A Guide to Work Zone Temporary Traffic Control Near Signalized/Unsignalized Intersections

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7. Author(s)
Steven D. Schrock, Alexandra Kondyli, Hemin Mohammed, and Amin Asgharzadeh

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16. Abstract

The objective of this document is to assist transportation engineers and traffic control professionals in improving their knowledge on safety and operations of work zones in the immediate vicinity of signalized or unsignalized intersections. Intersections traditionally represent an area of safety concern given conflicting movements that increase the frequency and severity of traffic crashes as compared to other roadway locations. This issue is often exacerbated by work zones, which may present a sudden and unfamiliar setting for motorists, particularly when considering the increased levels of visual and cognitive complexity that can be present at intersections.

Topics discussed in this guide include:

- A discussion of the MUTCD and intersection-related Typical Applications (TAs);
- A discussion of pertinent sections of several state-specific MUTCDs;
- A discussion of how work zones can be modified for innovative intersection types such as roundabouts, diverging diamond interchanges (DDIs), restricted crossing U-turn intersections (RCUTs), and median U-turn intersections (MUTs); and
- A practical checklist that provides guidance on steps to consider when developing a temporary traffic control plan that includes an intersection.

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1. Introduction

The objective of this document is to assist transportation engineers and traffic control professionals in improving their knowledge on safety and operations of work zones in the immediate vicinity of signalized or unsignalized intersections. Intersections traditionally represent an area of safety concern given conflicting movements that increase the frequency and severity of traffic crashes as compared to other roadway locations. This issue is often exacerbated by work zones, which may present a sudden and unfamiliar setting for motorists, particularly when considering the increased levels of visual and cognitive complexity that can be present at intersections.

While the Manual on Uniform Traffic Control Devices (MUTCD) provides some general guidance for intersection work zone applications, there are a myriad of issues that merit special consideration (Federal Highway Administration (FHWA), 2022). This document uses the MUTCD as a starting point, but also makes use of other documents to assist the reader in better understanding the issues of designing intersection-related work zones.

The MUTCD was written with several objectives in mind. First, it was written to ensure the uniformity of traffic control devices (TCDs) in the U.S. Second, it establishes minimum standards for TCDs as well as recommended and allowable uses for specific TCDs. Promoting uniformity of TCDs is the overarching goal of the MUTCD. If the objectives of uniformity are accomplished it can provide several benefits to the driving public: crashes can be reduced and improvements can be made to the operating efficiency because drivers make fewer driving or navigational errors. Additionally, street and highway agencies benefit through reduced costs, more effective signs mean that agencies need fewer of them.

When drivers see consistent traffic control messages - in the same way - in the same general places - and at the right times - they spend less time processing the information. They can draw on their previous driving experiences at similar situations so they can react quicker to the information, and they are less likely to make a wrong decision that leads to a driving error such as a crash.

This is also true for temporary traffic control devices (TTCDs). First, because of its temporary nature, motorists may be surprised the first time they encounter a work zone. Even if motorists were previously aware of the work zone, the traveled path may have changed to allow for another phase of the work to progress - and this could catch motorists by surprise.

Second, TTCDs are very often placed where there are other permanent traffic control devices, so it is important to ensure that the messages do not conflict or confuse motorists. Additionally, work zones can be more complex driving situations because they frequently include the presence of workers and the work activity is often in close proximity to traffic. Depending on the nature of the work activity, there may often be traveled areas taken from motorists for equipment, supplies, and the work activity itself, leading to less space for motorists. Finally, as typically no two work zones are the same, this can add challenges to providing the MUTCD's goal of uniformity.

Topics discussed in this guide include:

- A discussion of the MUTCD and intersection-related Typical Applications (TAs);
- A discussion of pertinent sections of several state-specific MUTCDs;
- A discussion of how work zones can be modified for innovative intersection types such as roundabouts, diverging diamond interchanges (DDIs), restricted crossing U-turn intersections (RCUTs), and median U-turn intersections (MUTs); and
- A practical checklist that provides guidance on steps to consider when developing a temporary traffic control plan that includes an intersection.

2. Intersection-Related Sections of the MUTCD, Part VI

Intersections can be more complicated than other roadway areas due to many factors, including:

- Additional traffic control that is specific to intersections such as traffic signals;
- The geometry can be more complex;
- Intersections by definition include crossing and turning traffic;
- Intersections can also have nearby driveways that add to overall driving complexity; and
- They can also have nearby buildings or other obstructions that can make it more difficult for motorists and pedestrians from seeing and being seen.

Adding a temporary traffic control (TTC) plan to an intersection - even a pretty straightforward intersection - can add challenges to drivers in several ways. For example, it can add capacity restrictions if one or more lanes are closed. If the work zone is new or recently changed due to a new phase of construction drivers can be caught off guard. Adding more things to look at, read, understand, and avoid can add more visual and cognitive load on drivers. Additionally, the lanes could be narrower. Pedestrians and bicyclists may be closer to traffic due to the nature of the work activity. Finally, changes to turning movements can also make things more challenging. This makes Part 6 is a little different than other part of the MUTCD. The MUTCD considers that no two TTC zones are the same.

The MUTCD uses the concept of typical applications (TAs) as a guide on how to approach similar situations (FHWA, 2022). They provide guidance on how to use TTCs in many typical situations, denote minimum solutions for the situations depicted, and can generally be adapted to a broad range of conditions. The MUTCD has 46 TAs as examples of commonly encountered temporary traffic situations. While not every situation is addressed, the information illustrated can generally be adapted to a broad range of conditions. Additionally, an appropriate TTC plan can often be achieved by combining features from various typical applications.

Another way to consider TAs is that they are the most basic type of TTC plan. For extremely simple and common TTC situations, a TA may be all that is needed for a TTC plan. More complicated (but still common) situations can be addressed through the development of standard traffic control plans for a jurisdiction, while extremely complicated or unusual situations may require detailed one-off plans to deal with the specific situation.

Not all of the TAs in the MUTCD are related to intersection locations (There are seven that are), but the principles are the same regardless. To better understand the ways that state transportation agencies have modified the original TAs found in the MUTCD, the research team examined over 100 documents including state-specific MUTCDs and standard plan sheets. Of the documents that were reviewed, it was found that several of the state-specific MUTCDs showed interesting variations to the MUTCD’s intersection-related TAs. This guide will focus on ones from California, Michigan, and Texas. These TAs can be generally categorized into three groups:

- When the work space is on the near side of an intersection;
- When the work space is on the far side of an intersection; and
- When the work space is in the intersection.

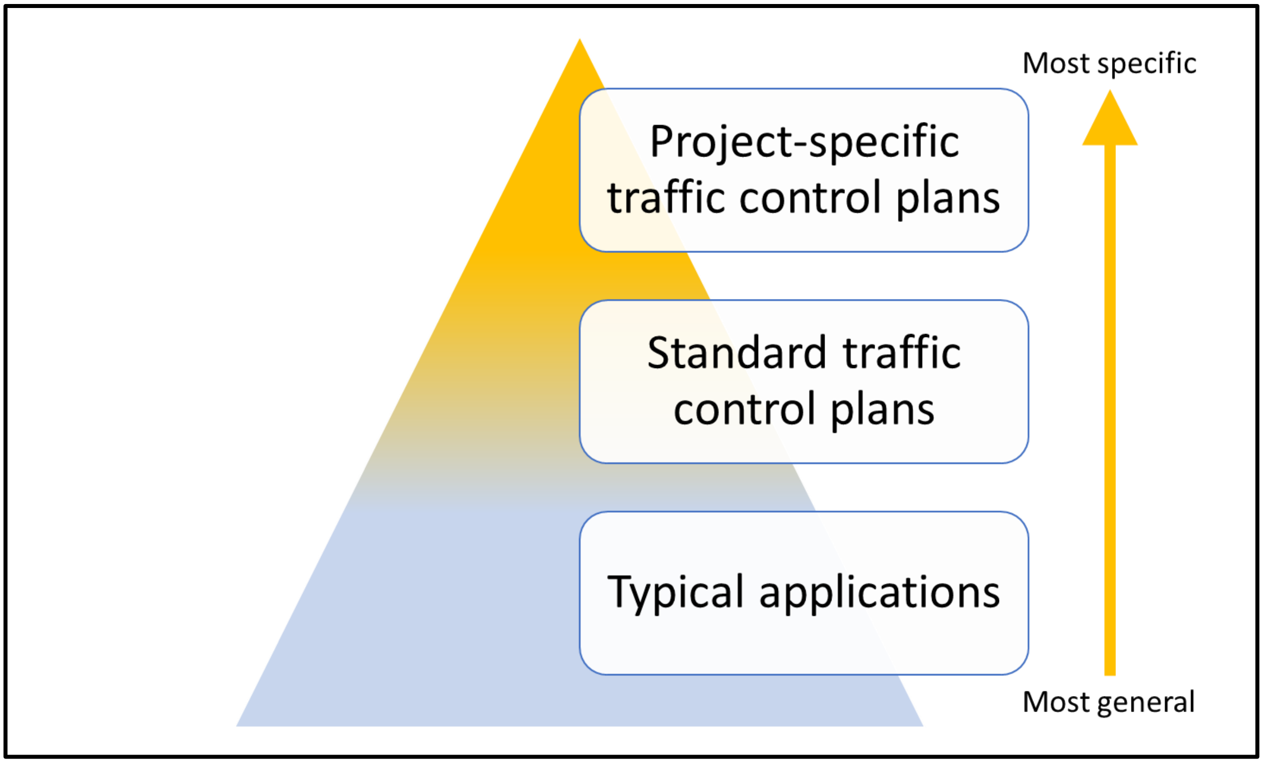

Figure 1. MUTCD Typical Applications Compared to Traffic Control Plans.

The purpose of the following sections is to show that there are acceptable variations of the MUTCD's TAs that may enhance a work zone TTC plan in certain situations.

2.1 When the Work Space is on the Near Side of an Intersection

The first set of TAs presented are when the work space is on the near side of an intersection. In the MUTCD the first of these is TA-21: Lane Closure on Near Side of an Intersection (MUTCD, 2012). As shown in Figure 2, there are three lanes with the center lane closed for work in advance of the intersection. But this TA could work just as well when there are two lanes in one direction with the presence of a left- or right-turn lane.

Figure 3 illustrates one variation on this typical application, which comes from the Texas Department of Transportation's (TxDOT) MUTCD (TxDOT, 2014). In their version you can see that the advance warning signing that says "CENTER LANE CLOSED AHEAD" can be replaced with a sign showing specifically which lane is closed. This can be especially helpful when there are more than three lanes as it would not otherwise be clear to motorists which lane is actually being closed.

Figure 4 illustrates another variation on TA-21, this time from the California Department of Transportation's (Caltrans) MUTCD (Caltrans, 2014). In their variation they specifically state that a high-level warning device is not to be used, but that an arrow board is to be used to help clarify to motorists what they are supposed to do.

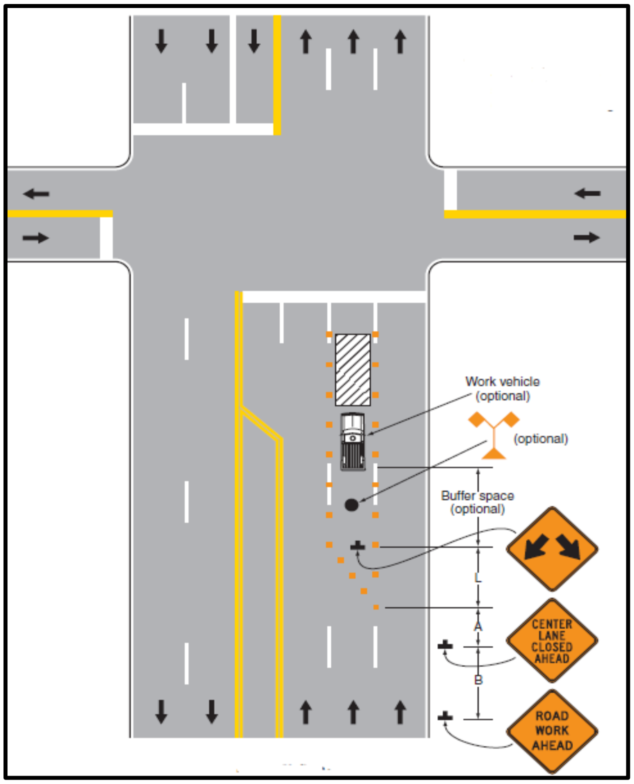

Figure 2: TA-21: Lane Closure on Near Side of an Intersection (Source: FHWA, 2022)

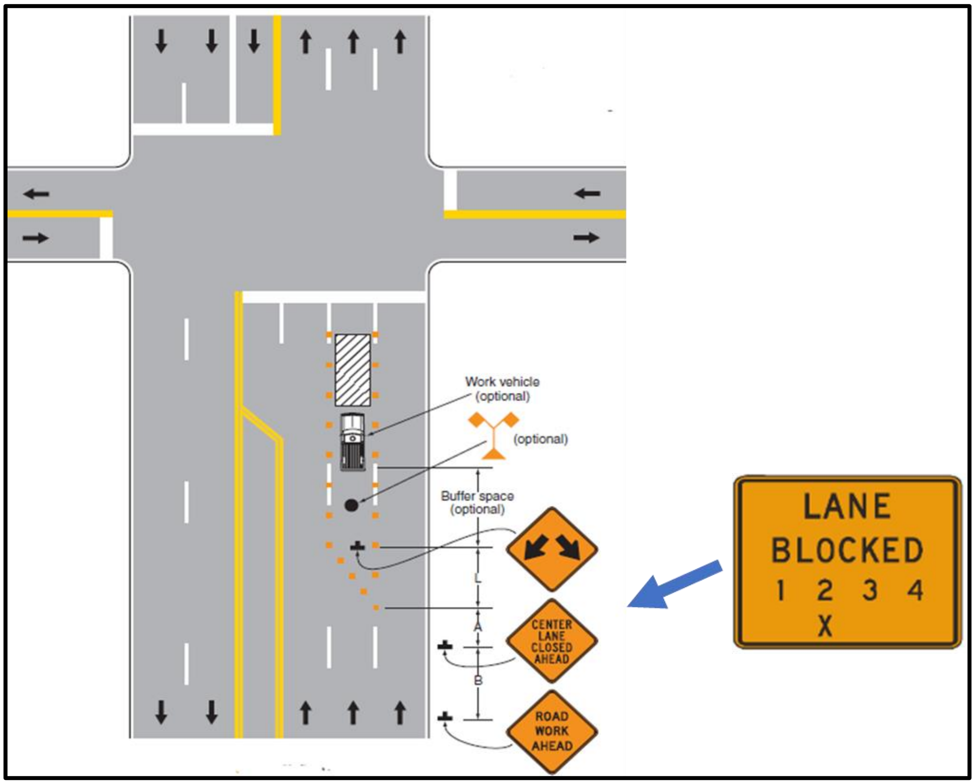

Figure 3: TA-21: Lane Closure on Near Side of an Intersection (Source: TxDOT, 2014)

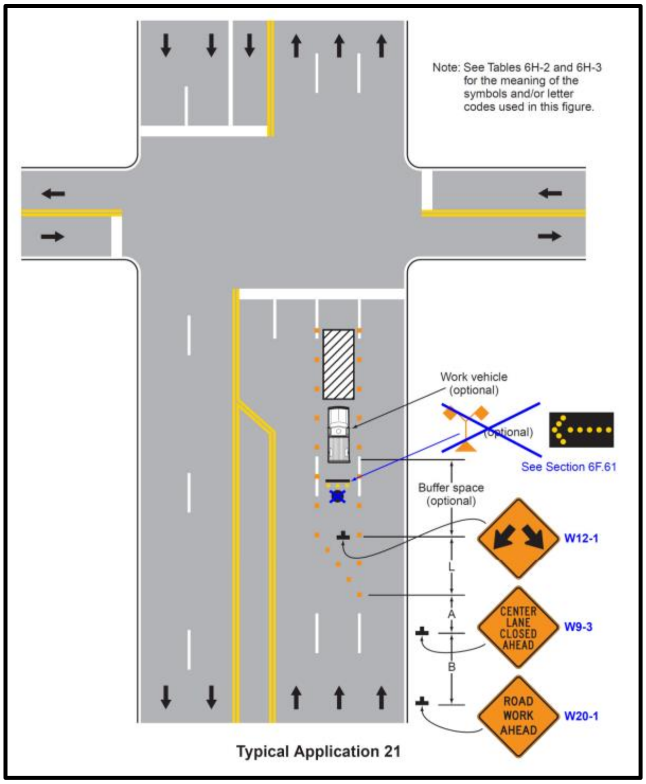

Figure 4: TA-21: Lane Closure on Near Side of an Intersection (Source: Caltrans, 2014)

2.2 When the Work Space is on the Far Side of an Intersection

There are several TAs presented in the MUTCD to address various versions of a lane being closed on the far side of an intersection. The first of these is the case where a right-hand lane is closed on the far side of an intersection, as shown in Figure 5. The normal procedure is to close on the near side of the intersection any lane that is not carried through the intersection, but if a right-hand lane has significant right turning movements, then the right-hand lane may be restricted to right turns only.

