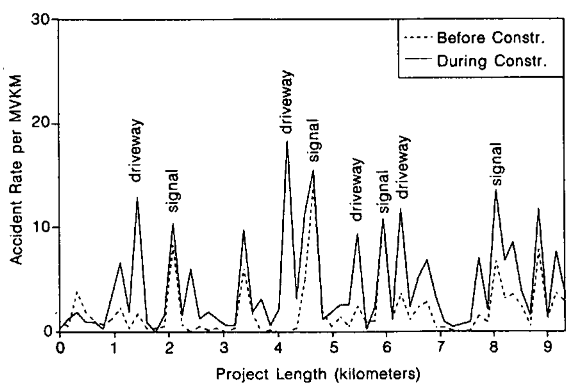



**FIGURE 1 Accident rate by arterial segment.**

### Motorist Surveys

Two motorist surveys were conducted near the study sites (*8,9*). The surveys evaluated motorist understanding of work zone traffic control devices and identified motorist concerns related to construction activities. The surveys indicated that drivers are more concerned with issues such as the length of the project, duration of construction, and travel delay than they are with traffic control devices. Therefore, it is not surprising that the surveys found several devices with low comprehension levels. Some symbol signs were not understood very well, and about half of the drivers could not identify the difference between identical orange and yellow signs.

### Analysis of Urban Arterial Lane Closure Capacity

An estimate of the capacity of a lane closure located within an urban arterial work zone was determined by measuring traffic flow at one site in Arlington, Texas. Two lanes were reduced to one. Volumes were measured for 25 periods, each of 5 min. A queue was present at all times. As indicated in Table 2, the 5-min flow rates ranged between 612 and 864 vehicles per hour (vph), and the 15-min flow rates for the same time period ranged between 652 and 808 vph. The average flow rate for both the 5- and 15-min periods was about 736 vph. These preliminary observations indicate that a realistic estimate of the capacity of a lane closure in an urban arterial work zone is in the range of 750 to 800 vph. This represents about 56 to 60 percent of the capacity of a freeway lane closure with similar geometrics as described in Chapter 6 of the *Highway Capacity Manual* (*10*).

### Signal Operation near a Lane Closure

One of the major concerns associated with lane closures in urban arterial work zones is that the queue resulting from the lane closure may back up into an upstream intersection and prevent cross-street traffic from entering the intersection. This situation is particularly critical when the lane closure is located a short distance downstream of a signalized intersection. In situations where the lane closure queue has the potential to block a signalized intersection, it may be appropriate to locate the lane closure upstream of the intersection.

**TABLE 2 Flow Rates for Arterial Work Zone Lane Closure**

| Time Start | 5-Minute Volume | Equivalent Hourly Flow | 15-Minute Volume | Equivalent Hourly Flow |
|---|---|---|---|---|
| 7:43 | 57 | 684 | --- | --- |
| 7:48 | 54 | 648 | | |
| 7:53 | 60 | 720 | 176 | 704 |
| 7:58 | 62 | 744 | | |
| 8:08 | 52 | 624 | | |
| 8:13 | 51 | 612 | 163 | 652 |
| 8:18 | 60 | 720 | | |
| 11:09 | 51 | 612 | | |
| 11:14 | 53 | 636 | 169 | 676 |
| 11:19 | 65 | 780 | | |
| 11:24 | 68 | 816 | | |
| 11:29 | 68 | 816 | 192 | 768 |
| 11:34 | 56 | 672 | | |
| 11:39 | 63 | 756 | | |
| 11:44 | 63 | 756 | 189 | 756 |
| 11:49 | 63 | 648 | | |
| 11:57 | 68 | 816 | | |
| 12:02 | 65 | 780 | 201 | 804 |
| 12:07 | 68 | 816 | | |
| 12:12 | 61 | 732 | | |
| 12:17 | 62 | 744 | 195 | 780 |
| 12:22 | 72 | 864 | | |
| 12:27 | 68 | 816 | | |
| 12:32 | 62 | 744 | 190 | 760 |
| 12:37 | 60 | 720 | | |
| **Average** | 61 | 735 | 184 | 738 |
| **Minimum** | 51 | 612 | 163 | 652 |
| **Maximum** | 72 | 864 | 202 | 808 |

--- indicates no data

A simplified operational analysis of the relationship between a lane closure queue and an upstream signal indicated that the maximum queue typically forms as the result of saturated flow from the intersection during the initial portion of the green interval. In other words, a queue of vehicles forms at the intersection during the red portion of the signal cycle. When the signal changes to green, this queue moves downstream to the lane closure as a platoon and forms a queue at the lane closure. If the capacity of the lane closure is greater than the arrival rate of vehicles, the queue length will decrease following the arrival of the saturation platoon.

The purpose of the operational analysis was to determine the separation distance needed between the lane closure and the signal to prevent the lane closure queue from blocking the upstream traffic signal. The lane closure capacity described earlier was used as the basis of the analysis, and it was assumed that the arterial volume is less than the capacity of the lane closure and that cross-street turning volumes are low enough that the lane closure queues clear before the arterial platoon arrives at the lane closure. The Poisson distribution was used to determine the probability that the separation distance would be exceeded.

Figure 2 shows a simplified graphical method of determining the separation distance as a function of the arterial volume, length of arterial red, and the probability that the queue will not exceed the separation distance. A minimum separation of 50 ft is recommended. Figure 2 applies only to an arterial with two lanes in each direction. If the separation distance cannot be obtained, the beginning of the lane closure should be extended upstream of the signal.

## URBAN ARTERIAL WORK ZONE GUIDELINES

The following guidelines were developed from the results of research activities and investigations into current arterial work zone practices. The guidelines have not undergone an extensive experimentation or evaluation period in the field.

### Traffic Control Guidelines

Traffic control guidelines include those related directly to the movement of traffic through the work zone and the traffic control devices used to control the traffic. The traffic control guidelines address signalized intersections, intersections, lane closures, speed control, channelization, and pavement markings.

#### *Signalized Intersections*

The overall capacity of an arterial is typically limited to the capacity of the signals on that arterial. During construction,