Figure 6 illustrates the first California variation, with a simple change to the advance warning to provide additional detail for motorists. Figure 7 illustrates a second Caltrans variation to consider when work is on the far side of an intersection. When the right-turn movements are high, the pavement markings can be altered showing the righthand lane more explicitly as a right-turn only lane. The typical application also provides some variation in the advance warning compared to the MUTCD.

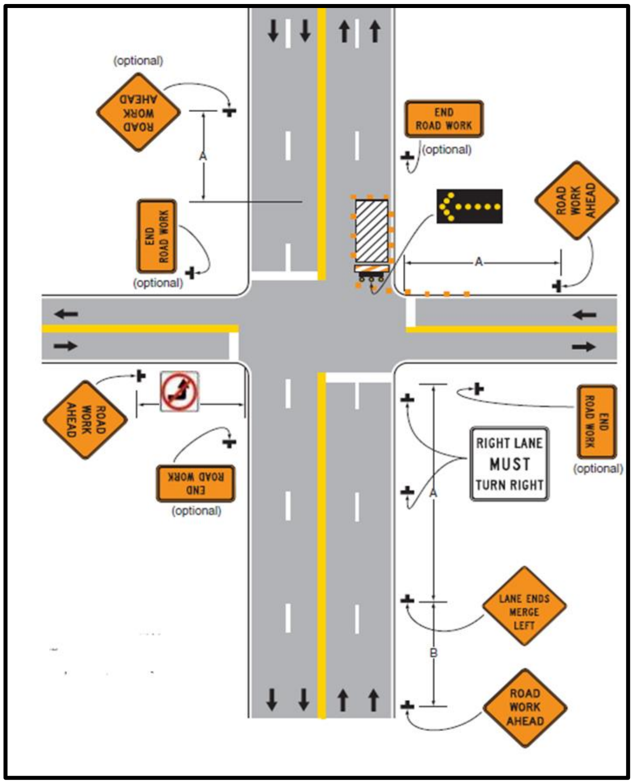

Figure 5. TA-22: Right-Hand Lane Closure on Far Side of Intersection (Source: FHWA, 2022).

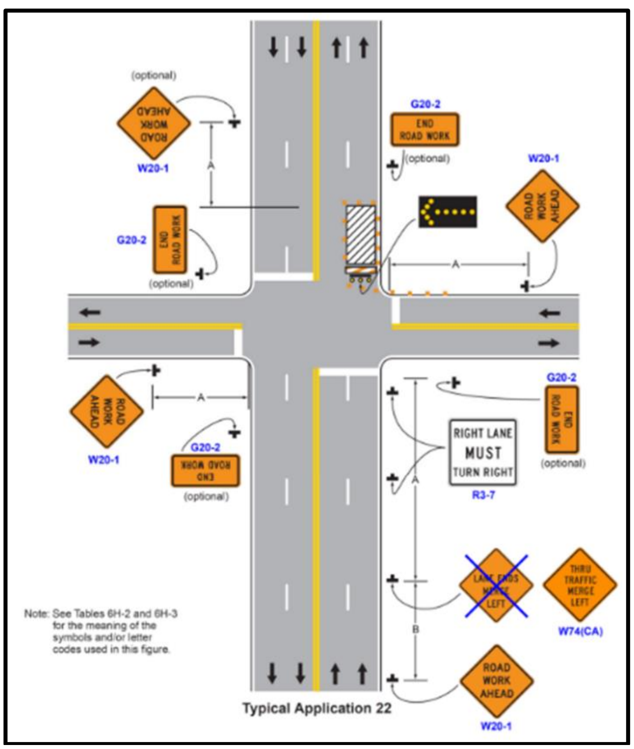

Figure 6. TA-22: Right-Hand Lane Closure on Far Side of Intersection, California Variation (Source: Caltrans, 2014)

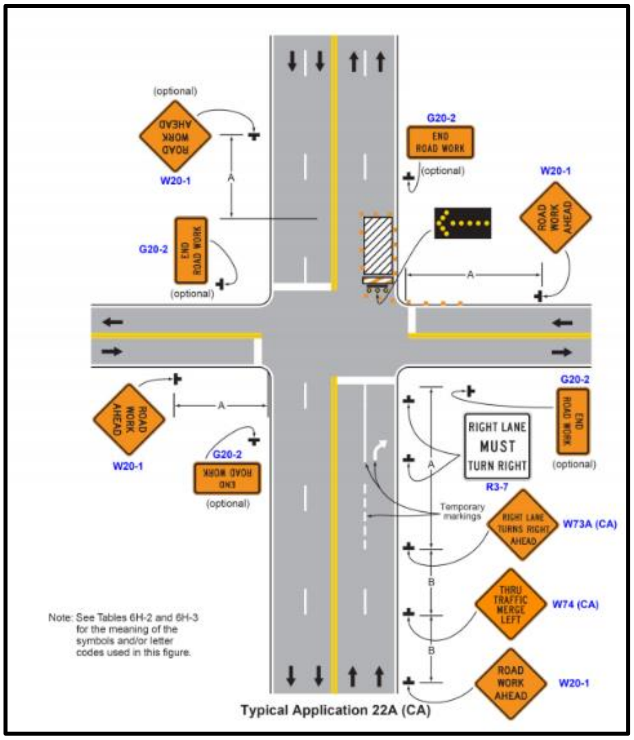

Figure 7. TA-22: Right-Hand Lane Closure on Far Side of Intersection, Second California Variation (Source: Caltrans, 2014)

There is even a third Caltrans variation in their MUTCD for TA-22, as illustrated in Figure 8. In this case they have installed a merge taper to move traffic out of the righthand lane prior to the intersection, and then provided access back into the righthand lane for right-turning traffic. The typical application also provides some variation in the advance warning. This further limits the risk of through traffic crossing the intersection and entering the work space on the far side of the intersection, or congestion caused by through traffic trying to merge left within the intersection itself.

Figure 9 illustrates TA-23, Left-Hand Lane Closure on Far Side of an Intersection. This is still on the far side of the intersection but in the other lane from the TAs discussed previously. Key points to notice:

- The normal procedure is to close on the near side of the intersection any lane that is not carried through the intersection; and
- The left lane may be reopened as a turn bay for left turns only.

Note how this is largely a mirror image of the traffic control that was used by Caltrans for the last of their variations for TA-22 shown in Figure 8.

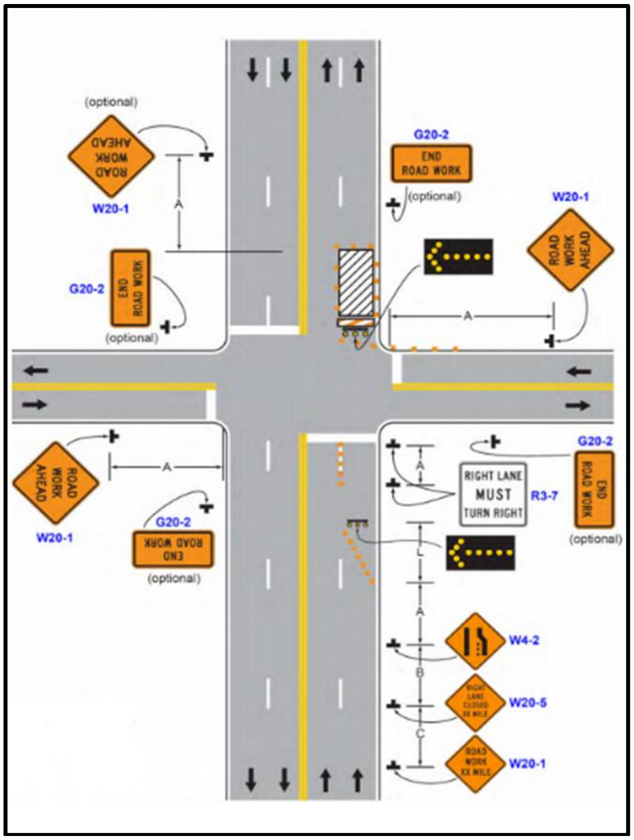

Figure 8. TA-22: Right-Hand Lane Closure on Far Side of Intersection, Third California Variation (Source: Caltrans, 2014)

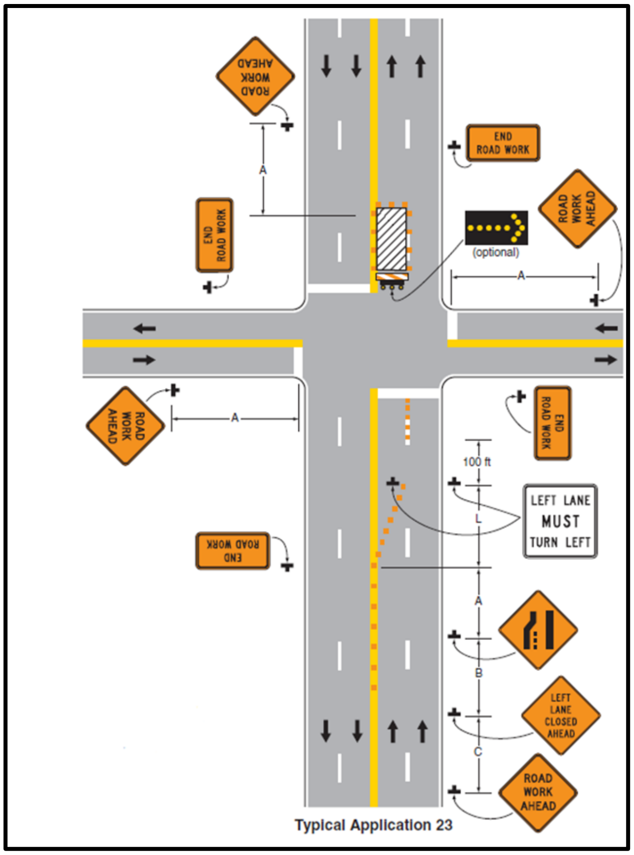

Figure 9. TA-23: Left-Hand Lane Closure on Far Side of Intersection (Source: FHWA, 2022)

Figure 10 illustrates TA-24, Half Road Closure on Far Side of Intersection. In this case both through lanes are closed on the far side. In order to accommodate traffic, one lane is taken from the opposing direction of traffic, providing one lane in each direction past the work space.

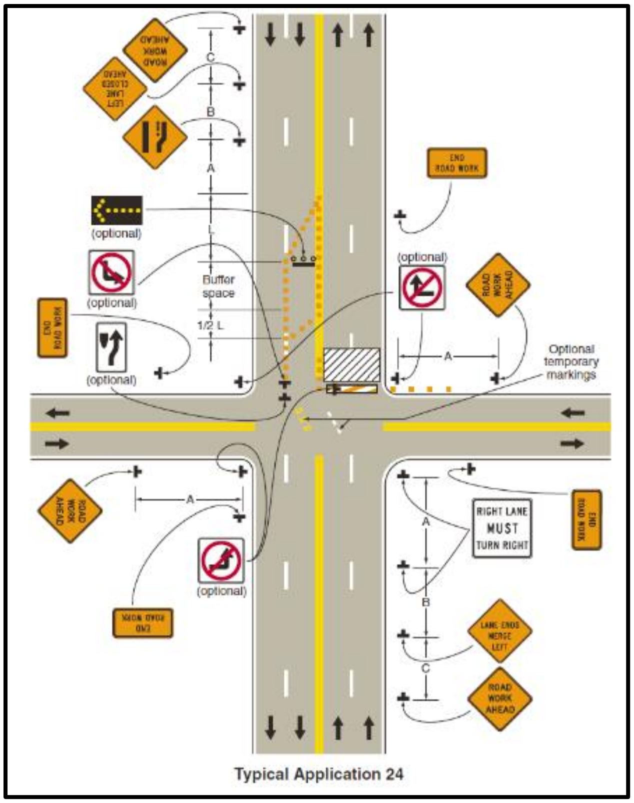

Figure 10. TA-24: Half Road Closure on Far Side of Intersection (Source: FHWA, 2022)

In the Michigan Department of Transportation's (MDOT) MUTCD there is a useful variation of the half road closure scenario (MDOT, 2022). Specifically, they show that a buffer space should be used between opposing directions of vehicular travel, as shown in Figure 11. They accomplish this by the placement of two rows of channelizing devices when the opposing lanes of traffic are directly adjacent to each other. In a practical sense this would require that both lanes are slightly reduced in width to accommodate this buffer, or the work space may not use all of the closed lanes. Of course, the needs of the work activity and the available width of the open lanes would dictate the ability to provide such a buffer.

Once again, Caltrans provides some variations on this as shown in their MUTCD. The first of these are shown in Figure 12 and provide a few key differences from the original TA-24. Specific variations include:

- The inclusion of stop line pavement markings in all directions.
- They also changed the information provided in the advance warning area to provide additional information. Their sign says "THRU TRAFFIC MERGE LEFT" rather than the MUTCD version which says "LANE ENDS MERGE LEFT."

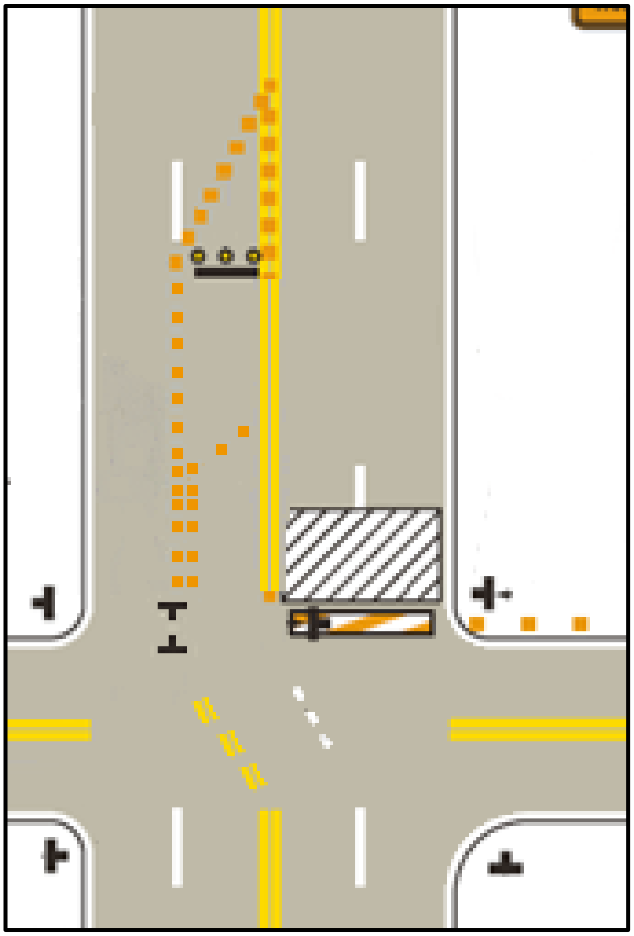

Figure 11. TA-24: Half Road Closure on Far Side of Intersection, Michigan Variation (Source: MDOT, 2022)

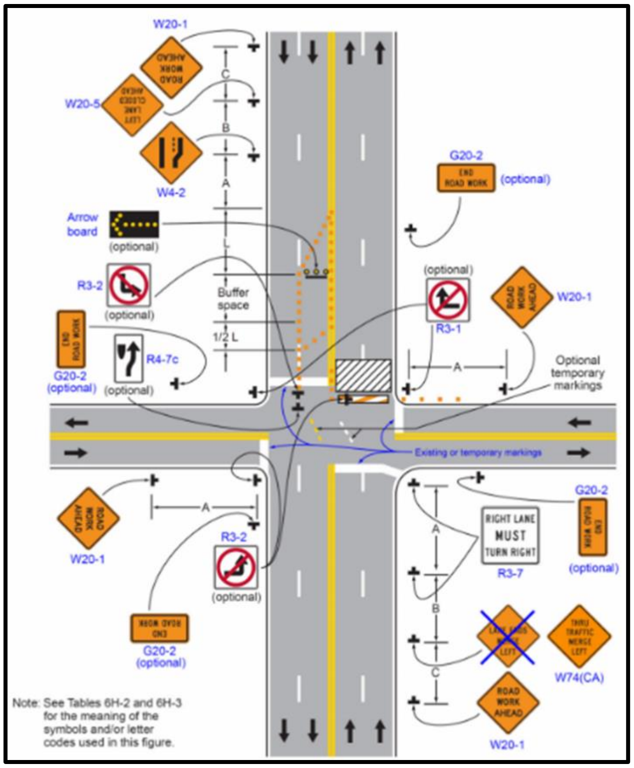

Figure 12. TA-24: Half Road Closure on Far Side of Intersection (Source: Caltrans, 2014)

Figure 13 shows a second Caltrans variation of TA-24, named TA-24 A. Caltrans has made additional changes to the advance warning area and added a merge area as shown on the right. Specifically:

- In this variation, all traffic is shifted into the left lane, and then the directions of traffic are split where through and left traffic are sent left, while the right-turning traffic is sent right. This can have the effect of creating additional protection of the work space, as the approaching drivers (especially through drivers) are forced into maneuvers prior to reaching the intersection.
- In order to do this, it can be seen that some of the opposing lanes of traffic have been used on the near side of the intersection, so that once the through traffic reaches the intersection they are already properly lined up to cross the intersection.
- It can also be seen that the advance warning signs have been modified to alert drivers of the added merge taper.

Figure 14 illustrates TA 25, for use when multiple directions of travel are closed on the far side of an intersection. Again, the normal procedure is to close on the near side of the intersection any lane that is not carried through the intersection as an effective way of limiting the chance of a through vehicle entering the activity space. Again, if the left-turning movement that normally uses the closed turn bay is small and/or the gaps in opposing vehicular traffic are frequent, left turns may be permitted on that approach.

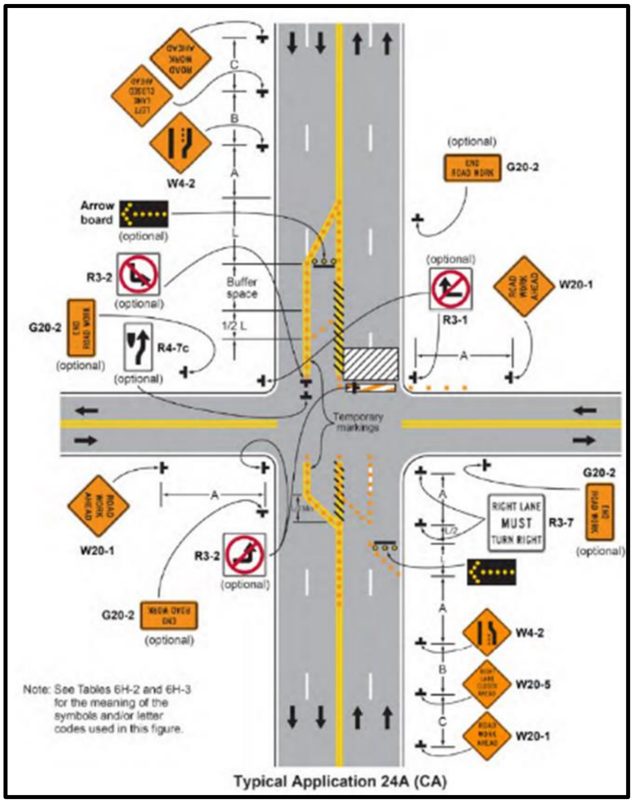

Figure 13. TA-24 A: Half Road Closure on Far Side of Intersection (Source: Source: Caltrans, 2014)

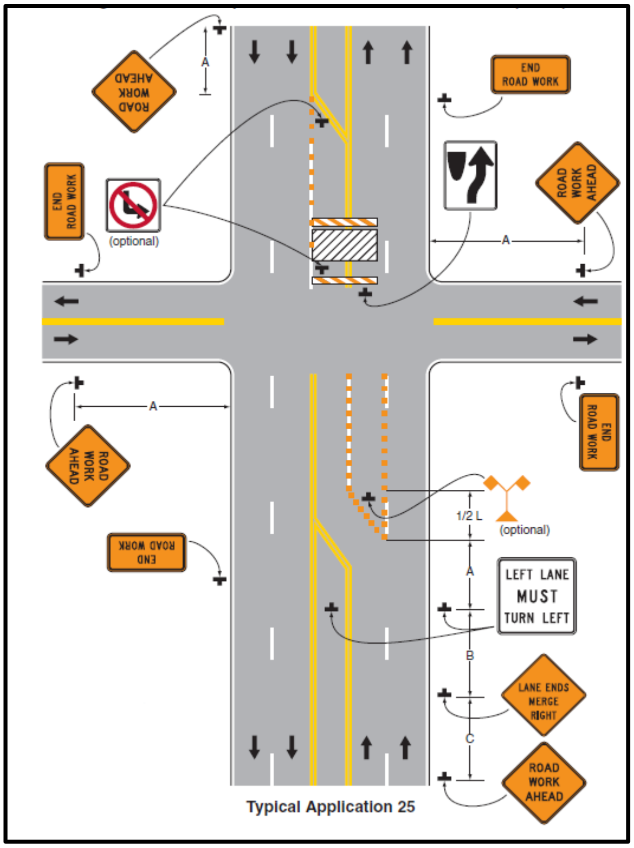

Figure 14. TA-25: Multiple Lane Closures at an Intersection (Source: FHWA, 2022)

Again, Caltrans provides an interesting variation of TA-25 in Figure 15, where traffic is first moved to the right out of the closed lane (in this case the left through lane) and then allows left turning traffic to pass back to the left and into the left turn lane. In addition, the advance warning signs are different from the MUTCD to reflect the change in traffic flow.

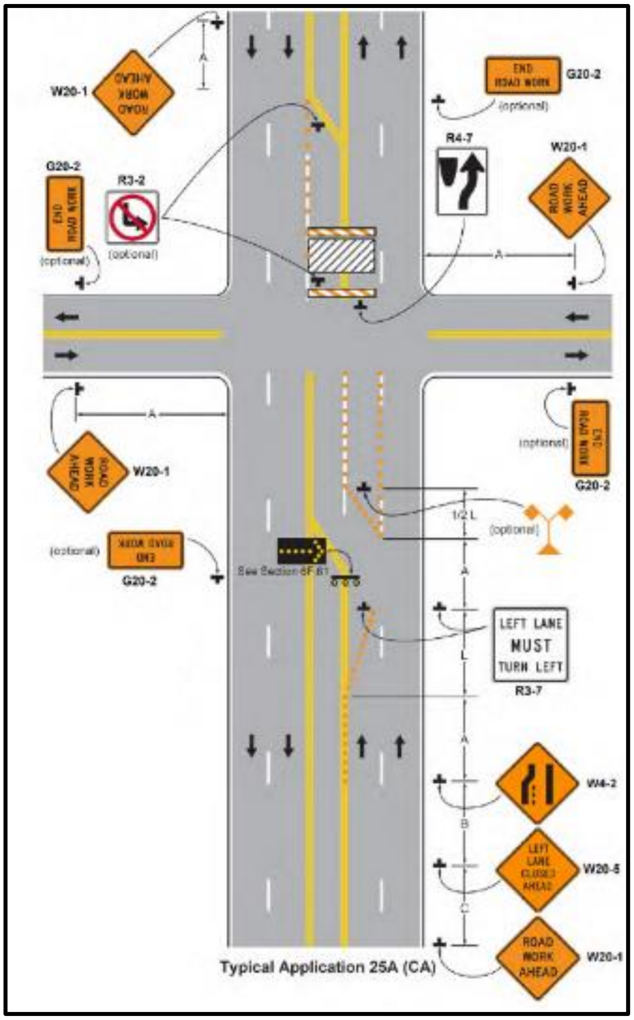

Figure 15. TA-25: Multiple Lane Closures at an Intersection (Source: Caltrans, 2014)

2.3 When the Work Space is in the Intersection

For situations where the work space is in the center of the intersection, and when traffic will be allowed to pass around it in all directions, TA-26 applies as shown in Figure 16. This may result in a restriction in lane width, and the MUTCD states that all lanes should be a minimum of 10 feet in width as measured to the near face of the channelizing devices (MUTCD, 2012). If that is not feasible, nine feet may be used for short-term work zones if the location has low volumes, low speeds, and does not include commercial vehicles. For short-duration work operations, channelizing devices may be replaced with a vehicle displaying high-intensity rotating, flashing, oscillating, or strobe lights is positioned in the work space.

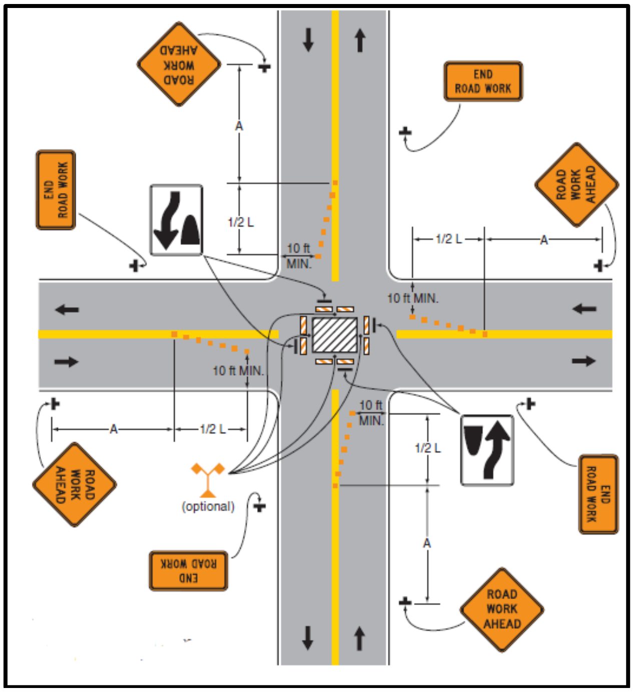

Figure 16. TA-26: Closure in the Center at an Intersection (Source: FHWA, 2022)

Figure 17 illustrates the final intersection-specific TA from the MUTCD, TA-27: Closure at the Side of an Intersection (FHWA, 2022). The situation depicted can be simplified by closing one or more of the intersection approaches. If this cannot be done, and/or when capacity is a problem, through vehicular traffic should be detoured to other roadways. Depending on road user conditions, flagger(s) or uniformed law enforcement officer(s) should be used to direct road users within the intersection.

Figure 18 shows a final variation from Caltrans (Caltrans, 2014). The main difference from the national MUTCD is that in California the advance warning sign for a flagger is different. California uses the flagger ahead symbol sign shown to the right in Figure 18. This is a good example of how even for other typical applications, designers should follow the standardization that is used in their jurisdiction at least in terms of the sign symbols that are used.

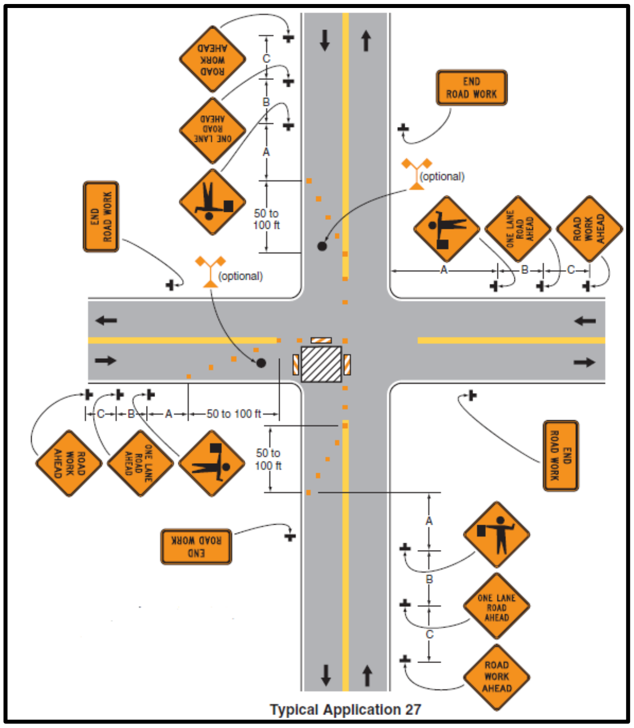

Figure 17. TA-27: Closure at the Side of an Intersection (Source: FHWA, 2022)

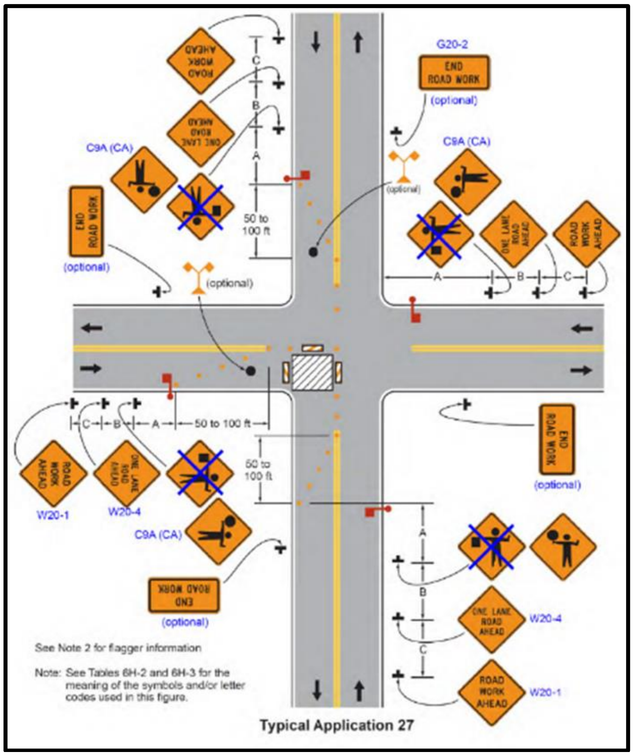

Figure 18. TA-27: Closure at the Side of an Intersection (Source: Caltrans, 2014)

3. Proposed New Typical Applications for Innovative Intersection Types

Placing a work zone at or near an intersection can be more challenging when the intersection is not a traditional intersection. A traditional intersection in this context is one that drivers most often encounter when driving, such as T-intersections and four-leg intersections. There are a variety of alternative intersection types that have been developed and implemented over the past 30 years or so. These are shown in Figure 19 and include such intersection as:

- Roundabouts;
- Single-Point Urban Interchanges;
- Diverging Diamond Interchanges;
- Restricted Crossing U-Turn Intersections;
- Median U-Turn Intersections; and
- Displaced Left Turn Intersections.

As a group, these will be generally referred to in this document as innovative intersections. The MUTCD already provides enough detail generally to place work zones in single point urban interchanges and displaced left turn intersections - no additional guidance is provided here. Therefore, this document focuses on intersection types that could benefit from some additional consideration, specifically: roundabouts, DDIs, restricted crossing U-turn intersections, and median U-turn intersections. DDIs are - as the name points out - interchanges, but these are included here as there are intersections present at either end.

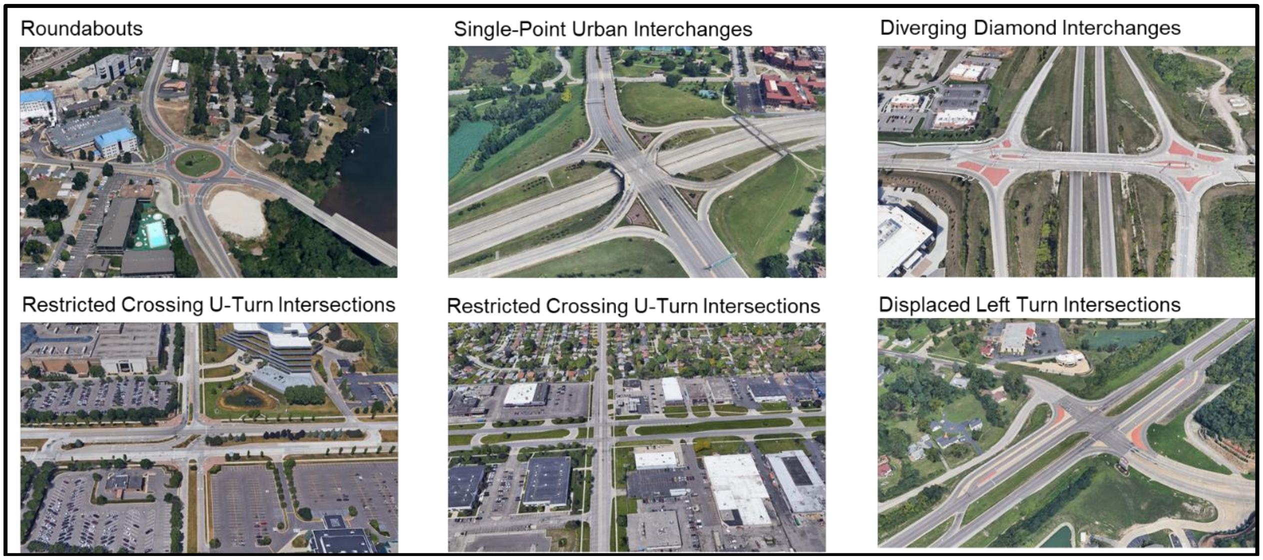

Figure 19. Aerial Views of Various Innovative Intersections (Source: Google, 2021)

3.1 Roundabouts

It is true that roundabouts have been installed in the US since the 1990s, but they have been included on the list of innovative because while they are mentioned in other parts of the MUTCD, there is no specific guidance on how to place a work zone at or near a roundabout in Part VI of the MUTCD. So, there is a need to consider how best to do this.