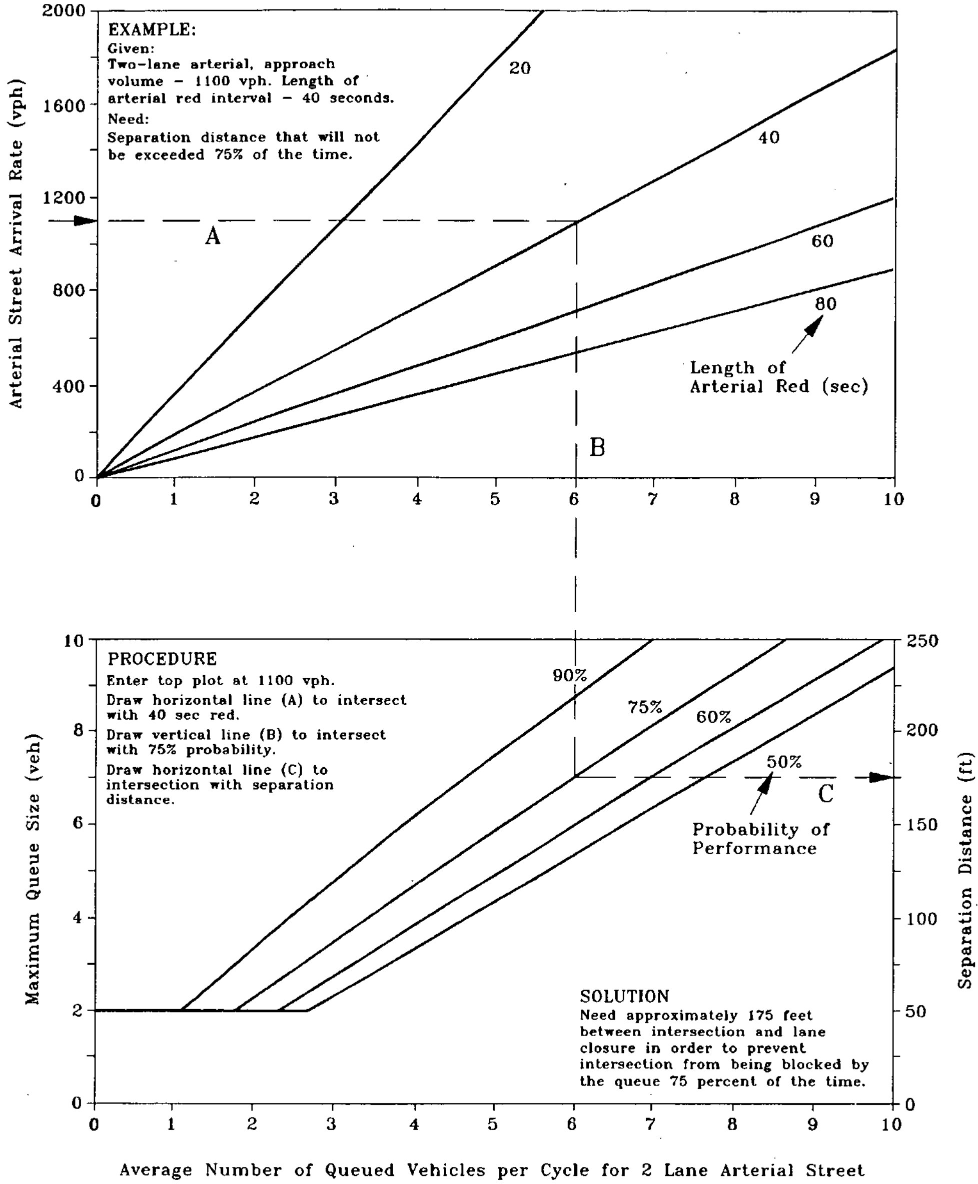



**FIGURE 2 Lane closure-intersection separation.**

the capacity of signalized intersections is often reduced. Therefore, it is important that steps be taken to ensure that the traffic signals within the work zone are operating in the most effective manner possible, given the restrictions of the work zone.

Signal phasing and timing should be adjusted with each change in construction phasing, and signal operation should be checked in the field after each adjustment. Construction activities cause a significant disruption of normal traffic patterns, and construction phasing may alter the lane arrangements at approaches to signalized intersections. All of these factors may negate preconstruction signal phasing and timing. Because changes in construction phasing may take place on a relatively frequent basis, changes in phasing or timing may be required more often than normal. As with normal signal operation, the effectiveness of new phasing or timings should be regularly checked in the field after implementation.

Short cycle lengths may be useful in reducing queue backup into the intersection. The effects of cycle length on queuing should be carefully observed at signalized intersections in the work zone. If queues due to construction activities or traffic generators are common, a shorter cycle length may be effective at minimizing queue lengths.

The positions of traffic signal heads should be shifted to line up with lane arrangements any time lane positions are modified. Signal heads should be located within the cone of visibility described in the MUTCD. The typical construction phasing plan for an urban arterial work zone uses narrow lanes and shifts the positions of the lanes within the intersection. If the signal head positions are not changed accordingly, the signals may not have enough target value for drivers to identify them in a complex urban work zone environment.

The operation of actuated signal detectors should be checked on a regular basis. If detection capability is lost, actuated controllers should be converted to pretimed operation. Any number of construction activities may affect or prevent the operation of traffic signal detectors. Without detection capability, an actuated signal becomes a pretimed signal by default, and the signal phasing and timings should be developed accordingly.

Time base coordination should be used to provide progression if the interconnection between signals is disrupted. Interconnection between signalized intersections may be lost in the same way that detection capabilities may be lost. If this occurs, progression cannot be provided for a series of signals. Maintaining progression is especially important if the traffic signals must operate in a pretimed mode. If progression is needed during construction to minimize motorists' delay, time-based coordinators can be used to provide progression without a physical connection between the controllers.