One example document that provides guidance for this is the Virginia Department of Transportation's (VDOT) "Virginia Work Area Protection Manual" as shown in Figure 20 (VDOT, 2015). There are several key differences between this arrangement and a standard four-leg intersection. First, it is recommended that no more than one-quarter of the roundabout be closed at any one time, unless it is planned to just close the entire intersection. This will allow all movements to be accommodated simultaneously from one approach. Only one entry point at a time is permitted to allow some drivers to pass through the roundabout in reverse of the normal direction in order to make their movement. In order to make this happen one flagger will need to be stationed at each entry point. As a practical matter, if the roundabout has any sight obstructions in the center island (raised gardens, landscaping, etc.) these flaggers may not be able see their counterpart on the far side of the intersection. In these cases it may be necessary to provide radio communication to coordinate their activities.

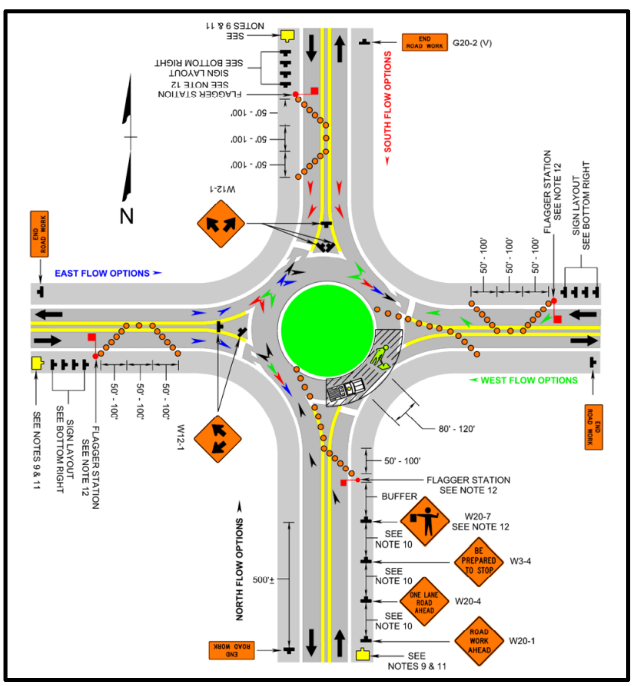

Figure 20. Flagger Operation on a Single Lane Roundabout (Source: VDOT, 2015)

The American Traffic Safety Services Administration (ATSSA) expanded on this approach to consider pilot car operations as an additional traffic control feature. This is considered an advantage, and it was pointed out that multiple pilot cars would be needed to guide some traffic through, for at entrances some traffic will need to go clockwise through the roundabout, while other directions of travel will go counterclockwise from the same entrance. This can have the effect of helping traffic know it is acceptable to pass through the work zone in the 'wrong' direction from normal travel.

> "On approaches where traffic flow will be split during flagging operations, two pilot vehicles may be used to guide traffic through the roundabout. Care should be taken such that split traffic doesn't interfere with other queued or moving traffic" (ATTSA, 2012).

Additionally, there are several other considerations that are similar to traditional intersections when a work space is inside the roundabout. These include considering if trucks or other large vehicles will be able to traverse the roundabout. This is especially true if workers are present in the inside lane of a multilane roundabout as shown in Figure 21. In these cases, accommodations for the turning radius of tractor trailer vehicles (including the off-tracking behavior of the trailer wheels) and other large vehicles should be considered and the work zone designed accordingly.

If there are concerns about the safety of workers in the inside or outside lane in a multilane roundabout, then it may be necessary to close a quadrant of the outer lane so that no traffic passes near the work space, as shown in Figure 22. In effect, this arrangement reduces the multilane roundabout work zone to the same situation as the single lane roundabout work zone that was discussed above.

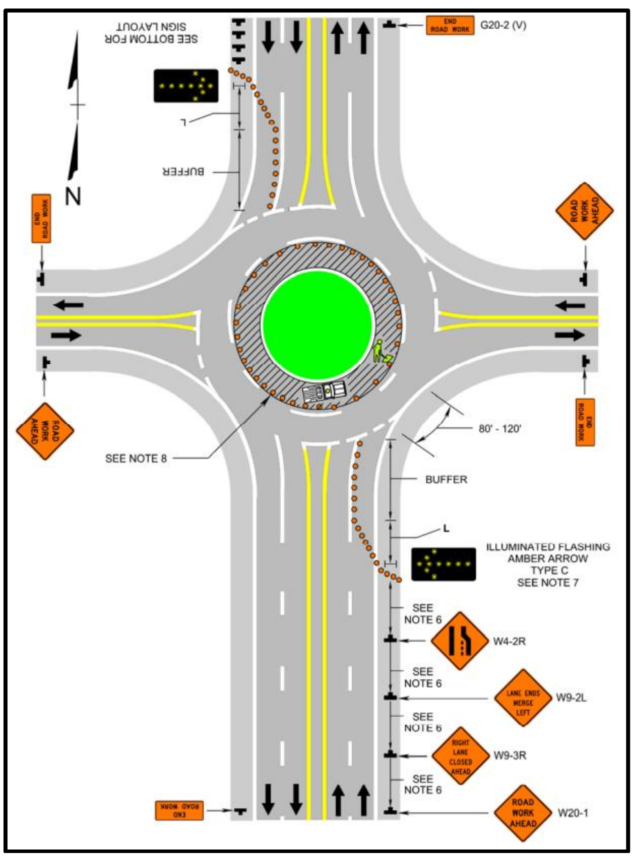

Figure 21. Inside Lane Closure Operation on a Multi-Lane Roundabout (Source: VDOT, 2015)

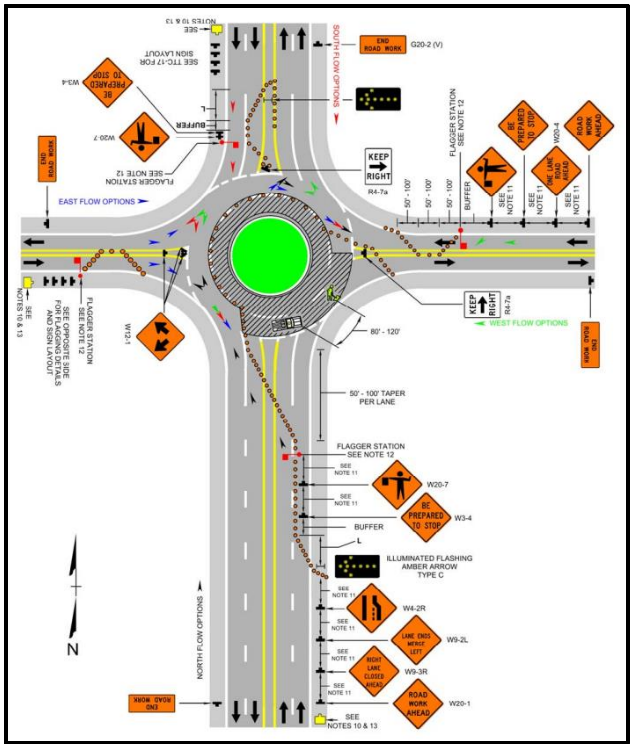

Figure 22. Outside Lane Closure Operation on a Multi-Lane Roundabout (Source: VDOT, 2015)

Another final consideration for roundabouts is whether or not to remove or cover any existing pavement markings when the work zone is present. For example, lane direction arrow pavement markings that are pointing opposite to the work zone traffic patterns may confuse drivers. Removing these for the duration of the work may improve driver understanding of what they are being asked to do, and may be worth the effort of removal, especially for long-term projects.

3.2 Diverging Diamond Interchanges

For the remaining discussion on innovative intersection types, one document was used for source material, “Maintenance of Traffic for Innovative Geometric Design Work Zones,” (Brown, et al., 2015). That report discusses phasing strategies for converting traditional intersections or interchanges into various innovative types, and was at the time of this writing the only document found that discussed in detail how to place a work zone in innovative intersections. While their document focused solely on the initial construction during the conversion of these intersections, many useful tips were found that can be converted to subsequent work zones.

An example of a DDI is shown in Figure 23. The main differences from a traditional diamond interchange are the two intersections where the freeway on- and off-ramps meet the intersecting roadway. At these locations the traffic flow crosses in an ‘x’ pattern, allowing traffic to flow across the bridge overpass in the opposite direction - meaning oncoming traffic is to the right instead of to the left. There are many reasons why this interchange could be used, including better accommodating left-turning traffic onto the freeways, and limiting the width of the bridge by avoiding the need for left-turn storage lanes.


Figure 23. Aerial view of a DDI (K-10 and Ridgeview Road, Olathe/Lenexa, Kansas) (Source: Google Maps, 2022)

Brown et al. created a scheme to help designers understand how to stage the work of converting a typical diamond interchange to a DDI. Figures 24 through 29 show the five proposed stages to accomplish this while allowing the passage of traffic.

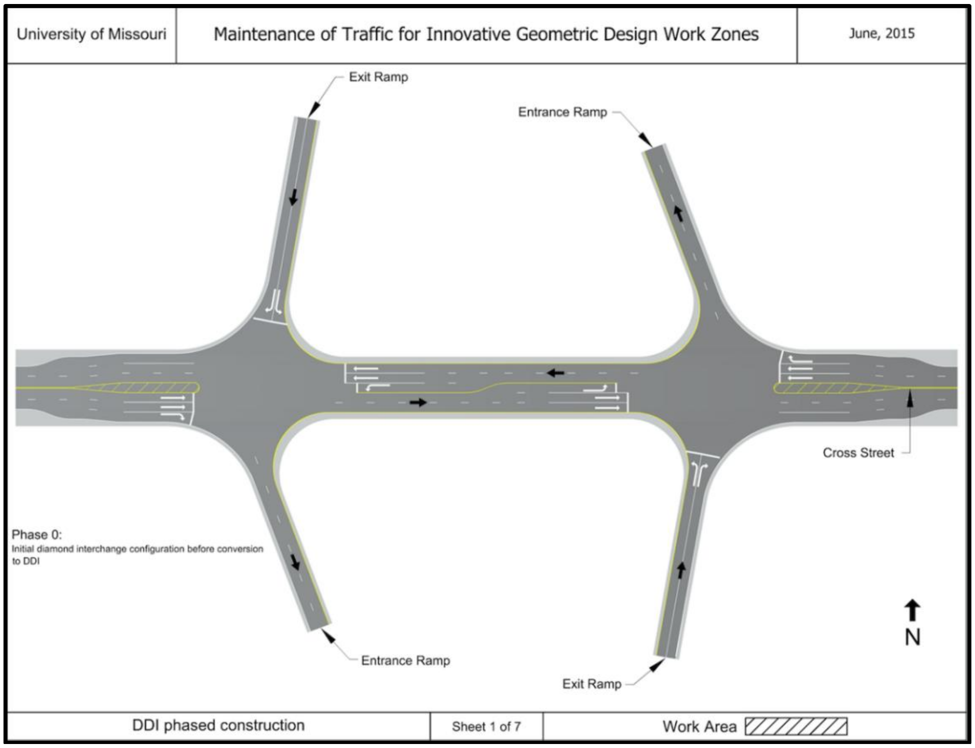

Figure 24. DDI Phased Construction Initial Condition (Source: Brown et al., 2015)

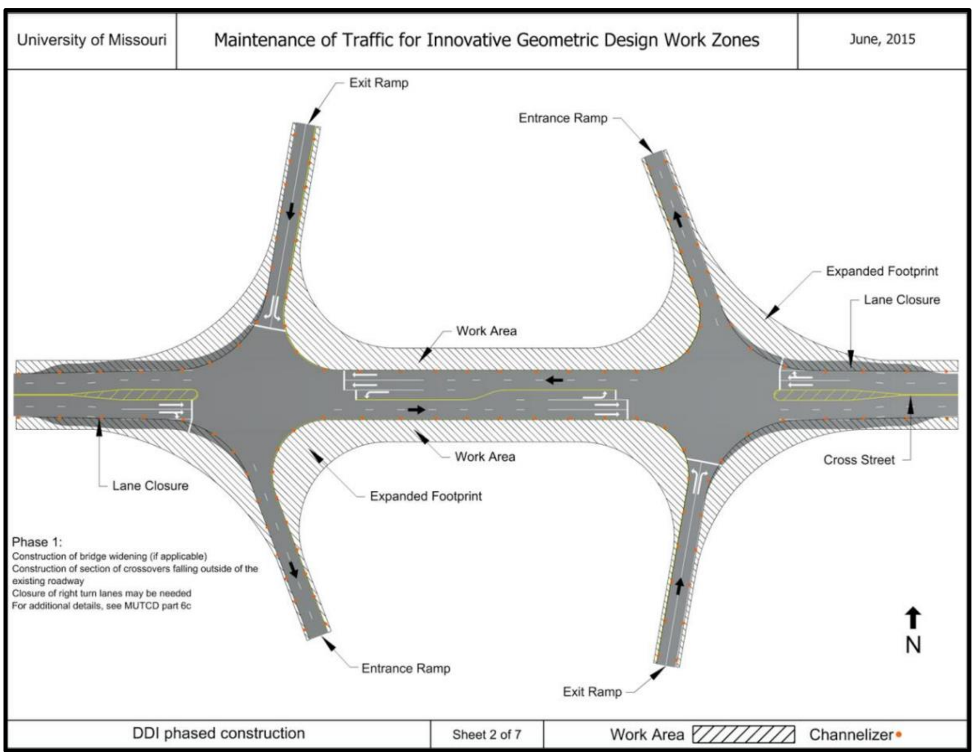

Figure 25. DDI phased construction Phase 1 (Bridge Widening and Crossover Construction) (Source: Brown et al., 2015)

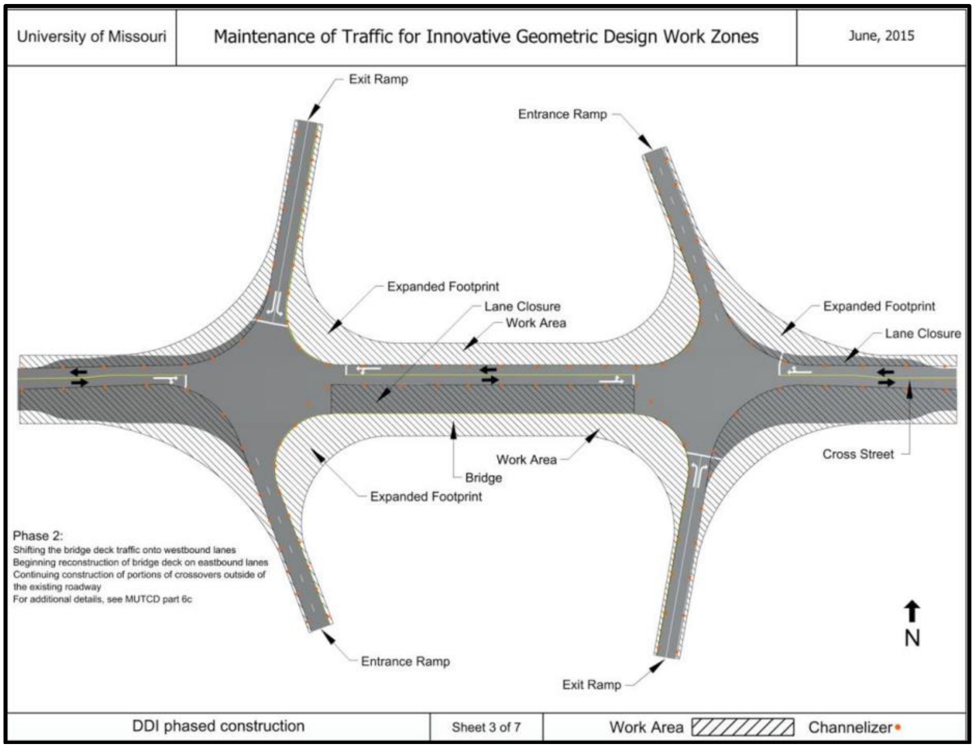

Figure 26. DDI phased construction Phase 2 (construction on south side of bridge deck) (Source: Brown et al., 2015)

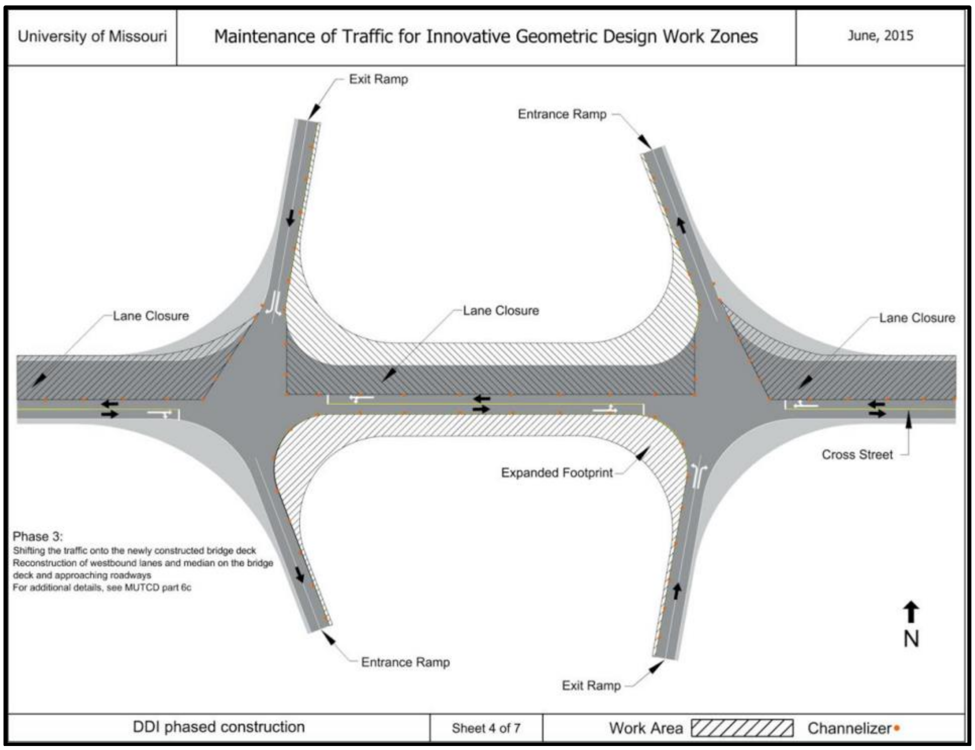

Figure 27. DDI phased construction Phase 3 (construction on north side of bridge deck and median) (Source: Brown et al., 2015)

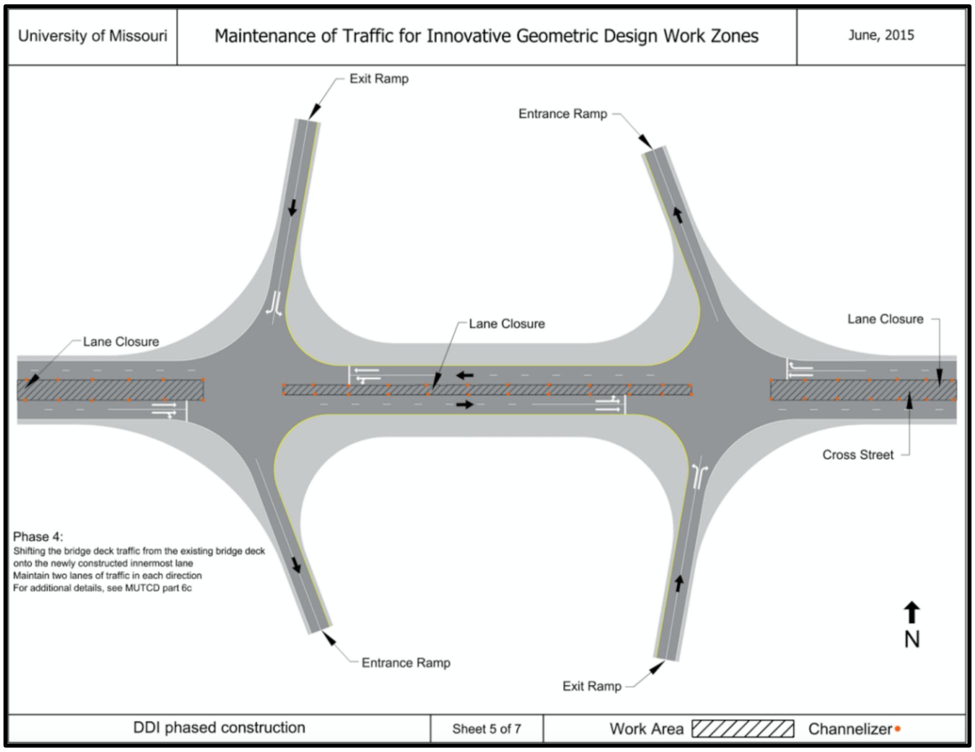

Figure 28. DDI phased construction Phase 4 (median construction) (Source: Brown et al., 2015)

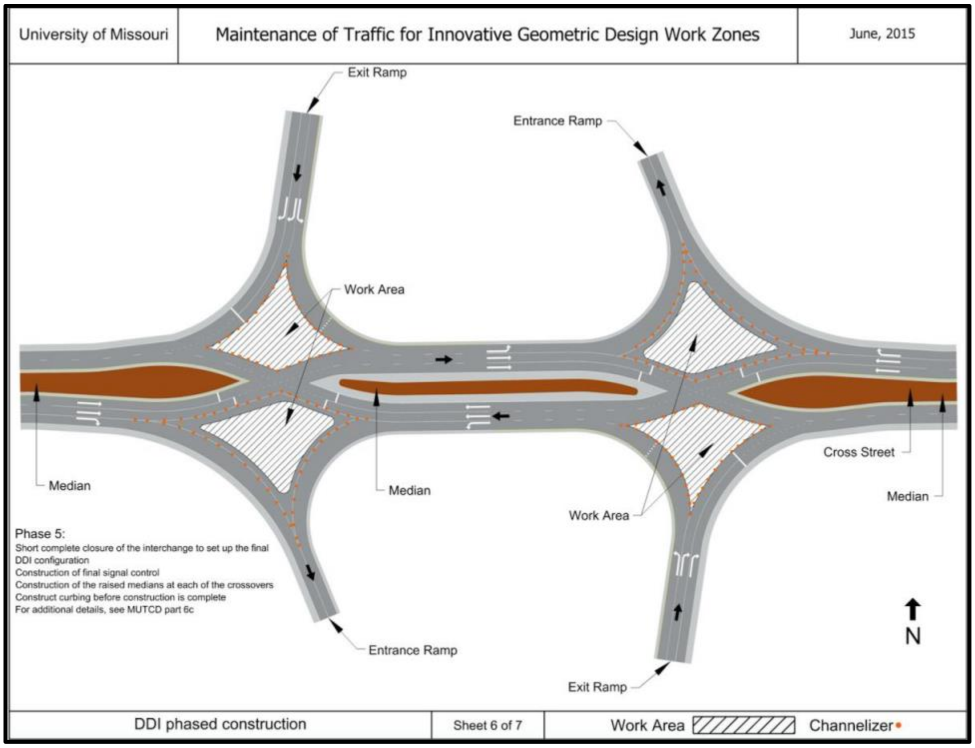

Figure 29. DDI phased construction Phase 5 (short complete closure and final conversion to DDI) (Source: Brown et al., 2015)

To provide additional guidance for work zone designers when placing a work zone into an *already-existing* DDI, the research team developed pseudo-typical applications showing signing and their locations, as well as any lanes that are closed to traffic. Unlike the typical applications in the MUTCD, to properly show the various phases of work in a DDI it was necessary to show a series of these diagrams. Designers are then able to select the diagram that best suits their needs based on which portion of the interchange that contains the work space.

These pseudo-typical applications include:

- When the left lane on the bridge is closed (this assumes the minor roadway passes over the major roadway - meaning the minor roadway is on a bridge overpass), Figure 30;
- When the two left lanes on the bridge are closed, Figure 31; and
- When the left-turn lane on the freeway exit ramp is closed, Figure 32.

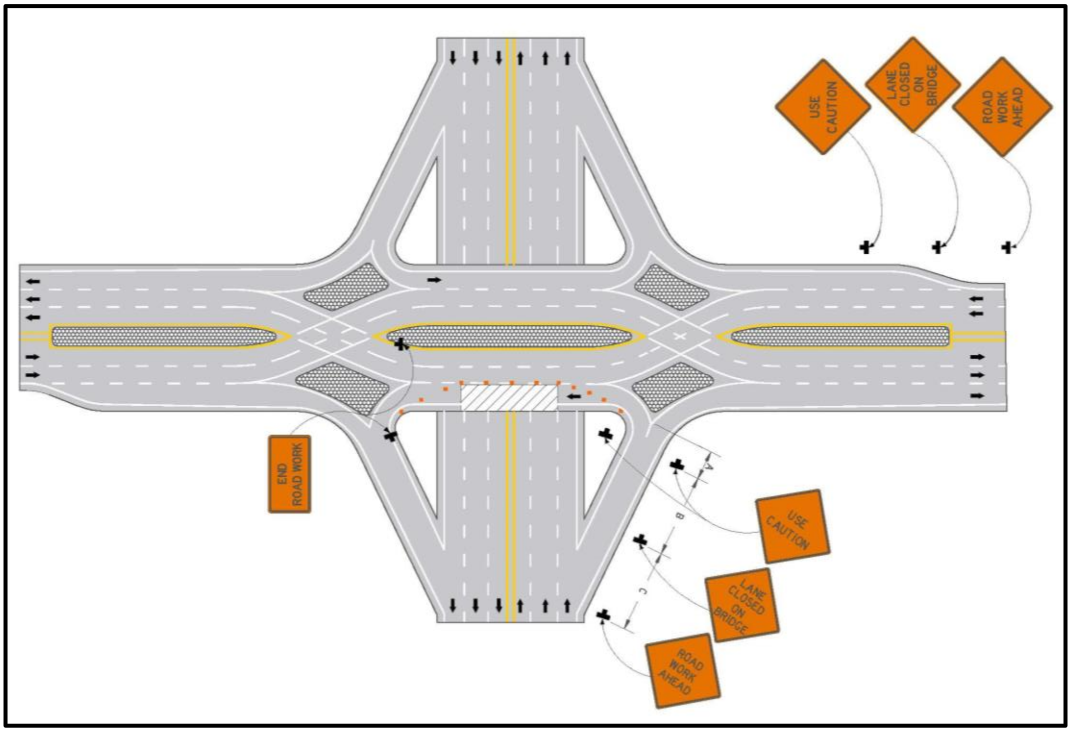

Figure 30. Pseudo-Typical Example of DDI Work Zone within the Outermost Lane

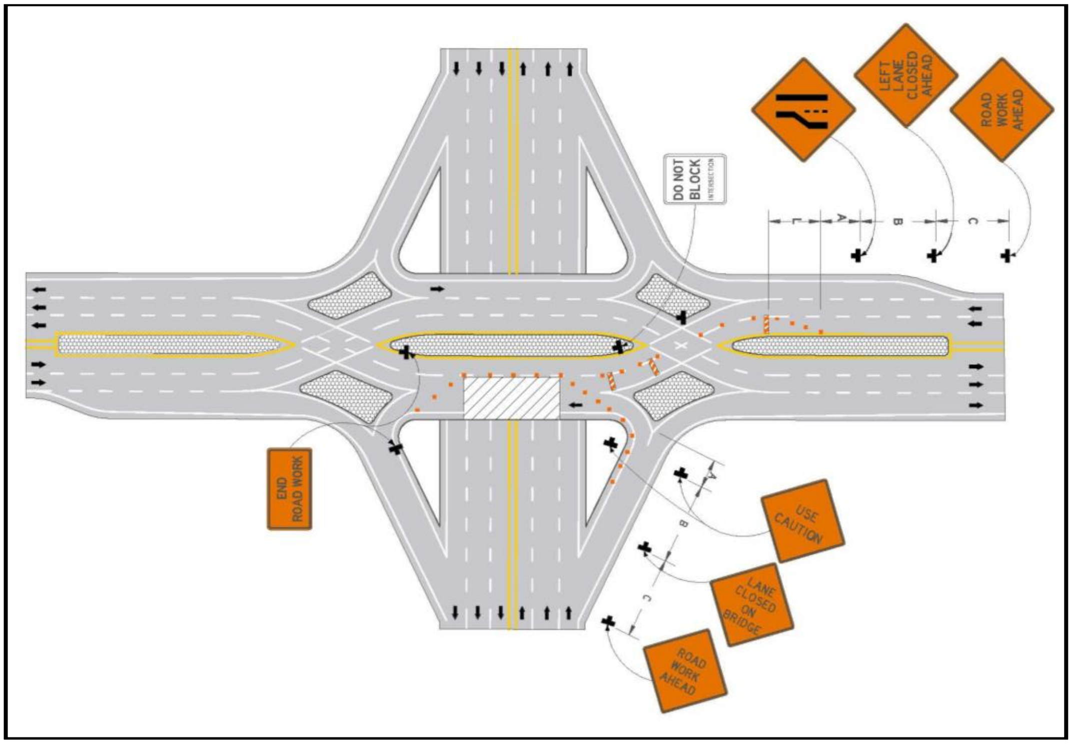

Figure 31. Pseudo-Typical Example of DDI Work Zone on the Two Outermost Lane

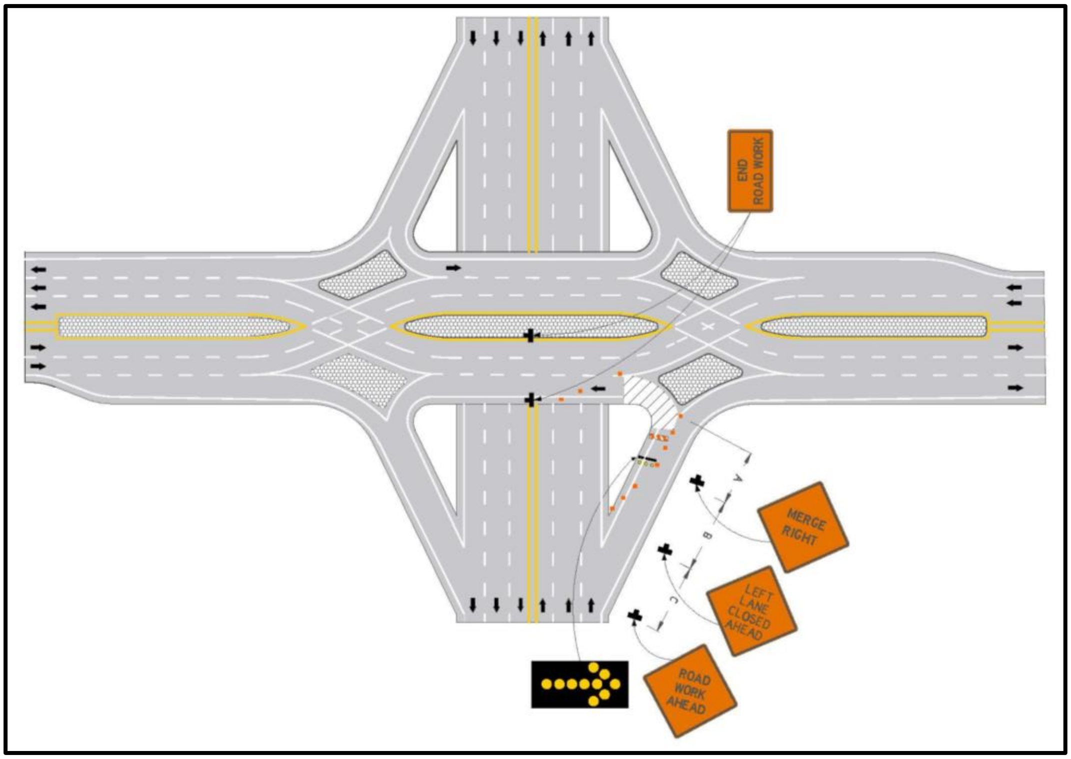

Figure 32. Pseudo-Typical Example of DDI Work Zone on within the Left-Turn Exit Ramp Lane

3.3 Restricted Crossing U-Turn Intersections

Restricted Crossing U-Turn intersections (RCUTs), are different from traditional intersections in that drivers on the minor approaches to the intersection are not allowed to make left or through movements, they are only allowed to turn right. Drivers that wanted to turn left or go through first need to turn right onto the major roadway, then make a U-turn at a downstream U-turn access point as shown in Figure 33. RCUTs have advantages to drivers by eliminating the left turn and through movements across the major road, thus improving safety by eliminating opportunities for right-angle crashes. It is not possible for traffic on the minor approaches to travel straight. In order to travel straight, drivers on the minor approaches need to turn right, then complete a U-turn at a mid-block turnaround area downstream on the major route, and then make another right turn to get back onto the minor roadway. More details on the operations of RCUT intersections can be found in the report "Restricted Crossing U-Turn Informational Guide" (Hummer et al., 2014).