Pedestrian push buttons should be used with actuated controllers to maximize the efficiency of signals in a work zone. The congestion and delays associated with signals in a work zone are compounded by the need to accommodate pedestrians at signals. Although pedestrians are usually infrequent, sufficient crossing time must be provided for them. The most efficient method of accommodating pedestrians is to install pedestrian push buttons to reduce the amount of unused green. Even if vehicle detection capability is lost and the signals are operated in a pretimed manner, the pedestrian phase can still operate in an actuated mode.

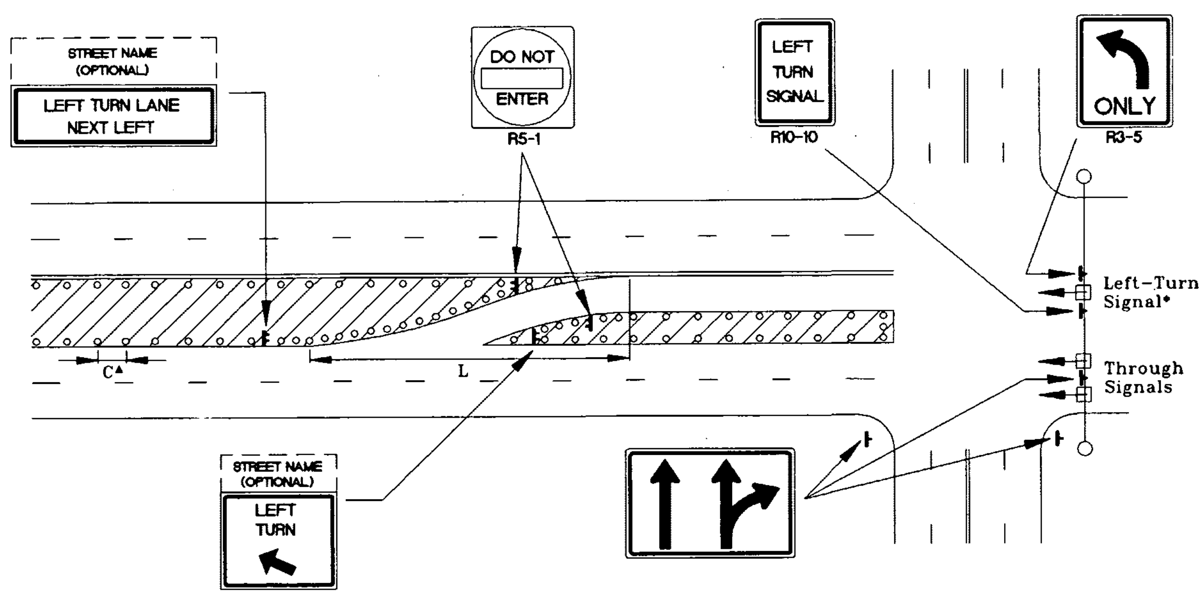
New or temporary signals in arterial work zones should use 305-mm (12-in.) signal lenses. The large number of construction activities, traffic control devices, other vehicles, vehicle maneuvering, and development present in urban arterial work zones creates many demands for the driver's attention. Using 305-mm (12-in.) signal lenses will help the driver identify new or relocated traffic signals in the work zone.

Left-turn lanes should be provided at major signalized intersections. Left-turn movements can be a significant hindrance to traffic flow at signalized intersections. The lack of a left-turn bay can significantly increase delay because of left-turning vehicles blocking a through lane while waiting for an acceptable gap. Although the addition of left-turn lanes may create some difficulties for construction scheduling and activities, the benefits associated with these lanes make it desirable to provide them at major signalized intersections where left-turning vehicles are present. Figure 3 shows a potential layout for a left-turn lane that can be used when construction is taking place in the center of the road. The actual position of the lane can be shifted as needed to allow work to take place in the center area.