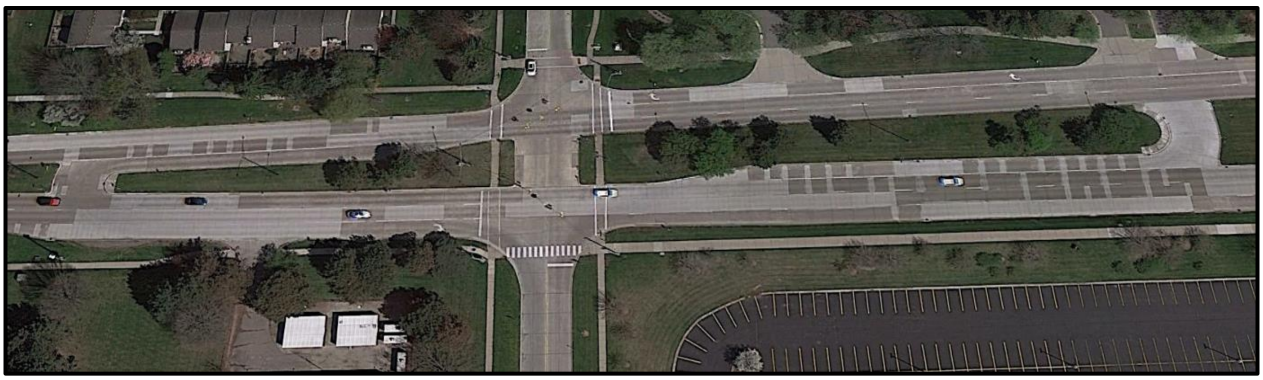

Figure 33. Restricted Crossing U-Turn Intersection, Intersection of West Long Lake Road and Northfield Parkway, Troy, MI (Source: Google Earth, 2022)

Many aspects of an RCUT are actually similar to a traditional intersection with respect to placing a work zone. However, when the work includes work at the U-turn area downstream from the main area of the intersection, it is recommended that the left-turn lane be closed between the main part of the intersection and the U-turn area, with advance warning occurring prior to reaching the intersection, as shown in Figure 34. However, there may be times when a temporary U-turn area could be placed upstream from the permanent U-turn area, so then instead of completely closing the left-hand approach lane, traffic could be routed to the temporary U-turn. In that case the left-most lane would not need to be closed, as shown in Figure 35.

If the work space involves the left-turn area or areas where traffic from the major roadway turns left to the minor roadway, then this should result in closing the entire left-turn lane or lanes and forcing this left-turning traffic to proceed to the downstream U-turn lane, as shown in Figure 36. Incidentally, this actually shows one of the benefits of an RCUT intersection - left-turning traffic has a second path that can be used to make their desired maneuver. And even more interestingly, this scenario basically turns an RCUT temporarily into a Median U-Turn Intersection, which will be presented next. All other areas affected by a work zone can be properly accommodated using existing intersection layouts provided by the MUTCD.

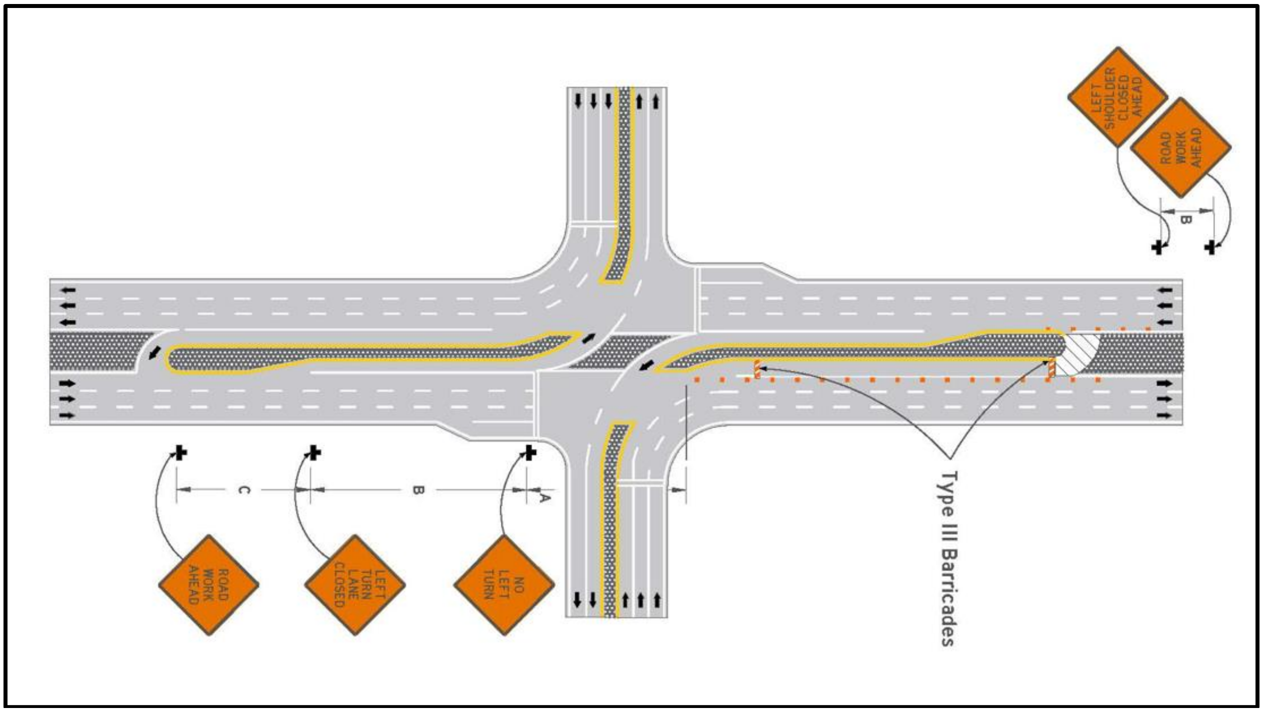

Figure 34. Restricted Crossing U-Turn Intersection with U-Turn Closed.

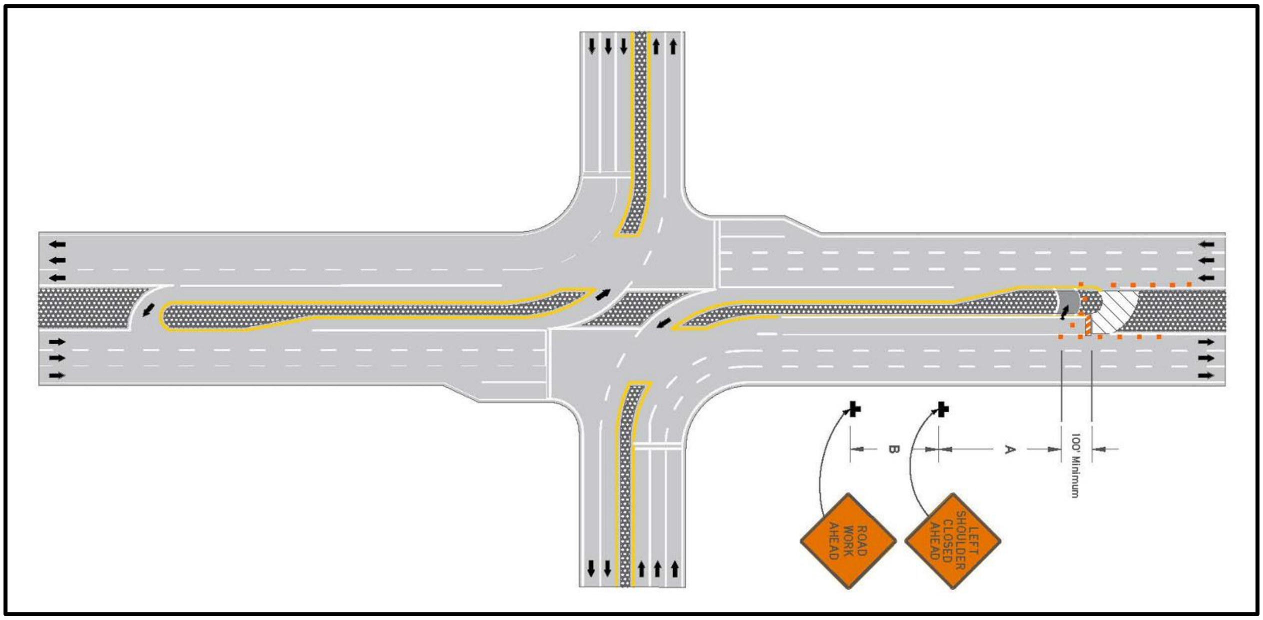

Figure 35. Restricted Crossing U-Turn Intersection with U-Turn Closed and a Temporary U-Turn Lane Provided.

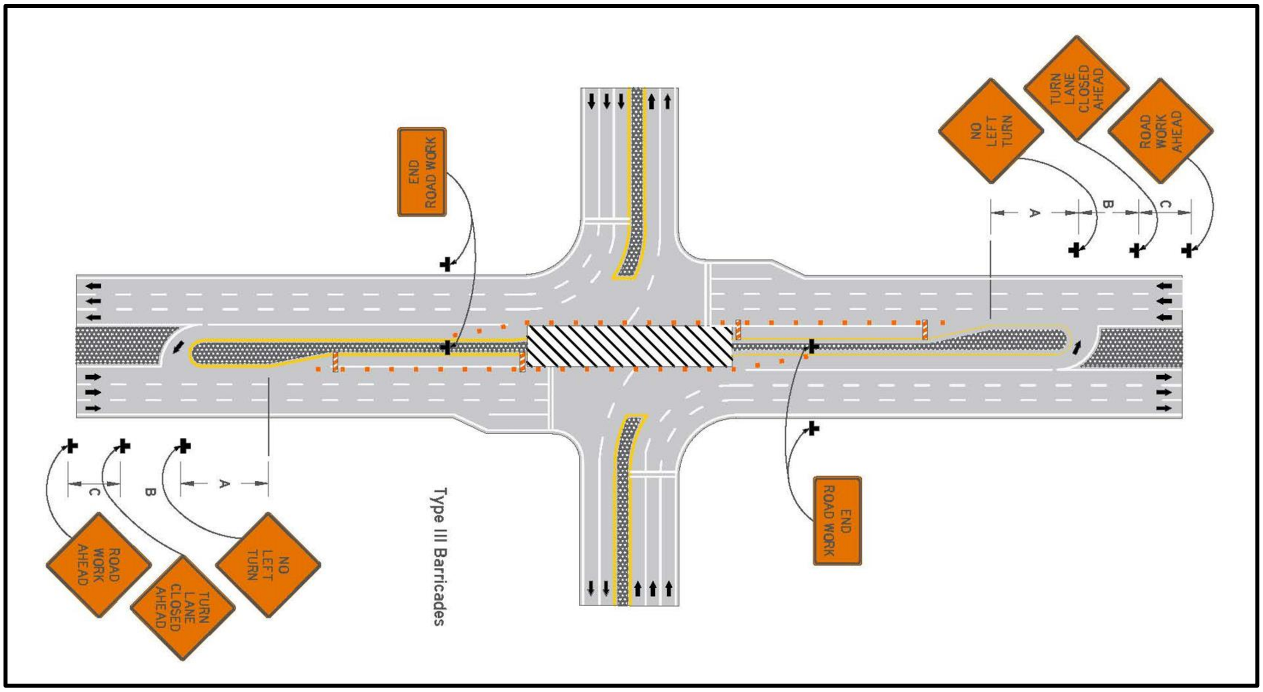

Figure 36. Restricted Crossing U-Turn Intersection with Major Route Left-Turn Lanes Closed.

3.4 Median U-Turn Intersections

Median U-Turn Intersections (MUTs) are similar to traditional intersections except that no left turns are allowed at the intersection itself from any direction (Hughes, 2010). In order to make a left turn, a driver is required to make a right turn, and then make a U-turn across the downstream median U-turn access point. In many ways it is similar to the last version of the RCUT that was discussed in the preceding section where the major route left-turn lanes were closed due to a work space. As with the DDIs and RCUTs, examples comparable to typical applications from the MUTCD were prepared to provide guidance on how to place work zones through these intersections. These include:

- If the outside of three lanes are closed between the minor roadway at the U-turn location. This case is actually similar to the typical applications provided in the MUTCD where one lane is closed downstream of an intersection. This is shown in Figure 37.
- If the center lane of three lanes are closed between the minor roadway and the U-turn location. This case is also similar to typical applications provided in the MUTCD where one lane is closed downstream of an intersection, and is shown in Figure 38.
- If the innermost lane of three lanes are closed between the minor roadway and the U-turn location, then consideration should be given to provide access to the downstream U-turn area. This is shown in Figure 39.
- If a U-turn lane needs to be closed, then consideration should be given to provide a temporary U-turn lane. This is shown in Figure 40.

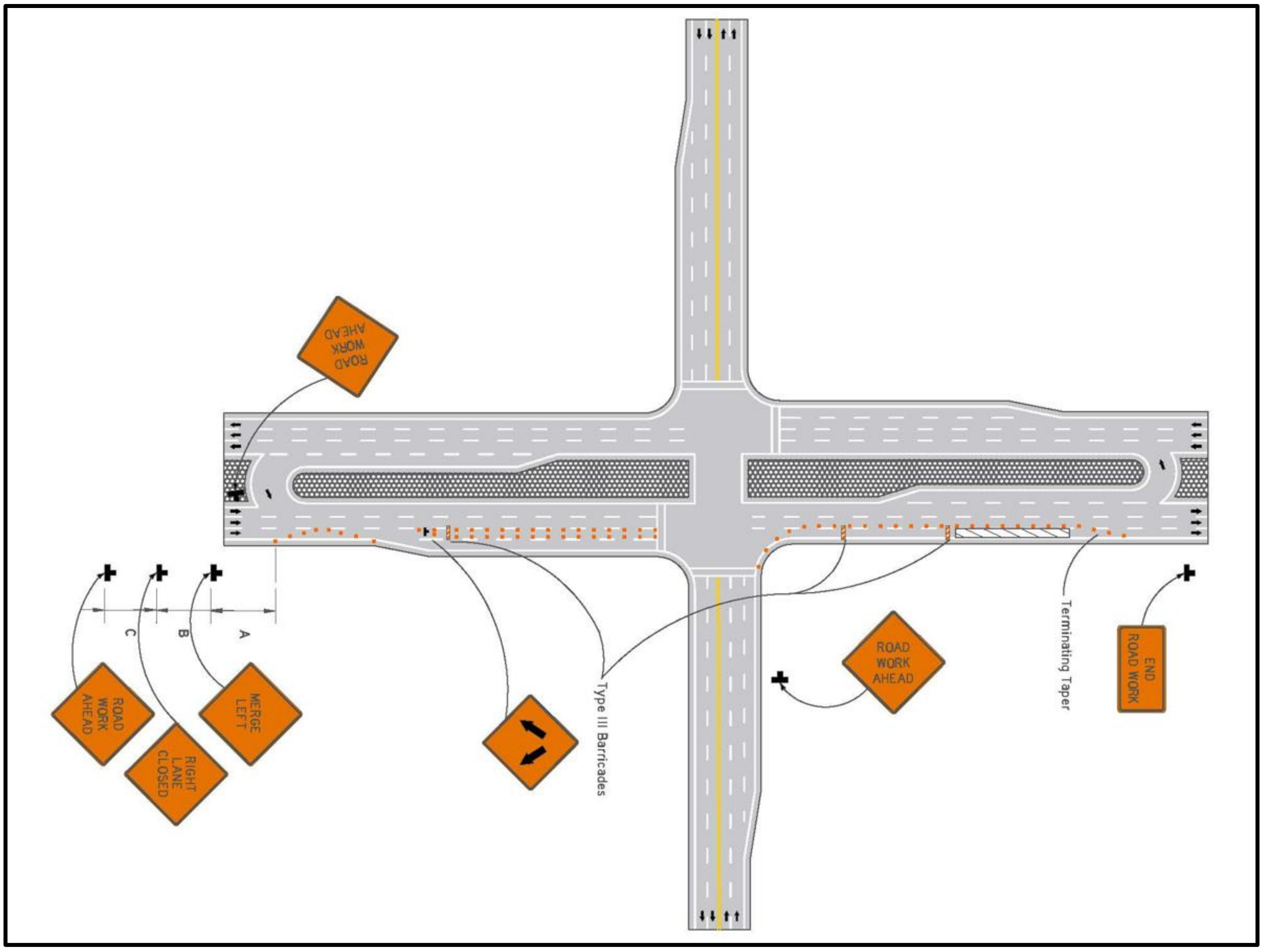

Figure 37. Median U-Turn Intersection with Work in the Outside Lane.

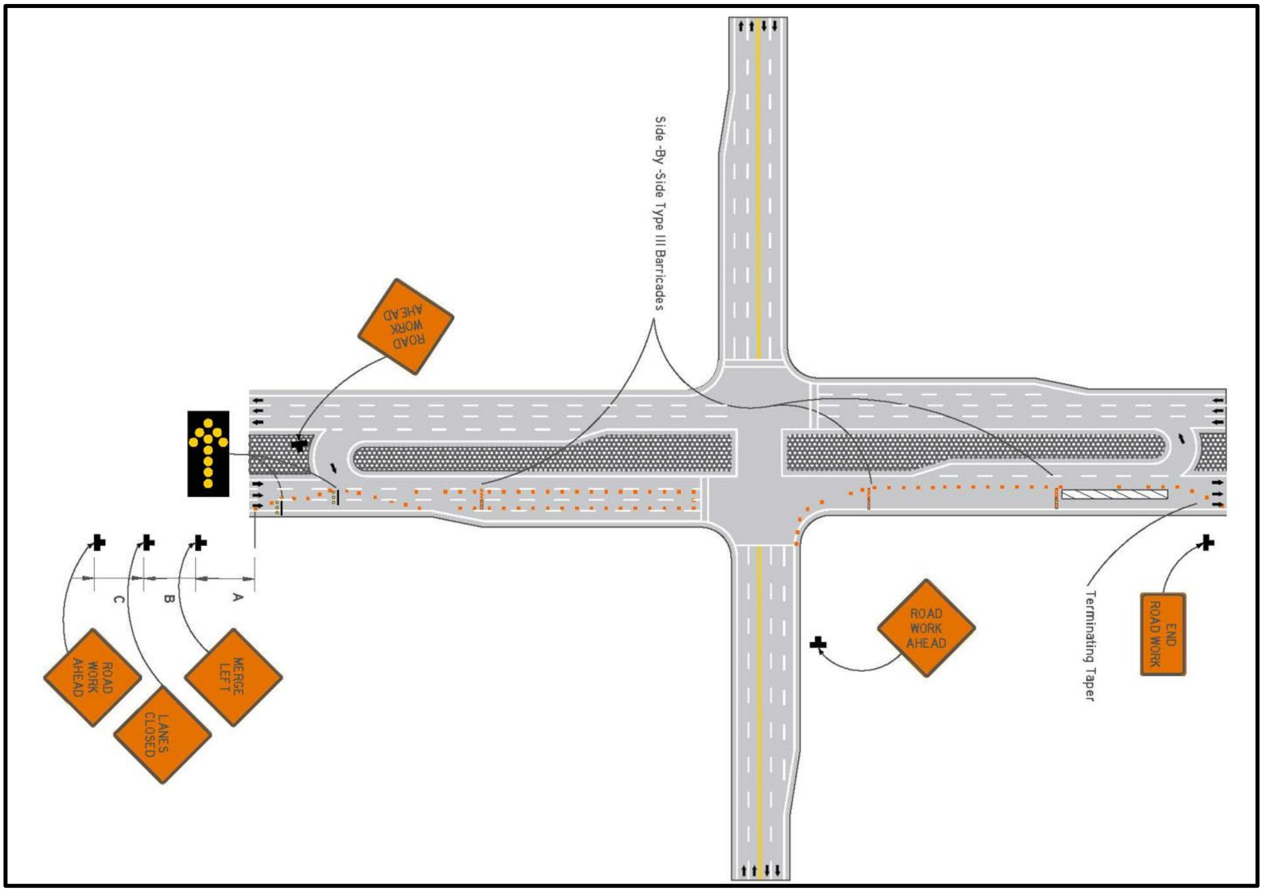

Figure 38. Median U-Turn Intersection with Work in the Center Lane.

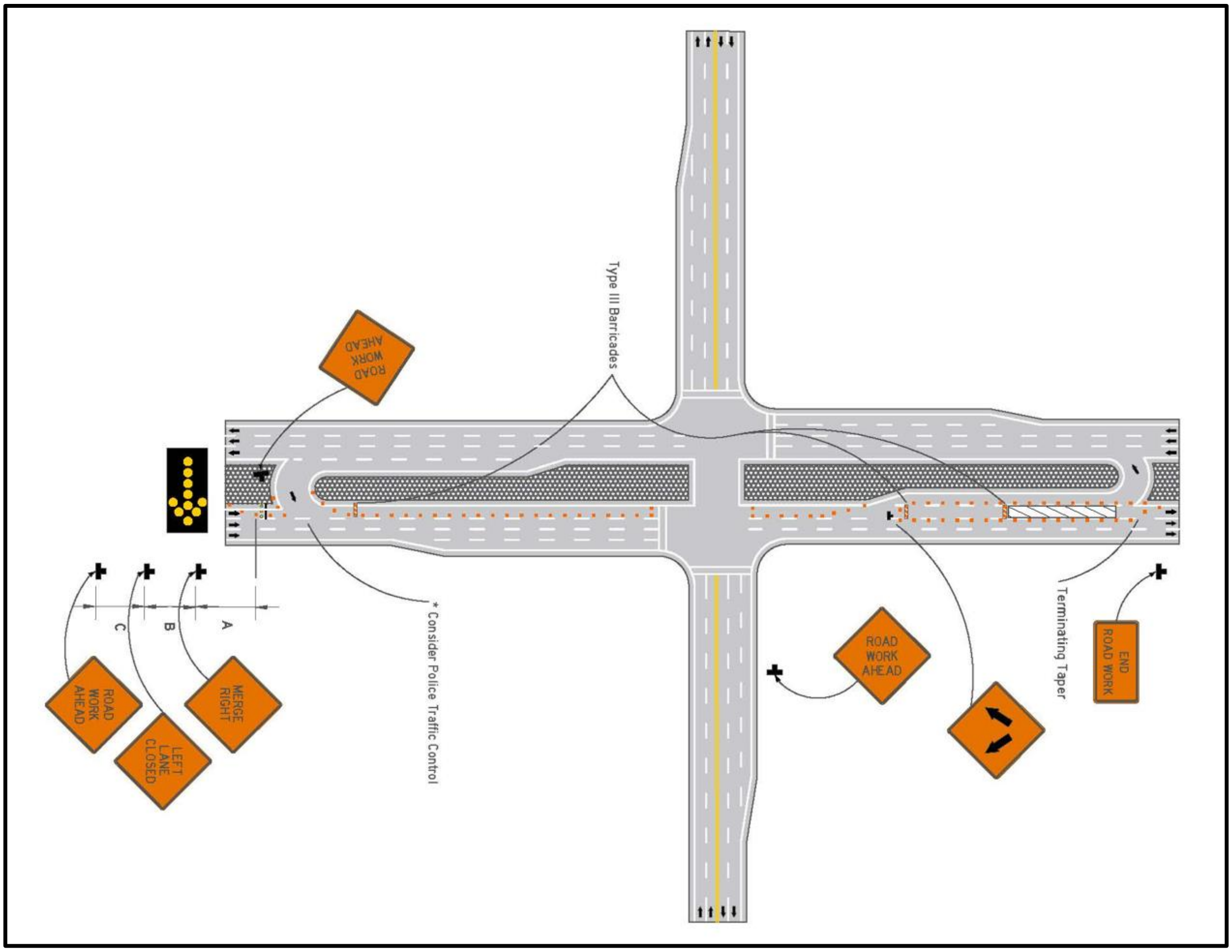

Figure 39. Median U-Turn Intersection with Work in the Innermost Lane.

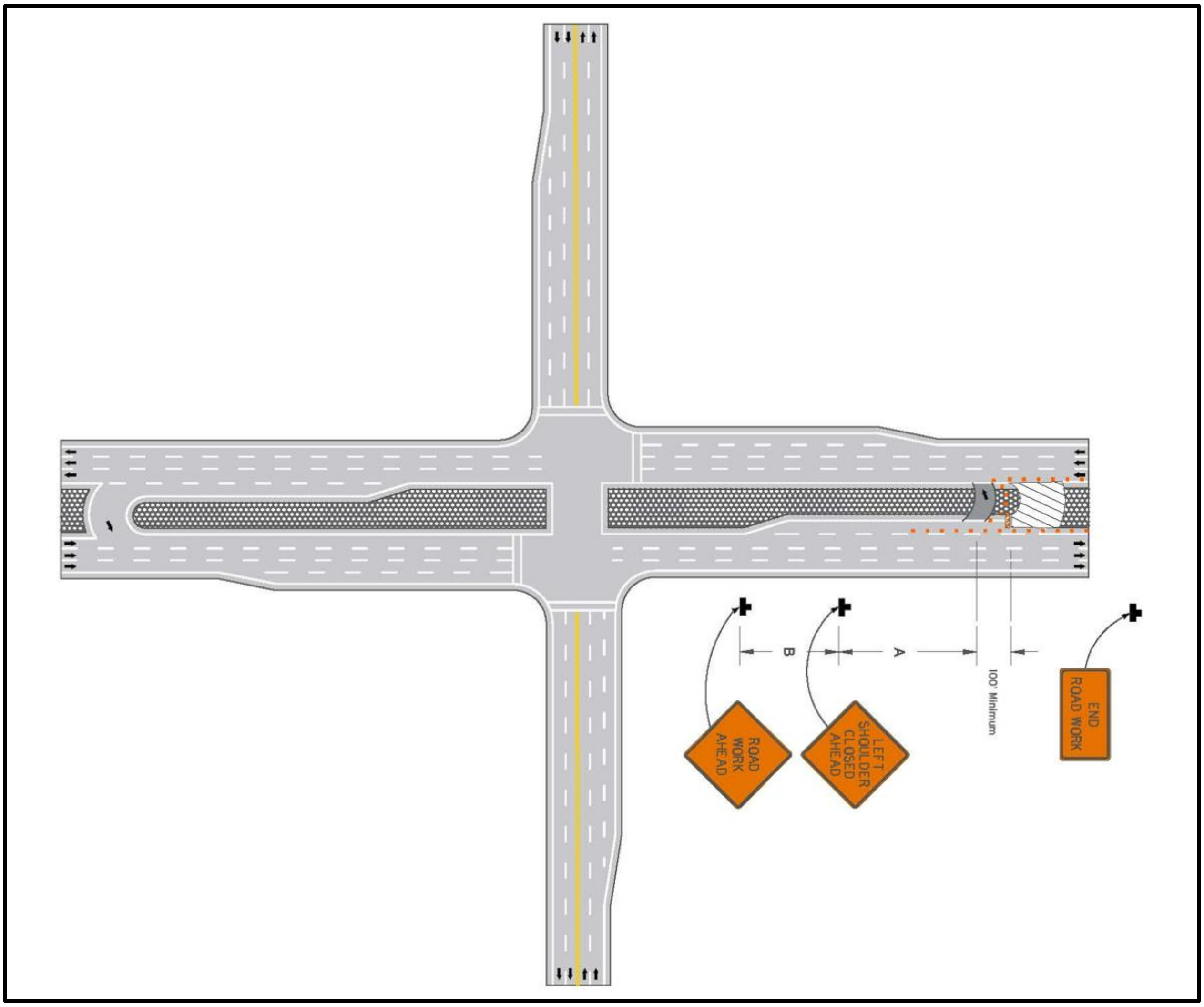

Figure 40. Median U-Turn Intersection with Temporary U-Turn Area Provided.

- Finally, if a U-turn lane needs to be closed, but no temporary U-turn lane can be provided, then then an alternative would be to simply close the U-turn lane and provide a detour route. This is shown in Figure 41.

These variations allow flexibility for providing the temporary traffic control plan needed for a specific situation.

In summary:

- Intersections with work zones have their own complexities for drivers.
- Innovative intersections have the potential to create challenges to designing a temporary traffic control zone.
- TTC plan designers may not have much experience with innovative intersection types.

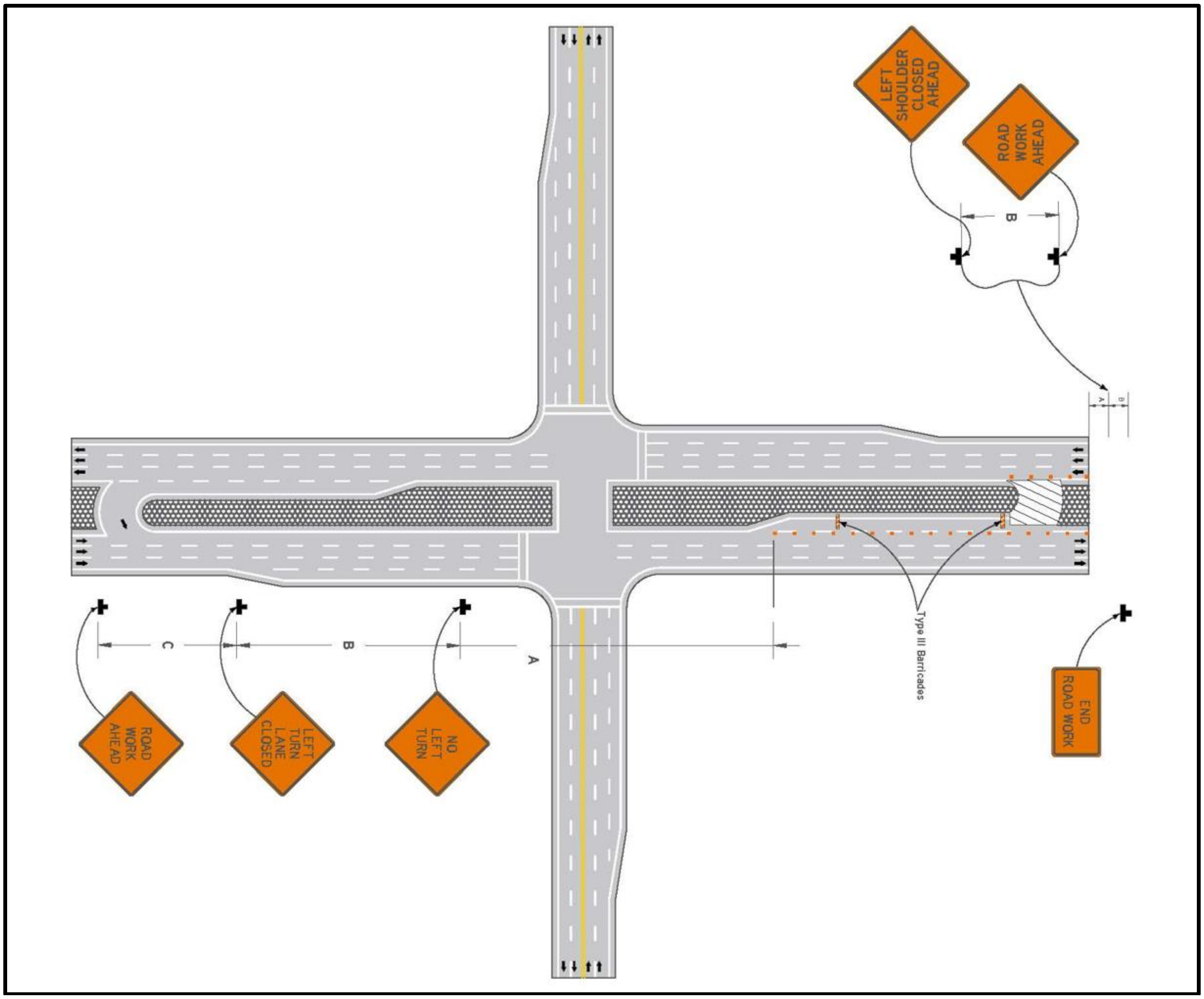

Figure 41. Median U-Turn Intersection with U-Turn Area Closed.