### *Intersections*

The large number of intersections associated with urban arterial work zones introduce many difficulties related to work zone traffic control. Most of these difficulties are related to vehicle maneuvering and the intersection geometrics.

Large street name signs with block numbers should be provided at major signalized intersections, if possible. These street signs should be mounted overhead (on signal mast arms or span wire) to increase their visibility. When construction begins, many of the navigational aids, such as business signs and addresses, that drivers use are removed or become less visible. In addition, the preconstruction street signs may no longer be visible to drivers if the work space is located between the




Note:

* ∗ Left-turn signal should be positioned over the left-turn lane
* ▲ Channelizing devices should be spaced at 1/2 C on the taper

LEGEND

- ▨ - Work Space
- o - Channelizing Device
- L - Taper Length
  - $= WS^2/60$ for $S \leq 40$ mph
  - $= WS$ for $S \geq 45$ mph
- C - Spacing of Channelizing Devices

**FIGURE 3 Layout of left-turn lane in work zone.**

sign and traffic. Locating street signs overhead at signalized intersections will improve the visibility of street name signs.

As large a turning radius as possible should be maintained at driveways and intersections. The accident data from the study sites indicated an increase in the proportion of accidents occurring at intersections and driveways. One potential method of reducing accidents is to make it easier for vehicles to turn in and out of intersections and driveways by increasing the turn radius to reduce the potential for encroaching on adjacent lanes.

Driveways should be clearly marked and safe sight distances checked for each driveway. The presence of channelization devices may make it difficult for drivers on the roadway to identify the specific location of driveways and may create sight distance restrictions. Therefore, each driveway within the activity area should be checked to ensure that it is visible to drivers traveling down the roadway and that drivers in the driveway can adequately see traffic on the roadway.

### *Lane Closures*

Although lane closures have a significant impact on traffic flow, they are a necessary part of any construction project. The detrimental effects of lane closures include the creation of queues that block intersections and driveways, the compounding of peak-period traffic congestion, and an increase in erratic lane changing.

An arrow panel should be used for lane closures on major arterial streets. Major arterials typically have high speeds and heavy volumes—conditions well suited to the use of an arrow panel for lane closures. On high-speed, high-volume arterials, an arrow panel should be used for lane closures in the same manner as for freeway lane closures. Arrow panels help motorists identify the location of the lane closure, and they may be more visible than some advance signing due to their greater mounting height.

Lane closures should be set up so that the queue will not block signalized intersections upstream of the lane closure. Queues often form upstream of a lane closure when volumes are high. If the lane closure is located too close to a signalized intersection, the queue may back up into the intersection and prevent cross-street traffic from entering the intersection. Sufficient distance should be provided between the lane closure and the intersection so that the queue will not block cross-street traffic. Figure 2 shows the minimum separation distance for various combinations of arterial volume, length of red, and probability of performance. If this distance cannot be obtained, the lane closure should be extended upstream of the intersection.

Lane closures should be located on a tangent section of roadway, if possible. Lane closures located on a curve present sight distance and maneuvering difficulties. A lane closure on a tangent section is more visible to approaching drivers, allowing them to change lanes further in advance of the merge point. Also, the lane change maneuver becomes less complicated because the driver is not negotiating a curve while changing lanes.

If possible, the lane closure should be located so that there are no intersections, driveways, or temporary median crossovers in the taper area or within 60 to 90 m (197 to 295 ft) of the beginning of the taper, as shown in Figure 4. Introducing turning and crossing maneuvers into the area where lane changing and merging are taking place brings turbulence into the traffic stream, creates more conflicts, and limits operational efficiency.

The lower capacity of an arterial lane closure should be considered when planning and implementing lane closures. Preliminary measurements of the capacity of a lane closure in an urban arterial work zone indicate that the capacity of two lanes being reduced to one is about 750 to 800 vph. This value is approximately 56 to 60 percent of the capacity of a freeway lane closure with similar geometrics (*10*).

Signing for a lane closure should be located upstream of a signalized intersection if the lane closure is less than 460 m (1,508 ft) downstream of a signalized intersection and arterial traffic volumes are high. Drivers may not be able to see a lane closure or signing for a lane closure when it is located close to a signalized intersection. However, the higher traffic density associated with saturation flow from a signalized in-

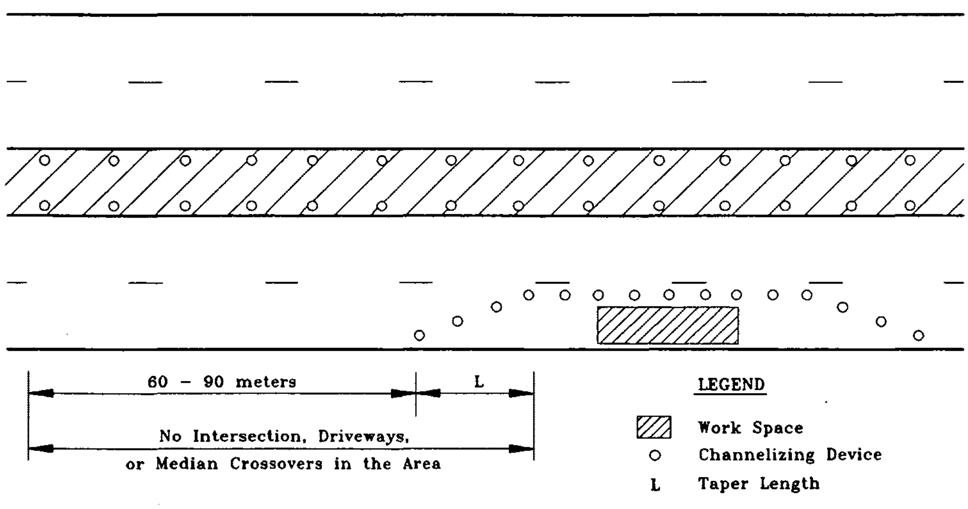



**FIGURE 4 Lane closure taper location.**

tersection eliminates many lane-changing opportunities. Placing the lane closure signing in advance of the signalized intersection gives drivers the opportunity to change lanes before reaching the queue at the intersection.

### *Speed Control*

Speed reductions (both advisory and regulatory) are sometimes used in work zones for safety reasons. However, drivers do not always adhere to the speed reductions. Therefore, actions having an impact on vehicle speeds through the work zone should be evaluated carefully.

Speed restrictions should be avoided, if possible. If they are necessary, they should be carefully selected, recognizing that it may be necessary to supplement them with other more positive means of controlling driver behavior. Advisory speeds should be selected to be consistent with site conditions. Research has shown that drivers do not reduce their speed upon entering a work zone. Therefore, the normal arterial speed should be maintained in the urban arterial work zone, if at all possible. If speed restrictions are necessary, they should be carefully selected with the recognition that additional measures may be needed to slow traffic.

Speed information should be consistent. Advisory speed plates and speed limit signs with different speeds should not be placed within view of one another. The placement of speed limit and advisory speed information should be evaluated to ensure that conflicting speed information is not visible to the driver at one time. If a speed limit sign and advisory speed plate are visible to the driver at the same time, the driver will likely select the higher of the two speeds.

An enforcement area should be provided for police activities. The space restrictions associated with arterial construction may reduce the ability of police to enforce traffic laws. Police may not have an acceptable location to observe traffic and are hesitant to issue citations if a safe area to do so is not available. The lack of enforcement can breed disrespect for traffic laws. This may result in increased accidents and poor operations. However, even if an enforcement area is not provided and citations are not being issued, police presence in the work zone may help reduce vehicle speeds.

### *Channelization*

Channelizing devices are often used in work zones for lane closures or for shifting the travel path of vehicles. The spacing of channelizing devices has some unique implications in urban arterial work zones.