- There are limited examples of work zones in innovative intersections in available guidance documents, so several examples were developed to follow the concept of typical examples found in the MUTCD.

4. A Practical Checklist of Engineering Issues when a Work Zone is in or near an Intersection

A discussion with a panel of work zone experts yielded the following list of factors that were organized into a model checklist to guide designers placing a work zone in or near an intersections. These include:

- Selecting an initial TTC Plan. This could be based off TAs, standard plans, or previous work at the intersection. Unless this is a new intersection there should be some institutional experience of previous work zones placed at or near the intersection in question.
- The design vehicle should be known and this will play a role in the design of the work zone.
- There should be a consideration of the sight distance requirements for unsignalized intersections.
- There should also be consideration of any pavement elevation changes within work zone during any construction.
- Consider pedestrian/bicycle issues that may be present at the intersection.
- If the work zone is at or near a signalized intersection there may be an opportunity to improve operations by retiming the traffic signal to account for any changes in lanes or flow rates.

4.1 Selecting an initial TTC Plan

The purpose of selecting an initial TTC plan is to quickly develop one or more options on how to accommodate the work activity and handle traffic. It does not need to address all aspects right away – it's just a starting point for a design.
This could be based from:

- TAs from the MUTCD or state-specific MUTCDs;
- Standard plans; and/or
- Previous work at the intersection.

The benefit of using TAs, standard plans, or previous designs as your starting point is that it provides you a standardized set of examples to start your design. As stated in previous modules uniformity provides better understanding by motorists, which should result in better compliance with traffic control.

Unless this is a new intersection there should be some institutional experience of previous work zones placed at or near the intersection in question. Prior to starting work on the work zone design it is important to gather information on the intersection in question. There are several local agencies that should be approached for discussion, including:

- Emergency medical services (EMS);
- Fire departments;
- Local public works agencies; and
- Police departments.

There may be other groups based on the particulars of the specific location. The purpose of this activity is to gain knowledge of how previous work at this location may have impacted their operations (either positively or negatively).

Whether the TTC plan designers meet with them all in one meeting, or have discussions with them separately probably does not matter. The main point is to listen to as many perspectives as possible as early in the design process as possible. Regardless if they are together or separate, they should be asked about several broad areas, including:

- What happened the last few times a lane was closed at this intersection? As representatives of these services may have traveled through this intersection many times in the past they can provide useful information on how any prior work zones performed in terms of traffic flow or other potential issues.
- How do these organizations access the intersection? Specifically, do fire departments and EMS consider this intersection to be along a major path for them? Is it near a hospital or fire station, or other location nearby? It should not be assumed that all of their key routes are known.

4.2 Review Size of Design Vehicle

Each intersection and the adjoining roadways will have a specific design vehicle that should be accommodated. For most instances, the design vehicle will be a heavy truck. In other instances, it could be a firetruck or city bus. If work zone designers are able to fit the original design vehicle through the work zone, then no other work is required. If the vehicle does not fit however, then additional considerations need to be given. Considerations include:

- Redesign the work zone to ensure the design vehicle can be accommodated. This might be accomplished through thoughtful phasing of the work.
- If that is not possible or not practical, then the next option is to create a detour route for any vehicles that will not be accommodated by the work zone, and then place advance warning signs alerting drivers of the restriction.

The process of determining if a large vehicle can be accommodated through a work zone is known as a swept path analysis. There are standard descriptions of standard vehicles' swept path available in A Policy on Geometric Design of Highways and Streets (also known as the Green Book), published by the American Association of Street and Highway Transportation Officials (AASHTO, 2018). There are also several software packages that can conduct a swept path analysis directly in a CAD environment, and can even develop custom vehicles if needed.

If the design vehicle cannot be accommodated with the initial plan, then alternatives should be considered. For example:

- Can the travel space through the work zone be widened? If it can be widened enough to accommodate the design vehicle of the roadway then this should be done.
- If only one or two movements are at issue, can those movements be eliminated or restricted? For example, eliminating heavy vehicles' right or left turns at an intersection can reduce the need for space, while still allowing for through movements. Sometimes the best experience may be to detour traffic onto alternate routes – even if only some of

the vehicles. This is better than prohibiting large vehicles from the work zone without providing a defined path to navigate.

- Is this intersection on a hazardous materials route? If so this could affect where the detours need to happen. The Federal Motor Carrier Safety Administration (FMCSA) maintains a list of National Hazardous Materials Routes by state (FMCSA, 2019). While many of these routes are found on Interstates and other major highways, some routes do include at-grade intersections.

4.3 Consider Sight Distance Requirements for Unsignalized Intersections

Proper engineering design of an intersection includes examination of the intersection sight distance, resulting in a feature known as an intersection sight triangle. The diagram in Figure 42 shows a top-down view of two vehicles approaching an intersection, one moving left-to-right across the page, the other moving from bottom to top. The vehicle moving left-to-right is in the right lane of a four-lane facility. The triangle that connects the two vehicles with their crossing point in the intersection is the intersection sight triangle.

This guide does not provide detail how to calculate this in detail, as that is beyond the scope. If interested in learning more about this, please review the Policy on Geometric Design of Highway and Streets for details (AASHTO, 2018). The point of this analysis is to ensure that drivers are able to see each other with enough time to safety make crossing or turning movement decisions. The triangular area needs to remain free of visual obstructions in order for these decisions to be properly made.

When traffic is shifted on one or more of the approaches due to a work zone, the intersection sight triangle is changed. It is possible that this could provide advantages or disadvantages for drivers compared to a non-work zone situation. In Figure 42, the vehicle on the major roadway is in the right lane. in Figure 43 the right lane is closed, meaning that the vehicle is in the left lane. This may have the effect of increasing the length of the sight triangle, thereby improving the operation of the intersection. However, Figure 44 shows that if materials, equipment, etc. are placed in the closed lane it can create a visual obstacle and prevent the two vehicles from seeing each other. It is important to create obstruction-free areas inside the intersection sight triangles.

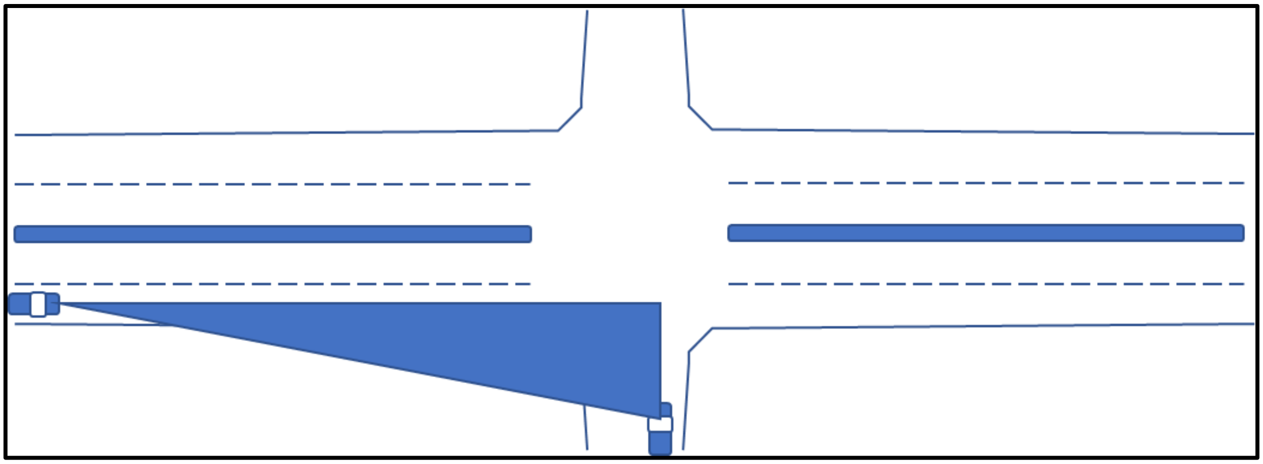

Figure 42. Normal Intersection Sight Triangle with No Work Zone Present.

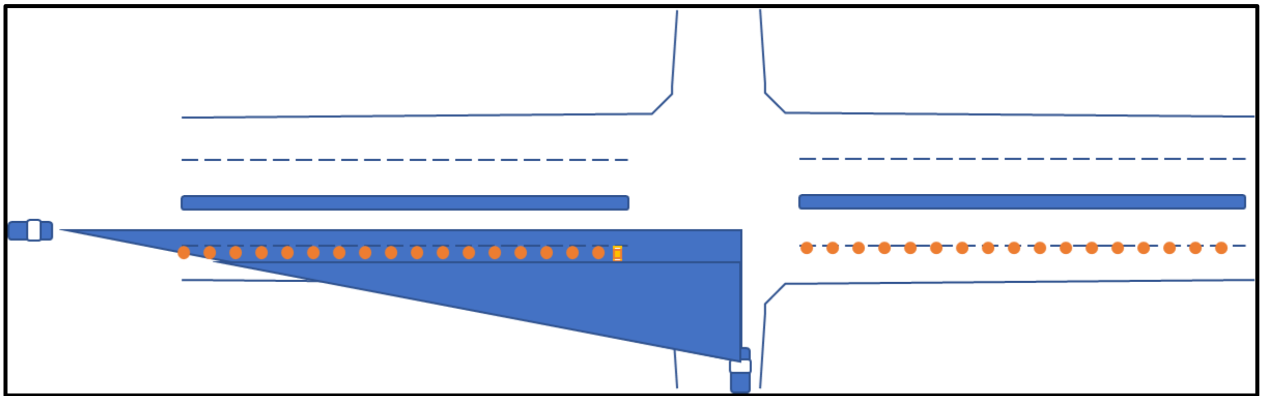

Figure 43. Intersection Sight Triangle with Work Zone Present, Right Lane Closed.

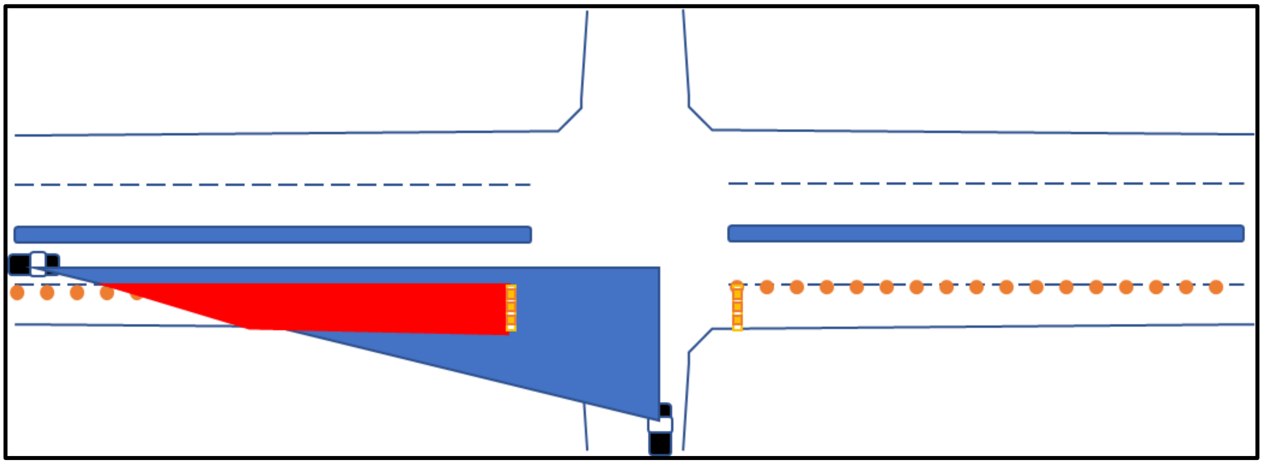

Figure 44. Intersection Sight Triangle with Work Zone Present, Right Lane Closed with Visual Obstruction.

4.4 Consider Elevation Changes within a Work Zone

Another factor to consider when placing a work zone through an intersection is how to deal with elevation changes during construction. Predominantly, this can happen during asphalt paving reconstruction, but other scenarios are possible. For non-intersection areas these elevation changes can be contained to parallel areas adjacent to traffic, but with intersections it may be that traffic is expected to cross the area where the pavement has been removed and still awaiting replacement. There are several key concepts to consider in these cases:

- Vertical drop-offs are to be avoided due to the potential to damage vehicles or the potential for drivers to lose control. This is especially true for motorcycles and bicycles. This can be handled through the use of temporary pavement wedges to provide ramps at the entrance and exits to the areas of elevation change.
- Even with temporary pavement wedges, it is preferential to have these elevation changes occur horizontally at 90-degree angles to the direction of travel. Again, this will help bicycle and motorcycle drivers to maintain control through the intersection.
- TTC warning signs should be provided alerting drivers they are approaching a pavement drop-off, and possibly to reduce speed prior to reaching the intersection.

4.5 Consider Signal Retiming

Signal retiming is a process that optimizes the operation of signalized intersections. When the amount of traffic, number of open approaches, or the number of available lanes changes due to the presence of a work zone, then traffic flow through the intersection might be degraded, resulting in additional intersection delay. It may be possible to minimize this additional intersection delay by retiming the traffic signal.

The signal timing process considers that multiple conflicting traffic movements are trying to access the same location – the intersection – at the same time. To greatly summarize what the signal timing plan attempts to do, it attempts to maximize traffic flow and minimize overall delays to motorists at an intersection by forcing traffic on differing approaches to take turns. Each traffic signal operates under a unique set of timing parameters, based on its geometry, approach speeds, and traffic volumes, are used to develop a timing plan. Many traffic signals are adaptive in nature and can adjust some of the times based on how much traffic is present at a particular moment in time. In this case the main parts of a traffic signal timing plan include:

- Minimum and maximum green durations;
- Pedestrian crossing duration requirements (not present on all traffic signals);
- Gap and extension times;
- Yellow change plus red clearance intervals; and
- Red time (Transportation Research Board, 2016).

All of these together add up to the cycle length, the amount of time from beginning of green for one approach until the beginning of green again for the same approach. Explaining all aspects of traffic signal timing plans is beyond the scope of this guide, but the main point is that under normal conditions the signal timing plan for a signalized intersection is optimized for its <u>current</u> condition.

How does it do this? Well in order to answer that, an explanation of the basic concepts is provided. The goal of signal retiming is to minimize delay for all drivers; not just one driver, but all drivers in certain categories, including:

- All drivers for an individual movement – known as a lane group;
- All drivers for each approach; and
- All drivers for the overall intersection.

Without going into too much detail here, the total amount of delay per cycle for each individual lane group, approach, or intersection are graded on an A to F scale, with an A being an optimal and an F considered to be failing (Transportation Research Board, 2016). This scale is known as Level of Service (LOS). The Maryland Department of Transportation State Highway Administration (MDOT SHA) has developed the Work Zone Lane Closure Analysis Guidelines, where they recommend an evaluation be conducted for all significant projects for the evaluation of work zone mobility impacts (MDOT SHA, 2008). MDOT SHA determined the allowable increase in delay based on the addition of a work zone, and is presented in this guide as a model to consider for use by other agencies when analyzing the impact of work zones on signalized intersections.

For signalized intersections:

- If the existing level of service is between ‘A’ and ‘C’, then the level of service during work zone operations shall not be reduced below a ‘D’ with a control delay of 45 seconds.
- If the existing level of service is a ‘D’, then the control delay during work zone operations shall not increase more than 30 percent.
- If the existing level of service an ‘E’, then the control delay during work zone operations shall not increase more than 30 percent with a maximum control delay of 80 seconds.
- Additional control delay is unacceptable at intersections already performing at level of service ‘F’ (MDOT SHA, 2008).

In general, signal retiming due to the presence of a work zone can have several advantages:

- Because the infrastructure is already in place, oftentimes the only costs associated with the retiming is the labor cost of doing the calculations and inputting the new signal timing plan into the signal controller.
- Signal retiming can have the advantage of minimizing the work zone-induced delay that is incurred on motorists.
- The plan can also be changed along with the phasing of the work zone, so if the number of open lanes etc. changes from one phase to another the timing plan can be adjusted accordingly.

However, it is important to remember that simply retiming a traffic signal cannot solve all issues at an intersection:

- While cycle lengths can be lengthened to allow more travel time, it can come at the cost of additional delay - there is no ‘free lunch.’

- If demand is too high, or if capacity is too constrained from a work zone, then the intersection may still fail to provide adequate traffic flow.
- In many urban areas the signal timing plan at an intersection may be coordinated with other intersections along a corridor, so changing the signal timing plan at one location needs to be checked for how it would affect nearby intersections.

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