Spacing between channelizing devices should be reduced in areas where vehicles may want to encroach on the construction area. The standard spacing for channelization devices on a tangent is a distance in meters (feet) equal to 0.379 (2.0) times the speed limit in kph (mph). At the speeds found on many arterials, vehicles can travel between the devices and drive on the wrong side. Drivers may cross the line of channelization devices to make an illegal turn, to pass an area of congestion, or because they are confused. Reducing the spacing of channelizing devices to a distance in meters (feet) equal to or less than 0.189 (1.0) times the speed limit in kph (mph) will discourage drivers from crossing into the work space.

### *Pavement Markings*

The relocation of traffic lanes requires old markings to be removed and temporary markings to be placed. However, it is difficult to completely remove obsolete pavement markings.

Raised pavement markers, in conjunction with or in lieu of painted markings, should be used to enhance lane delineation in potentially hazardous areas. The removal and placement of pavement markings is one of the biggest challenges in work zones. Short of placing an overlay over old pavement markings, there is no method that will obliterate permanent pavement markings without leaving a scar. Raised pavement markers possess many advantages for use in urban arterial work zones. They can be easily placed and removed, and after removal, the remains of the markings do not provide as visible an indication of the lane lines as other types of markings. Raised pavement markers have greater visibility in periods of wet weather. They also provide a tactile indication to the driver when the vehicle begins to change lanes.

## **Construction Activity Guidelines**

Issues associated with construction activities include difficulties related directly to performing construction activities: planning construction activities, scheduling the construction activities, and inspecting the traffic control.

### *Construction Planning*

Several issues can be addressed in the initial stages of planning the construction activities that will help make the work zone safer and more efficient.

The construction phasing should be planned to minimize, as much as possible, the length of arterial under construction at any one time. The motorist surveys indicated that one of the most frequent complaints was the length of arterial under construction.

Unused construction equipment should not be left in public view for extended periods. Comments from traffic engineers indicated that they receive complaints about construction equipment being left along the arterial for extended periods. The complaints reflected a concern that construction progress was not occurring if equipment was not being used. Although the public does not understand the specifics of construction, it is important to avoid a lackadaisical appearance. Therefore, if construction equipment will not be used on a regular basis, it should be stored where it will not be seen.

High early strength concrete should be used to minimize the duration of construction as much as possible. The curing requirements of materials affect project scheduling and traffic flow. Numerous difficulties are related to the time spent waiting for concrete to cure before vehicles are allowed to travel on it. In addition, the public does not understand the need for the concrete to cure and perceives dry concrete that is not open to traffic as an inefficient construction practice. The use of high early strength concrete will allow newly paved areas to be opened to the public more quickly.

The outside travel lane should be wider in areas with large numbers of driveways and intersections. One of the unique characteristics of urban arterial work zones is the large number of vehicles turning onto and off the arterial. In some cases, these turns occur at locations with short turning radii on the curb return, causing some turning vehicles to encroach on the inside travel lane. Providing a wider outside lane will reduce the potential for encroachment on the inside lane.

Bus stops should be relocated to appropriate locations. Temporarily relocating bus stops to midblock or off-street parking areas may help to improve traffic flow through the arterial work zone because of the effects of construction on transit operations and pedestrian movements.

If construction is planned for a major arterial and the duration or impacts of the construction are expected to be significant, consideration should be given to improving alternate routes before construction begins on the arterial. At a minimum, consideration should be given to modifying the signal phasing and timings on the alternate route.

### *Project and Work Activity Scheduling*

The impact of an urban arterial work zone on the nearby commercial, retail, and residential areas can be reduced through judicious scheduling of project and work activities.

To minimize traffic conflicts, lane and intersection closures during peak periods should be avoided. Traffic volumes on arterial streets are highest during the morning and evening peak periods. During these high-demand periods, all available capacity should be provided for traffic flow. Avoiding lane closures and intersection closures during these peak periods reduces congestion, delay, and vehicle conflicts. It may also be appropriate to avoid lane and intersection closures during the lunchtime peak period because of the high volumes that may be present at lunchtime in some areas.

If possible, projects should not be scheduled to begin construction between Thanksgiving and New Year's Day in heavy retail areas. The heaviest shopping period of the year is between Thanksgiving and the end of the year. Retail businesses generate more traffic than usual, and arterials adjacent to these businesses carry higher traffic volumes during this period. Therefore, it is desirable to avoid starting construction during the Christmas shopping season.

### *Inspection*

Because of the large number of motorists who drive through an urban arterial work zone, qualified personnel should regularly examine the traffic control devices in the work zone.

Inspectors with specific training in work zone traffic control should inspect urban arterial work zones on a regular basis. The primary concern for many construction inspectors is the quality and progress of the construction activities. In some cases, the construction inspector may have little or no formal training in work zone traffic control. Therefore, it is important that an inspector whose primary responsibility is traffic control inspect the arterial work zone on a regular basis. This individual should have specific training in work zone traffic control and risk management.

Traffic control in the work zone should be checked during periods of darkness. Accident data from the study sites indicated that there was an increase in the number of accidents occurring during periods of darkness, despite the fact that construction activities were not taking place at night. Regular nighttime inspections by qualified traffic control inspectors can help identify locations where visibility of devices can be improved and where glare from other lighting sources interferes with visibility of the work zone. Such inspections can identify the needs of large nighttime traffic generators and provide indications of nighttime traffic characteristics.

### *Temporary Median Crossovers*

The need for motorists to get from one side of the arterial to the other places many demands on a work zone. When the construction area is located between opposing traffic, the ability to provide temporary crossovers may be restricted by the proximity to traffic signals, the required geometrics of the crossover, and the relationship of a crossover to the arterial access locations.

In areas with heavy retail development and many access points on the arterial, it may be appropriate to locate one or more temporary median crossovers between each pair of traffic signals when the spacing between the signals exceeds 300 m (984 ft). However, temporary crossovers may not be necessary if through and left-turn movements at the intersection are light and the intersection can accommodate the increase in left-turn and U-turn volumes. Some areas create a heavy demand for left-turn movements. Typically, this type of area has a significant retail development and many access points on the arterial. When the work space is located between traffic flowing in opposite directions, left-turn movements are restricted to intersections and locations between intersections where temporary crossovers have been provided. If temporary crossovers are not provided, all left-turn demand is shifted to the intersections. If traffic volumes are heavy, the increased demand at the intersection may create operational problems and cause cycle failures. There should be enough distance between the signals so that the traffic turbulence created by the crossover does not affect operations at the signals. Temporary crossovers should be located a minimum of 90 to 125 m (295 to 410 ft) from any intersection. Signals spaced less than 300 m (984 ft) apart create some operational difficulties, which are compounded by the presence of a crossover between the signals.

The grade of a temporary crossover or temporary driveway should be as level as possible within 6 m (20 ft) of the higher elevation roadway to reduce sight distance restrictions. If a temporary crossover or temporary driveway is crossing an excavated area and has a pavement surface lower than the arterial, sight distance restrictions may be created by the channelizing devices along the activity area. By providing a nearly level approach to the arterial, these sight distance restrictions can be minimized. In some cases, the size of the activity area or the difference in elevation between the arterial pavement surfaces may make it difficult to provide a level crossover or driveway. If this is so, the sight distance should be checked. If sight distance is not adequate, the crossover or driveway should be eliminated.

U-turns should be permitted at traffic signals if a temporary crossover is not provided between the signal and the previous signal. If a temporary crossover is not provided between signals, vehicles will make left- and U-turns at the intersection to gain access to properties on the other side of the work space. Signal operation and intersection geometrics should be checked to ensure that U-turns are possible. If U-turns cannot be safely accommodated, alternative means of providing access to properties should be evaluated.

## SUMMARY

This paper describes a research study intended to identify the unique characteristics of urban arterial work zones and develop traffic control guidelines for them. The completed research confirms the lack of existing guidance and has identified numerous guidelines that should help to improve both traffic flow and worker safety in urban arterial work zones.

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